NINTH EDITION

Completely Updated with New Material on Factor Investing, ESG and Corporate Bond Investing, Bond Trading, and Financial Data Science

THE HANDBOOK OF FIXED INCOME SECURITIES

EDITED BY

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WITH THE ASSISTANCE OF FRANCESCO A. FABOZZI AND STEVE V. MANN

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PREFACE

This book is designed to provide extensive coverage of the wide range of fixed income products, fixed income analytics, and fixed income portfolio management strategies. Each chapter is written by an authority on the subject.

The ninth edition of the *Handbook* is divided into ten parts. Part One provides general information about the investment features of fixed income securities, the risks associated with investing in fixed income securities, and the structure of interest rates. Part Two explains the basics of fixed income analytics—bond pricing, yield measures, spot rates, forward rates, total return, and price volatility measures (duration and convexity). It contains a new chapter, Chapter 6, covering data science.

Parts Three and Four cover the basic characteristics of the instruments traded in the market. Government securities and corporate debt obligations (both bonds and loans) are covered in Part Three. Additions to the ninth edition are coverage of Commercial Paper (Chapter 13), Non-U.S. Sovereign Bonds (Chapter 16), and Private Infrastructure Debt (Chapter 20).

Part Four focuses on securitized products—mortgage-backed securities and asset-backed securities. The coverage of the nonagency residential mortgage-backed securities and commercial mortgage-backed securities reflects market developments since the subprime mortgage crisis in 2007. The two new chapters included in Part Four are Agency Mortgage-Passthrough Securities (Chapter 22) and Nonagency Residential Mortgage-Backed Securities (Chapter 25).

The focus in Part Five is on the yield curve and the term structure of interest rates, both the use of the information contained in those rates and the modeling of the term structure. Part Six builds on the analytical framework explained in Part One. In this part, two methodologies for valuing fixed income securities are discussed: the lattice model and the Monte Carlo model. A by-product of these models is the option-adjusted spread. A chapter on relative value trades (Chapter 35) is a new addition to the *Handbook*, as are chapters on the valuation of agency collateralized mortgage obligations (Chapter 37). Unlike the previous edition, there are now two chapters rather than one on the valuation of convertible bonds; the new chapter is Chapter 39.

The topic of credit risk and its analysis is the subject of Part Seven. Traditional methods of credit analysis for corporate bonds and municipal bonds are explained and illustrated. There is also coverage of the various approaches to credit risk modeling.

Part Eight, which has 18 chapters, covers bond portfolio management strategies. There are nine new chapters that are included in this part of the book. I will briefly describe these new chapters. Chapter 44 focuses on several problems, issues, challenges and tools, developments, and tendencies that help to mitigate the problems bond portfolio managers face when they trade. Because bond indexes are important sources of information for managers and investors with respect to performance measurement and new products such as smart beta portfolios, Chapter 45 focuses on bond indexes. Unlike equity indexes, bond indexes have a high level of complexity. Although factor investing has been around for a good number of years in equity portfolio management, it is relatively new in bond portfolio management. Chapters 47, 48, and 58 cover factor investing in bond portfolio management. Chapter 48 also covers applications of machine learning to bond portfolio management. The ESG issues a corporate bond manager faces are covered in Chapter 55. There is a chapter on cash flow matching strategies, Chapter 51. The chapter on international bond portfolio management, Chapter 57, has been completely revised.

Part Nine covers derivative instruments: interest-rate derivatives (futures/forward contracts, options, interest-rate swaps, and caps and floors) and credit derivatives (primarily credit default swaps). The basic feature of each instrument is described as well as how it is valued and used to control the risk of a fixed income portfolio.

Performance evaluation and return attribution analysis are covered in the last three chapters of the *Handbook* in Part Ten. Coverage includes how these models are built and used, as well as the underlying principles in building these models.

SUMMARY OF REVISIONS

The ninth edition is a substantial revision over the eighth edition. Although both editions have roughly the same number of chapters (72 in this ninth edition versus 71 in the eighth edition), there have been substantial changes. The following 18 chapters are new:

6 Data Science and the Corporate Credit Markets
13 Commercial Paper
16 Non-U.S. Sovereign Bonds
20 Private Infrastructure Debt
22 Agency Mortgage Passthrough Securities
25 Nonagency Residential Mortgage-Backed Securities: Legacy, RMBS 2.0, and Non-QM
35 Relative Value Trading
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38 Convertible Securities
44 Trading in the Bond Market
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47 Factor Investing in Fixed Income Securities
48 Active Factor Fixed Income Investing

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52 Building Corporate Bond Portfolios
55 Corporate Bonds and ESG
57 International Bond Portfolio Management
58 Factor Investing in Sovereign Bond Markets

Moreover, the following four chapters have been substantially revised:

8 Agency Debt Securities
11 Leveraged Loans
18 Fixed Income Exchange Traded Funds
38 Convertible Securities

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Editor

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The first edition of *The Handbook of Fixed Income Securities* was published in 1983. Over the 38 years and eight editions of the book, I have benefited from the guidance of many participants in the various sectors of the bond market. I would like to extend my deep personal appreciation to the contributing authors in all editions of the book. Francesco Fabozzi and Steven Mann provided assistance in reviewing and commenting on a majority of the chapters, as well as coauthoring several chapters.

There are two individuals whom I would like to single out who contributed to the first six editions and are now retired from the industry: Jane Tripp Howe and Richard Wilson. Jane was widely recognized as one of the top corporate credit analysts. She contributed not only to the *Handbook* but also to several other books that I edited. She was my "go-to" person when I needed a chapter on any aspect of corporate credit analysis. In the eighth and ninth editions, Martin Fridson, Adam Cohen, and I revised the chapter by Jane on corporate bond credit analysis and we thank her for granting us permission to use the core of her chapter that appeared in the sixth edition.

Richard Wilson contributed several chapters to earlier editions of the *Handbook*. When I began my study of the fixed income market in the late 1970s, he served as my mentor. At that time, there were so many nuances about the institutional aspects of the market that were not in print. His historical perspective and his insights helped me form my view of the market. In addition, from his many contacts in the industry, he identified for me potential contributors to the first edition.

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PART
ONE

INTRODUCTION

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CHAPTER
ONE

OVERVIEW OF THE TYPES AND FEATURES OF FIXED INCOME SECURITIES

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This chapter will explore some of the most important features of bonds, preferred stock, and structured products and provide the reader with a taxonomy of terms and concepts that will be useful in the reading of the specialized chapters to follow.

BONDS

Bonds are instruments of debt; the issuer of a bond borrows money from the bond investor. One important characteristic of a bond is the nature of its issuer. Although non-U.S. governments and firms raise capital in U.S. financial markets, the three largest issuers of debt are domestic corporations, municipal governments, and the federal government and its agencies. Each class of issuer, however, features additional and significant differences.

Domestic corporations, for example, include regulated utilities as well as less regulated manufacturers. Furthermore, each firm may sell different kinds of bonds: Some debt may be publicly placed, whereas other bonds may be sold directly to one or only a few buyers (referred to as a *private placement*); some debt is collateralized or "secured" by specific assets of the company, whereas other debt may be unsecured. Municipal debt is also varied: "general obligation" bonds (GOs) are backed by the full faith, credit, and taxing power of the governmental unit issuing them; "revenue bonds," on the other hand, have a safety, or creditworthiness, that depends on the vitality and success of the particular entity (such as toll roads, hospitals, or water systems) within the municipal government issuing the bond.

The U.S. Treasury has the most voracious appetite for debt, but the bond market often receives calls from its agencies. Federal government agencies include federally related institutions and government-sponsored enterprises (GSEs). Exhibit 1-1 summarizes the breakdown of U.S. fixed income market by issuer categories.

EXHIBIT 1-1

Outstanding Value of U.S. Fixed Income Sectors (as of December 31, 2019)

U.S. Fixed-Income Sector	USD Billion
Treasury	$16,673.3
Mortgage Related	10,333.6
Corporate Debt	9,597.8
Municipals	3,854.5
Federal Agency	1,825.9
Asset-Backed	1,799.3
Money Markets	1,045.2
Total	**$32,996.8**

Based on data from the Securities Industry and Financial Markets Association (SIFMA)

It is important for the investor to realize that, by law or practice or both, these different borrowers have developed different ways of raising debt capital over the years. As a result, the distinctions among the various types of issuers correspond closely to differences among bonds in yield, denomination, safety of principal, maturity, tax status, and such important provisions as the call privilege, put features, and sinking fund. As we discuss the key features of fixed income securities, we will point out how the characteristics of the bonds vary with the obligor or issuing authority. A more extensive discussion is provided in later chapters in this book that explain the various instruments.

Maturity of a Bond

The legal document that sets forth all of the parameters of the agreement between the bondholders and the issuer is the *indenture*. A key feature of any bond that is covered by the indenture is its *term-to-maturity,* that is, the number of years during which the borrower has promised to meet the conditions of the debt (which are contained in the bond's indenture). A bond's term-to-maturity is the date on which the debt will cease, and the borrower will redeem the issue by paying the face value, or principal. One indication of the importance of the maturity is that the code word or name for every bond contains its maturity (and coupon interest payment, described later). Thus, the title of the Anheuser Busch Company bond due, or maturing, in 2029 is given as "Anheuser Busch 4¾ s of 2029." In practice, the words *maturity, term,* and *term-to-maturity* are used interchangeably to refer to the number of years remaining in the life of a bond. Technically, however, *maturity* denotes the date the bond will be redeemed, and either *term* or *term-to-maturity* denotes the remaining number of years until that date.

A bond's maturity is crucial for several reasons. First, maturity indicates the expected life of the instrument, or the number of periods during which the holder of the bond can expect to receive the coupon interest and the number of years before the principal will be paid. Second, the yield on a bond depends substantially on its maturity. More specifically, at any given point in time, the yield offered on a long-term bond may be greater than, less than, or equal to the yield offered on a short-term bond. As will be explained in Chapter 32, the effect of maturity on the yield depends on the *shape of the yield curve*. Third, the volatility of a bond's price is closely associated with maturity: changes in the market level of rates will wrest much larger changes in price from bonds of long maturity than from otherwise similar debt of shorter life. Finally, as explained in Chapter 5, there are other risks associated with the maturity of a bond.

When considering a bond's maturity, the investor should be aware of any provisions that modify, or permit the issuer to modify, the maturity of a bond. Although corporate bonds (referred to as "corporates") are typically *term bonds* (issues that have a single maturity), they often contain arrangements by which the issuing firm either can or must retire the debt early, in full or in part. Some corporate bonds give the issuer a *call privilege,* which permits the issuing firm to redeem the bond before the scheduled maturity under certain conditions (these conditions are discussed below). Municipal bonds may have the same provision. The U.S. government no longer issues bonds that have a call privilege. The last callable bond was called in November 2009. Many industrials and some utilities have *sinking-fund provisions,* which mandate that the firm retire a substantial portion of the debt, according to a prearranged schedule, during its life and before the stated maturity. Municipal bonds may be *serial bonds* or, in essence, bundles of bonds with differing maturities. (Some corporates are of this type, too.)

Usually, the maturity of a corporate bond is between 1 and 30 years. This is not to say that there are not outliers. In fact, financially sound firms have begun to issue longer-term debt in order to lock in long-term attractive financing. For example, in the late 1990s, there were approximately 90 corporate bonds issued with maturities of 100 years.

Although classifying bonds as "short term," "intermediate term," and "long term" is not universally accepted, the following classification is typically used. Bonds with a maturity of 1 to 5 years are generally considered short term; bonds with a maturity between 5 and 12 years are viewed as intermediate term (and are often called *notes*). Long-term bonds are those with a maturity greater than 12 years.

Coupon and Principal

The indenture sets for the interest rate the issuer must pay bondholders, the frequency of the payments, the currency in which it must be paid, and the bond's par value.

The interest rate that the issuer must pay bondholders during the term of the bond is called the *coupon rate*. The coupon rate is always cited, along with maturity, in any quotation of a bond's price. Thus, one might hear about the "IBM 6.5 due in 2028" or the "Campbell's Soup 8.875 due in 2021" in discussions of current bond trading. The coupon rate is the interest rate that when multiplied by the *principal, par value,* or *face value* of the bond, provides the amount of the coupon payment to be made to the bondholders. The indenture will specify the currency in which the payment is to be made and its frequency.

Typically, but not universally, for bonds issued in the United States, the coupon payment is made in semiannual installments. An important exception is mortgage-backed and asset-backed securities that usually deliver monthly cash flows. In contrast, for bonds issued in some European bond markets and all bonds issued in the *Eurobond market,* the coupon payment is made annually.

The coupon rate has another major impact on an investor's experience with a bond. The coupon's size influences the volatility of the bond's price: the larger the coupon, the less the price will change in response to a change in market interest rates. Thus, the coupon and the maturity have opposite effects on the price volatility of a bond. This will be illustrated in Chapter 5.

One reason that debt financing is popular with corporations is that the interest payments are tax-deductible expenses. As a result, the true after-tax cost of debt to a profitable firm is usually much less than the stated coupon interest rate. The level of the coupon on any bond is typically close to the level of yields for issues of its class at the time the bond is first sold to the public. Some bonds are issued initially at a price substantially below par value (called *original-issue discount bonds,* or *OIDs*), and their coupon rate is deliberately set below the current market rate. However, firms usually try to set the coupon at a level that will make the market price close to par value. This goal can be accomplished by placing the coupon rate near the prevailing market rate.

The par value, also referred to as the *face value* or *principal*, of a bond is the amount to be repaid to the investor either at maturity or at those times when the bond is called or retired according to a repayment schedule or sinking-fund provisions that we describe later. But the principal plays another role, too: it is the basis on which the coupon or periodic interest rests. The coupon is the product of the principal and the coupon rate.

Bonds may be *bearer bonds* or *registered bonds.* With bearer bonds, investors clip coupons and send them to the obligor for payment. In the case of registered issues, bond owners receive the payment automatically at the appropriate time. All new bond issues must be registered.

Types of Coupon Structures

The coupon structure of a bond can be a fixed rate or a floating or variable rate. Below we describe the different types of coupon structures.

Zero-Coupon Bonds: Zero-coupon bonds have been issued by corporations and municipalities since the early 1980s. For example, Barclay's Bank PLC has a zero-coupon bond outstanding due in August 2036 that was issued on August 15, 2006. Although the U.S. Treasury does not issue zero-coupon debt with a maturity greater than one year, such securities are created by government securities dealers. Merrill Lynch was the first to do this with its creation of Treasury Investment Growth Receipts (TIGRs) in August 1982. The most popular zero-coupon Treasury securities today are those created by government dealer firms under the Treasury's Separate Trading of Registered Interest and Principal Securities (STRIPS) Program. Just how these securities—commonly referred to as *Treasury strips*—are created will be explained in Chapter 7. The investor in a zero-coupon security typically receives interest by buying the security at a price below its principal, or maturity value, and holding it to the maturity date. The reason for the issuance of zero-coupon securities is explained in Chapter 7. However, some zeros are issued at par and accrue interest during the bond's life, with the accrued interest and principal payable at maturity.

Inflation-Linked Bonds: Sovereign governments and corporations issue securities with the principal tied to the rate of inflation. These debt instruments, referred to as *inflation-linked bonds,* or simply "linkers," have been issued since 1945. The earlier issuers of linkers were the governments of Argentina, Brazil, and Israel. The modern linker is attributed to the U.K. government's index-linked gilt issued in 1981 followed by Australia, Canada, and Sweden. The United States introduced an inflation-linked security in January 1997, calling those securities *Treasury Inflation Protected Securities*, or TIPS. These securities, which carry the full faith and credit of the U.S. government, comprised approximately 10% of the outstanding U.S. Treasury market as of mid-2020. Shortly after the introduction of TIPS in 1997, U.S. government-related entities such as the Federal Farm Credit, the Federal Home Loan Bank, Fannie Mae, and the Tennessee Valley Authority began issuing linkers.

Different designs can be employed for linkers. The reference rate that is a proxy for the inflation rate is changes in the consumer price index (CPI). In the United Kingdom, for example, the index used is the Retail Prices Index (All Items), or RPI. In France, there are two linkers with two different indexes: the French CPI (excluding tobacco) and the Eurozone's Harmonised Index of

Consumer Prices (HICP) (excluding tobacco). In the United States, the Consumer Price Index–Urban, Non-Seasonally Adjusted (denoted by CPI-U), is calculated by the U.S. Bureau of Labor Statistics.[1]

Step-Up Notes: There are securities that have a coupon rate that increases over time. These securities are called *step-up notes* because the coupon rate "steps up" over time. For example, a six-year step-up note might have a coupon rate that is 5% for the first two years, 5.8% for the next two years, and 6% for the last two years. Consider a *stairway note* issued by Barclays Bank PLC in July 2009. The initial coupon was 2.8% until January 2010 and thereafter the coupon rate reset every six months to the maximum of the previous coupon rate or six-month LIBOR.

Floating-Rate Securities: In contrast to a coupon rate that is fixed for the bond's entire life, the term *floating-rate security* or *floater* encompasses several different types of securities with one common feature: the coupon rate will vary over the instrument's life. The coupon rate is reset at designated dates based on the value of some reference rate adjusted for a spread. For example, consider a floating-rate note issued in May 2017 by Apple that matures in May 2022. This floater delivers cash flows quarterly and had a coupon formula equal to three-month LIBOR plus 35 basis points.

Typically, floaters have coupon rates that reset more than once a year (e.g., semiannually, quarterly, or monthly). Conversely, the term *adjustable-rate* or *variable-rate security* refers to those issues whose coupon rates reset not more frequently than annually.

Features of Floaters: There are several features about floaters that deserve mention. First, a floater may have a restriction on the maximum (minimum) coupon rate that will be paid at any reset date called a *cap* (*floor*). Second, while the reference rate for most floaters is a benchmark interest rate or an interest rate index, a wide variety of reference rates appear in the coupon formulas. A floater's coupon could be indexed to movements in foreign exchange-rates, the price of a commodity (e.g., crude oil), movements in an equity index (e.g., the S&P 500), or movements in a bond index. Third, while a floater's coupon rate normally moves in the same direction as the reference rate, there are floaters whose coupon rate moves in the opposite direction from the reference rate. These securities are

1. The CPI-U is the most widely followed and perhaps the most understood inflation index among alternative choices, such as the Gross Domestic Product (GDP) deflator and the Personal Consumption Expenditure (PCE) deflator. Monthly changes in the CPI-U represent the average changes in prices facing urban consumers with regard to a fixed basket of goods and services. This group of urban consumers represents about 87% of the total U.S. population. The Treasury reserves the right to substitute an alternative price index under the following circumstances: (1) the CPI-U is discontinued, (2) the CPI-U is altered materially to the detriment of the investor and/or the security, or (3) the CPI-U is altered by legislation or executive order in a manner harmful to the investor and/or the security.

called *inverse floaters* or *reverse floaters*. Consider a hypothetical inverse floater that makes coupon payments according to the following formula:

$$18\% - 2.5 \times (\text{three-month LIBOR})$$

This inverse floater had a floor of 3% and a cap of 15.5%. Finally, *range notes* are floaters whose coupon rate is equal to the reference rate (adjusted for a spread) as long as the reference rate is within a certain range on the reset date. If the reference rate is outside the range, the coupon rate is zero for that period.

Reference Rates: Note that the Financial Conduct Authority (FCA) which oversees LIBOR submission process, announced in 2017 that FCA will no longer "persuade" London banks to make submission after the end of 2021. (In November 2020, regulators announced an extension of LIBOR publication until June 2023, in order to avoid any disruption from the originally planned ending of publication in 2021. The end date for LIBOR-linked new contracts remains the end of 2021, as originally planned.)To replace the LIBOR rates, a global process started in the search for an alternative reference rate. In the United States, Alternative Reference Rate Committee (ARRC) selected the Broad Treasury Funding Rate in 2017, and later renamed it as Secured Overnight Financing Rate (SOFR). The ARRC was created by the Federal Reserve (Fed), and the participants are over-the-counter derivative market players, supervisors, and central banks.

SOFR is a volume-weighted median rate based on actual transaction data from overnight tri-party repo and cleared overnight bilateral repo markets (excluding Fed transactions). In the past, banks/dealers were not obliged to submit repo trade to the Fed. Since April 2018, it has been mandatory to submit repo deal details via DTCC (Depository Trust & Clearing Corporation) to the Fed. While LIBOR is unsecured term rate with various maturities, SOFR itself is a secured overnight rate. SOFR rate has been published by the New York Fed since April 2, 2018.

As of May 2020, it is estimated that the total SOFR-based debt issuance has reached $630 billion. The biggest issuers of SOFR-linked floating-rate debt that are the Federal Home Loan Bank (FHLB), Freddie Mac, Fannie Mae, as well as banks, insurance companies, and the World Bank. For example, IBRD Floater 08/06/24 that was issued in 2019 pays quarterly coupon based on overnight (O/N) SOFR + 30 basis point formula.

A SOFR-based futures product also was introduced by the Chicago Mercantile Exchange (CME) in May 2018. Both one-month and three-month contracts exist, and the settlement rate is the compounded daily SOFR during the reference contract quarter. Currently SOFR contracts are available for up to 10 years (i.e., 39 quarterly months (March, June, September, December), and an active futures market would be critical for the interest rate swap market. In addition to SOFR in the United States, there is a global search for alternative rates: SONIA in the U.K., EONIA and ESTER in the Eurozone, or TONAR in Japan.

Coupon Structure on High-Yield Bonds: Structures in the *high-yield (junk bond) sector* of the corporate bond market have introduced variations in the way coupon payments are made. For example, in a leveraged buyout or recapitalization financed with high-yield bonds, the heavy interest payment burdens the corporation must bear places severe cash-flow constraints on the firm. To reduce this burden, firms involved in leveraged buyouts (LBOs) and recapitalizations have issued deferred-coupon structures that permit the issuer to defer making cash interest payments for a period of three to seven years. There are three types of deferred-coupon structures: (1) deferred interest bonds, (2) step-up bonds, and (3) payment-in-kind bonds. These structures are described in Chapter 10.

Another high-yield bond structure allows the issuer to reset the coupon rate so that the bond will trade at a predetermined price. The coupon rate may reset annually or reset only once over the life of the bond. Generally, the coupon rate will be the average of rates suggested by two investment banking firms. The new rate will then reflect the level of interest rates at the reset date and the credit spread the market wants on the issue at the reset date. This structure is called an *extendible reset bond.* Notice the difference between this bond structure and the floating-rate issue described earlier. With a floating-rate issue, the coupon rate resets based on a fixed spread to some benchmark, where the spread is specified in the indenture and the amount of the spread reflects market conditions at the time the issue is first offered. In contrast, the coupon rate on an extendible reset bond is reset based on market conditions suggested by several investment banking firms at the time of the reset date. Moreover, the new coupon rate reflects the new level of interest rates and the new spread that investors seek.

Bond Quote Convention

By convention, the prices of most bonds are quoted as percentages of par or face value. To convert the price quote into a dollar figure, one simply divides the price by 100 (converting it to decimal) and then multiplies by the par value. The following table illustrates this.

Price as a Percentage

Par Value ($)	Price Quote	Percent of Par Value	Price in Dollars
$1,000	$91\frac{3}{4}$	91.75	$917.50
5,000	$102\frac{1}{2}$	102.5	5,125.00
10,000	$87\frac{1}{4}$	87.25	8,725.00
25,000	$100\frac{3}{4}$	100.875	25,218.75
100,000	$71\frac{9}{32}$	71.28125	71,281.25
500,000	$97\frac{5}{16}$	97.15625	485,781.25
1,000,000	$88\frac{111}{256}$	88.43359375	884,335.94

Embedded Options

The indenture may have provisions that grant either the bondholders or the issuer the right to alter the maturity of the bond by taking certain action. Such rights are referred to as *embedded options* and the various types of embedded options are described below.

Call and refunding provisions: If a bond's indenture contains a *call feature* or *call provision,* the issuer retains the right to retire the debt, fully or partially, before the scheduled maturity date. The chief benefit of such a feature is that it permits the borrower, should market rates fall, to replace the bond issue with a lower-interest-cost issue. The call feature has added value for corporations and municipalities. It may in the future help them to escape the restrictions that frequently characterize their bonds (about the disposition of assets or collateral). The call feature provides an additional benefit to corporations, which might want to use unexpectedly high levels of cash to retire outstanding bonds or might wish to restructure their balance sheets.

The call provision is detrimental to investors, who run the risk of losing a high-coupon bond when rates begin to decline. When the borrower calls the issue, the investor must find other outlets, which presumably would have lower yields than the bond just withdrawn through the call privilege. Another problem for the investor is that the prospect of a call limits the appreciation in a bond's price that could be expected when interest rates decline.

Because the call feature benefits the issuer and places the investor at a disadvantage, callable bonds carry higher yields than bonds that cannot be retired before maturity. This difference in yields is likely to grow when investors believe that market rates are about to fall, and that the borrower may be tempted to replace a high-coupon debt with a new low-coupon bond. (Such a transaction is called *refunding.*) However, the higher yield alone is often not sufficient compensation to the investor for granting the call privilege to the issuer. Thus, the price at which the bond may be called, termed the *call price,* is normally higher than the principal or face value of the issue. The difference between call price and principal is the *call premium,* whose value may be as much as one year's interest in the first few years of a bond's life and may decline systematically thereafter.

An important limitation on the borrower's right to call is the *period of call protection,* or *deferment period,* which is a specified number of years in the early life of the bond during which the issuer may not call the debt. Such protection is another concession to the investor, and it comes in two forms. Some bonds are *noncallable* (often abbreviated NC) for any reason during the deferment period; other bonds are *nonrefundable* (NF) for that time. The distinction lies in the fact that nonrefundable debt may be called if the funds used to retire the bond issue are obtained from internally generated funds, such as the cash flow from operations or the sale of property or equipment, or from nondebt funding such as the sale of common stock. Thus, although the terminology is unfortunately confusing, a nonrefundable issue may be refunded under the circumstances just described and, as a result, offers less call protection than a noncallable bond, which cannot be called for any reason except to satisfy sinking-fund requirements, explained later. Beginning in early 1986, a number of corporations issued long-term debt with extended call protection, not refunding protection. A number are noncallable for the issue's life, such as Dow Chemical Company's $8^5/_8$s due in 2006. The issuer is expressly prohibited from redeeming the issue prior to maturity. These *noncallable-for-life issues* are referred to as *bullet bonds*. If a bond does not have any protection against an early call, then it is said to be *currently callable.*

Since the mid-1990s, an increasing number of public debt issues include a so-called *make-whole call provision*. Make-whole call provisions have appeared routinely in privately placed issues since the late 1980s. In contrast to the standard call feature that contains a call price fixed by a schedule, a make-whole call price varies inversely with the level of interest rates. A make-whole call price (i.e., redemption amount) is typically the sum of the present values of the remaining coupon payments and principal discounted at a yield on a Treasury security that matches the bond's remaining maturity plus a spread. For example, on January 22, 2008, an industrial firm issued $300 million in bonds with a make-whole call provision that mature on January 15, 2038. These bonds are redeemable at any time in whole or in part at the issuer's option. The redemption price is the greater of (1) 100% of the principal amount plus accrued interest or (2) the make-whole redemption amount plus accrued interest. In this case, the make-whole redemption amount is equal to the sum of the present values of the remaining coupon and principal payments discounted at the Adjusted Treasury Rate plus 15 basis points.[2] The Adjusted Treasury Rate is the bond-equivalent yield on a U.S. Treasury security having a maturity comparable to the remaining maturity of the bonds to be redeemed. Each holder of the bonds will be notified at least 30 days, but not more than 60 days, prior to the redemption date. This issue is callable at any time, as are most issues with make-whole call provisions. Note that the make-whole call price increases as interest rates decrease, so if the issuer exercises the make-whole call provision when interest rates have decreased, the bondholder receives a higher call price. Make-whole call provisions thus provide investors with some protection against reinvestment rate risk.

When will the issuer find it economically beneficial to refund an issue? It is important for investors to understand the process by which a firm decides whether to retire an old bond and issue a new one. A simple and brief example will illustrate that process and introduce the reader to the kinds of calculations a bondholder will make when trying to predict whether a bond will be refunded.

In municipal securities, refunding often refers to something different, although the concept is the same. Municipal bonds can be *prerefunded* prior to maturity (usually on a call date). Here, instead of issuing new bonds to retire the debt, the municipality will issue bonds and use the proceeds to purchase enough risk-free securities to fund all the cash flows on the existing bond issue. It places

2. A 30/360 day-count convention is employed in this present-value calculation.

these in an irrevocable trust. Thus, the municipality still has two issues outstanding, but the old bonds receive a new label—they are "prerefunded." If Treasury securities are used to prerefund the debt, the cash flows on the bond are guaranteed by Treasury obligations in the trust. As a result, they become AAA rated and trade at higher prices than previously. Municipalities often find this an effective means of lowering their cost of debt.

Sinking-fund provision: The *sinking-fund provision,* which is typical for publicly and privately issued industrial bonds and not uncommon among certain classes of utility debt, requires the obligor to retire a certain amount of the outstanding debt each year. Generally, the retirement occurs in one of two ways. The firm may purchase the amount of bonds to be retired in the open market if their price is below par, or the company may make payments to the trustee who is empowered to monitor the indenture and who will call a certain number of bonds chosen by lottery. In the latter case, the investor would receive the prearranged call price, which is usually par value. The schedule of retirements varies considerably from issue to issue. Some issuers, particularly in the private-placement market, retire most, if not all, of their debt before maturity. In the public market, some companies may retire as little as 20% to 30% of the outstanding par value before maturity. Further, the indenture of many issues includes a deferment period that permits the issuer to wait five years or more before beginning the process of sinking-fund retirements.

There are three advantages of a sinking-fund provision from the investor's perspective. The sinking-fund requirement ensures an orderly retirement of the debt so that the final payment, at maturity, will not be too large. Second, the provision enhances the liquidity of some debt, especially for smaller issues with thin secondary markets. Third, the prices of bonds with this requirement are presumably more stable because the issuer may become an active participant on the buy side when prices fall. For these reasons, the yields on bonds with sinking-fund provisions tend to be less than those on bonds without them.

The sinking fund, however, can work to the disadvantage of an investor. Suppose that an investor is holding one of the early bonds to be called for a sinking fund. All the time and effort put into analyzing the bond has now been wasted, and the investor will have to choose new instruments for purchase. Also, an investor holding a bond with a high coupon at the time rates begin to fall is still forced to relinquish the issue. For this reason, in times of high interest rates, one might find investors demanding higher yields from bonds with sinking funds than from other debt.

The sinking-fund provision also may harm the investor's position through the *optional acceleration feature,* a part of many corporate bond indentures. With this option, the corporation is free to retire more than the amount of debt the sinking fund requires (and often a multiple thereof) and to do it at the call price set for sinking-fund payments. Of course, the firm will exercise this option only if the price of the bond exceeds the sinking-fund price (usually near par), and this happens when rates are relatively low. If, as is typically the case, the sinking-fund provision becomes operative before the lapse of the call-deferment period, the firm can retire much of its debt with the optional acceleration feature and can do so at a price far below that of the call price it would have to pay in the event of refunding. The impact of such activity on the investor's position is obvious: The firm can redeem at or near par many of the bonds that appear to be protected from call and that have a market value above the face value of the debt.

Put provisions: A *putable bond* grants the investor the right to sell the issue back to the issuer at par value on designated dates. The advantage to the investor is that if interest rates rise after the issue date, thereby reducing the value of the bond, the investor can force the issuer to redeem the bond at par. Some issues with put provisions may restrict the amount that the bondholder may put back to the issuer on any one put date. Put options have been included in corporate bonds to deter unfriendly takeovers. Such put provisions are referred to as "poison puts."

Put options can be classified as *hard puts* and *soft puts.* A hard put is one in which the security must be redeemed by the issuer only for cash. In the case of a soft put, the issuer has the option to redeem the security for cash, common stock, another debt instrument, or a combination of the three. Soft puts are found in convertible debt, which we describe next.

Convertible or exchangeable debt: A *convertible bond* is one that can be exchanged for specified amounts of common stock in the issuing firm: The conversion cannot be reversed, and the terms of the conversion are set by the company in the bond's indenture. The most important terms are *conversion ratio* and *conversion price.* The conversion ratio indicates the number of shares of common stock to which the holder of the convertible has a claim. The conversion price at issuance is also referred to as the *stated conversion price.*

The conversion privilege may be permitted for all or only some portion of the bond's life. The conversion ratio may decline over time. It is always adjusted proportionately for stock splits and stock dividends. Convertible bonds are typically callable by the issuer. This permits the issuer to force conversion of the issue. (Effectively, the issuer calls the bond, and the investor is forced to convert the bond or allow it to be called.) There are some convertible issues that have call protection. This protection can be in one of two forms: Either the issuer is not allowed to redeem the issue before a specified date, or the issuer is not permitted to call the issue until the stock price has increased by a predetermined percentage price above the conversion price at issuance.

An *exchangeable bond* is an issue that can be exchanged for the common stock of a corporation other than the issuer of the bond. There are a handful of issues that are exchangeable into more than one security. One significant innovation in the convertible bond market was the "Liquid Yield Option Note" (LYON) developed by Merrill Lynch Capital Markets in 1985. A LYON is a zero-coupon, convertible, callable, and putable bond. Techniques for analyzing convertible and exchangeable bonds are described in Chapters 38 and 39.

Warrants: A *warrant* is an option a corporation grants to bondholders that permits the owner to buy from the firm a certain number of shares of common stock at a specified price. It is not uncommon for publicly held corporations to issue warrants with new bonds.

A valuable aspect of a warrant is its rather long life: Most warrants are in effect for at least two years from issuance, and some are perpetual.[3] Another key feature of the warrant is the *exercise price,* the price at which the warrant holder can buy stock from the corporation. This price is normally set at about 15% above the market price of common stock at the time the bond, and thus the warrant, is issued. Frequently, the exercise price will rise through time, according to the schedule in the bond's indenture. Another important characteristic of the warrant is its detachability. *Detachable warrants* are often actively traded on the American Stock Exchange. Other warrants can be exercised only by the bondholder, and these are called *nondetachable warrants.* The chief benefit to the investor is the financial leverage the warrant provides.

Bond Yields

Bond market participants use several measures to describe the potential return from investing in a bond: current yield, yield to maturity, yield-to-call for a callable bond, and yield-to-put for a putable bond. A *yield-to-worst* is often quoted for bonds. This is the lowest yield of the following: yield to maturity, yields to all possible call dates, and yields to all put dates. The calculation and limitations of these yield measures are explained and illustrated in Chapter 4.

Since the Global Financial Crisis of 2008–2009, government yields have continued their already prevailing declining secular trend and yields of several sovereign issuers went into the negative territory, including several governments within the Eurozone, Switzerland, Sweden, as well as Japan (see Exhibit 1-2). This decline in government yields is explained by various factors, including accommodative monetary policy, quantitative easing, as well as low inflation expectations. As of June 4, 2020, 27% of the market value of the Bloomberg Barclays Global Aggregate Treasury Index offer negative yield. The index overall has a duration (a measure described in Chapter 5) of 8.6 years, a yield of 0.55%, and a total market value of $31 trillion, and it is comprised of government bonds of 41 developed and emerging countries.

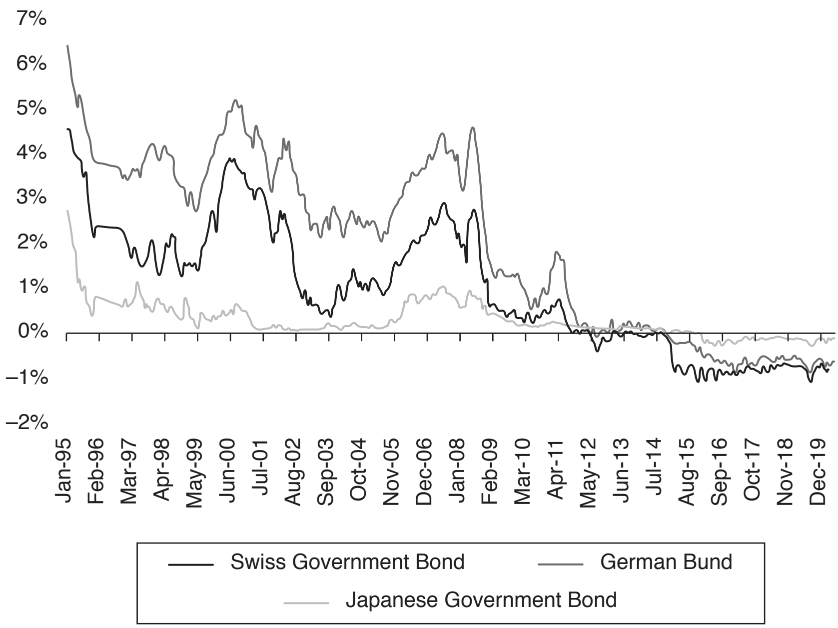
Government bonds "with negative yield" are issued either with positive coupon or no coupon, however, their current purchase price is so high, that the cash-flow stream comprised by their coupons (if any) and the face value at maturity would result in a negative yield to maturity. For example, the current 10-year German Bund matures on 02/15/2030 and has a coupon rate equal to zero, so its current market price of 103.141/103.165 translates to a yield to maturity of –0.319%/–0.321%. In other words, if an investor buys this bond at the currently available price, and holds till maturity, she or he would lock in a negative total

3. This long life contrasts sharply with the short life during which many exchange-traded call options on common stock, similar to warrants, are exercisable.

return. Negative yields alone, however, do not necessarily mean negative total return: a positive return can be generated by selling the bond before maturity at an even higher price, i.e., even more negative yield. This may be achieved either by rebalancing to a target duration while the yield-curve, albeit partly of fully in negative territory, has a positive slope (benefiting from the roll-down effect), or by active trading.

EXHIBIT 1-2

Two-Year Government Bond Yields (January 1995–December 2019)



MEDIUM-TERM NOTES

Medium-term notes are highly flexible debt instruments that can be easily structured in response to changing market conditions and investor tastes. "Medium term'' is a misnomer because these securities have ranged in maturity from nine months to 30 years and longer. Since the latter part of the 1980s, medium-term notes have become an increasingly important financing vehicle for corporations and federal agencies. Typically, medium-term notes are noncallable, unsecured, senior debt securities with fixed-coupon rates that carry an investment-grade credit rating. They generally differ from other bond offerings in their primary distribution process. *Structured medium-term notes,* or simply *structured notes,* are debt instruments linked to a derivative position and are discussed in Chapter12.

For example, structured notes are usually created with an underlying swap transaction. This "hedging swap" allows the issuer to create securities with interesting risk/return features demanded by bond investors.

PREFERRED STOCK

Preferred stock is a class of stock, not a debt instrument, but it shares characteristics of both common stock and debt. Like the holder of common stock, the preferred stockholder is entitled to dividends. Unlike those on common stock, however, preferred stock dividends are a specified percentage of par or face value.[4] The percentage is called the *dividend rate;* it need not be fixed but may float over the life of the issue.

Failure to make preferred stock dividend payments cannot force the issuer into bankruptcy. Should the issuer not make the preferred stock dividend payment, usually paid quarterly, one of two things can happen, depending on the terms of the issue. First, the dividend payment can accrue until it is fully paid. Preferred stock with this feature is called *cumulative preferred stock.* Second, if a dividend payment is missed and the security holder must forgo the payment, the preferred stock is said to be *noncumulative preferred stock.* Failure to make dividend payments may result in imposition of certain restrictions on management. For example, if dividend payments are in arrears, preferred stockholders might be granted voting rights.

Unlike debt, payments made to preferred stockholders are treated as a distribution of earnings. This means that they are not tax deductible to the corporation under the current tax code. (Interest payments, on the other hand, are tax deductible.) Although the after-tax cost of funds is higher if a corporation issues preferred stock rather than borrowing, there is a factor that reduces the cost differential: A provision in the tax code exempts 70% of qualified dividends from federal income taxation if the recipient is a qualified corporation. For example, if Corporation A owns the preferred stock of Corporation B, for each \$100 of dividends received by A, only \$30 will be taxed at A's marginal tax rate. The purpose of this provision is to mitigate the effect of double taxation of corporate earnings. There are two implications of this tax treatment of preferred stock dividends. First, the major buyers of preferred stock are corporations seeking tax-advantaged investments. Second, the cost of preferred stock issuance is lower than it would be in the absence of the tax provision because the tax benefits are passed through to the issuer by the willingness of buyers to accept a lower dividend rate.

Preferred stock has some important similarities with debt, particularly in the case of cumulative preferred stock: (1) the payments to preferred stockholders

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4. Almost all preferred stock limits the security holder to the specified amount. Historically, there have been issues entitling the preferred stockholder to participate in earnings distribution beyond the specified amount (based on some formula). Preferred stock with this feature is referred to as *participating preferred stock*.

promised by the issuer are fixed, and (2) preferred stockholders have priority over common stockholders with respect to dividend payments and distribution of assets in the case of bankruptcy. (The position of noncumulative preferred stock is considerably weaker than cumulative preferred stock.) It is because of this second feature that preferred stock is called a *senior security.* It is senior to common stock. On a balance sheet, preferred stock is classified as equity.

Preferred stock may be issued without a maturity date. This is called *perpetual preferred stock.* Almost all preferred stock has a sinking-fund provision, and some preferred stock is convertible into common stock. A trademark product of Morgan Stanley is the Preferred Equity Redemption Cumulative Stock (PERCS). This is a preferred stock with a mandatory conversion at maturity.

RESIDENTIAL MORTGAGE-BACKED SECURITIES

A *residential mortgage-backed security* (RMBS) is an instrument whose cash flow depends on the cash flows of an underlying pool of mortgages. In the U.S. market, RMBS are classified into two groups: agency RMBS and nonagency RMBS. An *agency RMBS,* the subject of Chapter 22, is one issued by the Government National Mortgage Association ("Ginnie Mae''), the Federal Home Loan Mortgage Corporation ("Freddie Mac''), or the Federal National Mortgage Association ("Fannie Mae''). Ginnie Mae is a federal government agency within the Department of Housing and Urban Development. The RMBS issued by this entity is guaranteed by the full faith and credit of the U.S. government. Freddie Mac and Fannie Mae are GSEs. In September 2008, these two entities were placed into conservatorship run by the Federal Housing Finance Agency. The agency RMBS market is the second largest sector of the U.S. bond market as of year-end 2019. In bond indexes such as the Bloomberg Barclays U.S. Aggregate Bond Index, this sector is referred to as simply "mortgage-backed securities" or the "MBS" sector despite the fact that there are also private-label RMBS.

Private-label RMBS, also referred to as *nonagency RMBS* and the subject of Chapter 25, are issued by thrifts, commercial banks, or private conduits that are not backed by any government entity. These securities are structured so as to provide credit enhancement that support the credit ratings that they receive. Up to the Great Financial Crisis of 2008–2009, the private-label RMBS market was divided into two sectors: prime RMBS and subprime RMBS. The classification depended on the credit quality of the pool of borrowers and the type of lien on the properties that were mortgaged.

The primary attribute used to categorize the borrower's credit quality has long been the borrower's Fair Isaacs or FICO credit score or any one of other related measures that are not discussed here (e.g., an income ratio indicating the borrower's ability to pay and the loan-to-value ratio measuring the borrower's equity in the property). Prime borrowers are generally those with FICO scores of 660 or higher. Subprime borrowers are those with impaired credit ratings, typically with FICO scores below 660. However, because of the difficulties faced in the RMBS subprime market that started in the summer of 2007, and the poor performance of the collateral underlying both prime and subprime RMBS, investors no longer draw a sharp distinction between these two sectors of the private-label RMBS market.

RMBS can take three forms: (1) mortgage pass-through securities, (2) collateralized mortgage obligations (CMOs), and (3) stripped mortgage-backed securities. Agency RMBS come in all three forms. Typically, private-label RMBS come only in the second form and, as a result, this sector of the market is referred to as the private-label CMO market.

Agency RMBS expose an investor to *prepayment risk*. This is the risk that the borrowers in a mortgage pool will prepay their loans when interest rates decline. Prepayment risk is effectively the same as call risk faced by an investor in a callable corporate or municipal bond. Private-label RMBS expose investors to both prepayment risk and credit risk, although the major concern by investors in this space is credit risk.

COMMERCIAL MORTGAGE-BACKED SECURITIES

Commercial mortgage-backed securities (CMBSs) are backed by a pool of commercial mortgage loans on income-producing property—multifamily properties (i.e., apartment buildings), office buildings, industrial properties (including warehouses), shopping centers, hotels, and health care facilities (i.e., senior housing care facilities). The basic building block of the CMBS transaction is a commercial loan that was originated either to finance a commercial purchase or to refinance a prior mortgage obligation. There are two major types of CMBS deal structures that have been of interest to bond investors, multi-property single borrowers, and multi-property conduits. The fastest-growing segment of the CMBS is conduit-originated transactions. *Conduits* are commercial-lending entities that are established for the sole purpose of generating collateral to securitize.

Unlike residential mortgage loans, where the lender relies on the ability of the borrower to repay and has recourse to the borrower if the payment terms are not satisfied, commercial mortgage loans are nonrecourse loans. This means that the lender can only look to the income-producing property backing the loan for interest and principal repayment. If there is a default, the lender looks to the proceeds from the sale of the property for repayment and has no recourse to the borrower for any unpaid balance. Basically, this means that the lender must view each property as a stand-alone business and evaluate each property using measures that have been found useful in assessing credit risk.

ASSET-BACKED SECURITIES

Asset-backed securities are securities collateralized by assets that are not mortgage loans. In structuring an asset-backed security, issuers have drawn from the structures used in the mortgage-backed securities market. Asset-backed securities have been structured as pass-throughs and as structures with multiple bond classes called *pay-throughs,* which are similar to CMOs. Credit enhancement is provided by letters of credit, over-collateralization, or senior/subordination.

Three common types of asset-backed securities are those backed by credit card receivables, home equity loans, and automobile loans. Chapters 28 and 29 cover these securities. There are also asset-backed securities supported by a pool of manufactured homes, Small Business Administration (SBA) loans, student loans, boat loans, equipment leases, recreational vehicle loans, senior bank loans, and possibly, the future royalties of your favorite entertainer.

COVERED BONDS

In the wake of the financial crisis of 2008–2009, a bond structure very familiar to European investors—covered bonds—was touted as an alternative funding source for residential mortgage loans. Collateral in the typical European covered bond includes residential/commercial mortgages and public sector debt.

A *covered bond* is a debt instrument secured by a specific pool of collateralizing assets. Covered bonds, the subject of Chapter 26, differ from the typical mortgage-backed security issued in the United States on a number of dimensions. First, the cover pool remains on the issuer's balance sheet rather than being sold to a special-purpose entity. Second, the mortgages in the cover pool serve only as collateral for investors, whereas the covered bond's principal and interest are serviced by the issuer's cash flows. Third, mortgage-backed securities are claims to static pools, whereas the cover pool is dynamic, and nonperforming mortgages must be replaced with performing ones. Fourth, unlike MBS, covered bonds are structured to prevent prepayments before maturity. Finally, investors in covered bonds retain an unsecured claim on the issuer for any shortfall due to them (i.e., unpaid principal and interest).

BEYOND TRADITIONAL LIQUID FIXED INCOME INSTRUMENT

Before the Great Financial Crisis of 2008–2009, traditional liquid fixed income market was the place for investors to get interest rate and credit exposure. Regulatory changes, pressures on banks to rebuild their capital and keep their balance sheet lean, as well as the secular decline in interest rates gave a boost to the rise of private credit since then. Private credit is usually mentioned within the context of *alternative credit*. The concept of alternative credit is very broad and covers a wide range of strategies—including liquid investments like below-investment-grade corporate and securitized bonds, as well as less liquid or illiquid strategies like direct lending, nonperforming loans, and distressed credit.

Private direct lending grew as a result of banks lending less than before the crisis, while borrowers who could not access the public market are still in need of funding. Private debt borrowers can be grouped into residential (e.g., nonqualified mortgage borrowers), commercial real estate (e.g., commercial real estate whole loans), corporate (e.g., middle market direct lending, mezzanine lending), and other categories (e.g., trade finance). By investing in private credit, investors can take advantage of higher expected return since these opportunities reside in less efficient markets, as well as demanding an additional illiquidity premium.

Compared to traditional bond investments when a portfolio manager is buying and selling publicly traded securities, the fund manager of private credit strategies has more direct control over the lending decisions, and, if necessary, is actively involved in the workout process. Investors can get exposure to alternative credit either in a hedge fund structure or in a drawdown structure as private direct lending fund limited partners.

KEY POINTS

- Bonds differ on a number of dimensions, which include type of issuer, maturity, coupon, principal amount, method of redemption, and embedded options.
- Embedded options in a debt instrument are call and refunding provisions, prepayment provisions, optional accelerated provision, put provision, and conversion provision.
- Medium-term notes are highly flexible debt instruments that can be easily structured in response to changing market conditions and investor tastes.
- Structured notes are debt instruments that are linked to a derivative position and allow an issuer to create a customized debt instrument for an investor.
- Preferred stock is a security that shares characteristics of debt and equity.
- Residential RMBS are classified into agency and private-label (also called nonagency) securities.
- There are three types of RMBS: (1) pass-throughs, (2) collateralized mortgage obligations (CMOs), and (3) stripped mortgage-backed securities. Private-label RMBS typically have the CMO structure.
- Asset-backed securities are collateralized by financial assets other than residential mortgages.
- A covered bond is a debt instrument secured by a specific pool of collateral called a collateral pool and remains on the balance sheet of the issuer.
- Alternative credit covers a wide range of strategies such as including liquid investments like below-investment-grade corporate and securitized bonds, as well as less liquid or illiquid strategies like direct lending, nonperforming loans, and distressed credit.

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CHAPTER
TWO

RISKS ASSOCIATED WITH INVESTING IN FIXED INCOME SECURITIES

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The return obtained from a fixed income security from the day it is purchased to the day it is sold can be divided into two parts: (1) the change in market value of the security when it is eventually sold and (2) the cash flows received from the security over the time period that it is held, plus any additional income from reinvestment of the cash flow. Several environmental factors affect one or both of these two parts. We can define the risk associated with any security as a measure of the impact of these factors on the return characteristics of the security.

The different types of risk that an investor in individual fixed income securities is exposed to are as follows:

- Interest-rate risk
- Reinvestment risk
- Call/prepayment risk
- Credit risk
- Inflation, or purchasing-power, risk
- Liquidity risk
- Exchange-rate, or currency, risk

- Volatility risk
- Political or legal risk
- Event risk
- Sector risk

There are also risks associated with bond portfolio strategies. These include statistical measures of portfolio risk and tracking error risk.

Each risk is briefly described in this chapter. A more detailed description of these risks is provided in the chapters that follow.

To manage a bond portfolio, it is important that a manager be able to quantify these risks. In later chapters, multifactor risk models for building and controlling a portfolio's risk profile relative to a bond index or benchmark will be described. These models depend crucially on the ability to measure the primary risk factors. Although not all of the risks described in this chapter are quantifiable, the primary risk factors associated with any bond index and portfolio can be quantified. The key in active bond portfolio management in which the investor's benchmark is a bond index is to quantify the major risk factors so that a portfolio manager who seeks to take a view on some or all of the primary risk factors can do so by constructing a portfolio with a targeted risk profile relative to the benchmark. In the case of passive bond portfolio management, the portfolio manager seeks to match the risk profile of the benchmark.

INTEREST-RATE RISK

Interest-rate risk is the risk associated with an adverse change in interest rates. This risk includes two types of risk: level risk and yield-curve risk. In multifactor risk models described in later chapters, interest-rate risk is referred to as *yield-curve risk* or *term structure risk.*

Level Risk

The price of a typical fixed income security moves in the opposite direction of the change in interest rates: as interest rates rise (fall), the price of a fixed income security will fall (rise).[1] This property is illustrated in Chapter 4. For an investor who plans to hold a fixed income security to maturity, the change in its price before maturity is not of concern, although a decline in the security's market value reflects on the opportunity cost of not investing at a higher yield; however, for an investor who may have to sell the fixed income security before the maturity date, an increase in interest rates will mean the realization of a capital loss. This risk is referred to as *interest-rate risk,* which is one of the primary risks faced by an investor in the fixed income market.

1. There are certain fixed income instruments whose price changes in the same direction as interest rates. Examples are put options and interest-only mortgage-backed securities.

It is customary to represent the market by the yield levels on Treasury securities. Most other yields are compared to the Treasury levels and are quoted as spreads off appropriate Treasury yields. To the extent that the yields of all fixed income securities are interrelated, their prices respond to changes in Treasury rates. As discussed in Chapter 5, the actual magnitude of the price response for any security depends on various characteristics of the security, such as coupon, maturity, and the options embedded in the security (e.g., call and put provisions).

To control interest-rate risk, it is necessary to quantify it. The most commonly used measure of interest-rate risk is *duration.* Duration is the approximate percentage change in the price of a bond or bond portfolio due to a 100-basis point change in yields. This measure and how it is computed is explained in Chapter 5.

Yield-Curve Risk

The yield curve is the graphic depiction of the relationship between the yield on bonds of the same credit quality but different maturities. The yield curve, and a related relationship called the *term structure of interest rates,* will be discussed in more detail in later chapters. A bond portfolio typically contains holdings with different maturities and each bond is subject to interest-rate risk. So, for example, consider two bond portfolios both consisting of three bonds: a 5-year bond, a 10-year bond, and a 20-year bond. The exposure of that portfolio depends on how interest rates change for each of the maturities. Suppose the first bond portfolio has 45% in both the 5-year and 20-year bonds and 10% in the 10-year bond. Suppose that the second bond portfolio has 5% in both the 5-year and 20-year bonds and 90% in the 10-year bond. It is not difficult to understand that the way in which interest rates change on the yield curve can have a substantially different impact on the change in these two bond portfolios.

Yield-curve risk is the exposure of a portfolio to changes in the shape (i.e., movement) of the yield curve. There are various measures that have been suggested for quantifying a portfolio's exposure to changes in the yield curve. The most common measure used is *key rate duration*.

Yield-curve risk is an important risk in bond portfolio management, and with the exception of mortgage-backed securities in which case refinancing risk could impact cohorts of MBS with various coupons and seasoning to a different degree, it is primarily a risk that must be dealt with at the portfolio level.

REINVESTMENT RISK

As explained in Chapter 4, the cash flows received from a security are usually (or are assumed to be) reinvested. The additional income from such reinvestment, sometimes called *interest-on-interest,* depends on the prevailing interest-rate levels at the time of reinvestment, as well as on the reinvestment strategy.

The variability in the returns from reinvestment from a given strategy due to changes in market rates is called *reinvestment risk.* The risk here is that the interest rate at which interim cash flows can be reinvested will fall. Reinvestment risk is greater for longer holding periods. It is also greater for securities with large, early cash flows such as high-coupon bonds. This risk is analyzed in more detail in Chapter 4.

It should be noted that interest-rate risk and reinvestment risk oppose each other. For example, interest-rate risk is the risk that interest rates will rise, thereby reducing the price of a fixed income security. In contrast, reinvestment risk is the risk that interest rates will fall.

CALL/PREPAYMENT RISK

As explained in Chapter 1, bonds may contain a provision that allows the issuer to retire, or "call," all or part of the issue before the maturity date. By including this provision, the issuer retains the right to refinance the bond in the future if market interest rates decline below the coupon rate.

From the investor's perspective, there are three disadvantages of the call provision and hence faces *call risk*. First, the cash-flow pattern of a callable bond is not known with certainty. Second, because the issuer may call the bonds when interest rates have dropped, the investor is exposed to reinvestment risk. That is, the investor will have to reinvest the proceeds received when the bond is called at lower interest rates. Finally, the capital appreciation potential of a bond will be reduced because the price of a callable bond may not rise much above the price at which the issuer may call the bond. (We describe this property of a callable bond, referred to as *negative convexity*, in Chapter 4.)

Agency, corporate, and municipal bonds may have embedded in them the option on the part of the borrower to call, or terminate, the issue before the stated maturity date. All mortgage-backed securities have this option. Even though the investor is usually compensated for taking the risk of call by means of a lower price or a higher yield, it is not easy to determine if this compensation is sufficient. In any case, the returns from a bond with call risk can be dramatically different from those obtained from a noncallable bond. The magnitude of this risk depends on the various parameters of the call, as well as on market conditions.

In the case of mortgage-backed securities, the cash flow depends on prepayments of principal made by the homeowners in the pool of mortgages that is the collateral for the security. Call risk in this case is called *prepayment risk.* It includes *contraction risk*—the risk that homeowners will prepay all or part of their mortgage when mortgage interest rates decline. The risk that prepayments will slow down when mortgage interest rates rise and force an investor who expected that the pool of mortgages would prepay at a faster rate is called *extension risk.*

CORPORATE CREDIT RISK

The *credit risk* of a bond includes:

1. The risk that the issuer will default on its obligation

2. The risk that the bond's value will decline and/or the bond's price performance will be worse than that of other bonds against which the investor is compared because either (a) the market requires a higher spread due to a perceived increase in the risk that the issuer will default or (b) companies that assign ratings to bonds will lower a bond's rating

The first risk is referred to as *default risk*. The second risk is labeled based on the reason for the adverse or inferior performance. The risk attributable to an increase in the spread or, more specifically, the credit spread demanded by the market, is referred to as *credit-spread risk*; the risk attributable to a lowering of the credit rating (i.e., a downgrading) is referred to as *downgrade risk*.

Credit-risk-bearing bonds are traded at higher yield levels than presumably credit-risk-free government bonds with similar maturity. This credit spread offers investors with (1) protection against credit default, and (2) extra yield compensation against taking credit risk. In case no credit event happens, such as default or downgrade, the investor would ideally harvest all the credit spread as excess return over government bonds. At the other extreme, in a theoretical "risk-neutral world," investors would not require extra compensation for risk taking, so all the spread would simply compensate realized credit losses.

In practice, the reality is somewhere in between these two extremes: credit events happen, reducing the excess return relative to the initial credit spreads, but over the long term, credit spreads still turn into some excess return for a well-diversified long-term credit investor. Rising credit spread levels, nevertheless, reflect increased expectation of coming credit losses, as well as more elevated risk aversion. In a risk-neutral world, a one-year credit risk bearing bond, say, 2% probability of default with zero recovery rate, would be fairly "compensated" with a 2.1% spread (or about 1.0% with a 50% recovery rate). However, should default happen, the 100% loss on a single bond would be devastating, so diversification is critical for a corporate bond portfolio. Note, however, that the average spread level of the Bloomberg Barclays U.S. Aggregate Corporate Bond index has been 1.34% from January 1988 to May 2020, whereas the default rate of investment-grade bonds have stayed below 0.5% every year (0.1% per year on average) between 1981 and 2019 based on S&P Global Rating reports.[2] This suggests that credit spreads offer extra compensation to investors beyond covering credit losses over the long term.

A *credit rating* is a formal opinion given by a specialized company of the default risk faced by investing in a particular issue of debt securities. The specialized companies that provide credit ratings are referred to as *rating agencies*. The three nationally recognized rating agencies in the United States are Moody's Investors Service, Standard & Poor's Corporation, and Fitch Ratings. The symbols used by these rating agencies and a summary description of each rating are given in Chapter 10.

2. S&P Global Ratings, "Default, Transition, and Recovery: 2019 Annual Global Corporate Default and Rating Transition Study." April 2020.

Once a credit rating is assigned to a debt obligation, a rating agency monitors the credit quality of the issuer and can reassign a different credit rating to its bonds. An "upgrade" occurs when there is an improvement in the credit quality of an issue; a "downgrade" occurs when there is a deterioration in the credit quality of an issue. As noted earlier, downgrade risk is the risk that an issue will be downgraded.

Typically, before an issue's rating is changed, the rating agency will announce in advance that it is reviewing the issue with the potential for upgrade or downgrade. The issue in such cases is said to be on "rating watch" or "credit watch." In the announcement, the rating agency will state the direction of the potential change in rating—upgrade or downgrade. Typically, a decision will be made within three months.

In addition, rating agencies will issue rating outlooks. A *rating outlook* is a projection of whether an issue in the long term (from six months to two years) is likely to be upgraded, be downgraded, or maintain its current rating. Rating agencies designate a rating outlook as either positive (i.e., likely to be upgraded), negative (i.e., likely to be downgraded), or stable (i.e., likely to be no change in the rating).

Gauging Default Risk and Downgrade Risk

The information available to investors from rating agencies about credit risk are (1) ratings, (2) rating watches or credit watches, and (3) rating outlooks. A study by Moody's found that for corporate bonds, its ratings combined with its rating watches and rating outlook status provide a better gauge for default risk than using the ratings alone.[3] Moreover, periodic studies by the rating agencies provide information to investors about credit risk.

Below we describe how the information provided by rating agencies can be used to gauge two forms of credit risk: default risk and downgrade risk.

For long-term debt obligations, a credit rating is a forward-looking assessment of (1) the probability of default and (2) the relative magnitude of the loss should a default occur. For short-term debt obligations (i.e., obligations with initial maturities of one year or less), a credit rating is a forward-looking assessment of the probability of default. Consequently, credit ratings are the rating agencies' assessments of the default risk associated with a bond issue.

Periodic studies by rating agencies provide information about two aspects of default risk—default rates and default loss rates. First, rating agencies study and make available to investors the percentage of bonds of a given rating at the beginning of a period that have defaulted at the end of the period. This percentage is referred to as the *default rate*. A *default loss rate* is a measure of the magnitude of the potential of the loss should a default occur.

Rating transition tables published periodically by rating agencies also provide information. A rating transition table shows the percentage of issues of each rating at the beginning of a period that were downgraded or upgraded by the end

3. David T. Hamilton and Richard Cantor, "Rating Transitions and Defaults Conditional on Watchlist, Outlook and Rating History," Moody's Investors Service, February 2004.

of the time period. Consequently, by looking at the percentage of downgrades for a given rating, an estimate can be obtained of the probability of a downgrade, and this can serve as a measure of downgrade risk.

Credit Risk Models

Beyond credit ratings, portfolio managers are employing other methodologies for estimating the probability distribution of losses for a bond portfolio in order to compute loss measures such as value at risk (VaR) and conditional VaR (CVaR). For banks, there have been changes in the supervisory framework, as put forward in the Basel II Capital Accord, that require new tools and concepts for measuring credit risk and the development of an internal rating system (IRB), as well as the collection of detailed data on credit exposures and recovery rates. These new tools and concepts will aid banks in evaluating and managing their credit risk profile.

Models for credit risks have long existed in the actuarial and corporate finance literatures. The traditional models concentrate on default rates, credit ratings, and credit risk premiums and focus on diversification, making the assumption that default risks are idiosyncratic and hence can be diversified away in large portfolios. For single isolated credits, the models calculate risk premiums as markups onto the risk-free rate. Since the mid-1990s, however, there have been major advances in modeling credit risk for estimating the probability distribution of losses for a bond portfolio. The models are divided into three categories: structural models, reduced-form models, and incomplete-information models. Each of these models is described in Chapter 42.

SOVEREIGN CREDIT RISK[4]

While we often speak about government bonds in terms of "risk-free" assets, in reality, sovereign issuers are not free of credit risk either. *Sovereign credit risk* has periodically become a concern, and while over the past decades, government defaults were mainly associated with developing and emerging countries, government balance sheets of developed markets can come under pressure as well. Governments in the United States and across Europe have accumulated significant debt by stimulating the economy after the Global Financial Crisis, and would potentially add to the sovereign debt as result of the additional stimulus packages that have been introduced during the COVID-19 pandemic.

Sovereign debt covers the outstanding debt obligations of the federal government, central administration, local governments, and all entities that borrow with an explicit guarantee from the government. Sovereign credit risk is the possibility

4. This discussion is based on Adam Kobor, "Sovereign Credit Risk Assessment: From Traditional Indicators to The Contingent Claim Approach," in Jerome L. Kreuser (ed.), *Risk Management for Sovereign Institutions: The Marketing & Management Collection*, Henry Stewart Talks Ltd, London 2012 (online at https://hstalks.com/expert/2134/dr-adam-kobor/).

that the government may default on its debt, thus it fails to service its interest and principal payment obligations in a timely manner. As discussed in the previous section in the context of corporate credit risk, sovereign credit risk can also impact investors by not only losing all or more typically part of the principal, but in many other forms as well. Credit risk may manifest in debt restructuring by credit downgrade, or significant spread widening as the market is anticipating a default.

While the concept of a credit default in principle is the same for sovereigns and corporate issuers, sovereign borrowers and corporations also differ in many respects. In the case of sovereigns, a default occurs either because the borrower is not able to repay its debt, or particularly in the case of local currency debt, because it is unwilling to service its obligation. Sovereigns, unlike corporations, do not go bankrupt, and a sovereign default may be a result of choice, by taking political and social as well as economic and financial consequences into account. With that in mind, why are investors willing to lend money to sovereigns? Unlike in the case of corporate debt, there are very limited legal means to reinforce the contract, especially in the case of domestic debt. Still, there are several incentives for a government to honor its debt. First, a default hugely deteriorates a country's market access and reputation and makes future borrowings particularly difficult and expensive. Second, a default can very negatively impact trade relations with other countries, and broad international relations and alliances can be also damaged by a default.

INFLATION, OR PURCHASING-POWER, RISK

Inflation risk, or *purchasing-power risk,* arises because of the variation in the value of cash flows from a security due to inflation, as measured in terms of purchasing power. For example, if an investor purchases a five-year bond in which he or she can realize a coupon rate of 7%, but the rate of inflation is 8%, then the purchasing power of the cash flow has declined. For all but inflation-linked securities (sometime referred to as "linkers"), an investor is exposed to inflation risk because the interest rate the issuer promises to make is fixed for the life of the security. To the extent that interest rates reflect the expected inflation rate, floating-rate bonds have a lower level of inflation risk than fixed-rate bonds.

LIQUIDITY RISK

Liquidity risk is the risk that the investor will have to sell a bond below its true value where the true value is indicated by a recent transaction. The primary measure of liquidity is the size of the spread between the bid price and the ask price quoted by a dealer. The wider the bid/ask spread, the greater is the liquidity risk.

A liquid market generally can be defined by "small bid/ask spreads which do not materially increase for large transactions."[5] How to define the bid/ask

5. Robert I. Gerber, "A User's Guide to Buy-Side Bond Trading," Chapter 16 in Frank J. Fabozzi (ed.), *Managing Fixed Income Portfolios* (New Hope, PA: Frank J. Fabozzi, 1997), p. 278.

spread in a multiple-dealer market is subject to interpretation. For example, consider the bid/ask spread for four dealers. Each quote is for 92 plus the number of 32nds shown:

	Dealer			
	1	2	3	4
Bid price	1	1	2	2
Ask price	4	3	4	5

The bid/ask spread for each dealer (in 32nds) is

	Dealer			
	1	2	3	4
Bid/ask spread	3	2	2	3

The bid/ask spread as computed above is measured relative to a dealer. The best bid/ask spread is two 32nds for Dealers 2 and 3.

From the perspective of the *market overall,* the bid/ask spread can be computed by looking at the best bid price (high price at which one of the dealers is willing to buy the security) and the lowest ask price (lowest offer price at which one of the dealers is willing to sell the security). This liquidity measure is called the *market bid/ask spread.* For the four dealers, the highest bid price is 92 plus two 32nds and the lowest ask price is 92 plus three 32nds. Thus, the market bid/ask spread is one 32nd.

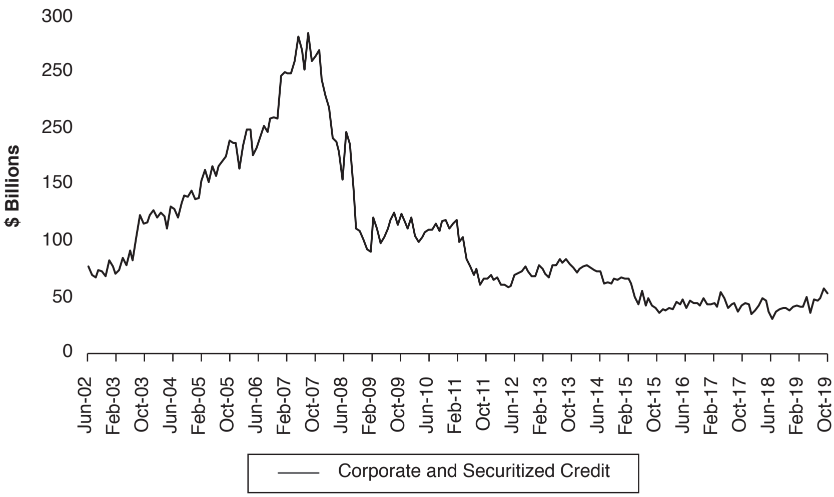
For investors who plan to hold a bond until maturity and need not mark a position to market, liquidity risk is not a major concern. An institutional investor who plans to hold an issue to maturity but is periodically marked to market is concerned with liquidity risk. By marking a position to market, it is meant that the security is revalued in the portfolio based on its current market price. For example, mutual funds are required to mark to market at the end of each day the holdings that are in their portfolio in order to compute the net asset value (NAV). While other institutional investors may not mark to market as frequently as mutual funds, they are marked to market when reports are periodically sent to clients or the board of directors or trustees.

Where are the prices obtained to mark a position to market? Typically, a portfolio manager will solicit indicative bids from several dealers and then use some process to determine the bid price used to mark the position. The less liquid the issue, the greater the variation there will be in the bid prices obtained from dealers. With an issue that has little liquidity, the price may have to be determined by a pricing service rather than by dealers. Moreover, lack of dealer indicative bids and concern with models used by pricing services may lead the manager to occasionally override a bid (subject to internal approval beyond the control of the manager).

Investors have faced challenging general fixed income market liquidity conditions several times over the recent years. Market liquidity is the capacity to sell or buy securities over reasonably short period of time without an adverse impact on the security prices. Traditionally, brokers/dealers have provided liquidity to the fixed income market, but regulatory changes following the Global Financial Crisis have reduced this liquidity-providing capacity.[6] Elevated bank capital requirements by the Dodd–Frank Act, and prohibitions on proprietary trading by the Volcker Rule have led to shrinking dealer inventories, and thus to declining bond market liquidity, following the crisis (see Exhibit 2-1). This shrinkage in dealer inventory did not only lead to a choppier bond market liquidity, but a declining repo market liquidity at the same time, especially challenging to investors during times close to quarter or year ends, as well as market stress periods like the outbreak of COVID-19.

EXHIBIT 2-1

Primary Dealer Position: Corporate and Securitized Credit



Source of data: Federal Reserve Bank of New York.

Another relatively recent market development has been the introduction of fixed income exchange-traded funds (ETFs). While bonds are typically traded in an over-the-counter market, fixed income ETFs made it easy for retail as well as

6. Arnab Das, Jennifer Johnson-Calari, and Adam Kobor, "Managing Liquidity Risk," Central Bank Whitepaper, INVESCO, October 20, 2017.

institutional investors to increase or reduce their portfolio's fixed income exposures by one click at an exchange traded market. Under a healthy market conditions, investors can buy and sell these fixed income index-replicating (and other, more exotic) products in a very short time, while the Authorized Participant may create or redeem shares in the underlying bond market if and as needed. During dried-up liquidity conditions, while investors could still trade these ETFs with a single click, the ETF prices and NAV could significantly deviate from each other, suggesting that investors cannot fully escape the adverse impact of the lack of liquidity in the underlying market.

EXCHANGE-RATE RISK (CURRENCY RISK)

A non-dollar-denominated bond (i.e., a bond whose payments occur in a foreign currency) has unknown U.S. dollar cash flows. The dollar cash flows are dependent on the foreign-exchange-rate at the time the payments are received. For example, suppose that an investor purchases a bond whose payments are in Japanese yen. If the yen depreciates relative to the U.S. dollar, then fewer dollars will be received. The risk of this occurring is referred to as *exchange-rate risk,* or *currency risk.* Of course, should the yen appreciate relative to the U.S. dollar, the investor will benefit by receiving more dollars.

In addition to the change in the exchange-rate, an investor is exposed to the interest-rate, or market, risk in the local market. For example, if a U.S. investor purchases German government bonds denominated in euros, the proceeds received from the sale of that bond prior to maturity will depend on the level of interest rates in the German bond market, in addition to the exchange-rate.

VOLATILITY RISK

As will be explained in later chapters, the price of a bond with an embedded option depends on the level of interest rates and factors that influence the value of the embedded option. One of the factors is the expected volatility of interest rates. Specifically, the value of an option rises when expected interest-rate volatility increases. In the case of a callable bond or mortgage-backed security, because the investor has granted an option to the borrower, the price of the security falls because the investor has given away a more valuable option. The risk that a change in volatility will adversely affect the price of a security is called *volatility risk.*

Multifactor risk models often refer to volatility risk as *vega*. This is because in option theory, there are measures of the exposure of an option to changes in the factors that affect an option's value. One of the factors is volatility, and vega is the term used to measure the sensitivity of an option's price to a change in volatility. Hence, the sensitivity of bonds with embedded options and a bond portfolio containing bonds with embedded options to changes in volatility is given the same name.

POLITICAL OR LEGAL RISK

Sometimes the government can declare withholding or other additional taxes on a bond or declare a tax-exempt bond taxable. In addition, a regulatory authority can conclude that a given security is unsuitable for investment entities that it regulates. These actions can adversely affect the value of the security. Similarly, it is also possible that a legal or regulatory action affects the value of a security positively. The possibility of any political or legal actions adversely affecting the value of a security is known as *political* or *legal risk*.

To illustrate political or legal risk, consider investors who purchase tax-exempt municipal securities. They are exposed to two types of political risk that can be more appropriately called *tax risk*. The first type of tax risk is that the federal income tax rate will be reduced. The higher the marginal tax rate, the greater is the value of the tax-exempt nature of a municipal security. As the marginal tax rates decline, the price of a tax-exempt municipal security will decline. For example, proposals for a flat tax with a low tax rate significantly reduced the potential tax advantage of owning municipal bonds. As a result, tax-exempt municipal bonds began trading at lower prices. The second type of tax risk is that a municipal bond issued as tax exempt eventually will be declared taxable by the Internal Revenue Service (IRS). This may occur because many municipal (revenue) bonds have elaborate security structures that could be subject to future adverse congressional actions and IRS interpretations. As a result of the loss of the tax exemption, the municipal bond will decline in value in order to provide a yield comparable to similar taxable bonds.

EVENT RISK

Occasionally, the ability of an issuer to make interest and principal payments is seriously and unexpectedly changed by (1) a natural disaster or industrial accident or (2) a takeover or corporate restructuring. These risks are referred to as *event risk*. The cancellation of plans to build a nuclear power plant illustrates the first type of event in relation to the utility industry.

An example of the second type of event risk is the takeover in 1988 of RJR Nabisco for $25 billion via a financing technique known as a *leveraged buyout* (LBO). In such a transaction, the new company incurred a substantial amount of debt to finance the acquisition of the firm. Because the corporation was required to service a substantially larger amount of debt, its quality rating was reduced to non-investment-grade quality. As a result, the change in yield spread to a benchmark Treasury, demanded by investors because of the LBO announcement, increased from about 100 to 350 basis points.

There are also spillover effects of event risk on other firms. For example, if there is a nuclear accident, this will affect all utilities producing nuclear power.

SECTOR RISK

Bonds in different sectors of the market respond differently to environmental changes because of a combination of some or all of the preceding risks, as well as others. Examples include discount versus premium coupon bonds, industrial versus utility bonds, and corporate versus mortgage-backed bonds. The possibility of adverse differential movement of specific sectors of the market is called *sector risk.*

OTHER RISKS

The various risks of investing in the fixed income markets reviewed in this chapter do not represent the entire range of risks. In the marketplace, it is customary to combine almost all risks other than market risk (interest-rate risk) and refer to it as *basis risk.*

STATISTICAL MEASURES OF PORTFOLIO RISK

In the development of portfolio theory as formulated by Harry Markowitz (also known as mean-variance analysis), a portfolio's risk is measured by the *standard deviation* of historical portfolio returns.[7] This statistical measure provides a range around the average return of a portfolio within which the actual return over a period is likely to fall with some specific probability. In evaluating actual and potential performance relative to a benchmark that is a bond index, the mean return and standard deviation of returns of the bond index and the portfolio are compared.

In addition to the standard deviation of returns, investors may be interested in various measures quantifying the downside risk they are facing. *Value at risk* (VaR) would quantify the lowest return over a specified time horizon they should expect at a certain (e.g., 95% or 99%) confidence level. *Drawdown at risk* (DaR) would indicate the lowest cumulative return from a portfolio peak to trough either based on historical and Monte Carlo simulation analysis.

Extensions of portfolio risk to take into account other statistical measures of a return distribution are being used in practice.[8] Two statistical measures most commonly used are skewness and kurtosis. A return distribution is said to be symmetric based on the probability distribution around the mean or expected value. If the return distribution is the same above and below the mean value, then the distribution is said to be symmetric. If a return distribution does not exhibit this property, it is said to be *asymmetric. Skewness* is a measure of the symmetry of a return distribution. Actually, it is more meaningful to say that skewness is a

7. Harry M. Markowitz, "Portfolio Selection," *Journal of Finance* 7(1), 1952, pp. 77–91.

8. Svetlozar T. Rachev, Christian Menn, and Frank J. Fabozzi, *Fat-Tailed and Skewed Asset Return Distributions: Implications for Risk Management, Portfolio Selection, and Option Pricing* (New York: John Wiley & Sons, 2005).

measure of the lack of symmetry of the return distribution. The normal distribution is a symmetric distribution. Consequently, when the return distribution is assumed to be normally distributed, skewness is not a concern. Return on fixed income securities or portfolios in fact exhibit some negative skewness: callability, refinanceability. Moreover, credit defaults contribute to a longer downside tail compared to the upside.

Kurtosis is a statistical measure of whether a return distribution is peaked or flat relative to a normal distribution. That is, a return distribution with high kurtosis tends to have a distinct peak near the mean value, decline rather rapidly, and have fat (or heavy) tails. This property for a return distribution occurs when in addition to many modest-sized deviations from the mean value there are also infrequent extreme deviations from the mean value. Return distributions that exhibit low kurtosis tend to have a flat top near the mean value rather than a sharp peak. Credit spreads exhibit much larger jumps during stressful periods than under normal conditions, thus the total return of credit risk dominated portfolios usually exhibits heavy tails.

TRACKING ERROR RISK

A bond portfolio's standard deviation and a designated benchmark's standard deviation are absolute numbers. A portfolio manager can compare the mean values and standard deviations to try to get a feel for the risk profile of the portfolio relative to the benchmark. If skewness and kurtosis are also considered, this would provide an expanded profile of the relative risks of the bond portfolio and the bond index.

A portfolio manager or client can also assess what the variation in the portfolio's return is relative to a benchmark (such as a bond index) by looking at the deviations of the periodic (weekly or monthly) portfolio return from that of the benchmark. The difference between the two is called the *active return*. That is,

Active return = Portfolio's actual return – Benchmark's actual return

From the active returns, a portfolio's risk relative to the benchmark can be calculated by the standard deviation of the active returns. This standard deviation is referred to as *tracking error risk* or *tracking error volatility,* or simply *tracking error*.

The larger a portfolio's tracking error, the more its risk profile deviates from that of the benchmark. In fact, when bond portfolio strategies are discussed in later chapters, we will see that there are active and passive strategies. The latter strategies involve little tracking error. For example, a portfolio constructed to match the performance of a bond index will have a tracking error close to zero. Active strategies will have higher tracking error, how much higher depends on the degree of risk the portfolio manager or client is willing to accept.

There are two types of tracking error. Tracking error calculated from a portfolio's historical active returns is called *backward-looking tracking error*. It is also called *historical tracking error* and *ex-post tracking error*. The limitation of backward-looking tracking error is that it fails to take into account the effect of current decisions by the portfolio manager on the future active returns and therefore may have little predictive value and can be misleading regarding the portfolio risks going forward. The other type of tracking error is *forward-looking tracking error*—also called *predicted tracking error* and *ex-ante tracking error*. This form of tracking error seeks to accurately reflect the portfolio's risk going forward. In practice, forward-looking tracking error is estimated using a multifactor risk model as described in Chapters 49 and 50.

KEY POINTS

- The risks associated with investing in individual fixed income securities are interest-rate risk, reinvestment risk, call/prepayment risk, credit risk, inflation (or purchasing-power) risk, liquidity risk, exchange-rate (or currency) risk, volatility risk, political or legal risk, event risk, and sector risk.
- Interest-rate risk is the risk associated with an adverse change in interest rates and includes level risk and yield-curve risk. The most popular measure of level risk is duration; key rate duration is the most popular measure of yield-curve risk.
- Credit risk includes default risk, credit-spread risk, and downgrade risk. Credit risk models seek to estimate the probability distribution of losses for a bond portfolio.
- Portfolio risk measures include statistical measures of return and tracking error risk.
- Statistical measures of portfolio and benchmark risk include the standard deviation, skewness, and kurtosis.
- Tracking error risk is the standard deviation of the active return of a portfolio (i.e., the difference between the portfolio's return and the benchmark's return). Backward-looking tracking error is used to assess a portfolio's performance relative to a benchmark. Forward-looking tracking error is used to predict future performance relative to a benchmark.

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CHAPTER
THREE

THE STRUCTURE OF INTEREST RATES

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There is no single interest rate for any economy; rather, there is an interdependent structure of interest rates. The interest rate that a borrower has to pay depends on a myriad of factors. In this chapter we describe these factors. We begin with a discussion of the *base interest rate:* the interest rate on U.S. government securities. Next, we explain the factors that affect the yield spread or risk premium for non-Treasury securities. Finally, we focus on one particular factor that affects the interest rate demanded in an economy for a particular security: maturity. The relationship between yield and maturity (or term) is called the *term structure of interest rates*, and this relationship is critical in the valuation of securities.

THE BASE INTEREST RATE

The securities issued by the U.S. Department of the Treasury are backed by the full faith and credit of the U.S. government. Despite the credit concerns arising from the U.S. budget deficit and the downgrading of the U.S. government credit rating from triple A to AA+ by the credit rating agency of Standard & Poor's in August 2011 (Moody's and Fitch still maintained a triple A rating but Fitch had a negative outlook as of July 2020), market participants throughout the world view U.S. government obligations as having minimal credit risk. Therefore, interest rates on Treasury securities are the benchmark interest rates throughout the U.S. economy. The large sizes of Treasury issues have contributed to making the Treasury market the most active and hence the most liquid market in the world.

The minimum interest rate or *base interest rate* that investors will demand for investing in a non-Treasury security is the yield offered on a comparable maturity for an on-the-run Treasury security. The base interest rate is also referred to as the *benchmark interest rate.*

RISK PREMIUM

Market participants describe interest rates on non-Treasury securities as trading at a spread to a particular on-the-run Treasury security. For example, if the yield on a 10-year non-Treasury security is 5% and the yield on a 10-year Treasury security is 4%, the spread is 100 basis points. This spread reflects the additional risks the investor faces by acquiring a security that is not issued by the U.S. government and therefore can be called a *risk premium*. Thus we can express the interest rate offered on a non-Treasury security as

Base interest rate + spread

or equivalently,

Base interest rate + risk premium

The factors that affect the spread include (1) the type of issuer, (2) the issuer's perceived creditworthiness, (3) the term or maturity of the instrument, (4) provisions that grant either the issuer or the investor the option to do something, (5) the taxability of the interest received by investors, and (6) the expected liquidity of the issue.

Types of Issuers

A key feature of a debt obligation is the nature of the issuer. In addition to the U.S. government, there are agencies of the U.S. government, municipal governments, corporations (domestic and foreign), and foreign governments that issue bonds.

The bond market is classified by the type of issuer. These are referred to as *market sectors*. The spread between the interest rate offered in two sectors of the bond market with the same maturity is referred to as an *intermarket-sector spread*.

Excluding the Treasury market sector, other market sectors have a wide range of issuers, each with different abilities to satisfy bond obligations. For example, within the corporate market sector, issuers are classified as utilities, transportations, industrials, and banks and finance companies. The spread between two issues within a market sector is called an *intramarket-sector spread*.

Perceived Creditworthiness of Issuer

Default risk or *credit risk* refers to the risk that the issuer of a bond may be unable to make timely payment of principal or interest payments. Most market participants rely primarily on commercial rating companies (Fitch Ratings, Moody's Investors Service, and Standard & Poor's) to assess the default risk of an issuer. The spread between Treasury securities and non-Treasury securities that are identical in all respects except for quality is referred to as a *credit spread* or *quality spread*.

Term-to-Maturity

As explained in Chapter 4, the price of a bond will fluctuate over its life as yields in the market change. As demonstrated in Chapter 5, the volatility of a bond's price is dependent on its maturity. With all other factors constant, the longer the maturity of a bond, the greater is the price volatility resulting from a change in market yields.

The spread between any two maturity sectors of the market is called a *yield-curve spread* or *maturity spread.* The relationship between the yields on comparable securities with different maturities, as mentioned earlier, is called the *term structure of interest rates*.

The term-to-maturity topic is very important, and we have devoted more time to this topic later in this chapter.

Inclusion of Options

It is not uncommon for a bond issue to include a provision that gives the bondholder or the issuer an option to take some action against the other party. An option that is included in a bond issue is referred to as an *embedded option.* We discussed the various types of embedded options in Chapter 1. The most common type of option in a bond issue is the call provision, which grants the issuer the right to retire the debt, fully or partially, before the scheduled maturity date. The inclusion of a call feature benefits issuers by allowing them to replace an old bond issue with a lower-interest-cost issue when interest rates in the market decline. In effect, a call provision allows the issuer to alter the maturity of a bond. The exercise of a call provision is disadvantageous to the bondholder because the bondholder must reinvest the proceeds received at a lower interest rate.

The presence of an embedded option affects both the spread of an issue relative to a Treasury security and the spread relative to otherwise comparable issues that do not have an embedded option. In general, market participants will require a larger spread to a comparable Treasury security for an issue with an embedded option that is favorable to the issuer (such as a call option) than for an issue without such an option. In contrast, market participants will require a smaller spread to a comparable Treasury security for an issue with an embedded option that is favorable to the investor (such as a put option or a conversion option). In fact, the interest rate on a bond with an option that is favorable to an investor may be less than that on a comparable Treasury security.

Taxability of Interest

Unless exempted under the federal income tax code, interest income is taxable at the federal level. In addition to federal income taxes, there may be state and local taxes on interest income.

The federal tax code specifically exempts the interest income from qualified municipal bond issues. Because of this tax exemption, the yield on municipal bonds is less than on Treasuries with the same maturity. The difference in yield between tax-exempt securities and Treasury securities is typically measured not in basis points but in percentage terms. More specifically, it is measured as the percentage of the yield on a tax-exempt security relative to a comparable Treasury security.

The yield on a taxable bond issue after federal income taxes are paid is equal to

$$\text{After-tax yield} = \text{pretax yield} \times (1 - \text{marginal tax rate})$$

For example, suppose that a taxable bond issue offers a yield of 4% and is acquired by an investor facing a marginal tax rate of 35%. The after-tax yield would be

$$\text{After-tax yield} = 0.04 \times (1 - 0.35) = 0.026 = 2.60\%$$

Alternatively, we can determine the yield that must be offered on a taxable bond issue to give the same after-tax yield as a tax-exempt issue. This yield is called the *equivalent taxable yield* and is determined as follows:

$$\text{Equivalent taxable yield} = \frac{\text{tax-exempt yield}}{(1 - \text{marginal tax rate})}$$

For example, consider an investor facing a 35% marginal tax rate who purchases a tax-exempt issue with a yield of 2.6%. The equivalent taxable yield is then

$$\text{Equivalent taxable yield} = \frac{0.026}{(1 - 0.35)} = 0.04 = 4\%$$

Notice that the lower the marginal tax rate, the lower is the equivalent taxable yield. For example, in our previous example, if the marginal tax rate is 25% rather than 35%, the equivalent taxable yield would be 3.47% rather than 4%, as shown below.

$$\text{Equivalent taxable yield} = \frac{0.026}{(1 - 0.25)} = 0.0347 = 3.47\%$$

State and local governments may tax interest income on bond issues that are exempt from federal income taxes. Some municipalities exempt interest income from all municipal issues from taxation; others do not. Some states exempt interest income from bonds issued by municipalities within the state but tax the interest income from bonds issued by municipalities outside the state. The implication is that two municipal securities of the same quality rating and the same maturity may trade at some spread because of the relative demand for bonds of municipalities in different states. For example, in a high-income-tax state such as New York, the demand for bonds of municipalities will drive down their yield relative to municipalities in a low-income-tax state, holding all credit issues aside.

Municipalities are not permitted to tax the interest income from securities issued by the U.S. Treasury. Thus part of the spread between Treasury securities and taxable non-Treasury securities of the same maturity reflects the value of the exemption from state and local taxes.

Expected Liquidity of an Issue

Bonds trade with different degrees of liquidity. The greater the expected liquidity at which an issue will trade, the lower is the yield that investors require. As noted earlier, Treasury securities are the most liquid securities in the world. The lower yield offered on Treasury securities relative to non-Treasury securities reflects the difference in liquidity as well as perceived credit risk. Even within the Treasury market, on-the-run issues have greater liquidity than off-the-run issues.

THE TERM STRUCTURE OF INTEREST RATES

In future chapters we will see the key role that the term structure of interest rates plays in the valuation of bonds. For this reason, we devote a good deal of space to this important topic.

The Yield Curve

The graphic depiction of the relationship between the yield on bonds of the same credit quality but different maturities is known as the *yield curve*. In the past, most market participants have constructed yield curves from the observations of prices and yields in the Treasury market. Two reasons account for this tendency. First, Treasury securities are viewed as free of default risk, and differences in creditworthiness do not affect yield estimates. Second, as the most active bond market, the Treasury market offers the fewest problems of illiquidity or infrequent trading. Exhibit 3-1 shows the shape of three hypothetical Treasury yield curves that have been observed in the United States, as well as other countries.

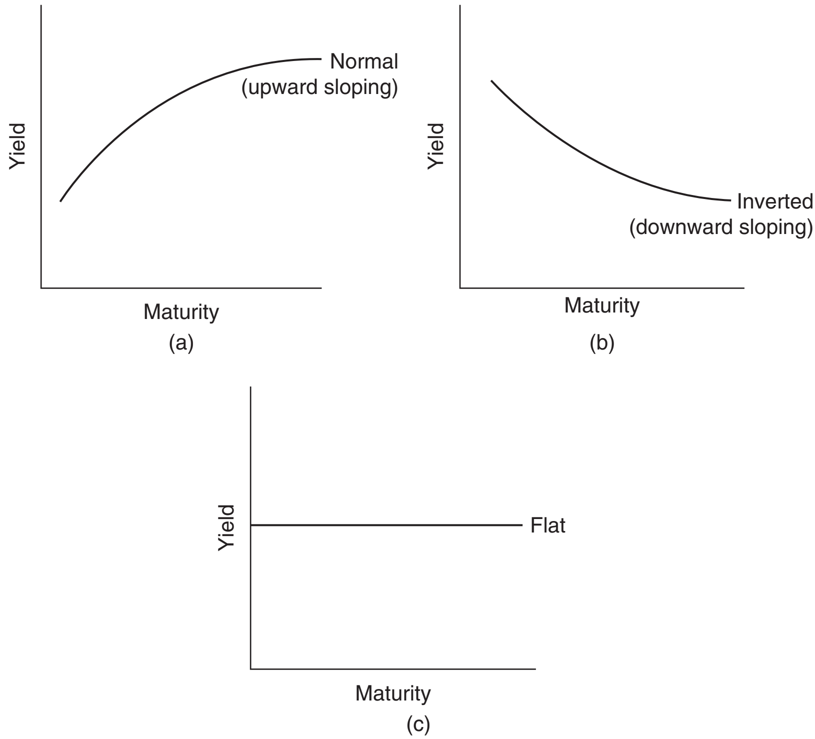
From a practical viewpoint, as we explained earlier in this chapter, the key function of the Treasury yield curve is to serve as a benchmark for pricing bonds and setting yields in other sectors of the debt market. However, market participants are coming to realize that the traditionally constructed Treasury yield curve is an unsatisfactory measure of the relation between required yield and maturity. The key reason is that securities with the same maturity actually may carry different yields. As we will explain, this phenomenon reflects the impact of differences in the bonds' coupon rates. Hence it is necessary to develop more accurate and reliable estimates of the Treasury yield curve. We will show the problems posed by traditional approaches to the Treasury yield curve, and we will explain the proper approach to building a yield curve. The approach consists of identifying yields that apply to zero-coupon bonds and, therefore, eliminates the problem of nonuniqueness in the yield-maturity relationship.

Using the Yield Curve to Price a Bond

The price of a bond is the present value of its cash flows. However, in the pricing of a bond as explained in Chapter 4, it is assumed that one interest rate should be used to discount all the bond's cash flows. The appropriate interest rate is the

EXHIBIT 3-1

Three Hypothetical Yield Curves



yield on a Treasury security with the same maturity as the bond plus an appropriate risk premium or spread.

However, there is a problem with using the Treasury yield curve to determine the appropriate yield at which to discount the cash flow of a bond. To illustrate this problem, consider two hypothetical five-year Treasury securities, A and B. The difference between these two Treasury securities is the coupon rate, which is 12% for A and 3% for B. The cash flow for these two securities per $100 of par value for the 10 six-month periods to maturity would be as follows:

Period	Cash Flow for A	Cash Flow for B
1–9	$ 6.00	$ 1.50
10	106.00	101.50

Because of the different cash flow patterns, it is not appropriate to use the same interest rate to discount all cash flows. Instead, each cash flow should be discounted at a unique interest rate that is appropriate for the time period in which the cash flow will be received. But what should be the interest rate for each period?

The correct way to think about Treasury securities A and B is not as a debt instrument but as packages of cash flows. More specifically, they are packages of zero-coupon instruments. Thus the interest earned is the difference between the maturity value and the price paid. For example, security A can be viewed as 10 zero-coupon instruments: One with a maturity value of $6 maturing six months from now, a second with a maturity value of $6 maturing one year from now, a third with a maturity value of $6 maturing 1.5 years from now, and so on. The final zero-coupon instrument matures 10 six-month periods from now and has a maturity value of $106. Likewise, security B can be viewed as 10 zero-coupon instruments: One with a maturity value of $1.50 maturing six months from now, one with a maturity value of $1.50 maturing one year from now, one with a maturity value of $1.50 maturing 1.5 years from now, and so on. The final zero-coupon instrument matures 10 six-month periods from now and has a maturity value of $101.50. Obviously, in the case of each coupon security its value or price is equal to the total value of its component zero-coupon instruments.

In general, any bond can be viewed as a package of zero-coupon instruments. That is, each zero-coupon instrument in the package has a maturity equal to its coupon payment date or, in the case of the principal, the maturity date. The value of the bond should equal the value of all the component zero-coupon instruments. If this does not hold, a market participant may generate riskless profits by stripping the security and creating stripped securities.

To determine the value of each zero-coupon instrument, it is necessary to know the yield on a zero-coupon Treasury with that same maturity. This yield is called the *spot rate,* and the graphic depiction of the relationship between the spot rate and its maturity is called the *spot-rate curve.* Because there are no zero-coupon Treasury debt issues with a maturity greater than one year issued by the U.S. Department of the Treasury, it is not possible to construct such a curve solely from observations of Treasury yields. Rather, it is necessary to derive this curve from theoretical considerations as applied to the yields of actual Treasury securities. Such a curve is called a *theoretical spot-rate curve.*

Constructing the Theoretical Spot-Rate Curve

The theoretical spot-rate curve is constructed from the yield curve based on the observed yields of Treasury bills and Treasury coupon securities. The process of creating a theoretical spot-rate curve in this way is called *bootstrapping.*[1]

1. In practice, the securities used to construct the theoretical spot-rate curve are the most recently auctioned Treasury securities of a given maturity. Such issues are referred to as the *on-the-run Treasury issues*. As explained in Chapter 7, there are actual zero-coupon Treasury securities with a maturity greater than one year that are outstanding in the market. These securities are not issued by the U.S. Treasury but are created by market participants from actual coupon Treasury securities. It would seem logical that the observed yield on zero-coupon Treasury securities can be used to construct an actual spot-rate curve. However, there are problems with this approach. First, the liquidity of these securities is not as great as that of the coupon Treasury market. Second, there are maturity sectors of the zero-coupon Treasury market that attract specific investors who may be willing to trade yield in exchange for an attractive feature associated with that particular maturity sector, thereby distorting the term-structure relationship.

EXHIBIT 3-2

Maturity and Yield-to-Maturity for 20 Hypothetical Treasury Securities

Maturity	Coupon Rate	Yield-to-Maturity	Price
0.50 years	0.0000	0.0800	$ 96.15
1.00	0.0000	0.0830	92.19
1.50	0.0850	0.0890	99.45
2.00	0.0900	0.0920	99.64
2.50	0.1100	0.0940	103.49
3.00	0.0950	0.0970	99.49
3.50	0.1000	0.1000	100.00
4.00	0.1000	0.1040	98.72
4.50	0.1150	0.1060	103.16
5.00	0.0875	0.1080	92.24
5.50	0.1050	0.1090	98.38
6.00	0.1100	0.1120	99.14
6.50	0.0850	0.1140	86.94
7.00	0.0825	0.1160	84.24
7.50	0.1100	0.1180	96.09
8.00	0.0650	0.1190	72.62
8.50	0.0875	0.1200	82.97
9.00	0.1300	0.1220	104.30
9.50	0.1150	0.1240	95.06
10.00	0.1250	0.1250	100.00

To explain this process, we use the data for the hypothetical price, annualized yield (yield-to-maturity), and maturity of the 20 Treasury securities shown in Exhibit 3-2.

Throughout the analysis and illustrations to come, it is important to remember that the basic principle of bootstrapping is that the value of a Treasury coupon security should be equal to the value of the package of zero-coupon Treasury securities that duplicates the coupon bond's cash flow.

Consider the six-month Treasury bill in Exhibit 3-2. As explained in Chapter 7, a Treasury bill is a zero-coupon instrument. Therefore, its annualized yield of 8% is equal to the spot rate. Similarly, for the one-year Treasury bill, the cited yield of 8.3% is the one-year spot rate. Given these two spot rates, we can compute the spot rate for a theoretical 1.5-year zero-coupon Treasury. The price of a theoretical 1.5-year Treasury should equal the present value of three cash flows from an actual 1.5-year coupon Treasury, where the yield used for discounting is the spot rate corresponding to the cash flow. Using $100 as par, the cash flow for the 1.5-year coupon Treasury is as follows:

$$\begin{array}{lll} 0.5 \text{ years} & 0.085 \times \$100 \times 0.5 & = \$4.25 \\ 1.0 \text{ years} & 0.085 \times \$100 \times 0.5 & = \$4.25 \\ 1.5 \text{ years} & 0.085 \times \$100 \times 0.5 + 100 & = \$104.25 \end{array}$$

The present value of the cash flow is then

$$\frac{4.25}{(1+z_1)^1} + \frac{4.25}{(1+z_2)^2} + \frac{104.25}{(1+z_3)^3}$$

where

z_1 = one-half the annualized six-month theoretical spot rate
z_2 = one-half the one-year theoretical spot rate
z_3 = one-half the 1.5-year theoretical spot rate

Because the six-month spot rate and one-year spot rate are 8.0% and 8.3%, respectively, we know that

$$z_1 = 0.04 \qquad \text{and} \qquad z_2 = 0.0415.$$

We can compute the present value of the 1.5-year coupon Treasury security as

$$\frac{4.25}{(1.0400)^1} + \frac{4.25}{(1.0415)^2} + \frac{104.25}{(1+z_3)^3}$$

Because the price of the 1.5-year coupon Treasury security (from Exhibit 3-2) is $99.45, the following relationship must hold:

$$99.45 = \frac{4.25}{(1.0400)^1} + \frac{4.25}{(1.0415)^2} + \frac{104.25}{(1+z_3)^3}$$

We can solve for the theoretical 1.5-year spot rate as follows:

$$99.45 = 4.08654 + 3.91805 + \frac{104.25}{(1+z_3)^3}$$

$$91.44541 = \frac{104.25}{(1+z_3)^3}$$

$$(1+z_3)^3 = 1.140024$$

$$z_3 = 0.04465$$

Doubling this yield, we obtain the bond-equivalent yield of 0.0893, or 8.93%, which is the theoretical 1.5-year spot rate. This rate is the rate that the market would apply to a 1.5-year zero-coupon Treasury security, if such a security existed.

Given the theoretical 1.5-year spot rate, we can obtain the theoretical two-year spot rate. The cash flow for the two-year coupon Treasury in Exhibit 3-2 is

$$\begin{array}{lll} 0.5 \text{ years} & 0.090 \times \$100 \times 0.5 & = \$4.50 \\ 1.0 \text{ years} & 0.090 \times \$100 \times 0.5 & = \$4.50 \\ 1.5 \text{ years} & 0.090 \times \$100 \times 0.5 & = \$4.50 \\ 2.0 \text{ years} & 0.090 \times \$100 \times 0.5 + 100 & = \$104.50 \end{array}$$

The present value of the cash flow is then

$$\frac{4.50}{(1+z_1)^1} + \frac{4.50}{(1+z_2)^2} + \frac{4.50}{(1+z_3)^3} + \frac{104.50}{(1+z_4)^4}$$

where

z_4 = one-half the two-year theoretical spot rate

Because the six-month spot rate, the one-year spot rate, and the 1.5-year spot rate are 8.0%, 8.3%, and 8.93%, respectively, then

$$z_1 = 0.04 \qquad z_2 = 0.0415 \qquad \text{and} \qquad z_3 = 0.04465$$

Therefore, the present value of the two-year coupon Treasury security is

$$\frac{4.50}{(1.0400)^1} + \frac{4.50}{(1.0415)^2} + \frac{4.50}{(1.04465)^3} + \frac{104.50}{(1+z_4)^4}$$

Because the price of the two-year coupon Treasury security is \$99.64, the following relationship must hold:

$$99.64 = \frac{4.50}{(1.0400)^1} + \frac{4.50}{(1.0415)^2} + \frac{4.50}{(1.04465)^3} + \frac{104.50}{(1+z_4)^4}$$

We can solve for the theoretical two-year spot rate as follows:

$$99.64 = 4.32692 + 4.14853 + 3.94730 + \frac{104.50}{(1+z_4)^4}$$

$$87.21725 = \frac{104.50}{(1+z_4)^4}$$

$$(1+z_4)^4 = 1.198158$$

$$z_4 = 0.046235$$

Doubling this yield, we obtain the theoretical two-year spot rate bond-equivalent yield of 9.247%.

One can follow this approach sequentially to derive the theoretical 2.5-year spot rate from the calculated values of z_1, z_2, z_3, and z_4 (the six-month, one-year, 1.5-year, and two-year rates) and the price and coupon of the bond with a maturity of 2.5 years. Further, one could derive theoretical spot rates for the remaining

EXHIBIT 3-3

Theoretical Spot Rates

Maturity	Yield-to-Maturity	Theoretical Spot Rate
0.50 years	0.0800	0.08000
1.00	0.0830	0.08300
1.50	0.0890	0.08930
2.00	0.0920	0.09247
2.50	0.0940	0.09468
3.00	0.0970	0.09787
3.50	0.1000	0.10129
4.00	0.1040	0.10592
4.50	0.1060	0.10850
5.00	0.1080	0.11021
5.50	0.1090	0.11175
6.00	0.1120	0.11584
6.50	0.1140	0.11744
7.00	0.1160	0.11991
7.50	0.1180	0.12405
8.00	0.1190	0.12278
8.50	0.1200	0.12546
9.00	0.1220	0.13152
9.50	0.1240	0.13377
10.00	0.1250	0.13623

15 half-yearly rates. The spot rates thus obtained are shown in Exhibit 3-3. They represent the term structure of interest rates for maturities up to 10 years at the particular time to which the bond price quotations refer.

Why Treasuries Must Be Priced Based on Spot Rates

Financial theory tells us that the theoretical price of a Treasury security should be equal to the present value of the cash flows, where each cash flow is discounted at the appropriate theoretical spot rate. What we did not do, however, is demonstrate the economic force that ensures that the actual market price of a Treasury security does not depart significantly from its theoretical price.

To demonstrate this, we will use the 20 hypothetical Treasury securities introduced in Exhibit 3-2. The longest-maturity bond given in that exhibit is the 10-year, 12.5% coupon bond selling at par with a yield-to-maturity of 12.5%. Suppose that a government dealer buys the issue at par and strips it, expecting to sell the zero-coupon Treasury securities at the yields-to-maturity indicated in Exhibit 3-3 for the corresponding maturity.

EXHIBIT 3-4

Illustration of Arbitrage Profit from Coupon Stripping

Maturity	Cash Flow	Present Value at 12.5%	Yield-to-Maturity	Present Value at Yield-to-Maturity
0.50 years	$ 6.25	$ 5.8824	0.0800	$6.0096
1.00	6.25	5.5363	0.0830	5.7618
1.50	6.25	5.2107	0.0890	5.4847
2.00	6.25	4.9042	0.0920	5.2210
2.50	6.25	4.6157	0.0940	4.9676
3.00	6.25	4.3442	0.0970	4.7040
3.50	6.25	4.0886	0.1000	4.4418
4.00	6.25	3.8481	0.1040	4.1663
4.50	6.25	3.6218	0.1060	3.9267
5.00	6.25	3.4087	0.1080	3.6938
5.50	6.25	3.2082	0.1090	3.4863
6.00	6.25	3.0195	0.1120	3.2502
6.50	6.25	2.8419	0.1140	3.0402
7.00	6.25	2.6747	0.1160	2.8384
7.50	6.25	2.5174	0.1180	2.6451
8.00	6.25	2.3693	0.1190	2.4789
8.50	6.25	2.2299	0.1200	2.3210
9.00	6.25	2.0987	0.1220	2.1528
9.50	6.25	1.9753	0.1240	1.9930
10.00	106.25	31.6046	0.1250	31.6046
Total		100.0000		$104.1880

Exhibit 3-4 shows the price that would be received for each zero-coupon Treasury security created. The price for each is the present value of the cash flow from the stripped Treasury discounted at the yield-to-maturity corresponding to the maturity of the security (from Exhibit 3-2). The total proceeds received from selling the zero-coupon Treasury securities created would be $104.1880 per $100 of par value of the original Treasury issue. This would result in an arbitrage profit of $4.1880 per $100 of the 10-year, 12.5% coupon Treasury security purchased.

To understand why the government dealer has the opportunity to realize this profit, look at the third column of Exhibit 3-4, which shows how much the government dealer paid for each cash flow by buying the entire package of cash flows (i.e., by buying the bond). For example, consider the $6.25 coupon payment in four years. By buying the 10-year Treasury bond priced to yield 12.5%, the dealer effectively pays a price based on 12.5% (6.25% semiannually) for that coupon payment or, equivalently, $3.8481. Under the assumptions of this illustration, however, investors were willing to accept a lower yield-to-maturity, 10.4% (5.2% semiannually), to purchase a zero-coupon Treasury security with four years to maturity. Thus investors were willing to pay \$4.1663. On this one coupon payment, the government dealer realizes a profit equal to the difference between \$4.1663 and \$3.8481 (or \$0.3182). From all the cash flows, the total profit is \$4.1880. In this instance, coupon stripping shows that the sum of the parts is greater than the whole.

Suppose that instead of the observed yield-to-maturity from Exhibit 3-2, the yields investors want are the same as the theoretical spot rates shown in Exhibit 3-3. If we use these spot rates to discount the cash flows, the total proceeds from the sale of the zero-coupon Treasury securities would be equal to \$100, making coupon stripping uneconomic.

In our illustration of coupon stripping, the price of the Treasury security is less than its theoretical price. Suppose instead that the price of the Treasury security is greater than its theoretical price. In such cases, investors can purchase a package of zero-coupon Treasury securities such that the cash flow of the package of securities replicates the cash flow of the mispriced coupon Treasury security. By doing so, the investor will realize a yield higher than the yield on the coupon Treasury security. For example, suppose that the market price of the 10-year Treasury security we used in our illustration (Exhibit 3-4) is \$106. By buying the 20 zero-coupon bonds shown in Exhibit 3-4 with a maturity value identical to the cash flow shown in the second column, the investor is effectively purchasing a 10-year Treasury coupon security at a cost of \$104.1880 instead of \$106.

The process of coupon stripping and reconstituting prevents the actual spot-rate curve observed on zero-coupon Treasuries from departing significantly from the theoretical spot-rate curve. As more stripping and reconstituting occurs, forces of demand and supply will cause rates to return to their theoretical spot-rate levels. This is what has happened in the Treasury market.

Forward Rates

Consider an investor who has a one-year investment horizon and is faced with the following two alternatives:

Alternative 1: Buy a one-year Treasury bill.

Alternative 2: Buy a six-month Treasury bill, and when it matures in six months, buy another six-month Treasury bill.

The investor will be indifferent between the two alternatives if they produce the same return over the one-year investment horizon. The investor knows the spot rate on the six-month Treasury bill and the one-year Treasury bill. However, the investor does not know what yield will be available on a six-month Treasury bill that will be purchased six months from now. The yield on a six-month Treasury bill six months from now is called a *forward rate.* Given the spot rates for the six-month Treasury bill and the one-year bill, we wish to determine the forward rate on a six-month Treasury bill that will make the investor indifferent between the two alternatives. That rate can be readily determined.

At this point, however, we need to digress briefly and recall several present-value and investment relationships. First, if you invested in a one-year Treasury bill, you would receive \$100 at the end of one year. The price of the one-year Treasury bill would be

$$\frac{100}{(1+z_2)^2}$$

where z_2 is one-half the bond-equivalent yield of the theoretical one-year spot rate.

Second, suppose that you purchased a six-month Treasury bill for \$$X$. At the end of six months, the value of this investment would be

$$X(1+z_1)$$

where z_1 is one-half the bond-equivalent yield of the theoretical six-month spot rate.

Let f represent one-half the forward rate (expressed as a bond-equivalent basis) on a six-month Treasury bill available six months from now. If the investor were to renew the investment by purchasing that bill at that time, then the future dollars available at the end of one year from the \$$X$ investment would be

$$X(1+z_1)(1+f)$$

Third, it is easy to use this formula to find out how many \$$X$ the investor must invest in order to get \$100 one year from now. This can be found as follows:

$$X(1+z_1)(1+f)=100$$

which gives us

$$X=\frac{100}{(1+z_1)(1+f)}$$

We are now prepared to return to the investor's choices and analyze what that situation says about forward rates. The investor will be indifferent between the two alternatives if the same dollar investment is made and \$100 is received from both alternatives at the end of one year. That is, the investor will be indifferent if

$$\frac{100}{(1+z_2)^2}=\frac{100}{(1+z_1)(1+f)}$$

Solving for f, we get

$$f=\frac{(1+z_2)^2}{(1+z_1)^1}-1$$

Doubling f gives the bond-equivalent yield for the six-month forward rate six months from now.

We can illustrate the use of this formula with the theoretical spot rates shown in Exhibit 3-3. From that exhibit, we know that

$$\text{Six-month bill spot rate} = 0.080 \quad \text{so} \quad z_1 = 0.0400$$
$$\text{One-year bill spot rate} = 0.083 \quad \text{so} \quad z_2 = 0.0415$$

Substituting into the formula, we have

$$\begin{aligned} f &= \frac{(1.0415)^2}{1.0400} - 1 \\ &= 0.043 \end{aligned}$$

Therefore, the forward rate on a six-month Treasury security, quoted on a bond-equivalent basis, is 8.6% (0.043 × 2). Let's confirm our results. The price of a one-year Treasury bill with a $100 maturity value is

$$\frac{100}{(1.0415)^2} = 92.19$$

If $92.19 is invested for six months at the six-month spot rate of 8%, the amount at the end of six months would be

$$92.19(1.0400) = 95.8776$$

If $95.8776 is reinvested for another six months in a six-month Treasury offering 4.3% for six months (8.6% annually), the amount at the end of one year would be

$$95.8776(1.043) = 100$$

Both alternatives will have the same $100 payoff if the six-month Treasury bill yield six months from now is 4.3% (8.6% on a bond-equivalent basis). This means that if an investor is guaranteed a 4.3% yield (8.6% bond-equivalent basis) on a six-month Treasury bill six months from now, the investor will be indifferent between the two alternatives.

We used the theoretical spot rates to compute the forward rate. The resulting forward rate is also called the *implied forward rate.*

We can take this sort of analysis much further. It is not necessary to limit ourselves to implied forward rates six months from now. The yield curve can be used to calculate the implied forward rate for any time in the future for any investment horizon. For example, the following can be calculated:

- The two-year implied forward rate five years from now
- The six-year implied forward rate two years from now
- The seven-year implied forward rate three years from now

Relationship Between Spot Rates and Short-Term Forward Rates

Suppose that an investor purchases a five-year zero-coupon Treasury security for \$58.42 with a maturity value of \$100. The investor could instead buy a six-month Treasury bill and reinvest the proceeds every six months for five years. The number of dollars that will be realized depends on the six-month forward rates. Suppose that the investor actually can reinvest the proceeds maturing every six months at the implied six-month forward rates. Let's see how many dollars would accumulate at the end of five years. The implied six-month forward rates were calculated for the yield curve given in Exhibit 3-3. Letting f_t denote the six-month forward rate beginning t six-month periods from now, the semiannual implied forward rates using the spot rates shown in that exhibit are as follows:

$$f_1 = 0.043000 \quad f_2 = 0.050980 \quad f_3 = 0.051005 \quad f_4 = 0.051770$$
$$f_5 = 0.056945 \quad f_6 = 0.060965 \quad f_7 = 0.069310 \quad f_8 = 0.064625$$
$$f_9 = 0.062830$$

If the investor invests the \$58.48 at the six-month spot rate of 4% (8% on a bondequivalent basis) and reinvests at the forward rates shown above, the number of dollars accumulated at the end of five years would be

$$\begin{aligned}&\$58.48(1.04)(1.043)(1.05098)(1.051005)(1.05177)(1.056945)\\&\times(1.060965)(1.069310)(1.064625)(1.06283) = \$100\end{aligned}$$

Therefore, we see that if the implied forward rates are realized, the \$58.48 investment will produce the same number of dollars as an investment in a five-year zero-coupon Treasury security at the five-year spot rate. From this illustration, we can see that the five-year spot rate is related to the current six-month spot rate and the implied six-month forward rates.

In general, the relationship between a t-period spot rate, the current six-month spot rate, and the implied six-month forward rates is as follows:

$$z_t = [(1+z_1)(1+f_1)(1+f_2)(1+f_3)\cdots(1+f_{t-1})]^{1/t} - 1$$

Why should an investor care about forward rates? There are actually very good reasons for doing so. Knowledge of the forward rates implied in the current long-term rate is relevant in formulating an investment policy. In addition, forward rates are key inputs into the valuation of bonds with embedded options.

For example, suppose that an investor wants to invest for one year (two six-month periods); the current six-month or short rate (z_1) is 7%, and the one-year (two-period) rate (z_2) is 6%. Using the formulas we have developed, the investor finds that by buying a two-period security, the investor is effectively making a forward contract to lend money six months from now at the rate of 5% for six months. If the investor believes that the second-period rate will turn out to be higher than 5%, it will be to the investor's advantage to lend initially on a one-period contract and then at the end of the first period to reinvest interest and principal in the one-period contract available for the second period.

Determinants of the Shape of the Term Structure

If we plot the term structure—the yield-to-maturity, or the spot rate, at successive maturities against maturity—what will it look like? Exhibit 3-1 shows three shapes that have appeared with some frequency over time. Panel *a* shows an upward-sloping yield curve; that is, yield rises steadily as maturity increases. This shape is commonly referred to as a *normal* or *upward-sloping yield curve.* Panel *b* shows a *downward-sloping* or *inverted yield curve,* where yields decline as maturity increases. Finally, panel *c* shows a *flat yield curve.*

Two major theories have evolved to account for these shapes: the *expectations theory* and the *market-segmentation theory*.

There are three forms of the expectations theory: the *pure expectations theory,* the *liquidity theory*, and the *preferred-habitat theory*. All share a hypothesis about the behavior of short-term forward rates and also assume that the forward rates in current long-term bonds are closely related to the market's expectations about future short-term rates. These three theories differ, however, on whether other factors also affect forward rates and how. The pure expectations theory postulates that no systematic factors other than expected future short-term rates affect forward rates; the liquidity theory and the preferred-habitat theory assert that there are other factors. Accordingly, the last two forms of the expectations theory are sometimes referred to as *biased expectations theories*.

The Pure Expectations Theory

According to the pure expectations theory, the forward rates exclusively represent expected future rates. Thus the entire term structure at a given time reflects the market's current expectations of future short-term rates. Under this view, a rising term structure, as shown in panel *a* of Exhibit 3-1, must indicate that the market expects short-term rates to rise throughout the relevant future. Similarly, a flat term structure reflects an expectation that future short-term rates will be mostly constant, and a falling term structure must reflect an expectation that future short-term rates will decline steadily.

We can illustrate this theory by considering how an expectation of a rising short-term future rate would affect the behavior of various market participants resulting in a rising yield curve. Assume an initially flat term structure, and suppose that economic news leads market participants to expect interest rates to rise.

- Market participants interested in a long-term investment would not want to buy long-term bonds because they would expect the yield structure to rise sooner or later, resulting in a price decline for the bonds and a capital loss on the long-term bonds purchased. Instead, they would want to invest in short-term debt obligations until the rise in yield had occurred, permitting them to reinvest their funds at the higher yield.

- Speculators expecting rising rates would anticipate a decline in the price of long-term bonds and therefore would want to sell any long-term bonds they own and possibly to "short sell" some they do not now own. (Should interest rates rise as expected, the price of longer-term bonds will fall. Because the speculator sold these bonds short and can then purchase them at a lower price to cover the short sale, a profit will be earned.) The proceeds received from the selling of long-term debt issues or the shorting of longer-term bonds will be invested in short-term debt obligations.
- Borrowers wishing to acquire long-term funds would be pulled toward borrowing now, in the long end of the market, by the expectation that borrowing at a later time would be more expensive.

All these responses would tend either to lower the net demand for or to increase the supply of long-maturity bonds, and two responses would increase demand for short-term debt obligations. This would require a rise in long-term yields in relation to short-term yields; that is, these actions by investors, speculators, and borrowers would tilt the term structure upward until it is consistent with expectations of higher future interest rates. By analogous reasoning, an unexpected event leading to the expectation of lower future rates will result in a downward-sloping yield curve.

Unfortunately, the pure expectations theory suffers from one serious shortcoming. It does not account for the risks inherent in investing in bonds and like instruments. If forward rates were perfect predictors of future interest rates, then the future prices of bonds would be known with certainty. The return over any investment period would be certain and independent of the maturity of the instrument initially acquired and of the time at which the investor needed to liquidate the instrument. However, with uncertainty about future interest rates and hence about future prices of bonds, these instruments become risky investments in the sense that the return over some investment horizon is unknown.

There are two risks that cause uncertainty about the return over some investment horizon. The first is the uncertainty about the price of the bond at the end of the investment horizon. For example, an investor who plans to invest for five years might consider the following three investment alternatives: (1) invest in a 5-year bond and hold it for five years, (2) invest in a 12-year bond and sell it at the end of five years, and (3) invest in a 30-year bond and sell it at the end of five years. The return that will be realized for the second and third alternatives is not known because the price of each long-term bond at the end of five years is not known. In the case of the 12-year bond, the price will depend on the yield on 7-year debt securities five years from now, and the price of the 30-year bond will depend on the yield on 25-year bonds five years from now. Because forward rates implied in the current term structure for a future 7-year bond and a future 25-year bond are not perfect predictors of the actual future rates, there is uncertainty about the price for both bonds five years from now. Thus there is *price risk:* The risk that the price of the bond will be lower than currently expected at the end of the investment horizon. As explained in Chapter 5, an important feature of price risk is that it increases as the maturity of the bond increases.

The second risk involves the uncertainty about the rate at which the proceeds from a bond that matures during the investment horizon can be reinvested and is known as *reinvestment risk*. For example, an investor who plans to invest for five years might consider the following three alternative investments: (1) invest in a five-year bond and hold it for five years, (2) invest in a six-month instrument and, when it matures, reinvest the proceeds in six-month instruments over the entire five-year investment horizon, and (3) invest in a two-year bond and, when it matures, reinvest the proceeds in a three-year bond. The risk in the second and third alternatives is that the return over the five-year investment horizon is unknown because rates at which the proceeds can be reinvested are unknown.

Several interpretations of the pure expectations theory have been put forth by economists. These interpretations are not exact equivalents, nor are they consistent with each other, in large part because they offer different treatments of price risk and reinvestment risk.[2]

The broadest interpretation of the pure expectations theory suggests that investors expect the return for any investment horizon to be the same, regardless of the maturity strategy selected.[3] For example, consider an investor who has a five-year investment horizon. According to this theory, it makes no difference if a 5-year, 12-year, or 30-year bond is purchased and held for five years because the investor expects the return from all three bonds to be the same over five years. A major criticism of this very broad interpretation of the theory is that because of price risk associated with investing in bonds with a maturity greater than the investment horizon, the expected returns from these three very different bond investments should differ in significant ways.[4]

A second interpretation, referred to as the *local-expectations* form of the pure expectations theory, suggests that the return will be the same over a short-term investment horizon starting today. For example, if an investor has a six-month investment horizon, buying a 5-year, 10-year, or 20-year bond will produce the same six-month return. It has been demonstrated that the local expectations formulation, which is narrow in scope, is the only interpretation of the pure expectations theory that can be sustained in equilibrium.[5]

The third interpretation of the pure expectations theory suggests that the return an investor will realize by rolling over short-term bonds to some investment horizon will be the same as holding a zero-coupon bond with a maturity that is the same as that investment horizon. (A zero-coupon bond has no reinvestment risk, so future interest rates over the investment horizon do not affect the return.)

2. These formulations are summarized by John Cox, Jonathan Ingersoll, Jr., and Stephen Ross, "A Re-Examination of Traditional Hypotheses about the Term Structure of Interest Rates," *Journal of Finance* (September 1981), pp. 769–799.

3. F Lutz, "The Structure of Interest Rates," *Quarterly Journal of Economics* (1940–41), pp. 36–63.

4. Cox, Ingersoll, and Ross, *op. cit*., pp. 774–775.

5. Cox, Ingersoll, and Ross, *op. cit*., p. 788.

This variant is called the *return-to-maturity expectations* interpretation. For example, let's once again assume that an investor has a five-year investment horizon. If the investor buys a five-year zero-coupon bond and holds it to maturity, the return is the difference between the maturity value and the price of the bond, all divided by the price of the bond. According to the return-to-maturity expectations, the same return will be realized by buying a six-month instrument and rolling it over for five years. At this time, the validity of this interpretation is subject to considerable doubt.

The Liquidity Theory

We have explained that the drawback of the pure expectations theory is that it does not account for the risks associated with investing in bonds. Nonetheless, we have just shown that there is indeed risk in holding a long-term bond for one period, and that risk increases with the bond's maturity because maturity and price volatility are directly related.

Given this uncertainty, and the reasonable consideration that investors typically do not like uncertainty, some economists and financial analysts have suggested a different theory. This theory states that investors will hold longer-term maturities if they are offered a long-term rate higher than the average of expected future rates by a risk premium that is positively related to the term to maturity.[6] Put differently, the forward rates should reflect both interest-rate expectations and a liquidity premium (which is really a risk premium), and the premium should be higher for longer maturities.

According to this theory, which is called the *liquidity theory of the term structure,* the implied forward rates will not be an unbiased estimate of the market's expectations of future interest rates because they include a liquidity premium. Thus an upward-sloping yield curve may reflect expectations that future interest rates either will rise or will be flat (or even fall) but with a liquidity premium increasing fast enough with maturity so as to produce an upward-sloping yield curve.

The Preferred-Habitat Theory

Another theory, known as the *preferred-habitat theory,* also adopts the view that the term structure reflects the expectation of the future path of interest rates as well as a risk premium. However, the preferred-habitat theory rejects the assertion that the risk premium must rise uniformly with maturity.[7] Proponents of the preferred-habitat theory say that the latter conclusion could be accepted if all investors intend to liquidate their investment at the shortest possible date and all borrowers are anxious to borrow long. This assumption can be rejected because institutions have holding periods dictated by the nature of their liabilities.

6. John R. Hicks, *Value and Capital*, 2d ed. (London: Oxford University Press, 1946), pp. 141–145.

7. Franco Modigliani and Richard Sutch, "Innovations in Interest Rate Policy," *American Economic Review* (May 1966), pp. 178–197.

The preferred-habitat theory asserts that, to the extent that the demand and supply of funds in a given maturity range do not match, some lenders and borrowers will be induced to shift to maturities showing the opposite imbalances. However, they will need to be compensated by an appropriate risk premium that reflects the extent of aversion to either price or reinvestment risk.

Thus this theory proposes that the shape of the yield curve is determined by both expectations of future interest rates and a risk premium, positive or negative, to induce market participants to shift out of their preferred habitat. Clearly, according to this theory, yield curves sloping up, down, flat, or humped are all possible.

Market-Segmentation Theory

The *market-segmentation theory* recognizes that investors have preferred habitats dictated by the nature of their liabilities. This theory also proposes that the major reason for the shape of the yield curve lies in asset/liability management constraints (either regulatory or self-imposed) and creditors (borrowers) restricting their lending (financing) to specific maturity sectors.[8] However, the market-segmentation theory differs from the preferred-habitat theory in that it assumes that neither investors nor borrowers are willing to shift from one maturity sector to another to take advantage of opportunities arising from differences between expectations and forward rates. Thus, for the segmentation theory, the shape of the yield curve is determined by supply of and demand for securities within each maturity sector.

KEY POINTS

- In all economies, there is not just one interest rate but a structure of interest rates. The yield spread is the difference between the yields on any two bonds.
- The base interest rate is the yield on a Treasury security.
- The yield spread between a non-Treasury security and a comparable on-the-run Treasury security is called a risk premium. The factors that affect the risk premium include (1) the type of issuer (e.g., agency, corporate, municipality), (2) the issuer's perceived creditworthiness as measured by the rating system of commercial rating companies, (3) the term or maturity of the instrument, (4) the embedded options in a bond issue (e.g., call, put, or conversion provisions), (5) the taxability of interest income at the federal and municipal levels, and (6) the expected liquidity of the issue.
- The relationship between yield and maturity is referred to as the term structure of interest rates. The graphic depiction of the relationship between the yield on bonds of the same credit quality but different maturities is known as the yield curve.

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8. This theory was suggested in J. M. Culbertson, "The Term Structure of Interest Rates," *Quarterly Journal of Economics* (November 1957), pp. 489–504.

- Because the yield on Treasury securities is the base rate from which a nongovernment bond's yield often is benchmarked, the most commonly constructed yield curve is the Treasury yield curve.
- There is a problem with using the Treasury yield curve to determine the one yield at which to discount all the cash payments of any bond. Each cash flow should be discounted at a unique interest rate that is applicable to the time period in which the cash flow is to be received. Because any bond can be viewed as a package of zero-coupon instruments, its value should equal the value of all the component zero-coupon instruments. The zero-coupon rate is also known as the spot rate.
- The theoretical spot-rate curve for Treasury securities can be estimated from the Treasury yield curve using a bootstrapping method.
- Under certain assumptions, the market's expectation of future interest rates can be extrapolated from the theoretical Treasury spot-rate curve. The resulting forward rate is called the implied forward rate.
- Several theories have been proposed about the determinants of the term structure: the pure expectations theory, the biased expectations theories (the liquidity theory and the preferred-habitat theory), and the market-segmentation theory.
- All the expectation theories hypothesize that the one-period forward rates represent the market's expectations of future rates. The pure expectations theory asserts that these rates constitute the only factor. The biased expectations theories assert that there are other factors that determine the term structure.

PART
TWO

BASICS OF FIXED INCOME ANALYTICS

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CHAPTER
FOUR

BOND PRICING, YIELD MEASURES, AND TOTAL RETURN

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In this chapter the pricing of fixed income securities and the various measures of computing return (or yield) from holding a fixed income security will be explained and illustrated. The chapter is organized as follows: In the first section, we apply the present-value analysis to explain how a bond's price is determined. Then we turn to yield measures, first focusing on conventional yield measures for a fixed-rate bond (yield-to-maturity and yield-to-call in the case of a callable bond) and a floating-rate bond. After highlighting the deficiencies of the conventional yield measures, a better measure of potential return—total return—is then presented.

BOND PRICING

The price of any financial instrument is equal to the present value of the expected cash flow. The interest rate or discount rate used to compute the present value depends on the yield offered on comparable securities in the market. In this chapter we shall explain how to compute the price of an option-free bond (i.e, a bond that is not callable, putable, or convertible). The pricing of callable and putable bonds is explained in Chapter 36. Chapters 38 and 39 describe models for the pricing of convertible bonds. The valuation of agency mortgage-backed securities is the subject of Chapter 37.

Determining the Cash Flow

The first step in determining the price of a bond is to determine its cash flow. The cash flow of an option-free bond consists of (1) periodic coupon interest payments to the maturity date and (2) the par (or maturity) value at maturity. Although the periodic coupon payments can be made over any time interval (weekly, monthly, quarterly, semiannually, or annually), most bonds issued in the United States pay coupon interest semiannually. In our illustrations, we shall assume that the coupon interest is paid semiannually. Also, to simplify the analysis, we shall assume that the next coupon payment for the bond will be made exactly six months from now. Later in this section we explain how to price a bond when the next coupon payment is less than six months from now.

In practice, determining the cash flow of a bond is not simple, even if we ignore the possibility of default. The only case in which the cash flow is known with certainty is for fixed-rate, option-free bonds. For callable bonds, the cash flow depends on whether the issuer elects to call the issue. In the case of a putable bond, it depends on whether the bondholder elects to put the issue. In either case, the date that the option will be exercised is not known. Thus the cash flow is uncertain. For mortgage-backed and asset-backed securities, the cash flow depends on prepayments. The amount and timing of future prepayments are not known, and therefore, the cash flow is uncertain. When the coupon rate is floating rather than fixed, the cash flow depends on the future value of the reference rate. The techniques discussed in Part 6 have been developed to cope with the uncertainty of cash flows. In this chapter, the basic elements of bond pricing where the cash flow is assumed to be known are presented.

The cash flow for an option-free bond consists of an annuity (i.e., the fixed coupon interest paid every six months) and the par or maturity value. For example, a 20-year bond with a 9% (4.5% per six months) coupon rate and a par or maturity value of $1,000 has the following cash flows:

$$\begin{aligned}\text{Semiannual coupon interest} &= \$1{,}000 \times 0.045\\ &= \$45\\ \text{Maturity value} &= \$1{,}000\end{aligned}$$

Therefore, there are 40 semiannual cash flows of $45, and a $1,000 cash flow 40 six-month periods from now.

Notice the treatment of the par value. It is *not* treated as if it will be received 20 years from now. Instead, it is treated on a consistent basis with the coupon payments, which are semiannual.

Determining the Required Yield

The interest rate that an investor wants from investing in a bond is called the *required yield.* The required yield is determined by investigating the yields offered on comparable bonds in the market. By comparable, we mean option-free bonds of the same credit quality and the same maturity.[1]

The required yield typically is specified as an annual interest rate. When the cash flows are semiannual, the convention is to use one-half the annual interest rate as the periodic interest rate with which to discount the cash flows. A periodic interest

1. In Chapter 5, we introduce a measure of interest-rate risk known as *duration*. Instead of talking in terms of a bond with the same maturity as being comparable, we can recast the analysis in terms of the same duration.

rate that is one-half the annual yield will produce an effective annual yield that is greater than the annual interest rate.

Although one yield is used to calculate the present value of all cash flows, there are theoretical arguments for using a different yield to discount the cash flow for each period. Essentially, the theoretical argument is that each cash flow can be viewed as a zero-coupon bond, and therefore, the cash flow of a bond can be viewed as a package of zero-coupon bonds. As explained in Chapter 3, the appropriate yield for each cash flow then would be based on the theoretical rate on a zero-coupon bond with a maturity equal to the time that the cash flow will be received. For purposes of this chapter, however, we shall use only one yield to discount all cash flows.

Determining the Price

Given the cash flows of a bond and the required yield, we have all the necessary data to price the bond. The price of a bond is equal to the present value of the cash flows, and it can be determined by adding (1) the present value of the semiannual coupon payments and (2) the present value of the par or maturity value.

Because the semiannual coupon payments are equivalent to an ordinary annuity, the present value of the coupon payments and maturity value can be calculated from the following formula:[2]

$$c\left[\frac{1-\left\{\frac{1}{(1+i)^n}\right\}}{i}\right]+\frac{M}{(1+i)^n}$$

where

c = semiannual coupon payment ($)
n = number of periods (number of years times 2)
i = periodic interest rate (required yield divided by 2) (in decimal)
M = maturity value

Illustration 1. Compute the price of a 9% coupon bond with 20 years to maturity and a par value of $1,000 if the required yield is 12%.

The cash flows for this bond are as follows: (1) 40 semiannual coupon payments of $45 and (2) $1,000 40 six-month periods from now. The semiannual or periodic interest rate is 6%.

2. The first term in the formula is the same as the formula for the present value of an ordinary annuity for n periods.

The present value of the 40 semiannual coupon payments of \$45 discounted at 6% is \$677.08, as shown below:

$$c = \$45$$
$$n = 40$$
$$i = 0.06$$

$$\$45\left[\frac{1-\left\{\frac{1}{(1.06)^{40}}\right\}}{0.06}\right]$$

$$= \$45\left[\frac{1-\left\{\frac{1}{10.28572}\right\}}{0.06}\right]$$

$$= \$45\left[\frac{1-0.097222}{0.06}\right]$$

$$= \$45(15.04630)$$

$$= \$677.08$$

The present value of the par or maturity value *40 six-month periods* from now discounted at 6% is \$97.22, as shown below:

$$M = \$1{,}000$$
$$n = 0.40$$
$$i = 0.06$$

$$\$1{,}000\left[\frac{1}{(1.06)^{40}}\right]$$

$$= \$1{,}000\left[\frac{1}{10.28572}\right]$$

$$= \$1{,}000(0.097222)$$

$$= \$97.22$$

The price of the bond is then equal to the sum of the two present values:

Present value of coupon payments	\$677.08
Present value of par (maturity) value	97.22
Price	\$774.30

Illustration 2. Compute the price of the bond in Illustration 1 assuming that the required yield is 7%.

The cash flows are unchanged, but the periodic interest rate is now 3.5% (7%/2).

The present value of the 40 semiannual coupon payments of \$45 discounted at 3.5% is \$960.98, as shown below:

$$c = \$45$$
$$n = 40$$
$$i = 0.035$$
$$\$45\left[\frac{1-\left\{\frac{1}{(1.035)^{40}}\right\}}{0.035}\right]$$
$$= \$45\left[\frac{1-\left\{\frac{1}{3.95926}\right\}}{0.035}\right]$$
$$= \$45\left[\frac{1-0.252572}{0.035}\right]$$
$$= \$45(21.35509)$$
$$= \$960.98$$

The present value of the par or maturity value of \$1,000 *40 six-month periods from now* discounted at 3.5% is \$252.57, as shown below:

$$M = \$1,000$$
$$n = 40$$
$$= 0.035$$
$$\$1,000\left[\frac{1}{(1.035)^{40}}\right]$$
$$= \$1,000\left[\frac{1}{3.95926}\right]$$
$$= \$1,000(0.252572)$$
$$= \$252.57$$

The price of the bond is then equal to the sum of the two present values:

Present value of coupon payments	\$960.98
Present value of par (maturity) value	252.57
Price	\$1,213.55

EXHIBIT 4-1

Price/Yield Relationship for a 20-Year, 9% Coupon Bond

Required Yield	Price of Bond
5%	$1,502.05
6	1,346.72
7	1,213.55
8	1,098.96
9	1,000.00
10	914.21
11	839.54
12	774.30
13	717.09
14	666.71

Relationship Between Required Yield and Price at a Given Time

The price of an option-free bond changes in the direction opposite to the change in the required yield. The reason is that the price of the bond is the present value of the cash flows. As the required yield increases, the present value of the cash flows decreases; hence the price decreases. The opposite is true when the required yield decreases: The present value of the cash flows increases, and therefore, the price of the bond increases.

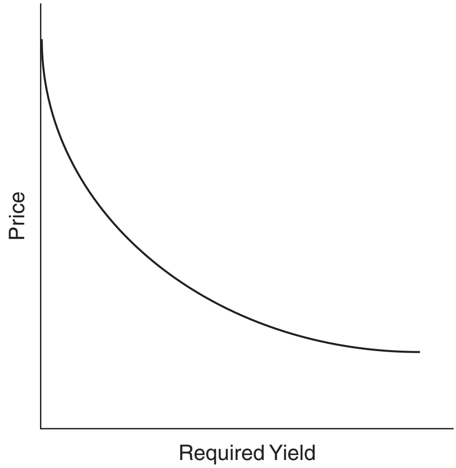
We can see this by comparing the price of the 20-year, 9% coupon bond that we priced in Illustrations 1 and 2. When the required yield is 12%, the price of the bond is $774.30. If, instead, the required yield is 7%, the price of the bond is $1,213.55. Exhibit 4-1 shows the price of the 20-year, 9% coupon bond for required yields from 5% to 14%.

If we graphed the price/yield relationship for any option-free bond, we would find that it has the "bowed" shape shown in Exhibit 4-2. This shape is referred to as *convex*.[3] The convexity of the price/yield relationship has important implications for the investment properties of a bond. We've devoted Chapter 5 to examining this relationship more closely.

3. In the exhibit, the curve representing the price/yield relationship intersects the price axis when the required yield is zero and is the maximum price for the bond assuming positive yields. That price is simply the undiscounted value of the cash flows.

EXHIBIT 4-2

Price/Yield Relationship



The Relationship Among Coupon Rate, Required Yield, and Price

For a bond issue at a given point in time, the coupon rate and the term-to-maturity are fixed. Consequently, as yields in the marketplace change, the only variable that an investor can change to compensate for the new yield required in the market is the price of the bond. As we saw in the preceding section, as the required yield increases (decreases), the price of the bond decreases (increases).

Generally, when a bond is issued, the coupon rate is set at approximately the prevailing yield in the market.[4] The price of the bond then will be approximately equal to its par value. For example, in Exhibit 4-1, we see that when the required yield is equal to the coupon rate, the price of the bond is its par value. Consequently, we have the following properties:

When the coupon rate equals the required yield, the price equals the par value.

When the price equals the par value, the coupon rate equals the required yield.

When yields in the marketplace rise above the coupon rate *at a given point in time,* the price of the bond has to adjust so that the investor can realize some additional interest. This adjustment is accomplished by having the bond's price fall below the par value. The difference between the par value and the price is a capital gain and represents a form of interest to the investor to compensate for the coupon rate being lower than the required yield. When a bond sells below its par value, it is said to be selling at a *discount.* We can see this in Exhibit 4-1. When the required

4. The exception is an original-issue discount bond such as a zero-coupon bond.

yield is greater than the coupon rate of 9%, the price of the bond is always less than the par value. Consequently, we have the following properties:

When the coupon rate is less than the required yield, the price is less than the par value.

When the price is less than the par value, the coupon rate is less than the required yield.

Finally, when the required yield in the market is below the coupon rate, the price of the bond must be above its par value. This occurs because investors who could purchase the bond at par would be getting a coupon rate in excess of what the market requires. As a result, investors would bid up the price of the bond because its yield is attractive. It will be bid up to a price that offers the required yield in the market. A bond whose price is above its par value is said to be selling at a *premium*. Exhibit 4-1 shows that for a required yield less than the coupon rate of 9%, the price of the bond is greater than its par value. Consequently, we have the following properties:

When the coupon rate is greater than the required yield, the price is greater than the par value.

When the price is greater than the par value, the coupon rate is greater than the required yield.

Time Path of a Bond

If the required yield is unchanged between the time the bond is purchased and the maturity date, what will happen to the price of the bond? For a bond selling at par value, the coupon rate is equal to the required yield. As the bond moves closer to maturity, the bond will continue to sell at par value. Thus, for a bond selling at par, its price will remain at par as the bond moves toward the maturity date.

The price of a bond will *not* remain constant for a bond selling at a premium or a discount. For all discount bonds, the following is true: As the bond moves toward maturity, its price will increase if *the required yield* does not change. This can be seen in Exhibit 4-3, which shows the price of the 20-year, 9% coupon bond as it moves toward maturity, assuming that the required yield remains at 12%. For a bond selling at a premium, the price of the bond declines as it moves toward maturity. This can also be seen in Exhibit 4-3, which shows the time path of the 20-year, 9% coupon bond selling to yield 7%.

Reasons for the Change in the Price of a Bond

The price of a bond will change because of one or more of the following reasons:

- *A change in the level of interest rates in the economy.* For example, if interest rates in the economy increase (fall) because of Fed policy, the price of a bond will decrease (increase).

EXHIBIT 4-3

Time Paths of 20-Year, 9% Coupon Discount and Premium Bonds

Years Remaining to Maturity	Price of Discount Bond*	Price of Premium Bond†
20	$774.30	$1,213.55
18	780.68	1,202.90
16	788.74	1,190.89
14	798.91	1,176.67
12	811.75	1,160.59
10	827.95	1,142.13
8	848.42	1,120.95
6	874.24	1,096.63
4	906.85	1,068.74
2	948.02	1,036.73
1	972.50	1,019.00
0	1,000.00	1,000.00

*Selling to yield 12%.
†Selling to yield 7%.

- *A change in the price of the bond selling at a price other than par as it moves toward maturity without any change in the required yield.* As we demonstrated, over time a discount bond's price increases if yields do not change; a premium bond's price declines over time if yields do not change.
- *For non-Treasury bonds, a change in the required yield due to changes in the spread to Treasuries.* If the Treasury rate does not change but the spread to Treasuries changes (narrows or widens), non-Treasury bond prices will change.
- *A change in the perceived credit quality of the issuer.* Assuming that interest rates in the economy and yield spreads between non-Treasuries and Treasuries do not change, the price of a non-Treasury bond will increase (decrease) if its perceived credit quality has improved (deteriorated).
- *For bonds with embedded options (callable bonds, putable bonds, and convertible bonds), the price of the bond will change as the factors that affect the value of the embedded options change.*

Pricing a Zero-Coupon Bond

So far we have determined the price of coupon-bearing bonds. Some bonds do not make any periodic coupon payments. Instead, the investor realizes interest by the difference between the maturity value and the purchase price.

The pricing of a zero-coupon bond is no different from the pricing of a coupon bond: Its price is the present value of the expected cash flows. In the case of a zero-coupon bond, the only cash flow is the maturity value. Therefore, the price of a zero-coupon bond is simply the present value of the maturity value. The number of periods used to discount the maturity value is double the number of years to maturity. This treatment is consistent with the manner in which the maturity value of a coupon bond is handled.

Illustration 3. The price of a zero-coupon bond that matures in 10 years and has a maturity value of \$1,000 if the required yield is 8.6% is equal to the present value of \$1,000 20 periods from now discounted at 4.3%. That is,

$$\$1{,}000\left[\frac{1}{(1.043)^{20}}\right] = \$430.83$$

Determining the Price When the Settlement Date Falls Between Coupon Periods

In our illustrations we assumed that the next coupon payment is six months away. This means that settlement occurs on the day after a coupon date. Typically, an investor will purchase a bond between coupon dates so that the next coupon payment is less than six months away. To compute the price, we have to answer the following three questions:

- How many days are there until the next coupon payment?
- How should we determine the present value of cash flows received over fractional periods?
- How much must the buyer compensate the seller for the coupon interest earned by the seller for the fraction of the period that the bond was held?

The first question is the day-count question. The second is the compounding question. The last question asks how accrued interest is determined. Below we address these questions.

Day Count

Market conventions for each type of bond dictate the answer to the first question: The number of days until the next coupon payment.

For Treasury coupon securities, a nonleap year is assumed to have 365 days. The number of days between settlement and the next coupon payment is therefore the actual number of days between the two dates. The day count convention for a coupon-bearing Treasury security is said to be "actual/actual," which means the actual number of days in a month and the actual number of days in the coupon period. For example, consider a Treasury bond whose last coupon payment was on March 1; the next coupon would be six months later on September 1. Suppose that this bond is purchased with a settlement date of July 17. The actual number of days between July 17 (the settlement date) and September 1 (the date of the next coupon payment) is 46 days (the actual number of days in the coupon period is 184), as shown below:

July 17 to July 31	14 days
August	31 days
September 1	1 day
	46 days

In contrast to the actual/actual day count convention for coupon-bearing Treasury securities, for corporate and municipal bonds and agency securities, the day count convention is "30/360." That is, each month is assumed to have 30 days and each year 360 days. For example, suppose that the security in our previous example is not a coupon-bearing Treasury security but instead either a coupon-bearing corporate bond, municipal bond, or agency security. The number of days between July 17 and September 1 is shown below:

Remainder of July	13 days
August	30 days
September 1	1 day
	44 days

Compounding

Once the number of days between the settlement date and the next coupon date is determined, the present value formula must be modified because the cash flows will not be received six months (one full period) from now. The Street convention is to compute the price is as follows:

1. Determine the number of days in the coupon period.
2. Compute the following ratio:

$$w = \frac{\text{number of days between settlement and next coupon payment}}{\text{number of days in the coupon period}}$$

For a corporate bond, a municipal bond, and an agency security, the number of days in the coupon period will be 180 because a year is assumed to have 360 days. For a coupon-bearing Treasury security, the number of days is the actual number of days. The number of days in the coupon period is called the *basis*.

3. For a bond with n coupon payments remaining to maturity, the price is

$$p = \frac{c}{(1+i)^w} + \frac{c}{(1+i)^{1+w}} + \frac{c}{(1+i)^{2+w}} + \cdots + \frac{c}{(1+i)^{n-1+w}} + \frac{M}{(1+i)^{n-1+w}}$$

where

p = price ($)
c = semiannual coupon payment ($)
M = maturity value
n = number of coupon payments remaining
i = periodic interest rate (required yield divided by 2) (in decimal)

The period (exponent) in the formula for determining the present value can be expressed generally as $t - 1 + w$. For example, for the first cash flow, the period is $1 - 1 + w$, or simply w. For the second cash flow, it is $2 - 1 + w$, or simply $1 + w$. If the bond has 20 coupon payments remaining, the last period is $20 - 1 + w$, or simply $19 + w$.

Illustration 4. Suppose that a corporate bond with a coupon rate of 10% maturing March 1, 2027 is purchased with a settlement date of July 17, 2021. What would the price of this bond be if it is priced to yield 6.5%?

The next coupon payment will be made on September 1, 2021. Because the bond is a corporate bond, based on a 30/360 day-count convention, there are 44 days between the settlement date and the next coupon date. The number of days in the coupon period is 180. Therefore,

$$w = \frac{44}{180} = 0.24444$$

The number of coupon payments remaining, n, is 12. The semiannual interest rate is 3.25% (6.5%/2).

The calculation based on the formula for the price is given in Exhibit 4-4. The price of this corporate bond would be $120.0281 per $100 par value. The price calculated in this way is called the *full price* or *dirty price* because it reflects the portion of the coupon interest that the buyer will receive but that the seller has earned.

Accrued Interest and the Clean Price

The buyer must compensate the seller for the portion of the next coupon interest payment the seller has earned but will not receive from the issuer because the issuer will send the next coupon payment to the buyer. This amount is called *accrued interest* and depends on the number of days from the last coupon payment to the settlement date.[5] The accrued interest is computed as follows:

$$\text{AI} = c\left(\frac{\text{number of days from last coupon payment to settlement date}}{\text{number of days in coupon period}}\right)$$

5. Accrued interest is not computed for all bonds. No accrued interest is computed for bonds in default or income bonds. A bond that trades without accrued interest is said to be traded “flat.”

EXHIBIT 4-4

Price Calculation When a Bond Is Purchased Between Coupon Payments

Period	Cash Flow per \$100 of Par	Present Value of \$1 at 3.25%	Present Value of Cash Flow
0.24444	\$ 5.000	\$0.992212	\$4.961060
1.24444	5.000	0.960980	4.804902
2.24444	5.000	0.930731	4.653658
3.24444	5.000	0.901435	4.507175
4.24444	5.000	0.873060	4.365303
5.24444	5.000	0.845579	4.227896
6.24444	5.000	0.818963	4.094815
7.24444	5.000	0.793184	3.965922
8.24444	5.000	0.768217	3.841087
9.24444	5.000	0.744036	3.720181
10.24444	5.000	0.720616	3.603081
11.24444	105.000	0.697933	73.283000
		Total	\$120.028100

where

AI = accrued interest (\$)
c = semiannual coupon payment (\$)

Illustration 5. Let's continue with the hypothetical corporate bond in Illustration 4. Because the number of days between settlement (July 17, 2021) and the next coupon payment (September 1, 2021) is 44 days and the number of days in the coupon period is 180, the number of days from the last coupon payment date (March 1, 2021) to the settlement date is 136 (180 − 44). The accrued interest per \$100 of par value is

$$\text{AI} = \$5\left(\frac{136}{180}\right) = \$3.777778$$

The full or dirty price includes the accrued interest that the seller is entitled to receive. For example, in the calculation of the full price in Exhibit 4-4, the next coupon payment of \$5 is included as part of the cash flow. The *clean price* or *flat price* is the full price of the bond minus the accrued interest.

The price that the buyer pays the seller is the full price. It is important to note that in calculation of the full price, the next coupon payment is a discounted value, but in calculation of accrued interest, it is an undiscounted value. Because of this market practice, if a bond is selling at par and the settlement date is not a coupon date, the yield will be slightly less than the coupon rate. Only when the settlement date and coupon date coincide is the yield equal to the coupon rate for a bond selling at par.

In the U.S. bond market, the convention is to quote a bond's clean or flat price. The buyer, however, pays the seller the full price. In some non-U.S. bond markets, the full price is quoted.

CONVENTIONAL YIELD MEASURES

In the preceding section we explained how to compute the price of a bond given the required yield. In this section we'll show how various yield measures for a bond are calculated given its price. First let's look at the sources of potential return from holding a bond.

An investor who purchases a bond can expect to receive a *dollar* return from one or more of the following sources:

- The coupon interest payments made by the issuer
- Any capital gain (or capital loss—negative dollar return) when the bond matures, is called, or is sold
- Income from reinvestment of the coupon interest payments

This last source of dollar return is referred to as *interest-on-interest.*

Three yield measures are commonly cited by market participants to measure the potential return from investing in a bond—current yield, yield-to-maturity, and yield-to-call. These yield measures are expressed as a *percent* return rather than as a dollar return. However, any yield measure should consider each of the three potential sources of return just cited. Below we discuss these three yield measures and assess whether they consider the three sources of potential return.

Current Yield

The current yield relates the *annual* coupon interest to the market price. The formula for the current yield is

$$\text{Current yield} = \frac{\text{annual dollar coupon interest}}{\text{price}}$$

Illustration 6. The current yield for an 18-year, 6% coupon bond selling for \$700.89 per \$1,000 par value is 8.56%, as shown below:

$$\begin{aligned}\text{Annual dollar coupon interest} &= \$1{,}000 \times 0.06\\ &= \$60\end{aligned}$$

$$\text{Current yield} = \frac{\$60}{\$700.89} = 0.0856, \text{ or } 8.56\%$$

The current yield considers only the coupon interest and no other source of return that will affect an investor's return. For example, in Illustration 6, no consideration is given to the capital gain that the investor will realize when the bond matures. No recognition is given to a capital loss that the investor will realize when a bond selling at a premium matures. In addition, interest-on-interest from reinvesting coupon payments is ignored.

Yield-to-Maturity

The yield or internal rate of return on any investment is the interest rate that will make the present value of the cash flows equal to the price (or initial investment).[6] The yield-to-maturity is computed in the same way as the yield; the cash flows are those which the investor would realize by holding the bond to maturity. For a semiannual-pay bond, doubling the interest rate or discount rate gives the yield-to-maturity.

The calculation of a yield involves a trial-and-error procedure. Practitioners usually use calculators or software to obtain a bond's yield-to-maturity. There are several calculators available online. The following illustration shows how to compute the yield-to-maturity for a bond.

Illustration 7. In Illustration 6 we computed the current yield for an 18-year, 6% coupon bond selling for $700.89. The maturity value for this bond is $1,000. The yield-to-maturity for this bond is 9.5%, as shown in Exhibit 4-5. Cash flows for the bond are

- 36 coupon payments of $30 every six months
- $1,000 36 six-month periods from now

Different interest rates must be tried until one is found that makes the present value of the cash flows equal to the price of $700.89. Because the coupon rate on the bond is 6% and the bond is selling at a discount, the yield must be greater than 6%. Exhibit 4-5 shows the present value of the cash flows of the bond for semiannual interest rates from 3.25% to 4.75% (corresponding to annual interest rates from 6.5% to 9.50%). As can be seen, when a 4.75% interest rate is used, the present value of the cash flows is $700.89. Therefore, the yield-to-maturity is 9.50% (4.75% $\times$ 2).

The yield-to-maturity considers the coupon income and any capital gain or loss that the investor will realize by *holding the bond to maturity.* The yield-to-maturity also considers the timing of the cash flows. It does consider interest-on-interest; *however, it assumes that the coupon payments can be reinvested at an interest rate equal to the yield-to-maturity.* Thus, if the yield-to-maturity for a bond is 9.5%, to earn that yield, the coupon payments must be reinvested at an interest rate equal to 9.5%. The following example clearly demonstrates this.

6. For asset-backed and mortgage-backed securities, the equivalent measure is called the cash flow yield.

EXHIBIT 4-5

Computation of Yield-to-Maturity for an 18-Year, 6% Coupon Bond Selling at $700.89

Objective: Find, by trial and error, the semiannual interest rate that will make the present value of the following cash flows equal to $700.89:

36 coupon payments of $30 every six months
$1,000 36 six-month periods from now

Annual Interest Rate	Semi-annual Rate	Present Value of 36 Payments of $30*	Present Value of $1,000 10 Periods from Now†	Present Value of Cash Flows
6.50%	3.25%	$631.20	$316.20	$947.40
7.00	3.50	608.71	289.83	898.54
7.50	3.75	587.42	265.72	853.14
8.00	4.00	567.25	243.67	810.92
8.50	4.25	548.12	223.49	771.61
9.00	4.50	529.98	205.03	735.01
9.50	4.75	512.76	188.13	700.89

$$*30\left[\frac{1-\left\{\dfrac{1}{(1+\text{semiannual interest rate})^{36}}\right\}}{\text{semiannual interest rate}}\right]$$

$$^{\dagger}\$1{,}000\left[\frac{1}{(1+\text{semiannual interest rate})^{36}}\right]$$

Suppose that an investor has $700.89 and places the funds in a certificate of deposit (CD) that pays 4.75% every six months for 18 years, or 9.5% per year. At the end of 18 years, the $700.89 investment will grow to $3,726. Instead, suppose that the investor buys a 6%, 18-year bond selling for $700.89. This is the same as the price of our bond in Illustration 7. The yield-to-maturity for this bond is 9.5%. The investor would expect that at the end of 18 years, the total dollars from the investment will be $3,726.

Let's look at what he will receive. There will be 36 semiannual interest payments of $30, which will total $1,080. When the bond matures, the investor will receive $1,000. Thus the total dollars that he will receive is $2,080 if the investor holds the bond to maturity, but this is $1,646 less than the $3,726 necessary to produce a yield of 9.5% (4.75% semiannually). How is this deficiency supposed to be made up? If the investor reinvests the coupon payments at a semiannual interest rate of 4.75% (or a 9.5% annual rate), it is a simple exercise to demonstrate that the interest earned on the coupon payments will be $1,646.

Consequently, of the \$3,025 total dollar return (\$3,726 – \$700.89) necessary to produce a yield of 9.5%, about 54% (\$1,646 divided by \$3,025) must be generated by reinvesting the coupon payments.

Clearly, the investor will realize the yield-to-maturity stated at the time of purchase only if (1) the coupon payments can be reinvested at the yield-to-maturity and (2) if the bond is held to maturity. With respect to the first assumption, the risk that an investor faces is that future reinvestment rates will be less than the yield-to-maturity at the time the bond is purchased. This risk is referred to as *reinvestment risk.* If the bond is not held to maturity, the price at which the bond may have to be sold is less than its purchase price, resulting in a return that is less than the yield-to-maturity. The risk that a bond will have to be sold at a loss because interest rates rise is referred to as *interest-rate risk.*

Reinvestment Risk

There are two characteristics of a bond that determine the degree of reinvestment risk. First, for a given yield-to-maturity and a given coupon rate, the longer the maturity, the more the bond's total dollar return is dependent on the interest-on-interest to realize the yield-to-maturity at the time of purchase. That is, the greater the reinvestment risk. The implication is that the yield-to-maturity measure for long-term coupon bonds tells little about the potential yield that an investor may realize if the bond is held to maturity. In high-interest-rate environments, the interest-on-interest component for long-term bonds may be as high as 80% of the bond's potential total dollar return.

The second characteristic that determines the degree of reinvestment risk is the coupon rate. For a given maturity and a given yield-to-maturity, the higher the coupon rate, the more dependent the bond's total dollar return will be on the reinvestment of the coupon payments in order to produce the yield-to-maturity at the time of purchase. This means that holding maturity and yield-to-maturity constant, premium bonds will be more dependent on interest-on-interest than bonds selling at par. For zero-coupon bonds, none of the bond's total dollar return is dependent on interest-on-interest; a zero-coupon bond carries no reinvestment risk if held to maturity.

Interest-Rate Risk

As we explained in the preceding section, a bond's price moves in the direction opposite to the change in interest rates. As interest rates rise (fall), the price of a bond will fall (rise). For an individual investor who plans to hold a bond to maturity, the change in the bond's price before maturity is of no concern; however, for an individual investor who may have to sell the bond prior to the maturity date, an increase in interest rates after the bond is purchased will mean the realization of a capital loss. Not all bonds have the same degree of interest-rate risk. In Chapter 5, the characteristics of a bond that determine its interest-rate risk are discussed.

Given the assumptions underlying yield-to-maturity, we can now demonstrate that yield-to-maturity has limited value in assessing the potential return of bonds.

Suppose that an investor who has a five-year investment horizon is considering the following four option-free bonds:

Bond	Coupon Rate	Maturity	Yield-to-Maturity
W	5%	3 years	9.0%
X	6	20	8.6
Y	11	15	9.2
Z	8	5	8.0

Assuming that all four bonds are of the same credit quality, which one is the most attractive to this investor? An investor who selects bond Y because it offers the highest yield-to-maturity is failing to recognize that the bond must be sold after five years, and the selling price of the bond will depend on the yield required in the market for 10-year, 11% coupon bonds at that time. Hence there could be a capital gain or capital loss that will make the return higher or lower than the yield-to-maturity promised now. Moreover, the higher coupon rate on bond Y relative to the other three bonds means that more of this bond's return will be dependent on the reinvestment of coupon interest payments.

Bond W offers the second highest yield-to-maturity. On the surface, it seems to be particularly attractive because it eliminates the problem faced by purchasing bond Y of realizing a possible capital loss when the bond must be sold before the maturity date. In addition, the reinvestment risk seems to be less than for the other three bonds because the coupon rate is the lowest. However, the investor would not be eliminating the reinvestment risk because after three years the investor must reinvest the proceeds received at maturity for two more years. The return that the investor will realize will depend on interest rates three years from now when the investor must roll over the proceeds received from the maturing bond.

Which is the best bond? The yield-to-maturity doesn't seem to help us identify the best bond. The answer depends on the expectations of the investor. Specifically, it depends on the interest rate at which the coupon interest payments can be reinvested until the end of the investor's investment horizon. Also, for bonds with a maturity longer than the investment horizon, it depends on the investor's expectations about interest rates at the end of the investment horizon. Consequently, any of these bonds can be the best investment vehicle based on some reinvestment rate and some future interest rate at the end of the investment horizon. In the next section we present an alternative return measure for assessing the potential performance of a bond.

Yield-to-Maturity for a Zero-Coupon Bond

When there is only one cash flow, it is much easier to compute the yield on an investment. A zero-coupon bond is characterized by a single cash flow resulting from an investment. Consequently, the following formula can be applied to compute the yield-to-maturity for a zero-coupon bond:

$$y = (\text{future value per dollar invested})^{1/n} - 1$$

where

$$y = \text{one-half the yield-to-maturity}$$

$$\text{Future value per dollar invested} = \frac{\text{maturity value}}{\text{price}}$$

Once again, doubling y gives the yield-to-maturity. *Remember that the number of periods used in the formula is double the number of years.*

Illustration 8. The yield-to-maturity for a zero-coupon bond selling for \$274.78 with a maturity value of \$1,000, maturing in 15 years, is 8.8%, as computed below:

$$n = 15 \times 2 = 30$$

$$\text{Future value per dollar invested} = \frac{\$1{,}000.00}{\$274.78} = 3.639275$$

$$\begin{aligned} y &= (3.639275)^{1/30} - 1 \\ &= (3.639275)^{0.033333} - 1 \\ &= 1.044 - 1 \\ &= 0.044, \text{ or } 4.4\% \end{aligned}$$

Doubling 4.4% gives the yield-to-maturity of 8.8%.

Relationship Among Coupon Rate, Current Yield, and Yield-to-Maturity

The following relationship should be recognized between the coupon rate, current yield, and yield-to-maturity:

Bond Selling at	Relationship
Par	Coupon rate = current yield = yield-to-maturity
Discount	Coupon rate < current yield < yield-to-maturity
Premium	Coupon rate > current yield > yield-to-maturity

Problem with the Annualizing Procedure

Multiplying a semiannual interest rate by 2 will give an underestimate of the effective annual yield. The proper way to annualize the semiannual yield is by applying the following formula:

$$\text{Effective annual yield} = (1 + \text{periodic interest rate})^k - 1$$

where

$$k = \text{number of payments per year}$$

For a semiannual-pay bond, the formula can be modified as follows:

$$\text{Effective annual yield} = (1 + \text{semiannual interest rate})^2 - 1$$

or

$$\text{Effective annual yield} = (1+y)^2 - 1$$

For example, in Illustration 7, the semiannual interest rate is 4.75%, and the effective annual yield is 9.73%, as shown below:

$$\begin{aligned}\text{Effective annual yield} &= (1.0475)^2 - 1\\ &= 1.0973 - 1\\ &= 0.0973, \text{ or } 9.73\%\end{aligned}$$

Although the proper way for annualizing a semiannual interest rate is given in the preceding formula, the convention adopted in the bond market is to double the semiannual interest rate. The yield-to-maturity computed in this manner—doubling the semiannual yield—is called a *bond-equivalent yield.* In fact, this convention is carried over to yield calculations for other types of fixed income securities.

Yield-to-Call

For a callable bond, investors also compute another yield (or internal rate of return) measure, the *yield-to-call*. The cash flows for computing the yield-to-call are those which would result if the issue were called on some assumed call date. Two commonly used call dates are the *first call date* and the *first par call date*. The yield-to-call is the interest rate that will make the present value of the cash flows if the bond is held to the assumed call date equal to the price of the bond (i.e., the full price).

Illustration 9. In Illustrations 6 and 7, we computed the current yield and yield-to-maturity for an 18-year, 6% coupon bond selling for \$700.89. Suppose that this bond is first callable in five years at \$1,030. The cash flows for this bond if it is called in five years are

- 10 coupon payments of \$30 every six months
- \$1,030 in 10 six-month periods from now

The interest rate we seek is one that will make the present value of the cash flows equal to \$700.89. From Exhibit 4-6, it can be seen that when the interest rate is 7.6%, the present value of the cash flows is \$700.11, which is close enough to \$700.89 for our purposes. Therefore, the yield-to-call on a bond-equivalent basis is 15.2% (double the periodic interest rate of 7.6%).

According to the conventional approach, conservative investors will compute the yield-to-call and yield-to-maturity for a callable bond selling at a premium, selecting the lower of the two as a measure of potential return. It is the smaller of the two yield measures that investors would use to evaluate the yield for a bond. Some investors calculate not just the yield to the first call date and yield to first par call date but the yield to all possible call dates. Because most bonds can be called

EXHIBIT 4-6

Computation of Yield-to-Call for an 18-Year, 6% Coupon Bond Callable in 5 Years at $1,030, Selling at $700.89

Objective: Find, by trial and error, the semiannual interest rate that will make the present value of the following cash flows equal to $700.89:

10 coupon payments of $30 every six months
$1,030 10 six-month periods from now

Annual Interest Rate	Semi-annual Rate	Present Value of 10 Payments of $30*	Present Value of $1,030 10 Periods from Now†	Present Value of Cash Flows
11.20%	5.60%	$225.05	$597.31	$822.36
11.70	5.85	222.38	585.35	805.73
12.20	6.10	219.76	569.75	789.51
12.70	6.35	217.19	556.50	773.69
13.20	6.60	214.66	543.58	758.24
13.70	6.85	212.18	531.00	743.18
14.20	7.10	209.74	518.73	728.47
14.70	7.35	207.34	506.78	714.12
15.20	7.60	204.99	495.12	700.11

$$^*\$30\left[\frac{1-\left\{\dfrac{1}{(1+\text{semiannual interest rate})^{10}}\right\}}{\text{semiannual interest rate}}\right]$$

$$^{\dagger}\$1,030\left[\frac{1}{(1+\text{semiannual interest rate})^{10}}\right]$$

at any time after the first call date, the approach has been to compute the yield to every coupon anniversary date following the first call date. Then all calculated yields-to-call and the yield-to-maturity are compared. The lowest of these yields is called the *yield-to-worst*. The conventional approach would have us believe that this yield is the appropriate one a conservative investor should use.

Let's take a closer look at the yield-to-call as a measure of the potential return of a callable bond. The yield-to-call does consider all three sources of potential return from owning a bond. However, as in the case of the yield-to-maturity, it assumes that all cash flows can be reinvested at the computed yield—in this case, the yield-to-call—until the assumed call date. As we noted earlier in this chapter, this assumption may be inappropriate. Moreover, the yield-to-call assumes that (1) the investor will hold the bond to the assumed call date and (2) the issuer will call the bond on that date.

The assumptions underlying the yield-to-call are often unrealistic. They do not take into account how an investor will reinvest the proceeds if the issue is called. For example, consider two bonds, M and N. Suppose that the yield-to-maturity for bond M, a five-year option-free bond, is 6.0%, whereas for bond N the yield-to-call, assuming that the bond will be called in three years, is 6.5%. Which bond is better for an investor with a five-year investment horizon? It's not possible to tell from the yields cited. If the investor intends to hold the bond for five years and the issuer calls the bond after three years, the total dollars that will be available at the end of five years will depend on the interest rate that can be earned from reinvesting funds from the call date to the end of the investment horizon.

More will be said about the analysis of callable bonds in Chapter 36.

Yield (Internal Rate of Return) for a Portfolio

The yield for a portfolio of bonds is not simply the average or weighted average of the yield-to-maturity of the individual bond issues. It is computed by determining the cash flows for the portfolio and then finding the interest rate that will make the present value of the cash flows equal to the market value of the portfolio.[7] As with any yield measure, it suffers from the same assumptions.

Illustration 10. Consider the following three-bond portfolio:[8]

Bond	Coupon Rate	Maturity	Par Value	Price Value	Yield-to-Maturity
A	7.0%	5 years	$ 10,000,000	$ 9,209,000	9.0%
B	10.5	7	20,000,000	20,000,000	10.5
C	6.0	3	30,000,000	28,050,000	8.5

The portfolio's total market value is $57,259,000. The cash flow for each bond in the portfolio and for the whole portfolio is as follows:

Period Cash Flow Received	Bond A	Bond B	Bond C	Portfolio
1	$ 350,000	$ 1,050,000	$ 900,000	$ 2,300,000
2	350,000	1,050,000	900,000	2,300,000
3	350,000	1,050,000	900,000	2,300,000
4	350,000	1,050,000	900,000	2,300,000
5	350,000	1,050,000	900,000	2,300,000
6	350,000	1,050,000	30,900,000	32,300,000
7	350,000	1,050,000	—	1,400,000
8	350,000	1,050,000	—	1,400,000

(Continued)

7. Chapter 5 discusses the concept of duration. A good approximation to the yield for a portfolio can be obtained by using duration to weight the yield-to-maturity of the individual bonds in the portfolio.
8. To simplify the illustration, it is assumed that the coupon payment date is the same for each bond.

(Continued)

Period Cash Flow Received	Bond A	Bond B	Bond C	Portfolio
9	350,000	1,050,000	—	1,400,000
10	10,350,000	1,050,000	—	11,400,000
11	—	1,050,000	—	1,050,000
12	—	1,050,000	—	1,050,000
13	—	1,050,000	—	1,050,000
14	—	21,050,000	—	21,050,000

To determine the yield (internal rate of return) for this three-bond portfolio, the interest rate that makes the present value of the cash flows shown in the last column of the table above equal to $57,259,000 (the total market value of the portfolio) must be found. If an interest rate of 4.77% is used, the present value of the cash flows will equal $57,259,000. Doubling 4.77% gives 9.54%, which is the yield on the portfolio on a bond-equivalent basis.

Yield Measure for Floating-Rate Securities

The coupon rate for a floating-rate security changes periodically based on some reference rate (such as LIBOR).[9] Because the value for the reference rate in the future is not known, it is not possible to determine the cash flows. This means that a yield-to-maturity cannot be calculated.

A conventional measure used to estimate the potential return for a floating-rate security is the security's *discount margin.* This measure estimates the average spread or margin over the reference rate that the investor can expect to earn over the life of the security. The procedure for calculating the discount margin is as follows:

1. Determine the cash flows assuming that the reference rate does not change over the life of the security.
2. Select a margin (spread).
3. Discount the cash flows found in step 1 by the current value of the reference rate plus the margin selected in step 2.
4. Compare the present value of the cash flows as calculated in step 3 to the price. If the present value is equal to the security's price, the discount margin is the margin assumed in step 2. If the present value is not equal to the security's price, go back to step 2 and try a different margin.

For a security selling at par, the discount margin is simply the spread over the reference rate.

Illustration 11. To illustrate the calculation, suppose that a six-year floating-rate security selling for 99.3098 pays a rate based on some reference rate plus 80 basis points. The coupon rate is reset every six months. Assume that the

9. Other spread measures are explained in Chapter 14.

current value for the reference rate is 10%. Exhibit 4-7 shows the calculation of the discount margin for this security. The second column shows the current discounted value for the reference rate (10%). The third column sets forth the cash flows for the security. The cash flow for the first 11 periods is equal to one-half the current value for the reference rate (5%) plus the semiannual spread of 40 basis points multiplied by 100. In the twelfth six-month period, the cash flow is 5.4 plus the maturity value of 100. The top row of the last five columns shows the assumed margin. The rows below the assumed margin show the present value of each cash flow. The last row gives the total present value of the cash flows. For the five assumed yield spreads, the present value is equal to the price of the floating-rate security (99.3098) when the assumed margin is 96 basis points. Therefore, the discount margin on a semiannual basis is 48 basis points and 96 basis points on an annual basis. (Notice that the discount margin is 80 basis points, the same as the spread over the reference rate, when the security is selling at par.)

EXHIBIT 4-7

Calculation of the Discount Margin for a Floating-Rate Security

Floating-rate security: Maturity = 6 years
Coupon rate = reference rate + 80 basis points
Reset every six months

			Present Value of Cash Flow: Assumed Annual Yield Spread (in bp)				
Period	**Reference Rate**	**Cash Flow***	**80**	**84**	**88**	**96**	**100**
1	10%	5.4	5.1233	5.1224	5.1214	5.1195	5.1185
2	10	5.4	4.8609	4.8590	4.8572	4.8535	4.8516
3	10	5.4	4.6118	4.6092	4.6066	4.6013	4.5987
4	10	5.4	4.3755	4.3722	4.3689	4.3623	4.3590
5	10	5.4	4.1514	4.1474	4.1435	4.1356	4.1317
6	10	5.4	3.9387	3.9342	3.9297	3.9208	3.9163
7	10	5.4	3.7369	3.7319	3.7270	3.7171	3.7122
8	10	5.4	3.5454	3.5401	3.5347	3.5240	3.5186
9	10	5.4	3.3638	3.3580	3.3523	3.3409	3.3352
10	10	5.4	3.1914	3.1854	3.1794	3.1673	3.1613
11	10	5.4	3.0279	3.0216	3.0153	3.0028	2.9965
12	10	105.4	56.0729	55.9454	55.8182	55.5647	55.4385
Present value			100.0000	99.8269	99.6541	99.3098	99.138

*For periods 1–11: cash flow = 100 (reference rate + assumed margin) (0.5); for period 12: cash flow = 100 (reference rate + assumed margin) (0.5) + 100.

There are two drawbacks of the discount margin as a measure of the potential return from investing in a floating-rate security. First, this measure assumes that the reference rate will not change over the life of the security. Second, if the floating-rate security has a cap or floor, this is not taken into consideration. Techniques described in Chapter 36 can allow interest rate volatility to be considered and can handle caps or floors.

TOTAL RETURN ANALYSIS

If conventional yield measures such as the yield-to-maturity and yield-to-call offer little insight into the potential return of a bond, what measure of return can be used? The proper measure is one that considers all three sources of potential dollar return over the investment horizon. This requires that an investor first project the total future dollars over an investment horizon. The return is then the interest rate that will make the bond's price (full price) grow to the projected total future dollars at the end of the investment horizon. The yield computed in this way is known as the *total return,* also referred to as the *horizon return.* In this section we explain this measure and demonstrate how it can be applied in assessing the potential return from investing in a bond.

Calculating the Total Return

The total return requires that the investor specify

- An investment horizon
- A reinvestment rate
- A selling price for the bond at the end of the investment horizon (which depends on the assumed yield at which the bond will sell at the end of the investment horizon)

More formally, the steps for computing a total return over some investment horizon are as follows.

Step 1: Compute the total coupon payments plus the interest-on-interest based on an assumed reinvestment rate. The reinvestment rate is one-half the annual interest rate that the investor believes can be earned on the reinvestment of coupon interest payments.

The total coupon payments plus interest-on-interest can be calculated using the formula for the future value of an annuity as shown:

$$\text{Coupon plus interest-on-interest} = \text{semiannual coupon}\left[\frac{\left\{(1+r)^h - 1\right)\}}{r}\right]$$

where

h = length of the investment horizon (in semiannual periods)
r = assumed semiannual reinvestment rate

Step 2: Determine the projected sale price at the end of the investment horizon. The projected sale price will depend on the projected yield on comparable bonds at the end of the investment horizon.

Step 3: Add the values computed in steps 1 and 2. The sum is the *total future dollars* that will be received from the investment given the assumed reinvestment rate and projected required yield at the end of the investment horizon.

Step 4: To obtain the semiannual total return, use the following formula:

$$\left(\frac{\text{total future dollars}}{\text{purchase price of bond}}\right)^{1/h} - 1$$

Step 5: Because coupon interest is assumed to be paid semiannually, double the interest rate found in step 4. The resulting interest rate is the total return expressed on a bond-equivalent basis. Alternatively, the total return can be expressed on an effective annual interest rate basis by using the following formula:

$$(1 + \text{semiannual total return})^2 - 1$$

Illustration 12. Suppose that an investor with a three-year investment horizon is considering purchasing a 20-year, 8% coupon bond for \$828.40. The yield-to-maturity for this bond is 10%. The investor expects to reinvest the coupon interest payments at an annual interest rate of 6% and that at the end of the investment horizon the 17-year bond will be selling to offer a yield-to-maturity of 7%. The total return for this bond is computed in Exhibit 4-8.

Objections to the total return analysis cited by some portfolio managers are that it requires them to make assumptions about reinvestment rates and future yields and forces a portfolio manager to think in terms of an investment horizon. Unfortunately, some portfolio managers find comfort in meaningless measures such as the yield-to-maturity because it is not necessary to incorporate any expectations. As explained below, the total return framework enables the portfolio manager to analyze the performance of a bond based on different interest-rate scenarios for reinvestment rates and future market yields. By investigating multiple scenarios, the portfolio manager can see how sensitive the bond's performance is in each scenario. There is no need to assume that the reinvestment rate will be constant for the entire investment horizon.

For portfolio managers who want to use the market's expectations of short-term reinvestment rates and the yield on the bond at the end of the investment

EXHIBIT 4-8

Illustration of Total Return Calculation

Assumptions:

Bond = 8% 20-year bond selling for \$828.40 (yield-to-maturity is 10%)

Annual reinvestment rate = 6%

Investment horizon = 3 years

Yield for 17-year bonds at end of investment horizon = 7%

Step 1: Compute the total coupon payments plus the interest-on-interest assuming an annual reinvestment rate of 6%, or 3% every six months. The coupon payments are \$40 every six months for three years or six periods (the investment horizon). The total coupon interest plus interest-on-interest is

$$\text{Coupon plus interest-on-interest} = \$40\left(\frac{(1.03)^6 - 1}{0.03}\right) = \$258.74$$

Step 2: The projected sale price at the end of 3 years, assuming that the required yield-to-maturity for 17-year bonds is 7%, is found by determining the present value of 34 coupon payments of \$40 plus the present value of the maturity value of \$1,000, discounted at 3.5%. The price can be shown to be \$1,098.51.

Step 3: Adding the amount in steps 1 and 2 gives total future dollars of \$1,357.25.

Step 4: Compute the following:

$$= \left(\frac{\$1,357.25}{828.40}\right)^{1/6} - 1$$

$$= (1.63840)^{0.16667} - 1$$

$$1.0858 - 1$$

$$= 0.0858, \text{ or } 8.58\%$$

Step 5: Doubling 8.58% gives a total return of 17.16% on a bond-equivalent basis. On an effective annual interest-rate basis, the total return is

$$(1.0858)^2 - 1$$

$$= 1.1790 - 1$$

$$= 0.1790$$

$$= 17.90\%$$

horizon, implied forward rates can be calculated from the yield-curve. Implied forward rates are explained in Chapters 3 and 31, and are calculated based on arbitrage arguments. A total return computed using implied forward rates is called an *arbitrage-free total return.*

Scenario Analysis

Because the total return depends on the reinvestment rate and the yield at the end of the investment horizon, portfolio managers assess performance over a wide range of scenarios for these two variables. This approach is referred to as *scenario analysis.*

Illustration 13. Suppose that a portfolio manager is considering the purchase of bond A, a 20-year, 9% option-free bond selling at $109.896 per $100 of par value. The yield-to-maturity for this bond is 8%. Assume also that the portfolio manager's investment horizon is three years and that the portfolio manager believes that the reinvestment rate can vary from 3% to 6.5% and that the yield at the end of the investment horizon can vary from 5% to 12%.

The top panel of Exhibit 4-9 shows the total future dollars at the end of three years under various scenarios. The bottom panel shows the total return (based on the effective annualizing of the six-month total return). The portfolio manager knows that the maximum and minimum total return for the scenarios analyzed will be 16.72% and –1.05%, respectively, and the scenarios under which each will be realized. If the portfolio manager faces three-year liabilities guaranteeing, say, 6%, the major consideration is scenarios that will produce a three-year total return of less than 6%. These scenarios can be determined from Exhibit 4-9.

Illustration 14. Suppose that the same portfolio manager owns bond B, a 14-year option-free bond with a coupon rate of 7.25% and a current price of $94.553 per $100 par value. The yield-to-maturity is 7.9%. Exhibit 4-10 reports the total future dollars and total return over a three-year investment horizon under the same scenarios as Exhibit 4-9. A portfolio manager considering swapping from bond B to bond A would compare the relative performance of the two bonds as reported in Exhibits 4-9 and 4-10. Exhibit 4-11 shows the difference between the performance of the two bonds in basis points. This comparative analysis assumes that the two bonds are of the same investment quality and ignores the financial accounting and tax consequences associated with the disposal of bond B to acquire bond A.

Evaluating Potential Bond Swaps

Portfolio managers commonly swap an existing bond in a portfolio for another bond. Bond swaps can be categorized as pure yield pickup swaps, substitution swaps, intermarket-spread swaps, or rate-anticipation swaps. Total return analysis can be used to assess the potential return from a swap.

- *Pure yield pickup swap.* Switching from one bond to another that has a higher yield is called a *pure yield pickup swap.* The swap may be undertaken to achieve either higher current coupon income or higher yield-to-maturity or both. No expectation is made about changes in interest rates, yield spreads, or credit quality.

EXHIBIT 4-9

Scenario Analysis for Bond A

Bond A: 9% coupon, 20-year option-free bond
Price: $109.896
Yield-to-maturity: 8.00%
Investment horizon: 3 years

	Yield at End of Horizon							
	5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
	Horizon Price							
	145.448	131.698	119.701	109.206	100.000	91.9035	84.763	78.4478
	Total Future Dollars							
Reinvestment Rate	5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
3.0%	173.481	159.731	147.734	137.239	128.033	119.937	112.796	106.481
3.5	173.657	159.907	147.910	137.415	128.209	120.113	112.972	106.657
4.0	173.834	160.084	148.087	137.592	128.387	120.290	113.150	106.834
4.5	174.013	160.263	148.266	137.771	128.565	120.469	113.328	107.013
5.0	174.192	160.443	148.445	137.950	128.745	120.648	113.508	107.193
5.5	174.373	160.623	148.626	138.131	128.926	120.829	113.689	107.374
6.0	174.555	160.806	148.809	138.313	129.108	121.011	113.871	107.556
6.5	174.739	160.989	148.992	138.497	129.291	121.195	114.054	107.739
	Total Return (Effective Rate)							
Reinvestment Rate	5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
3.0%	16.44	13.28	10.37	7.69	5.22	2.96	0.87	–1.05
3.5	16.48	13.32	10.41	7.73	5.27	3.01	0.92	–0.99
4.0	16.52	13.36	10.45	7.78	5.32	3.06	0.98	–0.94
4.5	15.56	13.40	10.50	7.83	5.37	3.11	1.03	–0.88
5.0	16.60	13.44	10.54	7.87	5.42	3.16	1.08	–0.83
5.5	16.64	13.49	10.59	7.92	5.47	3.21	1.14	–0.77
6.0	16.68	13.53	10.63	7.97	5.52	3.26	1.19	–0.72
6.5	16.72	13.57	10.68	8.02	5.57	3.32	1.25	–0.66

- *Rate-anticipation swap.* A portfolio manager who has expectations about the future direction of interest rates will use bond swaps to position the portfolio to take advantage of the anticipated interest-rate move. These are known as *rate-anticipation swaps.* If rates are expected to fall, for example, bonds with a greater price volatility will be swapped for existing bonds in the portfolio with lower price volatility (to take advantage of the larger change in price that will result if interest rates do in fact decline). The opposite will be done if rates are expected to rise.

EXHIBIT 4-10

Scenario Analysis for Bond B

Bond B: 7.25% coupon, 14-year option-free bond
Price: $94.553
Yield-to-maturity: 7.90%
Investment horizon: 3 years

	Yield at End of Horizon							
	5.00%	**6.00%**	**7.00%**	**8.00%**	**9.00%**	**10.00%**	**11.00%**	**12.00%**
Horizon Price	**118.861**	**109.961**	**101.896**	**94.5808**	**87.9386**	**81.9009**	**76.4066**	**71.4012**

Reinvestment Rate	Total Future Dollars 5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
3.0%	141.443	132.543	124.478	117.163	110.521	104.483	98.989	93.983
3.5	141.585	132.685	124.620	117.448	110.663	104.625	99.131	94.125
4.0	141.728	132.828	124.763	117.448	110.806	104.768	99.273	94.268
4.5	141.872	132.971	124.907	117.592	110.949	104.912	99.417	94.412
5.0	142.017	133.116	125.051	117.736	111.094	105.056	99.562	94.557
5.5	142.162	133.262	125.197	117.882	111.240	105.202	99.708	94.703
6.0	142.309	133.409	125.344	118.029	111.387	105.349	99.855	94.849
6.5	142.457	133.556	125.492	118.176	111.534	105.497	100.002	94.997

Reinvestment Rate	Total Return (Effective Rate) 5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
3.0%	14.37	11.92	9.60	7.41	5.34	3.38	1.54	–0.20
3.5	14.41	11.96	9.64	7.45	5.38	3.43	1.59	–0.15
4.0	14.44	12.00	9.68	7.50	5.43	3.48	1.64	–0.10
4.5	14.48	12.04	9.72	7.54	5.48	3.53	1.69	–0.05
5.0	14.52	12.08	9.77	7.58	5.52	3.57	1.74	0.00
5.5	14.56	12.12	9.81	7.63	5.57	3.62	1.79	0.05
6.0	14.60	12.16	9.85	7.67	5.61	3.67	1.84	0.10
6.5	14.64	12.20	9.90	7.72	5.66	3.72	1.89	0.16

- *Intermarket-spread swap.* These swaps are undertaken when the portfolio manager believes that the current yield spread between two bonds in the market is out of line with its historical yield spread and that the yield spread will realign by the end of the investment horizon. Yield spreads between bonds exist for the following reasons: (1) there is a difference in the credit quality of bonds (e.g., between Treasury bonds and double-A-rated public utility bonds of the same maturity),

EXHIBIT 4-11

Scenario Analysis Showing the Relative Performance of Bonds A and B

Reinvestment Rate	Total Return for Bond A minus Total Return for Bond B (in Basis Points)							
	5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
3.0%	207	136	77	28	–12	–43	–67	–85
3.5	207	136	77	28	–11	–42	–66	–84
4.0	207	136	77	28	–11	–42	–66	–84
4.5	207	136	77	29	–11	–42	–66	–83
5.0	207	137	78	29	–10	–41	–65	–83
5.5	208	137	78	29	–10	–41	–65	–82
6.0	208	137	78	30	–10	–41	–64	–82
6.5	208	137	78	30	–9	–40	–64	–81

or (2) there are differences in the features of corporate bonds that make them more or less attractive to investors (for example, callable and noncallable bonds, and putable and nonputable bonds).

- *Substitution swap.* In a substitution swap, a portfolio manager swaps one bond for another bond that is thought to be identical in terms of coupon, maturity, price sensitivity to interest-rate changes, and credit quality, but that offers a higher yield. This swap depends on a capital market imperfection. Such situations sometimes exist in the bond market because of temporary market imbalances. The risk that the portfolio manager faces is that the bond purchased may not be identical to the bond for which it is exchanged. For example, if credit quality is not the same, the bond purchased may be offering a higher yield because of higher credit risk rather than because of a market imbalance.

Comparing Municipal and Corporate Bonds

The conventional methodology for comparing the relative performance of a tax-exempt municipal bond and a taxable corporate bond is to compute the *taxable equivalent yield.* The taxable equivalent yield is the yield that must be earned on a taxable bond in order to produce the same yield as a tax-exempt municipal bond. The formula is

$$\text{Taxable equivalent yield} = \frac{\text{tax-exempt yield}}{1 - \text{marginal tax rate}}$$

For example, suppose that an investor in the 35% marginal tax bracket is considering a 10-year municipal bond with a yield-to-maturity of 4.5%. The taxable equivalent yield is

$$\frac{4.5\%}{1-0.35}=6.92\%$$

If the yield-to-maturity offered on a comparable-quality corporate bond with 10 years to maturity is more than 6.92%, those who use this approach would recommend that the corporate bond be purchased. If, instead, a yield-to-maturity of less than 6.92% on a comparable corporate bond is offered, the investor should invest in the municipal bond.

What's wrong with this approach? The tax-exempt yield of the municipal bond and the taxable equivalent yield suffer from the same limitations we discussed with respect to yield-to-maturity. Consider the difference in reinvestment opportunities for a corporate and a municipal bond. For the former, coupon payments will be taxed; therefore, the amount to be reinvested is not the entire coupon payment but an amount net of taxes. In contrast, because the coupon payments are free from taxes for a municipal bond, the entire coupon can be reinvested.

The total return framework can accommodate this situation by allowing us to explicitly incorporate the reinvestment opportunities. There is another advantage to the total return framework as compared with the conventional taxable equivalent yield approach. Changes in tax rates (because investors expect either their tax rate to change or the tax structure to change) can be incorporated into the total return framework.

KEY POINTS

- The price of a bond is equal to the present value of the expected cash flow.
- For bonds with embedded options, the cash flow is difficult to estimate.
- The required yield used to discount the cash flow is determined by the yield offered on comparable securities.
- The two most popular yield measures cited in the bond market are the yield-to-maturity and yield-to-call. Both yield measures consider the coupon interest and any capital gain (or loss) at the maturity date or call date in the case of the yield-to-call.
- The coupon interest and capital gain (or loss), however, are only two of the three components of the potential dollar return from owning a bond until it matures or is called. The other component is the reinvestment of coupon income, commonly referred to as the interest-on-interest component. This component can be as large as 80% of a bond's total dollar return.

- The yield-to-maturity assumes that the coupon payments can be reinvested at the calculated yield-to-maturity.
- The yield-to-call assumes that the coupon payments can be reinvested at the calculated yield-to-call.
- A better measure of the potential return from holding a bond over a predetermined investment horizon is the total return measure. This measure considers all three sources of potential dollar return and can be used to analyze bond swaps and bond performance.

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CHAPTER
FIVE

MEASURING INTEREST-RATE RISK

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The value of a bond changes in the opposite direction of the change in interest rates. A long bond position's value will decline if interest rates rise, resulting in a loss. For a short bond position, a loss will be realized if interest rates fall. However, an investor wants to know more than simply when a position will realize a loss. To control interest-rate risk, an investor must be able to quantify what will result.

The key to measuring interest-rate risk is the accuracy of the estimate of the value of the position after an adverse rate change. A valuation model is used to determine the value of a position after an adverse rate move. Consequently, if a reliable valuation model is not used, there is no way to properly measure interest-rate risk exposure.

There are two approaches to measuring interest-rate risk—*the full-valuation approach* and the *duration/convexity approach.* We begin with a discussion of the full-valuation approach. The balance of the chapter is devoted to the duration/convexity approach. As a background to the duration/convexity approach, we discuss the price volatility characteristics of option-free bonds and bonds with embedded options. We then look at how duration can be used to estimate interest-rate risk and distinguish between various duration measures (effective, modified, and Macaulay). Next, we show how a measure referred to as "convexity" can be used to improve the duration estimate of the price volatility of a bond to rate changes. In the next-to-the-last section we show the relationship between duration and another measure of price volatility used by investors, the price value of a basis point (or dollar value of an 01). In the last section we discuss the importance of incorporating yield volatility in estimates of exposure to interest-rate risk.

THE FULL-VALUATION APPROACH

The most obvious way to measure the interest-rate risk exposure of a bond position or a portfolio is to revalue it when interest rates change. The analysis is performed for a given scenario with respect to interest-rate changes. For example, an investor may want to measure the interest-rate exposure to a 50 basis point, 100 basis point, and 200 basis point instantaneous change in interest rates. This approach requires the revaluation of a bond or bond portfolio for a given interest-rate change scenario and is called the *full-valuation approach.* It is sometimes referred to as "scenario analysis" because it involves assessing the exposure to interest-rate change scenarios.

To illustrate this approach, suppose that an investor has a \$10 million par value position in a 5% coupon 20-year bond. The bond is option-free. The current price is 106.5484 for a yield (i.e., yield to maturity) of 4.5%. The market value of the position is \$10,654,840 (106.5484% × \$10 million). Since the investor owns the bond, she is concerned with a rise in yield, since this will decrease the market value of the position. To assess the exposure to a rise in market yields, the investor decides to look at how the value of the bond will change if yields change instantaneously for the following three scenarios: (1) 50 basis point increase, (2) 100 basis point increase, and (3) 200 basis point increase. This means that the investor wants to assess what will happen to the bond position if the yield on the bond increases from 4.5% to (1) 5%, (2) 5.5%, and (3) 6.5%. Because this is an option-free bond, valuation is straightforward. We will assume that one yield is used to discount each of the cash flows. That is, we will assume a flat yield-curve. The price of this bond per \$100 par value and the market value of the \$10 million par position is shown in Exhibit 5-1. Also shown is the change in the market value and the percentage change.

In the case of a portfolio, each bond is valued for a given scenario, and then the total value of the portfolio is computed for the scenario. For example, suppose that a manager has a portfolio with the following two option-free bonds: (1) 4% coupon 5-year bond and (2) 5% coupon 20-year bond. For the shorter-term bond, \$5 million of par value is owned, and the price is 109.4713 for a yield of 2%. For the longer-term bond, \$10 million of par value is owned, and the price is 106.5484 for a yield of 4.5%. Suppose that the manager wants to assess the interest-rate risk of this portfolio for a 50, 100, and 200 basis point increase in interest rates assuming that both the 5-year yield and the 20-year yield change by the same number

EXHIBIT 5-1

Illustration of Full-Valuation Approach to Assess the Interest-Rate Risk of a Bond Position for Three Scenarios

Current bond position: 5% coupon 20-year bond (option-free)
Price: 106.5484
Yield to maturity: 4.5%
Par value owned: $10 million
Market value of position: $10,654,840.00

Scenario	Yield Change (bp)	New Yield	New Price	New Market Value ($)	Percentage Change in Market Value (%)
1	50	5.0%	100.0000	10,000,000	–6.15%
2	100	5.5%	93.9805	9,398,050	–11.80%
3	200	6.5%	83.3437	8,334,370	–21.78%

of basis points. Exhibit 5-2 shows the exposure. Panel *a* of the exhibit shows the market value of the 5-year bond for the three scenarios. Panel *b* does the same for the 20-year bond. Panel *c* shows the total market value of the portfolio and the percentage change in the market value for the three scenarios.

In Exhibit 5-2, it is assumed that both the 5-year and the 20-year yields changed by the same number of basis points. The full-valuation approach also can handle scenarios where the yield-curve does not change in a parallel fashion. Exhibit 5-3 illustrates this for our portfolio that includes the 5-year and the 20-year bonds. The scenario analyzed is a yield-curve shift scenario combined with scenarios for shifts in the level of yields. In the illustration in Exhibit 5-3, the following yield changes for the 5-year and 20-year yields are assumed:

Scenario	Change in 5-Year Rate (bp)	Change in 20-Year Rate (bp)
1	50	10
2	100	50
3	200	100

The last panel in Exhibit 5-3 shows how the market value of the portfolio changes for each scenario.

The full-valuation approach seems straightforward. If one has a good valuation model, assessing how the value of a portfolio or individual bond will change for different scenarios for parallel and nonparallel yield-curve shifts measures the interest-rate risk of a portfolio.

EXHIBIT 5-2

Illustration of Full-Valuation Approach to Assess the Interest-Rate Risk of a Bond Portfolio for Three Scenarios Assuming a Parallel Shift in the Yield-Curve

Two-bond portfolio (both bonds are option-free bonds)

Panel a

Bond 1:	4% coupon 5-year bond	Par value:	$5,000,000
Initial price:	109.4713	Market value:	$5,473,565
Yield:	2%		

Scenario	Yield Change (bp)	New Yield	New Price	New Market Value ($)
1	50	2.5%	107.0091	5,350,455
2	100	3.0%	104.6111	5,230,555
3	200	4.0%	100.0000	5,000,000

Panel b

Bond 2:	5% coupon 20-year bond	Par value:	$10,000,000
Initial price:	106.5484	Market value:	$10,654,838
Yield:	4.5%		

Scenario	Yield Change (bp)	New Yield	New Price	New Market Value ($)
1	50	5.0%	100.0000	10,000,000
2	100	5.5%	93.9805	9,398,050
3	200	6.5%	83.3437	8,334,370

Panel c

Portfolio Market value: $16,128,403

		Market Value of			
Scenario	Yield Change (bp)	Bond 1 ($)	Bond 2 ($)	Portfolio ($)	Percentage Change in Market Value (%)
1	50	5,350,455	10,000,000	15,350,455	–4.82%
2	100	5,230,555	9,398,050	14,628,605	–9.30%
3	200	5,000,000	8,334,370	13,334,370	–17.32%

A common question that often arises when using the full-valuation approach is what scenarios should be evaluated to assess interest-rate risk exposure. For some regulated entities, there are specified scenarios established by regulators. For example, it is common for regulators of depository institutions to require

EXHIBIT 5-3

Illustration of Full-Valuation Approach to Assess the Interest-Rate Risk of a Bond Portfolio for Three Scenarios Assuming a Nonparallel Shift in the Yield-Curve

Two-bond portfolio (both bonds are option-free bonds)

Panel a

Bond 1:	4% coupon 5-year bond	Par value:	$5,000,000
Initial price:	109.4713	Market value:	$5,473,565
Yield:	2%		

Scenario	Yield Change (bp)	New Yield	New Price	New Market Value ($)
1	50	2.5%	107.0091	5,350,455
2	100	3.0%	104.6111	5,230,555
3	200	4.0%	100.0000	5,000,000

Panel b

Bond 2:	5% coupon 20-year bond	Par value:	$10,000,000
Initial price:	106.5484	Market value:	$10,654,838
Yield:	4.5%		

Scenario	Yield Change (bp)	New Yield	New Price	New Market Value ($)
1	10	4.6%	105.1940	10,519,400
2	50	5.0%	100.0000	10,000,000
3	100	5.5%	93.9805	9,398,050

Panel c

Portfolio market value: $16,128,403

	Market Value of			
Scenario	Bond 1 ($)	Bond 2 ($)	Portfolio ($)	Percentage Change in Market Value (%)
1	5,350,455	10,519,400	15,869,855	–1.60%
2	5,230,555	10,000,000	15,230,555	–5.57%
3	5,000,000	9,398,050	14,398,050	–10.73%

entities to determine the impact on the value of their bond portfolio for a 100, 200, and 300 basis point instantaneous change in interest rates (up and down). (Regulators tend to refer to this as "simulating" interest-rate scenarios rather than scenario analysis.) Risk managers and highly leveraged investors such as hedge funds tend to look at extreme scenarios to assess exposure to interest-rate changes. This practice is called *stress testing.*

Of course, in assessing how changes in the yield-curve can affect the exposure of a portfolio, there are an infinite number of scenarios that can be evaluated. The state-of-the-art technology involves using a complex statistical procedure to determine a likely set of yield-curve shift scenarios from historical data.

We can use the full-valuation approach to assess the exposure of a bond or portfolio to interest-rate change to evaluate any scenario, assuming—and this must be repeated continuously—*that the investor has a good valuation model to estimate what the price of the bonds will be in each interest-rate scenario.* While the full-valuation approach is the recommended approach for assessing the position of a single bond or a portfolio of a few bonds, for a portfolio with a large number of bonds and with even a minority of those bonds being complex (i.e., having embedded options), the full-valuation process is time-consuming. Investors want one measure they can use to get an idea of how a portfolio or even a single bond will change if rates change in a parallel fashion rather than having to revalue a portfolio to obtain that answer. Such a measure is duration. We will discuss this measure as well as a supplementary measure (convexity). To build a foundation to understand the limitations of these measures, we describe next the basic price volatility characteristics of bonds. The fact that there are limitations of using one or two measures to describe the interest-rate exposure of a position or portfolio should not be surprising. What is important to understand is that these measures provide a starting point for assessing interest-rate risk.

PRICE VOLATILITY CHARACTERISTICS OF BONDS

The characteristics of a bond that affect its price volatility are (1) maturity, (2) coupon rate, and (3) presence of embedded options. We also will see how the level of yields affects price volatility.

Price Volatility Characteristics of Option-Free Bonds

We begin by focusing on option-free bonds (i.e., bonds that do not have embedded options). A fundamental characteristic of an option-free bond is that the price of the bond changes in the opposite direction from a change in the bond's required yield. Exhibit 5-4 illustrates this property for four hypothetical bonds assuming a par value of $100.

When the price/yield relationship for any option-free bond is graphed, it exhibits the shape shown in Exhibit 5-5. Notice that as the required yield increases, the price of an option-free bond declines. However, this relationship is not linear (i.e., not a straight-line relationship). The shape of the price/yield relationship

EXHIBIT 5-4

Price/Yield Relationship for Four Hypothetical Option-Free Bonds

	Price ($)			
Yield (%)	**4%/5 Year**	**4%/20 Year**	**5%/5 Year**	**5%/20 Year**
2.00	109.4713	132.8347	114.2070	149.2520
3.00	104.6111	114.9579	109.2222	129.9158
3.50	102.2753	107.1486	106.8259	121.4457
3.90	100.4503	101.3798	104.9534	115.1783
3.99	100.0449	100.1369	104.5374	113.8266
4.00	100.0000	100.0000	104.4913	113.6777
4.01	99.9551	99.8633	104.4452	113.5291
4.10	99.5520	98.6441	104.0316	112.2027
4.50	97.7834	93.4516	102.2166	106.5484
5.00	95.6240	87.4486	100.0000	100.0000
6.00	91.4698	76.8852	95.7349	88.4426

for any option-free bond is called *convex*. This price/yield relationship is for an instantaneous change in the required yield.

The price sensitivity of a bond to changes in the required yield can be measured in terms of the dollar price change or the percentage price change. Exhibit 5-6 uses the four hypothetical bonds in Exhibit 5-4 to show the percentage change in each bond's price for various changes in yield, assuming that the initial yield for all

EXHIBIT 5-5

Price/Yield Relationship for a Hypothetical Option-Free Bond

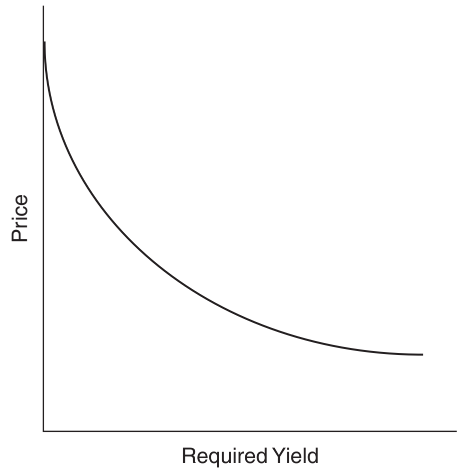


EXHIBIT 5-6

Instantaneous Percentage Price Change for Four Hypothetical Bonds
(Initial yield for all four bonds is 4%)

	Percentage Price Change			
New Yield	**4%/5 Year**	**4%/20 Year**	**5%/5 Year**	**5%/20 Year**
2.00	9.47	32.83	9.30	31.29
3.00	4.61	14.96	4.53	14.28
3.50	2.28	7.15	2.23	6.83
3.90	0.45	1.38	0.44	1.32
3.99	0.04	0.14	0.04	0.13
4.01	–0.04	–0.14	–0.04	–0.13
4.10	–0.45	–1.36	–0.44	–1.30
4.50	–2.22	–6.55	–2.18	–6.27
5.00	–4.38	–12.55	–4.30	–12.03
6.00	–8.53	–23.11	–8.38	–22.20

four bonds is 4%. An examination of Exhibit 5-6 reveals the following properties concerning the price volatility of an option-free bond:

Property 1: Although the price moves in the opposite direction from the change in required yield, the percentage price change is not the same for all bonds.

Property 2: For small changes in the required yield, the percentage price change for a given bond is roughly the same, whether the required yield increases or decreases.

Property 3: For large changes in required yield, the percentage price change is not the same for an increase in required yield as it is for a decrease in required yield.

Property 4: For a given large change in basis points in the required yield, the percentage price increase is greater than the percentage price decrease.

While the properties are expressed in terms of percentage price change, they also hold for dollar price changes.

The implication of Property 4 is that if an investor is long a bond, the price appreciation that will be realized if the required yield decreases is greater than the capital loss that will be realized if the required yield increases by the same number of basis points. For an investor who is short a bond, the reverse is true: The potential capital loss is greater than the potential capital gain if the yield changes by a given number of basis points.

Bond Features That Affect Interest-Rate Risk

The degree of sensitivity of a bond's price to changes in market interest rates (i.e., a bond's interest-rate risk) depends on various features of the issue, such as maturity, coupon rate, and embedded options.

The Impact of Maturity

All other factors constant, *the longer the bond's maturity, the greater is the bond's price sensitivity to changes in interest rates.* For example, for a 4% 20-year bond selling to yield 4%, a rise in the yield required by investors to 4.5% will cause the bond's price to decline from 100 to 93.4516, a 6.55% price decline. For a 4% 5-year bond selling to yield 4%, the price is 100. A rise in the yield required by investors from 4% to 4.5% would decrease the price to 97.7834. The decline in the bond's price is only 2.22%.

The Impact of Coupon Rate

A property of a bond is that all other factors constant, *the lower the coupon rate, the greater is the bond's price sensitivity to changes in interest rates.* For example, consider a 5% 20-year bond selling to yield 4%. The price of this bond would be 113.6777. If the yield required by investors increases by 50 basis points to 4.5%, the price of this bond would fall by 6.27% to 106.5484. This decline is less than the 6.55% decline for the 4% 20-year bond selling to yield 4%.

An implication is that zero-coupon bonds have greater price sensitivity to interest-rate changes than same-maturity bonds bearing a coupon rate and trading at the same yield.

The Impact of Embedded Options

In Chapter 1 the various embedded options that may be included in a bond issue were discussed. The value of a bond with embedded options will change depending on how the value of the embedded options changes when interest rates change. For example, as interest rates decline, the price of a callable bond may not increase as much as an otherwise option-free bond (i.e., a bond with no embedded options).

To understand why, we decompose the price of a callable bond into two parts, as shown below:

$$\begin{aligned}&\text{Price of callable bond}\\&\quad= \text{price of option-free bond} - \text{price of embedded call option}\end{aligned}$$

The reason for subtracting the price of the embedded call option from the price of the option-free bond is that the call option is a benefit to the issuer and a disadvantage to the bondholder. This reduces the price of a callable bond relative to an option-free bond.

Now, when interest rates decline, the price of an option-free bond increases. However, the price of the embedded call option increases when interest rates decline because the call option becomes more valuable to the issuer. Thus, when interest rates decline, both components increase, *but* the change in the price of the callable bond depends on the relative price change of the two components. Typically, a decline in interest rates will result in an increase in the price of the callable bond but not by as much as the price change of an otherwise comparable option-free bond.

Similarly, when interest rates rise, the price of a callable bond will not fall by as much as an otherwise option-free bond. The reason is that the price of the embedded call option declines. When interest rates rise, the price of the option-free bond declines but is partially offset by the decrease in the price of the embedded call option.

Price Volatility Characteristics of Bonds with Embedded Options

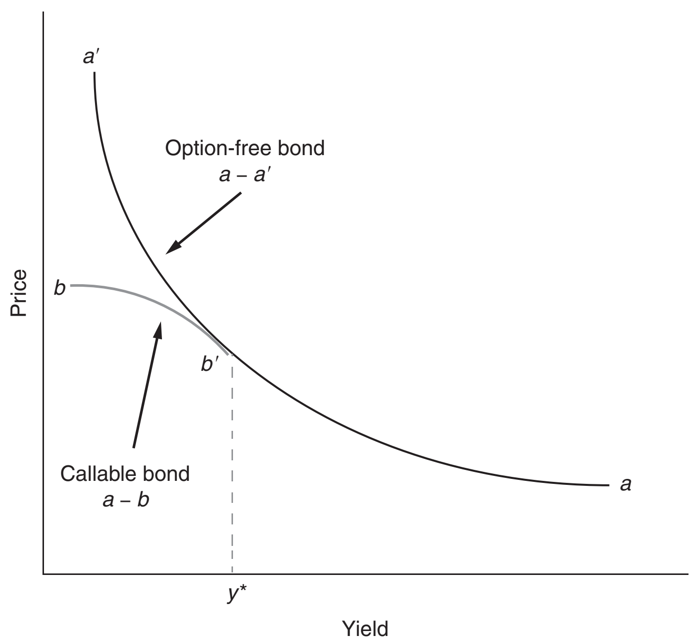
In this section we examine the price/yield relationship for bonds with both types of options (calls and puts) and implications for price volatility.

Bonds with Call and Prepay Options

In the discussion below we will refer to a bond that may be called or is prepayable as a callable bond. Exhibit 5-7 shows the price/yield relationship for an option-free bond and a callable bond. The convex curve given by *a–a′* is the price/yield relationship for an option-free bond. The unusually shaped curve denoted by *a–b* in the exhibit is the price/yield relationship for the callable bond.

EXHIBIT 5-7

Price/Yield Relationship for a Callable Bond and an Option-Free Bond



The reason for the price/yield relationship for a callable bond is as follows. When the prevailing market yield for comparable bonds is higher than the coupon rate on the callable bond, it is unlikely that the issuer will call the issue. For example, if the coupon rate on a bond is 3% and the prevailing market yield on comparable bonds is 6%, it is highly unlikely that the issuer will call a 3% coupon bond so that it can issue a 6% coupon bond. Since the bond is unlikely to be called, the callable bond will have a similar price/yield relationship as an otherwise comparable option-free bond. Consequently, the callable bond is going to be valued as if it is an option-free bond. However, since there is still some value to the call option, the bond won't trade exactly like an option-free bond.

As yields in the market decline, the concern is that the issuer will call the bond. The issuer won't necessarily exercise the call option as soon as the market yield drops below the coupon rate. Yet the value of the embedded call option increases as yields approach the coupon rate from higher yield levels. For example, if the coupon rate on a bond is 3% and the market yield declines to 3.50%, the issuer most likely will not call the issue. However, market yields are at a level at which the investor is concerned that the issue eventually may be called if market yields decline further. Cast in terms of the value of the embedded call option, that option becomes more valuable to the issuer, and therefore, it reduces the price relative to an otherwise comparable option-free bond.[1] In Exhibit 5-7, the value of the embedded call option at a given yield can be measured by the difference between the price of an option-free bond (the price shown on the curve a–a') and the price on the curve a–b. Notice that at low yield levels (below y^* on the horizontal axis), the value of the embedded call option is high.

Let's look at the difference in the price volatility properties relative to an option-free bond given the price/yield relationship for a callable bond shown in Exhibit 5-7. Exhibit 5-8 blows up the portion of the price/yield relationship for the callable bond where the two curves in Exhibit 5-7 depart (segment b–b' in Exhibit 5-7). We know from our discussion of the price/yield relationship that for a large change in yield of a given number of basis points, the price of an option-free bond increases by more than it decreases (Property 4 discussed previously). Is that what happens for a callable bond in the region of the price/yield relationship shown in Exhibit 5-8? No, it is not. In fact, as can be seen in the exhibit, the opposite is true! That is, for a given large change in yield, the price appreciation is less than the price decline.

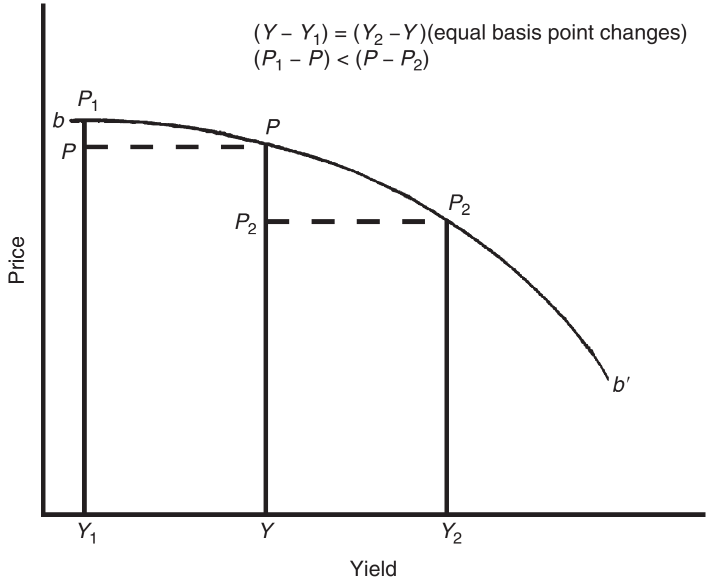
The price volatility characteristic of a callable bond is important to understand. The characteristic of a callable bond that its price appreciation is less than its price decline when rates change by a large number of basis points is called *negative convexity*.[2] But notice from Exhibit 5-7 that callable bonds do not exhibit this characteristic at every yield level. When yields are high (relative to

1. For readers who are already familiar with option theory, this characteristic can be restated as follows: When the coupon rate for the issue is below the market yield, the embedded call option is said to be "out-of-the-money." When the coupon rate for the issue is above the market yield, the embedded call option is said to be "in-the-money."

2. Mathematicians refer to this shape as being "concave."

EXHIBIT 5-8

Negative Convexity Region of the Price/Yield Relationship for a Callable Bond



the issue's coupon rate), the bond exhibits the same price/yield relationship as an option-free bond and therefore at high-yield levels also has the characteristic that the gain is greater than the loss. Because market participants have referred to the shape of the price/yield relationship shown in Exhibit 5-8 as negative convexity, market participants call the relationship for an option-free bond *positive convexity.* Consequently, a callable bond exhibits negative convexity at low yield levels and positive convexity at high-yield levels.

As can be seen from the exhibits, when a bond exhibits negative convexity, as rates decline, the bond compresses in price. That is, at a certain yield level there is very little price appreciation when rates decline. When a bond enters this region, the bond is said to exhibit "price compression."

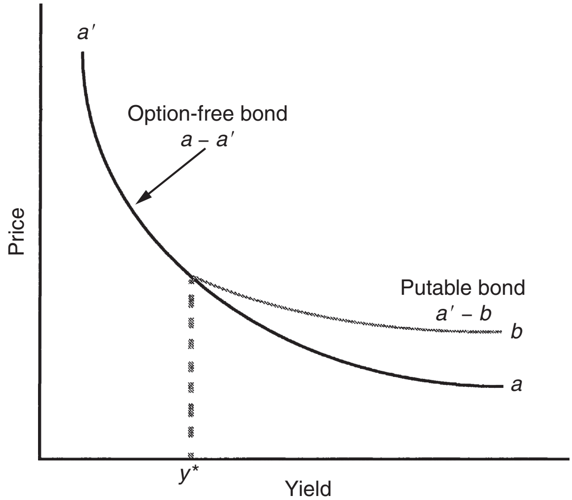
Bonds with Embedded Put Options

Putable bonds may be redeemed by the bondholder on the dates and at the put price specified in the indenture. Typically, the put price is par value. The advantage to the investor is that if yields rise such that the bond's value falls below the put price, the investor will exercise the put option. If the put price is par value, this means that if market yields rise above the coupon rate, the bond's value will fall below par, and the investor will then exercise the put option.

The value of a putable bond is equal to the value of an option-free bond plus the value of the put option. Thus the difference between the value of a putable bond and the value of an otherwise comparable option-free bond is the value of the embedded

EXHIBIT 5-9

Price/Yield Relationship for a Putable Bond and an Option-Free Bond



put option. This can be seen in Exhibit 5-9 which shows the price/yield relationship for a putable bond (the curve *a′–b*) and an option-free bond (the curve *a′–a*).

At low yield levels (low relative to the issue's coupon rate), the price of the putable bond is basically the same as the price of the option-free bond because the value of the put option is small. As rates rise, the price of the putable bond declines, but the price decline is less than that for an option-free bond. The divergence in the price of the putable bond and an otherwise comparable option-free bond at a given yield level is the value of the put option. When yields rise to a level where the bond's price would fall below the put price, the price at these levels is the put price.

Interest-Rate Risk for Floating-Rate Securities

The change in the price of a fixed-rate coupon bond when market interest rates change is due to the fact that the bond's coupon rate differs from the prevailing market interest rate. For a floating-rate security, the coupon rate is reset periodically based on the prevailing value for the reference rate plus the quoted margin. The quoted margin is set for the life of the security. The price of a floating-rate security will fluctuate depending on three factors.

First, the longer the time to the next coupon reset date, the greater is the potential price fluctuation.[3] For example, consider a floating-rate security whose coupon resets every six months and the coupon formula is the six-month Treasury rate plus

3. The coupon rate is set at the beginning of the period but is not paid until the end of the period.

20 basis points. Suppose that on the coupon reset date the six-month Treasury rate is 0.35%. If on the day after the coupon is reset the six-month Treasury rate rises to 0.75%, this means that this security is offering a six-month coupon rate that is less than the prevailing six-month rate for the remaining six months. The price of the security must decline to reflect this. Suppose instead that the coupon resets every month at the one-month Treasury rate and that this rate rises immediately after the coupon rate is reset. In this case, while the investor would be realizing a submarket one-month coupon rate, it is for only a month. The price decline will be less than for the security that resets every six months.

The second reason why a floating-rate security's price will fluctuate is that the required margin that investors demand in the market changes. For example, consider once again the security whose coupon formula is the six-month Treasury rate plus 20 basis points. If market conditions change such that investors want a margin of 30 basis points rather than 20 basis points, this security would be offering a coupon rate that is 10 basis points below the market rate. As a result, the security's price will decline.

Finally, a floating-rate security typically will have a cap. Once the coupon rate as specified by the coupon formula rises above the cap rate, the coupon will be set at the cap rate, and the security then will offer a below-market coupon rate, and its price will decline. In fact, once the cap is reached, the security's price will react much the same way to changes in market interest rates as that of a fixed-rate coupon security. This risk for a floating-rate security is called *cap risk.*

The Impact of the Yield Level

Because of credit risk, different bonds trade at different yields, even if they have the same coupon rate, maturity, and embedded options. How, then, holding other factors constant, does the level of interest rates affect a bond's price sensitivity to changes in interest rates? As it turns out, the higher the level of interest rates that a bond trades, the lower is the price sensitivity.

To see this, we can compare a 5% 20-year bond initially selling at a yield of 5% and a 5% 20-year bond initially selling at a yield of 9%. The former is initially at a price of 100, and the latter, 63.20. Now, if the yield on both bonds increases by 100 basis points, the first bond trades down by 11.56 points (11.56%) to a price of 88.44. After the assumed increase in yield, the second bond will trade at a price of 57.10, for a price decline of only 6.09 points (or 9.64%). Thus we see that the bond that trades at a lower yield is more volatile in both percentage price change and absolute price change as long as the other bond characteristics are the same. An implication is that for a given change in interest rates, price sensitivity is lower when the level of interest rates in the market is high, and price sensitivity is higher when the level of interest rates is low.

DURATION

With this background about the price volatility characteristics of a bond, we can now turn to an alternate approach to full valuation: the duration/convexity approach. *Duration is a measure of the approximate sensitivity of a bond's value to rate changes.* More specifically, *it is the approximate percentage change in value for a 100 basis point change in rates.* We'll see in this section that duration is the first approximation of the percentage price change. To improve the estimate provided by duration a measure called *convexity* can be used. Hence, using duration combined with convexity to estimate the percentage price change of a bond to changes in interest rates is called the *duration/convexity approach.*

Calculating Duration

The duration of a bond is estimated as follows:

$$\frac{\text{Price if yields decline} - \text{price if yields rise}}{2(\text{initial price})(\text{change in yield in decimal})}$$

If we let

$$\Delta y = \text{change in yield in decimal}$$
$$V_0 = \text{initial price}$$
$$V_- = \text{price if yields decline by } \Delta y$$
$$V_+ = \text{price if yields increase by } \Delta y$$

then duration can be expressed as

$$\text{Duration} = \frac{V_- - V_+}{2(V_0)(\Delta y)} \tag{5-1}$$

For example, consider a 5% coupon 20-year option-free bond selling at 113.6777 to yield 4% (see Exhibit 5-4). Let's change (i.e., shock) the yield down and up by 20 basis points and determine what the new prices will be for the numerator. If the yield is decreased by 20 basis points from 4.0% to 3.8%, the price would increase to 116.7049. If the yield increases by 20 basis points, the price would decrease to 110.7527. Thus

$$\Delta y = 0.002$$
$$V_0 = 113.6777$$
$$V_- = 116.7049$$
$$V_+ = 110.5727$$

Then

$$\text{Duration} = \frac{116.7049 - 110.7527}{2 \times (113.6777) \times (0.002)} = 13.09$$

Duration is interpreted as the approximate percentage change in price for a 100 basis point change in rates. Consequently, a duration of 13.09 means that the approximate change in price for this bond is 13.09% for a 100 basis point change in rates.

A common question asked about this interpretation of duration is the consistency between the yield change that is used to compute duration using Eq. (5-1) and the interpretation of duration. For example, recall that in computing the duration of the 5% coupon 20-year bond, we used a 20 basis point yield change to obtain the two prices to use in the numerator of Eq. (5-1). Yet we interpret the duration computed as the approximate percentage price change for a 100 basis point change in yield. The reason is that regardless of the yield change used to estimate duration in Eq. (5-1), the interpretation is the same. If we used a 25 basis point change in yield to compute the prices used in the numerator of Eq. (5-1), the resulting duration is interpreted as the approximate percentage price change for a 100 basis point change in yield. Later we will use different changes in yield to illustrate the sensitivity of the computed duration.

Approximating the Percentage Price Change Using Duration

The following formula is used to approximate the percentage price change for a given change in yield and a given duration:

$$\text{Approximate percentage price change} = -\text{duration} \times \Delta y \times 100 \tag{5-2}$$

The reason for the negative sign on the right-hand side of Eq. (5-2) is due to the inverse relationship between price change and yield change.

For example, consider the 5% 20-year bond trading at 113.6777 whose duration we just showed is 13.09. The approximate percentage price change for a 10 basis point increase in yield (i.e., $\Delta y = +0.001$) is

$$\text{Approximate percentage price change} = -13.09 \times (+0.001) \times 100 = -1.309\%$$

How good is this approximation? The actual percentage price change is –1.30% (as shown in Exhibit 5-6 when yield increases to 4.10%). Duration, in this case, did an excellent job in estimating the percentage price change. We would come to the same conclusion if we used duration to estimate the percentage price change if the yield declined by 10 basis points (i.e., $\Delta y = -0.001$). In this case, the approximate percentage price change would be +1.309% (i.e., the direction of the estimated price change is the reverse but the magnitude of the change is the same). Exhibit 5-6 shows that the actual percentage price change is +1.32%.

In terms of estimating the new price, let's see how duration performed. The initial price is 113.6777. For a 10 basis point increase in yield, duration estimates that the price will decline by 1.309%. Thus the price will decline to 112.1897 (found by multiplying 113.6777 by 1 minus 0.01309). The actual price from Exhibit 5-4 if the yield increases by 10 basis points is 112.2027. Thus the price estimated using duration is close to the actual price. For a 10 basis point decrease in yield, the actual price from Exhibit 5-4 is 115.1783, and the estimated price using duration is 115.1658 (a price increase of 1.309%). Consequently, the new price estimated by duration is close to the actual price for a 10 basis point change in yield.

Let's look at how well duration does in estimating the percentage price change if the yield increases by 200 basis points instead of 10 basis points. In this case, Δy is equal to +0.02. Substituting into Eq. (5-2) we have

$$\text{Approximate percentage price change} = -13.09 \times (+0.02) \times 100 = -26.18\%$$

How good is this estimate? From Exhibit 5-6 we see that the actual percentage price change when the yield increases by 200 basis points to 6% is –22.20%. Thus the estimate is not as accurate as when we used duration to approximate the percentage price change for a change in yield of only 10 basis points. If we use duration to approximate the percentage price change when the yield decreases by 200 basis points, the approximate percentage price change in this scenario is +26.18%. The actual percentage price change as shown in Exhibit 5-6 is +31.29%.

Again, let's look at the use of duration in terms of estimating the new price. Since the initial price is 113.6777 and a 200 basis point increase in yield will decrease the price by 26.18%, the estimated new price using duration is 83.9169 (found by multiplying 113.6777 by 1 minus 0.2618). From Exhibit 5-4 the actual price if the yield is 6% is 88.4426. Consequently, the estimate is not as accurate as the estimate for a 10 basis point change in yield. The estimated new price using duration for a 200 basis point decrease in yield is 143.4386 compared with the actual price (from Exhibit 5-4) of 149.2520. Once again, the estimation of the price using duration is not as accurate as for a 10 basis point change. *Notice that whether the yield is increased or decreased by 200 basis points, duration underestimates what the new price will be.* We will see why shortly.

Let's summarize what we found in our application of duration to approximate the percentage price change:

		New Price		***Percent Price Change***		
Yield Change (bp)	**Initial Price**	**Based on Duration**	**Actual**	**Based on Duration**	**Actual**	**Comment**
+10	113.6777	112.1897	112.2027	–1.309	–1.30	Estimated price close to new price
–10	113.6777	115.1658	115.1783	+1.309	+1.32	Estimated price close to new price
+200	113.6777	83.9169	88.4426	–26.180	–22.20	Underestimates new price
–200	113.6777	143.4386	149.2520	+26.180	+31.29	Underestimates new price

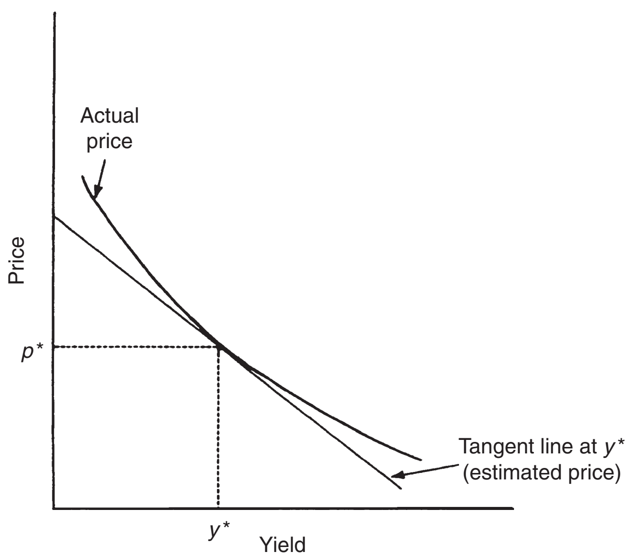
Look again at Eq. (5-2). Notice that whether the change in yield is an increase or a decrease, the approximate percentage price change will be the same except that the sign is reversed. This violates Properties 3 and 4 with respect to the price volatility of option-free bonds when yields change. Recall that Property 3 states that the percentage price change will not be the same for a large increase and decrease in yield by the same number of basis points. This is one reason why we see that the estimate is inaccurate for a 200 basis point yield change. Why did the duration estimate of the price change do a good job for a small change in yield of 10 basis points? Recall from Property 2 that the percentage price change will be approximately the same whether there is an increase or decrease in yield by a small number of basis points. We also can explain these results in terms of the graph of the price/yield relationship. We will do this next.

Graphic Depiction of Using Duration to Estimate Price Changes

The shape of the price/yield relationship for an option-free bond is convex. Exhibit 5-10 shows this relationship. In the exhibit, a tangent line is drawn to the price/yield relationship at yield y^*. [For those unfamiliar with the concept of a tangent line, it is a straight line that just touches a curve at one point within a relevant (local) range.] In Exhibit 5-10, the tangent line touches the curve at the point where the yield is equal to y^* and the price is equal to p^*. The tangent line

EXHIBIT 5-10

Price/Yield Relationship for an Option-Free Bond with a Tangent Line



can be used to estimate the new price if the yield changes. If we draw a vertical line from any yield (on the horizontal axis), as in Exhibit 5-10, the distance between the horizontal axis and the tangent line represents the price approximated by using duration starting with the initial yield y^*.

Now how is the tangent line, used to approximate what the new price will be if yields change, related to duration? Duration tells us the approximate percentage price change. Given the initial price and the approximate percentage price change provided by duration [i.e., as given by Eq. (5-2)], the approximate new price can be estimated. Mathematically, it can be demonstrated that the estimated price that is provided by duration is on the tangent line.

This helps us to understand why duration did an effective job of estimating the percentage price change or, equivalently, the new price when the yield changes by a small number of basis points. Look at Exhibit 5-11. Notice that for a small change in yield, the tangent line does not depart much from the price/yield relationship. Hence, when the yield changes up or down by 10 basis points, the tangent line does a good job of estimating the new price, as we found in our earlier numerical illustration.

Exhibit 5-11 also shows what happens to the estimate using the tangent line when the yield changes by a large number of basis points. Notice that the error in the estimate gets larger the further one moves from the initial yield. The estimate is less accurate the more convex the bond. This is illustrated in Exhibit 5-12.

EXHIBIT 5-11

Estimating the New Price Using a Tangent Line

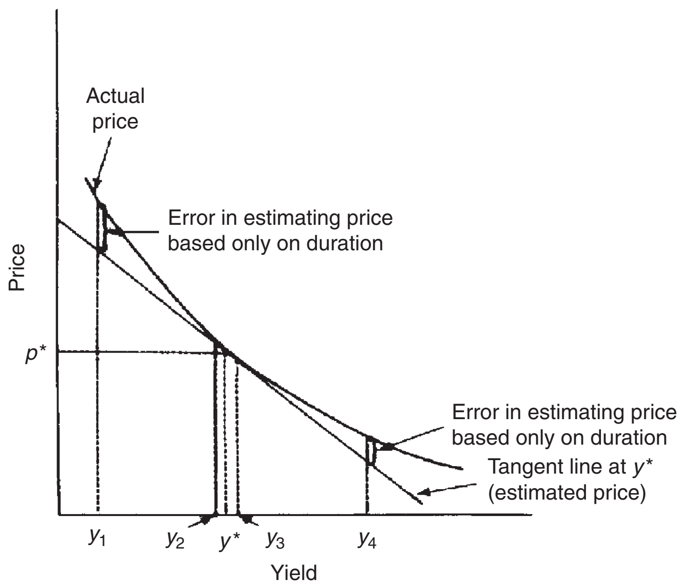
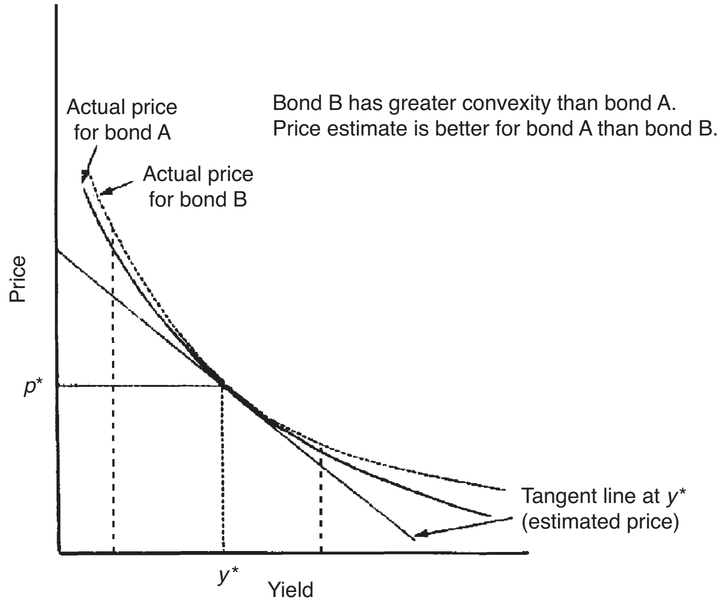


EXHIBIT 5-12

Estimating the New Price for a Large Yield Change for Bonds with Different Convexities



Also note that regardless of the magnitude of the yield change, the tangent line always underestimates what the new price will be for an option-free bond because the tangent line is below the price/yield relationship. This explains why we found in our illustration that when using duration we underestimated what the actual price will be.

Rate Shocks and Duration Estimate

In calculating duration using Eq. (5-1), it is necessary to shock interest rates (yields) up and down by the same number of basis points to obtain the values for V_- and V_+. In our illustration, 20 basis points was arbitrarily selected. But how large should the shock be? That is, how many basis points should be used to shock the rate?

In Exhibit 5-13, the duration estimate for our four hypothetical bonds using Eq. (5-1) for rate shocks of 1 basis point to 200 basis points is reported. The duration estimates for the two 5-year bonds are not affected by the size of the shock. The two 5-year bonds are less convex than the two 20-year bonds. But even for the two 20-year bonds, for the size of the shocks reported in Exhibit 5-13, the duration estimates are not materially affected by the greater convexity.

Thus it would seem that the size of the shock is unimportant. However, the results reported in Exhibit 5-13 are for option-free bonds. When we deal with more

EXHIBIT 5-13

Duration Estimates for Different Rate Shocks

Bond	1 bp	10 bps	20 bps	50 bps	100 bps	150 bps	200 bps
4% 5-year	4.49	4.49	4.49	4.49	4.49	4.50	4.50
4% 20-year	13.68	13.68	13.68	13.70	13.75	13.85	13.99
5% 5-year	4.41	4.41	4.41	4.41	4.41	4.42	4.42
5% 20-year	13.09	13.09	13.09	13.10	13.16	13.25	13.37

Initial yield: 4%

complicated securities, small rate shocks that do not reflect the types of rate changes that may occur in the market do not permit the determination of how prices can change because expected cash flows may change when dealing with bonds with embedded options. In comparison, if large rate shocks are used, we encounter the asymmetry caused by convexity. Moreover, large rate shocks may cause dramatic changes in the expected cash flows for bonds with embedded options that may be far different from how the expected cash flows will change for smaller rate shocks.

There is another potential problem with using small rate shocks for complicated securities. The prices that are inserted into the duration formula as given by Eq. (5-1) are derived from a valuation model. In Chapters 36 and 37 we will discuss various valuation models and their underlying assumptions. The duration measure depends crucially on a valuation model. If the rate shock is small and the valuation model used to obtain the prices for Eq. (5-1) is poor, dividing poor price estimates by a small shock in rates in the denominator will have a significant effect on the duration estimate.

What is done in practice by dealers and vendors of analytical systems? Each system developer uses rate shocks he or she believes to be realistic based on historical rate changes.

MODIFIED DURATION VERSUS EFFECTIVE DURATION

One form of duration that is cited by practitioners is *modified duration.* Modified duration is the approximate percentage change in a bond's price for a 100 basis point change in yield *assuming that the bond's expected cash flows do not change when the yield changes.* What this means is that in calculating the values of V_- and V_+ in Eq. (5-1), the same cash flows used to calculate V_0 are used. Therefore, the change in the bond's price when the yield is changed is due solely to discounting cash flows at the new yield level.

The assumption that the cash flows will not change when the yield is changed makes sense for option-free bonds such as noncallable Treasury securities. This is so because the payments made by the U.S. Department of the Treasury to holders of its obligations do not change when interest rates change. However, the same

EXHIBIT 5-14

Modified Duration versus Effective Duration

Duration

Interpretation: Generic description of the sensitivity of a bond's price (as a percentage of initial price) to a change in yield

Modified duration

Duration measure in which it is assumed that yield changes do not change the expected cash flows

Effective duration

Duration measure in which recognition is given to the fact that yield changes may change the expected cash flows

cannot be said for bonds with embedded options (i.e., callable and putable bonds and mortgage-backed securities). For these securities, a change in yield may alter the expected cash flows significantly.

Earlier we showed the price/yield relationship for callable and prepayable bonds. Failure to recognize how changes in yield can alter the expected cash flows will produce two values used in the numerator of Eq. (5-1) that are not good estimates of how the price actually will change. The duration is then not a good number to use to estimate how the price will change.

In later chapters where valuation models for bonds with embedded options will be discussed, it will be explained how these models take into account how changes in yield will affect the expected cash flows. Thus, when V_- and V_+ are the values produced from these valuation models, the resulting duration takes into account both the discounting at different interest rates and how the expected cash flows may change. When duration is calculated in this manner, it is called *effective duration* or *option-adjusted duration.* Exhibit 5-14 summarizes the distinction between modified duration and effective duration.

The difference between modified duration and effective duration for bonds with embedded options can be quite dramatic. For example, a callable bond could have a modified duration of 5 but an effective duration of only 3. For certain collateralized mortgage obligations, the modified duration could be 7 and the effective duration 20! Thus, using modified duration as a measure of the price sensitivity of a security with embedded options to changes in yield would be misleading. The more appropriate measure for any bond with an embedded option is effective duration.

Macaulay Duration and Modified Duration

It is worth comparing the relationship between modified duration and Macaulay duration. Modified duration also can be written as[4]

$$\frac{1}{(1+\text{yield}/k)}\left(\frac{1\times \text{PVCF}_1 + 2\times \text{PVCF}_2 + \cdots + n\times \text{PVCF}_n}{k\times \text{price}}\right) \qquad (5\text{-}3)$$

4. More specifically, this is the formula for the modified duration of a bond on a coupon anniversary date.

where

k = number of periods, or payments, per year (e.g., $k = 2$ for semiannual-pay bonds and $k = 12$ for monthly-pay bonds)
n = number of periods until maturity (i.e., number of years to maturity times k)
yield = yield to maturity of the bond
PVCF_t = present value of the cash flow in period t discounted at the yield to maturity

The expression in the parentheses on the right of the modified duration formula given by Eq. (5-3) is a measure formulated in 1938 by Frederick Macaulay.[5] This measure is popularly called the *Macaulay duration.* Thus modified duration is commonly expressed as

$$\text{Modified duration} = \frac{\text{Macaulay duration}}{(1 + \text{yield}/k)}$$

The general formulation for duration as given by Eq. (5-1) provides a shortcut procedure for determining a bond's modified duration. Because it is easier to calculate the modified duration using the shortcut procedure, most vendors of analytical software will use Eq. (5-1) rather than Eq. (5-3) to reduce computation time.

However, it must be understood clearly that modified duration is a flawed measure of a bond's price sensitivity to interest-rate changes for a bond with an embedded option, and therefore, so is Macaulay duration. The use of the formula for duration given by Eq. (5-3) *misleads* the user because it masks the fact that changes in the expected cash flows must be recognized for bonds with embedded options. Although Eq. (5-3) will give the same estimate of percent price change for an option-free bond as Eq. (5-1), Eq. (5-1) is still better because it acknowledges that cash flows and thus value can change owing to yield changes.

Interpretations of Duration

At the outset of this section we defined duration as the approximate percentage change in price for a 100 basis point change in rates. If you understand this definition, you need never use the equation for the approximate percentage price change given by Eq. (5-2), and you can easily calculate the change in a bond's value.

For example, suppose that we want to know the approximate percentage change in price for a 50 basis point change in yield for our hypothetical 5% coupon 20-year bond selling for 113.6777. Since the duration is 13.09, a 100 basis point change in yield would change the price by about 13.09%. For a 50 basis point

5. Frederick Macaulay, *Some Theoretical Problems Suggested by the Movement of Interest Rates, Bond Yields, and Stock Prices in the U.S. Since 1856* (New York: National Bureau of Economics Research, 1938).

change in yield, the price will change by approximately 6.545% (= 13.09%/2). Thus, if the yield changes by 50 basis points, the price will change by 6.545% from 113.6777 to 106.2375.

Now let's look at some other definitions or interpretations of duration that have been used.

Duration Is the "First Derivative"

Sometimes a market participant will refer to duration as the "first derivative of the price/yield function" or simply the "first derivative." *Derivative* here has nothing to do with "derivative instruments" (i.e., futures, swaps, options, etc.). A derivative as used in this context is obtained by differentiating a mathematical function. There are first derivatives, second derivatives, and so on. When market participants say that duration is the first derivative, here is what they mean. If it were possible to write a mathematical equation for a bond in closed form, the first derivative would be the result of differentiating that equation the first time. While it is a correct interpretation of duration, it is an interpretation that in no way helps us understand what the interest-rate risk is of a bond. That is, it is an operationally meaningless interpretation.

Why is it an operationally meaningless interpretation? Go back to the \$10 million bond position with a duration of 6. Suppose that a client is concerned with the exposure of the bond to changes in interest rates. Now, tell that client the duration is 6 and that it is the first derivative of the price function for that bond. What have you told the client? Not much. In contrast, tell that client that the duration is 6 and that duration is the approximate price sensitivity of a bond to a 100 basis point change in rates, and you've told the client a great deal with respect to the bond's interest-rate risk.

Duration Is Some Measure of Time

When the concept of duration was introduced by Macaulay in 1938, he used it as a gauge of the time that the bond was outstanding. More specifically, Macaulay defined *duration* as the weighted average of the time to each coupon and principal payment of a bond. Subsequently, *duration* has too often been thought of in temporal terms, that is, years. This is most unfortunate for two reasons.

First, in terms of dimensions, there is nothing wrong with expressing duration in terms of years because that is the proper dimension of this value. But the proper interpretation is that duration is the price volatility of a zero-coupon bond with that number of years to maturity. Thus, when a manager says that a bond has a duration of four years, it is not useful to think of this measure in terms of time, but rather that the bond has the price sensitivity to rate changes of a four-year zero-coupon bond.

Second, thinking of duration in terms of years makes it difficult for managers and their clients to understand the duration of some complex securities. Here are a few examples. For a mortgage-backed security that is an interest-only security, the duration is negative. What does a negative number of, say, –4 mean? In terms of our interpretation as a percentage price change, it means that when rates change by 100 basis points, the price of the bond changes by about 4%, but the change is in the same direction as the change in rates.

As a second example, consider the duration of an option that expires in one year. Suppose that it is reported that its duration is 60. What does that mean? To someone who interprets duration in terms of time, does that mean 60 years, 60 days, or 60 seconds? It doesn't mean any of these. It simply means that the option tends to have the price sensitivity to rate changes of a 60-year zero-coupon bond.

Forget First Derivatives and Temporal Definitions

The bottom line is that one should not care if it is technically correct to think of duration in terms of years (volatility of a zero-coupon bond) or in terms of first derivatives. There are even some who interpret duration in terms of the "half life" of a security. Subject to the limitations that we will describe later, duration is used as a measure of the sensitivity of a security's price to changes in yield. We will fine-tune this definition as we move along.

Users of this interest-rate risk measure are interested in what it tells them about the price sensitivity of a bond (or a portfolio) to changes in rates. Duration provides the investor with a feel for the dollar price exposure or the percentage price exposure to potential rate changes.

Spread Duration

For non-Treasury securities, the yield is equal to the Treasury yield plus a spread to the Treasury yield-curve. Non-Treasury securities are called *spread products.* The risk that the price of a bond changes due to changes in spreads is called *spread risk.* A measure of how a spread product's price changes if the spread sought by the market changes is called *spread duration.* Spread duration indicates the approximate percentage change in price for a 100 basis point change in the spread, holding the Treasury yield constant. For example, suppose that the spread duration of a corporate bond is 1. This means that for a 100 basis point change in the spread, the value of the corporate bond will change by approximately 1%.

Portfolio Duration

A portfolio's duration can be obtained by calculating the weighted average of the duration of the bonds in the portfolio. The weight is the proportion of the portfolio that a security comprises. Mathematically, a portfolio's duration can be calculated as follows:

$$w_1 D_1 + w_2 D_2 + w_3 D_3 + \cdots + w_K D_K$$

where

w_i = market value of bond i/market value of the portfolio
D_i = duration of bond i
K = number of bonds in the portfolio

To illustrate this calculation, consider the following three-bond portfolio in which all three bonds are option free:

Bond	Price ($)	Yield (%)	Par Amount Owned	Market Value	Duration
9% 5-year	122.4565	4	$5 million	$6,122,823	4.147
5% 20-year	113.6777	4	2 million	2,273,555	13.087
5.5% 30-year	126.0707	4	2 million	2,521,413	16.290

In this illustration it is assumed that the next coupon payment for each bond is exactly six months from now (i.e., there is no accrued interest). The market value for the portfolio is $10,917,791. Since each bond is option free, the modified duration can be used. The market price per $100 par value of each bond, its yield, and its duration are given below:

In this illustration, K is equal to 3 and:

$$w_1 = \$6{,}122{,}823/\$10{,}917{,}791 = 0.561 \quad D_1 = 4.147$$
$$w_2 = \$2{,}273{,}555/\$10{,}917{,}791 = 0.208 \quad D_2 = 13.087$$
$$w_3 = \$2{,}521{,}413/\$10{,}917{,}791 = 0.231 \quad D_3 = 16.290$$

The portfolio's duration is:

$$0.561\ (4.147) + 0.208\ (13.087) + 0.231\ (16.290) = 8.81$$

A portfolio duration of 8.81 means that for a 100 basis point change in the yield of all three bonds, the market value of the portfolio will change by approximately 8.81%. But keep in mind that the yield on all three bonds must change by 100 basis points for the duration measure to be useful. This is a *critical assumption,* and its importance cannot be overemphasized.[6]

An alternative procedure for calculating the duration of a portfolio is to calculate the dollar price change for a given number of basis points for each security in the portfolio and then add up all the price changes. Dividing the total of the price changes by the initial market value of the portfolio produces a percentage price change that can be adjusted to obtain the portfolio's duration.

For example, consider the three-bond portfolio shown above. Suppose that we calculate the dollar price change for each bond in the portfolio based on its respective duration for a 50 basis point change in yield. We would then have

6. This is equivalent to saying that the correlation between the yield change for every maturity is equal to 1.

Bond	Market Value	Duration	Change in Value for 50 bp Yield Change
9% 5-year	$6,122,823	4.147	$126,957
5% 20-year	2,273,555	13.087	148,770
5.5% 30-year	2,521,413	16.290	205,369
		Total	$481,096

Thus a 50 basis point change in all rates changes the market value of the three-bond portfolio by $481,096. Since the market value of the portfolio is $10,917,791, a 50 basis point change produced a change in value of 4.41% ($481,096 divided by $10,917,791). Since duration is the approximate percentage change for a 100 basis point change in rates, this means that the portfolio duration is 8.82 (found by doubling 4.41). This is the same value for the portfolio's duration as found earlier.

The spread duration for a portfolio or a bond index is computed as a market-weighted average of the spread duration for each sector.

Contribution to Portfolio Duration

Some portfolio managers look at exposure of a portfolio or a benchmark index to an issue or to a sector simply in terms of the market value percentage of that issue or sector in the portfolio. A better measure of exposure to an individual issue or sector is its *contribution to portfolio duration* or *contribution to benchmark index duration*. This is found by multiplying the percentage of the market value of the portfolio represented by the individual issue or sector by the duration of the individual issue or sector. That is,

$$\text{Contribution to portfolio duration} = \text{weight of issue or sector in portfolio} \times \text{duration of issue or sector}$$

$$\text{Contribution to benchmark index duration} = \text{weight of issue or sector in benchmark index} \times \text{duration of issue or sector}$$

A portfolio manager who wants to determine the contribution of a sector to portfolio duration relative to the contribution of the same sector in a broad-based market index can compute the difference between the two contributions. The difference in the percentage distribution by sector is not as meaningful as is the difference in the contribution to duration.

CONVEXITY

The duration measure indicates that regardless of whether interest rates increase or decrease, the approximate percentage price change is the same. However, as we noted earlier, this is not consistent with Property 3 of a bond's price volatility. Specifically, while for small changes in yield the percentage price change will be the same for an increase or decrease in yield, for large changes in yield this is not true. This suggests that duration is only a good approximation of the percentage price change for small changes in yield.

We demonstrated this property earlier using a 5% 20-year bond selling to yield 4% with a duration of 13.09. For a 10 basis point change in yield, the estimate was accurate for both an increase or a decrease in yield. However, for a 200 basis point change in yield, the approximate percentage price change was off considerably.

The reason for this result is that duration is in fact a first (linear) approximation for a small change in yield.[7] The approximation can be improved by using a second approximation. This approximation is referred to as "convexity." *The use of this term in the industry is unfortunate because the term convexity is also used to describe the shape or curvature of the price/yield relationship.* The *convexity measure* of a security can be used to approximate the change in price that is not explained by duration.

Convexity Measure

The convexity measure of a bond is approximated using the following formula:

$$\text{Convexity measure} = \frac{V_+ + V_- - 2V_0}{2V_0(\Delta y)^2} \tag{5-4}$$

where the notation is the same as used earlier for duration as given by Eq. (5-1).

For our hypothetical 5% 20-year bond selling to yield 4%, we know that for a 20 basis point change in yield ($\Delta y = 0.002$),

$$V_0 = 113.6777, \quad V_- = 116.7049, \quad \text{and} \quad V_+ = 110.7527$$

Substituting these values into the convexity measure given by Eq. (5-4) gives

$$\text{Convexity measure} = \frac{110.7527 + 116.7049 - 2(113.6777)}{2(113.6777)(0.002)^2} = 112.38$$

We'll see how to use this convexity measure shortly. Before doing so, there are three points that should be noted. First, there is no simple interpretation of the convexity measure. Second, in contrast to duration, it is more common for market participants to refer to the value computed in Eq. (5-4) as the "convexity of a bond" rather than the "convexity measure of a bond." Finally, the convexity measure reported by dealers and vendors will differ for an option-free bond. The reason is that the value obtained from Eq. (5-4) is often scaled for the reason explained after we demonstrate how to use the convexity measure.

7. The reason it is a linear approximation can be seen in Exhibit 5-11, where the tangent line is used to estimate the new price. That is, a straight line is being used to approximate a nonlinear (i.e., convex) relationship.

Convexity Adjustment to Percentage Price Change

Given the convexity measure, the approximate percentage price change adjustment due to the bond's convexity (i.e., the percentage price change not explained by duration) is

$$\text{Convexity adjustment} = \text{convexity measure} \times (\Delta y)^2 \times 100 \qquad (5\text{-}5)$$

For example, for the 5% coupon bond maturing in 20 years, the convexity adjustment to the percentage price change based on duration if the yield increases from 4% to 6% is

$$112.38 \times (0.02)^2 \times 100 = 4.50\%$$

If the yield decreases from 4% to 2%, the convexity adjustment to the approximate percentage price change based on duration also would be 4.50%.

The approximate percentage price change based on duration and the convexity adjustment is found by adding the two estimates. Thus, for example, if yields change from 4% to 6%, the estimated percentage price change would be

$$\begin{aligned} \text{Estimated change using duration} &= -26.18\% \\ \text{Convexity adjustment} &= \underline{+4.50\%} \\ \text{Total estimated percentage price change} &= -21.68\% \end{aligned}$$

The actual percentage price change is –22.20%.

For a decrease of 200 basis points, from 4% to 2%, the approximate percentage price change would be as follows:

$$\begin{aligned} \text{Estimated change using duration} &= +26.18\% \\ \text{Convexity adjustment} &= \underline{+4.50\%} \\ \text{Total estimated percentage price change} &= +30.68\% \end{aligned}$$

The actual percentage price change is +31.29%. Thus duration combined with the convexity adjustment does a better job of estimating the sensitivity of a bond's price change to large changes in yield.

Notice that when the convexity measure is positive, we have the situation described earlier that the gain is greater than the loss for a given large change in rates. That is, the bond exhibits positive convexity. We can see this in the preceding example. However, if the convexity measure is negative, we have the situation where the loss will be greater than the gain. For example, suppose that a callable bond has an effective duration of 4 and a convexity measure of –30. This means that the approximate percentage price change for a 200 basis point change is 8%. The convexity adjustment for a 200 basis point change in rates is then

$$-30 \times (0.02)^2 \times 100 = -1.2$$

The convexity adjustment is –1.2%, and therefore, the bond exhibits the negative convexity property illustrated in Exhibit 5-7. The approximate percentage price change after adjusting for convexity is

$$\begin{aligned} \text{Estimated change using duration} &= -8.0\% \\ \text{Convexity adjustment} &= \underline{-1.2\%} \\ \text{Total estimated percentage price change} &= -9.2\% \end{aligned}$$

For a decrease of 200 basis points, the approximate percentage price change would be as follows:

$$\begin{aligned} \text{Estimated change using duration} &= +8.0\% \\ \text{Convexity adjustment} &= \underline{-1.2\%} \\ \text{Total estimated percentage price change} &= 6.8\% \end{aligned}$$

Notice that the loss is greater than the gain—a property called *negative convexity* that we discussed earlier and illustrated in Exhibit 5-7.

Scaling the Convexity Measure

The convexity measure as given by Eq. (5-4) means nothing in isolation. It is the substitution of the computed convexity measure into Eq. (5-5) that provides the estimated adjustment for convexity. Therefore, it is possible to scale the convexity measure in any way and obtain the same convexity adjustment.

For example, in some books the convexity measure is defined as follows:

$$\text{Convexity measure} = \frac{V_+ + V_- - 2V_0}{V_0(\Delta y)^2} \tag{5-6}$$

Equation (5-6) differs from Eq. (5-4) because it does not include 2 in the denominator. Thus the convexity measure computed using Eq. (5-6) will be double the convexity measure using Eq. (5-4). Thus, for our earlier illustration, since the convexity measure using Eq. (5-4) is 112.38, the convexity measure using Eq. (5-6) would be 224.76.

Which is correct, 112.38 or 224.76? The answer is both. The reason is that the corresponding equation for computing the convexity adjustment would not be given by Eq. (5-5) if the convexity measure is obtained from Eq. (5-6). Instead, the corresponding convexity adjustment formula would be

$$\text{Convexity adjustment} = (\text{convexity measure}/2) \times (\Delta y)^2 \times 100 \tag{5-7}$$

Equation (5-7) differs from Eq. (5-5) in that the convexity measure is divided by 2. Thus the convexity adjustment will be the same whether one uses Eq. (5-4) to get the convexity measure and Eq. (5-5) to get the convexity adjustment or one uses Eq. (5-6) to compute the convexity measure and Eq. (5-7) to determine the convexity adjustment.

Some dealers and vendors scale the convexity measure in a different way. One also can compute the convexity measure as follows:

$$\text{Convexity measure} = \frac{V_+ + V_- - 2V_0}{2V_0(\Delta y)^2(100)} \tag{5-8}$$

Equation (5-8) differs from Eq. (5-4) by the inclusion of 100 in the denominator. In our illustration, the convexity measure would be 1.1238 rather than 112.38 using Eq. (5-4). The convexity adjustment formula corresponding to the convexity measure given by Eq. (5-8) is then

$$\text{Convexity adjustment} = \text{convexity measure} \times (\Delta y)^2 \times 10{,}000 \tag{5-9}$$

Similarly, one can express the convexity measure as shown in Eq. (5-10):

$$\text{Convexity measure} = \frac{V_+ + V_- - 2V_0}{V_0(\Delta y)^2(100)} \tag{5-10}$$

For the bond we have been using in our illustrations, the convexity measure is 2.2476. The corresponding convexity adjustment is

$$\text{Convexity adjustment} = (\text{convexity measure}/2) \times (\Delta y)^2 \times 10{,}000 \tag{5-11}$$

Consequently, the convexity measures (or just simply "convexity" as it is referred to by some market participants) that could be reported for this option-free bond are 112.38, 224.76, 1.1238, and 2.2476. All these values are correct, but they mean nothing in isolation. To use them to obtain the convexity adjustment to the price change estimated by duration requires knowing how they are computed so that the correct convexity adjustment formula is used. *It is the convexity adjustment that is important—not the convexity measure in isolation.*

It is also important to understand this when comparing the convexity measures reported by dealers and vendors. For example, if one dealer shows a portfolio manager bond A with a duration of 4 and a convexity measure of 50, and a second dealer shows the manager bond B with a duration of 4 and a convexity measure of 80, which bond has the greater percentage price change response to changes in interest rates? Since the duration of the two bonds is identical, the bond with the larger convexity measure will change more when rates decline. However, not knowing how the two dealers computed the convexity measure means that the manager does not know which bond will have the greater convexity adjustment. If the first dealer used Eq. (5-4) and the second dealer used Eq. (5-6), then the convexity measures must be adjusted in terms of either equation. For example, using Eq. (5-4), the convexity measure of 80 computed using Eq. (5-6) is equal to a convexity measure of 40 based on Eq. (5-4).

Modified Convexity and Effective Convexity

The prices used in Eq. (5-4) to calculate convexity can be obtained by assuming that when the yield changes the expected cash flows either do not change or they do change. In the former case, the resulting convexity is called *modified convexity.* (Actually, in the industry, convexity is not qualified by the adjective *modified.*) In contrast, *effective convexity* assumes that the cash flows do change when yields change. This is the same distinction made for duration.

As with duration, there is little difference between modified convexity and effective convexity for option-free bonds. However, for bonds with embedded options, there can be quite a difference between the calculated modified convexity and the effective convexity measures. In fact, for all option-free bonds, either convexity measure will have a positive value. For bonds with embedded options, the calculated effective convexity can be negative when the calculated modified convexity measure is positive.

Illustrations of Effective Duration and Convexity

As noted earlier, modified duration and effective duration are two ways to measure the price sensitivity of a fixed income security. Modified duration ignores any effect on cash flows that might take place as a result of changes in interest rates. Effective duration does not ignore the potential for such changes in cash flows. For example, bonds with embedded options will have very different cash flow properties as interest rates (or yields) change. Modified duration ignores these effects completely. In order to apply effective duration, an available interest-rate model and corresponding valuation model are needed. The example in this section shows how to compute the effective duration of securities with cash flows that are dependent on interest rates.

There is no difference between modified and effective duration for option-free or straight bonds. In fact, it can be shown that they are mathematically identical when the change in rates (or yields) becomes very small. As shown in the example, even for bonds with embedded options, the differences between the two measures are minimal over certain ranges of yields. For example, when the embedded option is far out-of-the-money, the cash flows of the bond are not affected by small changes in yields, resulting in almost no difference in cash flows between the two measures.

Convexity (sometimes referred to as "standard convexity") suffers the same limitations as modified duration and therefore is not generally useful for securities with embedded options. However, similar to the duration measures, in ranges of rates (or yields) where the cash flows are not materially affected by small changes in yields, the two convexity measures are almost identical.

The following example illustrates how to calculate and interpret effective duration and effective convexity for option-free bonds and bonds with embedded options.

Suppose that we need to measure the interest-rate sensitivity of the following three securities:

1. A five-year 2.50% coupon option-free semiannual coupon bond with a current price of 97.69% of par
2. A five-year 2.25% coupon bond, callable at par in years 2 through 5 on the semiannual coupon dates, with a current price of 96.54% of par
3. A five-year 2.75% coupon bond, putable at par in years 2 through 5 on the semiannual coupon dates, with a current price of 100.4410453 of par

The cash flows of these securities are very different as interest rates change. Consequently, the sensitivities to changes in interest rates are also very different.

Using an interest-rate model that is based on the existing term structure,[8] the term structure of interest rates is shifted up and down by 10 basis points (bps), and the resulting price changes are recorded. Using the notation for duration and convexity earlier in this chapter, V_- corresponds to the price after a downward shift in interest rates, V_+ corresponds to the price after an upward shift in interest rates, V_0 is the current price, and Δy is the assumed shift in the term structure.[9] Exhibit 5-15 shows these prices for each bond using Eq. (5-1) for duration and Eq. (5-6) for the convexity measure.

It is very important to realize the importance of the valuation model in this exercise. The model must account for the change in cash flows of the securities as interest rates change. The callable and putable bonds have very different cash flow characteristics that depend on the level of interest rates. The valuation model used must account for this property. (Note that when calculating the measures, users are cautioned not to round values. Since the denominators of both the duration and convexity terms are very small, any rounding will have a significant impact on results.)

Option-Free Bond

The effective duration for the straight bond is found by recording the price changes from shifting the term structure up (V_+) and down (V_-) by 10 bps and then substituting these values into Eq. (5-1). The prices are shown in Exhibit 5-15. Consequently, the computation is

$$\text{Effective duration} = \frac{99.3018797 - 98.3796865}{2(98.8395557)(0.001)} = 4.67$$

Similarly, the calculation for effective convexity is found by substituting the corresponding prices into Eq. (5-6):

8. The Black-Derman-Toy no arbitrage binomial model was used to perform this analysis. See Fischer Black, Emanuel Derman, and William Toy, "A One-Factor Model of Interest Rates and Its Application to Treasury Bond Options," *Financial Analysts Journal* (January–February 1990), pp. 24–32.

9. Note that shifting the term structure in a parallel manner will result in a change in yields equal to the shift for option-free bonds.

EXHIBIT 5-15

Original Prices and Resulting Prices from a Downward and Upward 10 Basis Point Interest-Rate Shift and the Corresponding Effective Duration and Effective Convexity for Three Bonds Based on the Black-Derman-Toy Model

Price Changes Following 10-bp Shift

Variable	Original Price, V_0	Upward Shift of 10 bp, V_+	Downward Shift of 10 bp, V_-
Option-free bond price	98.8395557	98.3796865	99.3018797
Callable bond price	97.6550524	97.2132182	98.0922517
Putable bond price	100.4410453	100.1343384	100.7706854

Effective Duration and Effective Convexity Measures Calculated from Using the Price Changes Resulting from the 10-bp Shifts in the Term Structure

	Effective Duration	Effective Convexity
Option-free bond	4.67	24.84
Callable bond	4.50	–47.46
Putable bond	3.17	228.32

$$\text{Effective convexity} = \frac{99.3018797 + 98.3796865 - 2(98.8395557)}{98.8395557(0.001)^2}$$

$$= 24.84$$

For the option-free bond, the modified duration is 4.67 and the convexity is 24.84. These are very close to the effective measures shown in Exhibit 5-15. This demonstrates that, for option-free bonds, the two measures are almost the same for small changes in yields.

Exhibit 5-16 shows the effects of the term structure shifts on the effective duration and effective convexity of the option-free bond. The effective duration increases as yields decrease because as yields decrease the slope of the price/yield relationship for option-free bonds becomes steeper and effective duration (and modified duration) is directly proportional to the slope of this relationship. For example, the effective duration at very low yields (–250-bp shift) is 4.74 and decreases to 4.44 at very high rates (+1,000 bps). Exhibit 5-17 illustrates this phenomenon; as yields increase, notice how the slope of the price/yield relationship decreases (becomes more horizontal or flatter).

As the term structure shifts up (i.e., as rates rise), the yield to maturity on an option-free bond increases by approximately the same amount. As the yield increases, the bond's convexity decreases. Exhibit 5-17 illustrates this property. As yields increase, the curvature (or the rate of change of the slope) decreases.

EXHIBIT 5-16

Effective Duration and Effective Convexity for Various Shifts in the Term Structure for Three Bonds

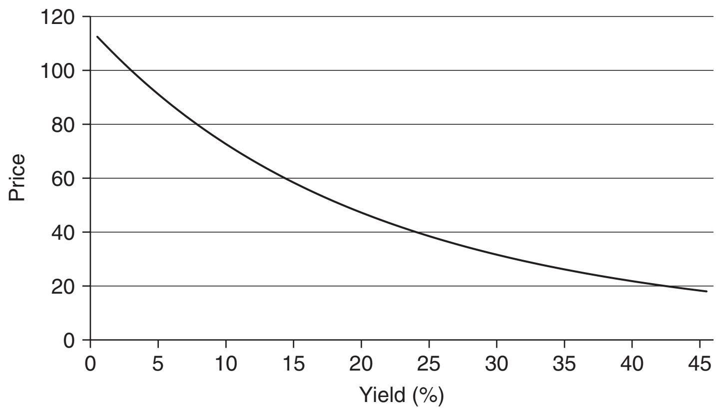
Term Structure Shift (bps)	Option-Free Bond		Callable Bond		Putable Bond	
	Effective Duration	Effective Convexity	Effective Duration	Effective Convexity	Effective Duration	Effective Convexity
–250	4.74	25.59	1.97	4.88	4.72	25.43
0	4.67	24.84	4.50	–47.46	3.17	228.32
250	4.59	24.10	4.61	24.28	1.91	4.62
500	4.51	23.39	4.54	23.57	1.88	4.50
1,000	4.44	22.70	4.47	22.89	1.86	4.39

The results in Exhibit 5-16 for the option-free bond also bear this out. The effective convexity values become smaller as yields increase. For example, the effective convexity at very low yields (–250-bp shift) is 25.59 and decreases to 22.70 at very high rates (+1,000-bp shift).

These are both well-documented properties of option-free bonds. The modified duration and convexity numbers for the option-free bond are almost identical to the effective measures for the option-free bond shown in Exhibit 5-16.

EXHIBIT 5-17

Price/Yield Relationship of the Option-Free Bond



Callable Bond

The effective duration for the callable bond is found by recording the price changes from shifting the term structure up (V_+) and down (V_-) by 10 bps and then substituting these values into Eq. (5-1). The prices are shown in Exhibit 5-15. Note that these prices take into account the changing cash flows resulting from the embedded call option. Consequently, the computation is

$$\text{Effective duration} = \frac{98.0922517 - 97.2132182}{2(97.6550524)(0.001)} = 4.50$$

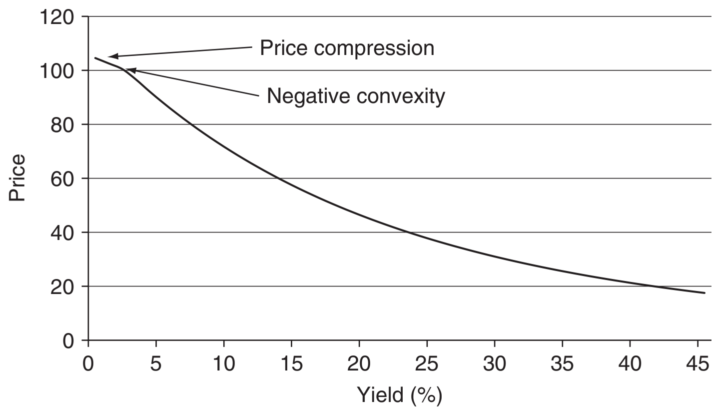
Similarly, the calculation for effective convexity is found by substituting the corresponding prices into Eq. (5-6):

$$\text{Effective convexity} = \frac{98.0922517 + 97.2132182 - 2(97.6550524)}{97.6550524(0.001)^2}$$
$$= -47.46$$

The relationship between the shift in rates and effective duration is shown in Exhibit 5-16 and in Exhibit 5-18. As rates increase, the effective duration of the callable bond becomes larger. For example, the effective duration at very low yields (–250-bp shift) is 1.97 and increases to 4.47 at very high rates (+1,000 bps). This reflects the fact that as rates increase, the likelihood of the bond being called decreases, and as a result, the bond behaves more like an option-free bond; hence its effective duration increases. Conversely, as rates drop, this likelihood increases, and the bond and its effective duration behave more like a bond with a two-year maturity because of the call option becoming effective in two years. As rates decrease significantly, the likelihood of the issuer calling the bond in two years increases. Consequently, at very low and intermediate rates, the difference between the effective duration measure and modified duration is large, and at very high rates, the difference is small.

EXHIBIT 5-18

Price/Yield Relationship of the Callable Bond



Effective convexity measures the curvature of the price/yield relationship of bonds. Low values for effective convexity simply mean that the relationship is becoming linear (an effective convexity of zero represents a linear relationship). As shown in Exhibit 5-16, the effective convexity values of the callable bond at extremely low interest rates (i.e., for the –250-bp shift in the term structure) are very small positive numbers 4.88. This means that the relationship is almost linear but exhibits slight convexity. This is due to the call option being delayed by two years. At these extremely low interest rates, the callable bond exhibits slight positive convexity because the price compression at the call price is not complete for another two years.[10] If this bond were immediately callable, the price/yield relationship would exhibit positive convexity at high yields and negative convexity at low yields. At the current level of interest rates, the effective convexity is negative, as expected. At these rate levels, the embedded call option causes enough price compression to cause the curvature of the price/yield relationship to be negatively convex (i.e., concave). Exhibit 5-18 illustrates these properties. It is at these levels that the embedded option has a significant effect on the cash flows of the callable bond.

Exhibit 5-16 shows that for large positive yield-curve shifts (i.e., for the +250-bp, +500-bp, and +1,000-bp shifts in the term structure), the effective convexity of the callable bond becomes positive and very close to the effective convexity values of the straight bond. For example, the effective convexity at the +250-bp shift is 24.28 for the callable bond and 24.10 for the straight bond. The only reason they are not the same is because the coupon rates of the bonds are not equal. Consequently, at very low and intermediate rates, the difference between effective convexity and standard convexity is large, and at very high rates, the difference is small. The intuition behind these findings is straightforward. At low rates, the cash flows of the callable bond are severely affected by the likelihood of the embedded call option being exercised by the issuer. At high rates, the embedded call option is so far out-of-the-money that it has almost no effect on the cash flows of the callable bond, and so the callable bond behaves like an option-free bond.

Putable Bond

The effective duration for the putable bond is found by recording the price changes from shifting the term structure up (V_+) and down (V_-) by 10 bps and then substituting these values into Eq. (5-1). The prices are shown in Exhibit 5-15. Note that these prices take into account the changing cash flows resulting from the embedded put option. Consequently, the computation is

$$\text{Effective duration} = \frac{100.7706854 - 100.1343384}{2(100.4410453)(0.001)} = 3.17$$

10. As noted earlier in this chapter, price compression for a callable bond refers to the property that a callable bond's price appreciation potential is severely limited as yields decline. As shown in Exhibit 5-18, as yields fall below a certain level (i.e., where the yield corresponds to the call price), the price appreciation of the callable bond is being compressed.

Similarly, the calculation for effective convexity is found by substituting the corresponding prices into Eq. (5-6):

$$\text{Effective convexity} = \frac{100.7706854 + 100.1343384 - 2(100.4410453)}{100.4410453(0.001)^2}$$
$$= 228.32$$

Because the putable bond behaves so differently from the other two bonds, the effective duration and effective convexity values are very different. As rates increase, the bond behaves more like a two-year bond because the owner will, in all likelihood, exercise his right to put the bond back at the put price as soon as possible. As a result, the effective duration of the putable bond is expected to decrease as rates increase. This is due to the embedded put option severely affecting the cash flows of the putable bond. Conversely, as rates fall, the putable bond behaves more like a five-year straight bond because the embedded put option is so far out-of-the-money and has little effect on the cash flows of the putable bond. Effective duration should reflect these properties. Exhibit 5-16 shows that this is indeed the case. For example, the effective duration at very low yields (–250-bp shift) is 4.72 and decreases to 1.86 at very high rates (+1,000 bps). Consequently, at very high and intermediate rates, the difference between the effective duration and modified duration measures is large, and at low rates, the difference is small.

Exhibit 5-16 shows that the effective convexity of the putable bond is positive for all rate shifts, as would be expected, but it becomes smaller as rates increase (i.e., for the +250-bp, +500-bp, and +1,000-bp shifts in the term structure). As rates increase, the putable bond price/yield relationship will become linear because of the bond's price truncation at the put price.[11] This is the reason for the small effective convexity values for the putable bond for the three positive shifts in the term structure (4.62, 4.50, and 4.39, respectively). It is at these levels that the embedded put option has a significant effect on the cash flows of the putable bond. Consequently, at very high and intermediate rates, the difference between the effective convexity and standard convexity is very large. Exhibit 5-19 illustrates these properties.

At very low rates (i.e., for the 250-bp downward shift in the term structure), the putable bond behaves like a five-year straight bond because the put option is so far out-of-the-money. Therefore, as the term structure is shifted downward, the putable bond's effective convexity values approach those of a comparable five-year option-free bond. Comparing the effective convexity measures for the putable bond and the option-free bond illustrates this characteristic. For example, the effective convexity at the –250-bp shift is 25.43 for the putable bond and 25.59 for the option-free bond. The two convexity measures are almost identical. In fact, they would be identical if their coupon rates were equal.

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11. *Price truncation* for a putable bond refers to the property that the putable bond's price depreciation potential is severely limited as yields increase. As shown in Exhibit 5-19, as yields rise above a certain level (i.e., where the yield corresponds to the put price), the price depreciation of the putable bond is truncated.

EXHIBIT 5-19

Price/Yield Relationship of the Putable Bond

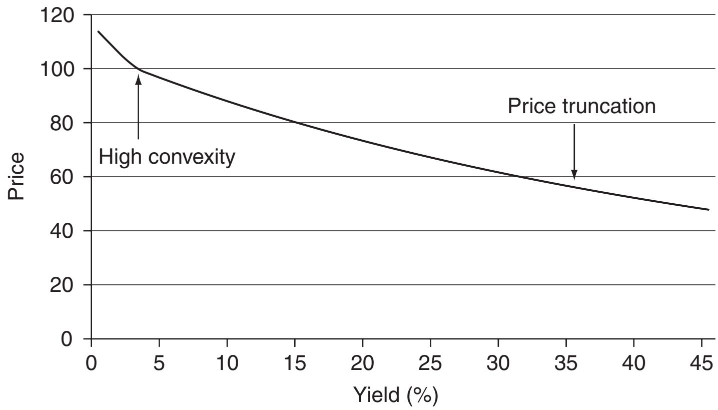


Exhibit 5-19 illustrates these properties. Also notice how the transition from low yields to high yields forces the price/yield relationship to have a very high convexity at intermediate levels of yields. For example, the current effective convexity of the putable bond is 228.32 compared with 24.84 for the straight bond and 47.46 for the callable bond. This is so because as yields increase, the embedded put option moves from out-of-the-money to in, and the behavior of the bond goes from that of a five-year bond to a two-year bond as a result. This corresponding price truncation causes the price/yield relationship to have to transition very quickly from the five-year (high effective duration) to the two-year (low effective duration), resulting in very high effective convexity.

Putting It All Together

Notice in Exhibit 5-16 how effective duration changes much more across yields for the callable and putable bonds than it does for the option-free bond. This is to be expected because the embedded options have such a significant influence over cash flows as yields change over a wide spectrum. Interestingly, at high (low) yields, the callable (putable) bond's effective duration is very close to the option-free bond. This is where the embedded call (put) option is so far out-of-the-money that the two securities behave similarly. The same intuition holds for the effective convexity measures.

As explained and illustrated earlier, the common use of effective duration and effective convexity is to estimate the percentage price changes in fixed income securities for assumed changes in yield. In fact, it is not uncommon for effective duration and effective convexity to be presented in terms of estimated percentage price change for a given change in yield (typically 100 bp). Exhibits 5-20 and 5-21 show this alternative presentation for a ±100-bp change in yield using Eqs. (5-2) and (5-7).

EXHIBIT 5-20

Using Effective Duration and Effective Convexity to Illustrate the Impact of 100 bps Increase in Yield Across Different Term Structure Levels

	Option-Free Bond			*Callable Bond*			*Putable Bond*		
Starting Term Structure Level Relative to Current Term Structure (bps)	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**
–250	–4.74	0.1280	–4.6143	–1.97	0.0244	–1.9408	–4.72	0.1271	–4.5930
0	–4.67	0.1242	–4.5409	–4.50	–0.2373	–4.7380	–3.17	1.1416	–2.0261
250	–4.59	0.1205	–4.4681	–4.61	0.1214	–4.4924	–1.91	0.0231	–1.8854
500	–4.51	0.1169	–4.3958	–4.54	0.1179	–4.4214	–1.88	0.0225	–1.8619
1,000	–4.44	0.1135	–4.3239	–4.47	0.1144	–4.3508	–1.86	0.0220	–1.8389

EXHIBIT 5-21

Using Effective Duration and Effective Convexity to Illustrate the Impact of 100 bps Decline in Yield Across Different Term Structure Levels

	Option-Free Bond			*Callable Bond*			*Putable Bond*		
Starting Term Structure Level Relative to Current Term Structure (bps)	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**	**% Price Change Using Effective Duration**	**% Price Change Using Effective Convexity**	**Total % Price Change**
–250	4.74	0.1280	4.8702	1.97	0.0244	1.9896	4.72	0.1271	4.8473
0	4.67	0.1242	4.7893	4.50	–0.2373	4.2634	3.17	1.1416	4.3094
250	4.59	0.1205	4.7091	4.61	0.1214	4.7352	1.91	0.0231	1.9315
500	4.51	0.1169	4.6297	4.54	0.1179	4.6571	1.88	0.0225	1.9069
1,000	4.44	0.1135	4.5508	4.47	0.1144	4.5797	1.86	0.0220	1.8828

PRICE VALUE OF A BASIS POINT

Some managers use another measure of the price volatility of a bond to quantify interest-rate risk—*the price value of a basis point* (PVBP). This measure, also called the *dollar value of an 01* (DV01), is the absolute value of the change in the price of a bond for a 1 basis point change in yield. That is,

$$\text{PVBP} = \left|\, \text{initial price} - \text{price if yield is changed by 1 basis point} \,\right|$$

Does it make a difference if the yield is increased or decreased by 1 basis point? It does not because of Property 2—the change will be about the same for a small change in basis points.

To illustrate the computation, we use the values in Exhibit 5-4. If the initial yield is 4%, we can compute the PVBP by using the prices for either the yield at 3.99% or 4.01%. The PVBP for both for each bond is shown below:

Coupon	**4.0%**	**4.0%**	**5.0%**	**5.0%**
Maturity	**5**	**20**	**5**	**20**
Initial price	$100.0000	$100.0000	$104.4913	$113.6777
Price at 3.99%	100.0449	100.1369	104.5374	113.8266
PVBP at 3.99%	$0.0449	$0.1369	$0.0461	$0.1489
Price at 4.01%	99.9551	99.8633	104.4452	113.5291
PVBP at 4.01%	$0.0449	$0.1367	$0.0461	$0.1486

The PVBP is related to duration. In fact, PVBP is simply a special case of dollar duration. We know that the duration of a bond is the approximate percentage price change for a 100 basis point change in interest rates. We also know how to compute the approximate percentage price change for any number of basis points given a bond's duration using Eq. (5-2). Given the initial price and the approximate percentage price change for 1 basis point, we can compute the change in price for a 1 basis point change in rates.

For example, consider the 5% 20-year bond. The duration for this bond is 13.09. Using Eq. (5-2), the approximate percentage price change for a 1 basis point increase in interest rates (i.e., $\Delta y = 0.0001$) ignoring the negative sign in Eq. (5-2) is

$$13.09 \times (0.0001) \times 100 = 0.1309\%$$

Given the initial price of 113.6777, the dollar price change estimated using duration is

$$0.1309\% \times 113.6777 = \$0.1488$$

This is the same price change as shown above for a PVBP for this bond. Below is (1) the PVBP based on a 1 basis point increase for each bond and (2) the estimated price change using duration for a 1 basis point increase for each bond:

Coupon	4.0%	4.0%	5.0%	5.0%
Maturity	5	20	5	20
PVBP for 1 bp increase	\$0.0449	\$0.1367	\$0.0461	\$0.1486
Duration of bond	4.4913	13.6777	4.4107	13.0871
Duration estimate	\$0.0449	\$0.1368	\$0.0461	\$0.01488

THE IMPORTANCE OF YIELD VOLATILITY

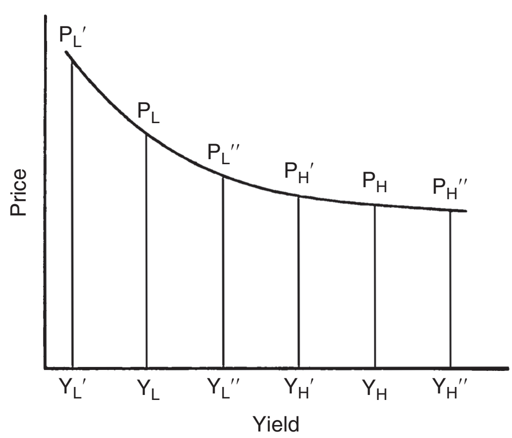
What we have not considered thus far is the volatility of interest rates. All other factors equal, the higher the coupon rate, the lower is the price volatility of a bond to changes in interest rates. In addition, the higher the level of yields, the lower is the price volatility of a bond to changes in interest rates. This is illustrated in Exhibit 5-22, which shows the price/yield relationship for an option-free bond. When the yield level is high (Y_H in the exhibit), a change in interest rates does not produce a large change in the initial price (P_H in the exhibit). However, when the yield level is low (Y_L in the exhibit), a change in interest rates of the same number of basis points as shown when the yield is high does produce a large change in the initial price (P_L in the exhibit).

This also can be cast in terms of duration properties: the higher the coupon, the lower is the duration, and the higher the yield level, the lower is the duration. Given these two properties, a 10-year non-investment-grade bond has a lower

EXHIBIT 5-22

The Effect of Yield Level on Price Volatility

$(Y_H' - Y_H) = (Y_H - Y_H'') = (Y_L' - Y_L) = (Y_L - Y_L'')$
$(P_H - P_H') < (P_L - P_L')$ and
$(P_H - P_H'') < (P_L - P_L'')$



duration than a current coupon 10-year Treasury note because the former has a higher coupon rate and trades at a higher yield level. Does this mean that a 10-year non-investment-grade bond has less interest-rate risk than a current coupon 10-year Treasury note? Consider also that a 10-year Swiss government bond has a lower coupon rate than a current coupon 10-year U.S. Treasury note and trades at a lower yield level. Therefore, a 10-year Swiss government bond will have a higher duration than a current coupon 10-year Treasury note. Does this mean that a 10-year Swiss government bond has greater interest-rate risk than a current coupon 10-year U.S. Treasury note? The missing link is the relative volatility of rates, which we shall call *yield volatility* or *interest-rate volatility.*

The greater the expected yield volatility, the greater is the interest-rate risk for a given duration and current value of a position. In the case of non-investment-grade bonds, while their durations are less than current coupon Treasuries of the same maturity, the yield volatility of non-investment-grade bonds is greater than that of current coupon Treasuries. For the 10-year Swiss government bond, while the duration is greater than for a current coupon 10-year U.S. Treasury note, the yield volatility of 10-year Swiss bonds is considerably less than that of 10-year U.S. Treasury notes.

A framework that ties together the price sensitivity of a bond position to rate changes and yield volatility is the value-at-risk (VaR) framework. *Risk* in this framework is defined as the maximum estimated loss in market value of a given position that is expected to happen with a specified probability.

KEY POINTS

- The full-valuation approach to interest-rate risk management involves repricing bonds under different interest rate scenarios to quantify price sensitivity to interest-rate changes.
- Important bond price volatility properties for option-free bonds are (1) prices move inversely to yields, but percentage price changes are not the same for all bonds; (2) for small changes in yield, the percentage price change is roughly the same, whether yields increase or decrease; (3) for large changes in yield, the percentage price change is not the same for yield increases compared with yield decreases, and; (4) for a given large change in yield, the percentage price increase is greater than the percentage price decrease.
- Bond features affect interest-rate risk. For option-free bonds, a longer maturity leads to more interest-rate risk, a higher coupon rate leads to less interest-rate risk, and interest-rate risk is greater at lower yields. Additionally, embedded options affect interest-rate risk.
- An alternative to the full-valuation approach is the duration/convexity approach. Duration is the approximate percentage price change in a bond's value for a 100 basis point change in rates.

- Duration assumes the term structure is flat and all interest-rate changes result from parallel shifts.
- Convexity adjustments improve duration estimates, particularly for large interest-rate changes.
- Bonds with embedded options, such as the issuer's right to call the bond or an investor's right to put the bond, have cash flows that change as interest rates change. Effective duration accounts for changes in the bond's cash flow. For this purpose, a term structure model is required.
- Callable bonds exhibit negative convexity and price compression at low interest rates. Putable bonds exhibit price truncation at high yields and high convexity at low yields.

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CHAPTER

SIX

DATA SCIENCE AND THE CORPORATE CREDIT MARKETS

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The field of data science encompasses skills and techniques from statistical and scientific analysis and combines them with computer science. Data science is being applied to finance in innovative ways, not just for finding trading anomalies in stocks and modeling of structured credit. In corporate credit markets it is being applied to credit selection, portfolio construction, scenario analysis, and multi-asset credit portfolio management as well as performance and risk analysis. While data science has been part of the investment world for decades utilizing statistical techniques that have been in place a long time, the analytical capabilities are being transformed by creatively applying modern computer science tools such as artificial intelligence (AI).

Virtually all analysts, portfolio managers, and traders need to be data scientists to some extent. They do not need to be running algorithms themselves, but they have to understand what the basic techniques behind the statistical side of data science are and what the more advanced algorithms can and cannot do. These tools improve with the input and collaboration from the investment team in the design of these systems. It also puts the investment team in a better position to question and exploit the output.

Data science has helped make the growth of passive investing possible. However, within credit markets, the greater value of data science is how it can improve the decision-making process within actively managed portfolios. It can be especially valuable to refine investment styles and create customized fixed-income solutions to meet investors' specific needs

Active management is about making decisions and making them better and faster. The amount of raw data that is available in digital form has boomed over time, and this will likely continue. The real differentiator in investment performance will not come from who has that data, but who can sort through it, prioritize it, and empower it. Data science can help drive this process and avoid the analysis paralysis that can come from massive dumps of data.

Data science can improve the speed at which you can transmit a research idea into an executed transaction. Applying data science to corporate credit portfolios has some great hurdles when compared to markets such as equities and rates. However, many of the same characteristics that cause these hurdles also create opportunities. The trading illiquidity and the vast diversity of data fields needed to analyze corporate bonds and loans are some of the defining features of these markets, but they increase the level of difficulty in using data science. The fact that many bonds and loans in the credit markets do not trade every day, week, or even month makes pricing data very poor. The diversity of the data that is needed for good analysis arises from the multitude of factors that can influence the performance of an investment in corporate debt. Corporate bonds and loans are influenced by the same macro and micro business trends that impact movement in equity valuations, but also require the integration of interest rate factors, bond math and structural analysis—that can vary for each bond and loan. These structural issues can include items such as coupons, maturity, seniority, imbedded options, and covenants. Additionally, the ability of companies to call bonds and loans and the natural turnover due to maturity schedules is constantly causing the constituents in the credit markets to change. All of these complexities can create great opportunities for those that can harness the data. In a market that lacks homogeneity, like credit, there is a high probability of asset values being mispriced.

One could argue that using data science for investment analysis goes back to the 1952 portfolio allocation model by Harry M. Markowitz, popularly referred to as "modern portfolio theory," where he distinguished between inefficient and efficient portfolios. However, Markowitz. wrote that the concepts probably go back at least to Shakespeare.[1] Whichever timeline you prefer, the application of statistical and economic techniques to making investment decisions is not new. What is new is the power and design of storing data and computing. This has allowed data science to be applied to an enormous amount of creative investment problems. Scenario analyses that could only be theoretical a few years ago now can be run in unending iterations. Analysis and decision techniques based on tools such as probability, regression, correlation, and decision trees can now be used by computers with selected algorithms to run and rerun scenarios to come up with the best potential solutions and unearth relationships that have not even been thought of by investors. This does not just improve the ability to pick good investments but also improves analysis of how all the factors in a portfolio interact and respond to shifts in market sentiment and changes in the macroeconomic outlook.

One of the challenges with all this potential is that all the data and all the possible analysis that could be undertaken can be distracting. That is why a defined process and structured approach to undertaking data science projects improves the output along with helping to maintain a clear view of goals and priorities to keep the process on track. The plan needs to be designed in the right

1. Harry M. Markowitz, "The Early History of Portfolio Theory: 1600–1960," *Financial Analysts Journal* 55 (4), 1999, pp. 5–16.

way for each firm, with regular collaboration from all stakeholders. To achieve better decisions with data science takes commitment to structure and process as well as a commitment to invest in the systems, people, and time necessary to produce useful reporting. It also requires an understanding that even when a great analytical system is built, the work is not over. It will take more commitment to keep the systems evolving so that the competitive edge does not get dulled and the system keeps up with the constant changes that occur in the corporate fixed income markets.

The chapter starts with trying to define and categorize types of data science. It then goes through some of the key techniques used in data science and how they can aid decision-making, increase efficiency, and enhance performance and risk analysis. It then addresses some of the unique challenges in using data analysis in corporate credit markets and ends with a summary of some items to consider when undertaking data science projects.

DEFINING DATA SCIENCE

Data science is always described as being a multidisciplinary field, but after that you can find a broad array of explanations of what it incorporates. Broadly, it involves analyzing data by applying statistics, economics, scientific methods, and related mathematical techniques with advanced computer science, often involving algorithms in AI. The field has grown along with the ability to gather and store digital data.

One way of thinking of the techniques in data science is to separate them into descriptive analysis and predictive analysis. Some tools can be used for both—as an example, certain aspects of regression and probability analysis are descriptive and other aspects can be used as predictive.

Descriptive techniques may focus more on analyzing what has happened and the drivers behind it. Much of this field can be aligned with a focus on central tendencies. In other words, establishing an average for a group of data (i.e., mean, mode, or median) and then using various techniques to analyze the data in relationship to this central tendency (e.g., standard deviation, coefficient of variation). These types of techniques could be used to highlight a bond or a loan that is an outlier or an anomaly in how a portfolio performed versus its historical trend. The growth in big data and the ability to rapidly manipulate data has dramatically increased the potential for this field. However, descriptive analysis can lead to the development of predictive techniques, as data distribution can be used to derive the probability of an outcome. There is also research done on whether changes in things like the skew of a distribution can be predictive of market movements.[2]

2. See, for example, Roman Kozhan, Anthony Neuberger, and Paul Schneider, "The Skew Risk Premium in the Equity Index Market," *Review of Financial Studies* 26(9), 2013, pp. 2174–2203, and James Picerno, "Considering Skewness Of Returns as a Risk Metric," Seekingalpha.com, March 22, 2018.

Predictive techniques use data to create models that can make a prediction about something. Regression models are a basic technique that is frequently used to make a prediction. In its simplest form, it shows how one data point (the dependent variable) will likely react in relation to the change in another data point (the independent variable) based on the relationship of how the two had acted in the past. So, if you can make a statement about the independent variable, it can make a prediction of where the dependent variable will move. Predictive techniques can take that simple concept to much more complex and intricate levels, and historical probabilities can get factored into the equation as well. Predictive techniques can be improved by running various iterations of probability and regression and examining patterns of past performance. The ability to run these types of scenarios is greatly enhanced by the use of AI.

AI is a field that is increasingly exciting to investors. However, it worries people, too. It was entertaining when AI programs beat people in chess and go, but as the possibility of it taking jobs away became real there has been pushback from some quarters. Like other technological developments, AI is not going to stop advancing and being used just because of some Luddite-like outcries against it. Many of the tools are likely to eventually become commonplace as AI becomes more accessible and will likely be part of almost everyone's daily life in the future.

AI should be understood and embraced as a tool to help make decisions. However, it should be recognized that it is not infallible and it can sometimes create a conclusion when the relationship between the data is actually random. Many of these techniques and methods have evolved from work in the physical sciences, and finance and economics are not physical sciences. Financial markets, and the economic and corporate actions behind them, are still driven by individual choices. Even great models cannot always predict what a chief executive officer will choose to post on social media, what event will go viral and change shopping habits, or who will win an election.

Typically, AI systems use different types of algorithms that often mimic the way humans learn. This allows computers to take massive amounts of information and process it to generate output that helps explain patterns in the data. Ideally, the more recent the data is that the system has to analyze, the smarter and timelier its output becomes. This is making good-quality digital data increasingly valuable.

There are different types of algorithms used in AI; these may include neural networks, clustering, and random forests, among others. AI techniques are broadly divided in to supervised learning and unsupervised learning. There are also techniques involving semi-supervised learning and reinforcement learning.

The data used in supervised learning are labeled. This labeling is a differentiator between supervised and unsupervised learning. So that if there is a bond and a loan in the data set, they will each be labeled when using supervised learning algorithms. These algorithms may also have more clearly defined output goals than in unsupervised methods. Supervised learning algorithms can include decision tress, regression techniques, and some Bayesian-related algorithms.

Unsupervised learning techniques do not have data labels and often have less guidance about inputs and output goals. These types of algorithms include clustering and density estimates (e.g., distribution information). These methods can take reams of data that the algorithm starts to identify and put it in patterns, and as it does this it begins to sort and make note of relationships. This is how AI programs do things like recognize that convenience store shoppers tend to buy beer and diapers at the same time.

Semi-supervised learning includes techniques where the data has some explanatory labels, but not every data field is labeled. This can minimize the time and expense of labeling data. Reinforcement learning is where the algorithm gets feedback if it is accomplishing certain tasks correctly to know if it needs to change direction or can keep going along the same pattern; theoretically, the outcomes will improve from that feedback.

Natural language processing (NLP), another area of AI, is designed to scan and search for key words or patterns of words. NLP increasingly is being used in voice recognition—reportedly, national security intelligence agencies use this technology in their communications intelligence gathering to sort through all the intercepted messages and prioritize them. In the investment world, similar technology can be used to find key words in economic reports or corporate filings and sort them, send alerts, or analyze the patterns or changes in the language. This can be useful to see if language about the earnings outlook has changed in a company's financial statement, or it could be used to sweep through thousands of quarterly reports to see if there is an increasing trend in the use of a phrase like "cost savings" versus prior reports.

This is by no means an exhaustive review of how data science is being used. However, it hopefully gives a rough idea of the major categories of data science tools and demystifies a bit how these techniques, which are based on basic statistical tools, are allowing investment teams to think of creative ways to analyze and improve their performance.

SELECTED DATA SCIENCE TOOLS, TECHNIQUES, AND USES FOR INVESTING

The base of data science involves various statistical techniques that have been applied to investment analysis for decades. However, computer science has allowed these techniques to move from evolutionary changes to revolutionary changes.

One of the unique challenges in applying statistical and economic tools to the credit markets is how many variables there are that can impact performance at each individual investment and across the entire portfolio. Choosing the right items to focus on and the best techniques to use can make a huge difference in plowing through all the available data. One of the advantages of computer science is it can take a technique like regression or probability analysis and run iterative calculations, using different variables to find the most meaningful factors on which to focus for different market environments or for different investment styles.

Using these techniques are not foolproof when applied to investing. Economics is not physics; there are very few laws of investment and portfolio construction that cannot change or produce frequent anomalies because of how much they are impacted by human actions. Additionally, with so much data being analyzed, the danger of randomness has to be considered. Techniques such as data mining have come under criticism that they torture the data until a relationship is created. You can find any number of scholarly and sensational articles wary of the misuse of algorithms in everything from driverless cars to mortgage approvals.[3] You always have to be aware that even though computers are being used, all of the typical biases that get discussed in behavioral economics can creep into the analysis. This can happen by what data is selected to input and what is being asked for on the output as well as how the data is presented. There are often statistical tests that can be run on the output of any analysis to check the validity of the conclusion, but in all cases, it is always good to apply common sense, especially when data analysis shows a shocking relationship.

What follows is a sampling of some of the most common decision-making tools used in data science. Investment professionals continue to develop creative ways to marry these techniques with computer science to address new problems and look for more opportunities.

Regression and Correlation

Regression is usually at the top of a list of data science techniques. Its output can produce both valuable descriptive statistics and be used predictively. Like many data science techniques, regression is a relational tool, it compares the relationship between various data sets. It can be used to aid decision-making in credit selection, portfolio construction, and about the macroeconomic drivers.

Regression is used to take the data about movements in the value of one or more "independent" variables and tries to fit this data into a relationship with the movements in value of a "dependent" variable. Linear regression forces this data into a formula that describes a line. The line tells you what the predicted value of the dependent variable is for each value of the independent variable. If the relationship is not strong, there are techniques that can be used to help smooth out the data and create a stronger relationship, such as using logs and exponents to fit the data into a stronger "fit."

The data from this analysis can generate interesting descriptive data. One of the most widely used outputs explains how strong the relationship between the independent and dependent variable is. Advanced computing techniques can help run series upon series of this data to see which set of independent variables has the most impact on the dependent variable you are trying to solve for. For

3. Ben Shneiderman, "The Dangers of Faulty, Biased, or Malicious Algorithms Requires Independent Oversight," *Proceedings of the National Academy of Sciences of the United States of America* 113(48), November 29, 2016, pp. 13538–13540.

example, if you are trying to solve for what the likely volatility of returns on a portfolio will be (dependent variable), you might want to see which has a stronger relationship with the changes in volatility: aggregate credit score changes, interest rates, or GDP (all independent variables). A data science program could run thousands of combinations of variables to try and solve for the strongest relationship.

Regression is often used as a predictive tool. Once a linear formula for a relationship is found, you could make an assumption on how the independent variable might move and the formula could predict an outcome for the dependent variable. Data analysis techniques can be combined and a program could run the probability of changes in the independent variable based on past patterns and choose the data points that had the highest probability, thus strengthening the predictive power of the regression model.

Regression output also produces residuals that show how far data points are from the regression line and this can be used for relative value analysis or as a predictive tool for what the gain or loss could be if an investment were to move to trade in line with the "fair value" predicted by the line.

Correlation

Correlation information is an output from regression analysis. Correlation is used to try to explain how strong a relationship there is between two or more variables. For example, you might want to examine the relationship between rising interest rates and consumer spending. In theory, the relationship could be strong, weak, nonexistent, or negative (meaning one goes up when the other goes down). Correlations can help to tell how well regression might work as a predictive tool. In situations where negative correlations exist between two investible assets, investors could create hedged positions being long one asset and short the other. The strength of the negative correlation could give some guidance of what ratio to use between the long and the short. Correlations are also often used in portfolio analysis; as an example, in credit markets you often want to look at the relationship between certain macroeconomic factors and how correlated your portfolio's performance is to them (e.g., sensitivity to interest rate movements or credit rating changes).

One of the valuable uses of tracking correlations is to have a system that can alert you when relationships between two assets breaks down or changes dramatically. If two assets regularly have a strong relationship but periodically this relationship gets disrupted, it may create investment opportunities, especially if the relationship is expected to revert. For example, there may be an extended period of time when the relationship in spread between BB-rated bonds and BBB-rated bonds is highly correlated. However, when investors' view of risk begins to change, this correlation can breakdown quickly and BB-rated bonds may sell off more than BBB-rated bonds. If an investor expects this breakdown in correlation to be short-lived, they may find this an opportunity to buy BB-rated bonds. This analysis could be enhanced by running probabilities of this reversion based on past periods of decoupling. However, you should be cautious on jumping in blindly when you see a correlation change; sometimes these changes are warranted and they are permanent. This is especially true when investing in corporates as technological disruption has increased the potential for more permanent disconnects.

Once you run one regression and look at the output, it is easy to see that you will want to run several others to refine your analysis and move down an iterative path. With advanced computing, it is much easier to proceed down this road. However, the information does have to be analyzed properly and tested. If you have sat through one statistics class, you have probably heard that "correlation is not causation" and any conclusion from regression has to be examined from both a logical and mathematical approach. Regression is so widely used that too often the output is not examined and simple tests are not run to check for items that could weaken the conclusions, including issues such as goodness of fit, as well as heteroskedasticity, autocorrelation, or multicollinearity in the variables.

Probability

Probability is used all the time in decision-making, though often it is done informally and intuitively. It is also the basis of many data science techniques. Conditional probability and specifically Bayesian probability could be viewed as the basis of much of AI. However, improper use of probability can result in poor decision-making whether in anchor and confirmation bias or base rate fallacy.[4]

Bayes' theorem helps you adjust the probability of an event as you get new data. With all the factors that impact a credit portfolio, it can be critical to understanding how new information can impact the probability of an outcome. For example, understanding how a change in interest rates, credit quality, or exchange rates may influence the probability of your portfolio outperforming a benchmark or how a decrease in interest rates could increase the probability of bonds being refinanced in a short-duration portfolio are all valuable pieces of information.

With the advent of digital data and increased computing power, the data available from which probabilities of events can be analyzed has exploded and enhanced the value of Bayes' theorem and this can improve the decision process exponentially. It also increases the value of decision trees, as you can build out a series of conditional probability relationships. As always, you do need to be aware that noise in the data (e.g., bad data, gaps in data sets, or biased selection of data) can distort probabilities.

Bayes' theorem lets you take an event that you have the probability for and then see how that probability changes due to another event occurring. To illustrate how conditional probability can help with decision-making, we will run through a quick scenario. In credit markets, much of the return comes from interest income. Therefore, the drag on performance from sitting in cash can be meaningful. Understanding the likelihood of more cash coming into a fixed income fund

4. Eric Angner, *A Course in Behavioral Economics* (New York: Palgrave MacMillan, 2012).

and managing the cash balance can impact performance. Assume you know the probability of a large amount of cash coming into the fund in the month after the European Central Bank meets, and assume you know the probability of the bank cutting interest rates at any given meeting. What you want to know is how does the probability of a large amount of cash coming into the fund change if the bank cuts rates at its meeting.

The theorem needs three key pieces of data: (1) the probability of an event A occurring, designated by $P(\mathrm{A})$, (2) the probability of a second event B occurring, designated by $P(\mathrm{B})$, and (3) the probability of event B occurring given that A has occurred; this is designated by $P(\mathrm{B}|\mathrm{A})$—the vertical line is read as "given that." You are solving for what the probability is of event A occurring if event B has occurred.

In the Bayes' theorem below, P = probability and $P(\mathrm{A}|\mathrm{B})$ reads "the probability of A given that B has occurred":

$$P(\mathrm{A}|\mathrm{B}) = [P(\mathrm{B}|\mathrm{A}) \times P(\mathrm{A})]/P(\mathrm{B})$$

If event B occurs (e.g., the European Central Bank cuts rates), it is clear that you have the ability to see how that changes the probability for event A. You have been able to apply new information and analyze how this new information impacted the probability of an event occurring. This also may help illustrate how AI takes new data and "learns" from it.

Imagine a program that has an enormous decision tree. Maybe it starts with an analysis of how often a key word appears in a central bank press release, like "unemployment," and calculates based on past data what the probability of a rate cut is if that word appears a certain number of times. The change in this probability then impacts the probability of new flows into credit mutual funds, which effects the probability of bond prices rising, which increases the probability of your portfolio underperforming the benchmark. This would likely alert you to consider realigning your portfolio. This type of modeling is all based on probability and is possible through the use of data science. You can come up with a broad array of ways to apply this capability if you had the data and endless computing power.

There are also adjustments to the Bayes' theorem that can make it more flexible. In some cases, you want to factor in a binary event, such as an interest rate cut occurring or not occurring. In this case, you would need the probability of B occurring given that A had occurred $P(\mathrm{B}|\mathrm{A}+)$ and the probability of B occurring given that A did not occur $P(\mathrm{B}|\mathrm{A}-)$. This binary model is often the case in investment analysis. The formula for this is

$$P(\mathrm{A}|\mathrm{B}) = \frac{[P(\mathrm{B}|\mathrm{A}) \times P(\mathrm{A})]}{[P(\mathrm{B}|\mathrm{A}-) \times (P\mathrm{A}-)] + [P(\mathrm{B}|\mathrm{A}+) \times (P(\mathrm{A}+)]}$$

A common intuitive problem that arises in probability is base rate fallacy, which can occur in many ways. Often it occurs when one takes the latest data and ignores prior probability data that is available, such as assuming $P(\mathrm{B}|\mathrm{A})$ is applicable to the probability of $P(A|B)$ without factoring in the information that you have on the separate probabilities of A and B. Bayes' theorem prevents this base rate fallacy.[5]

Momentum and Technical Measures

Moving averages have been used for many years to try to predict momentum and trends in prices of assets. Studying these trends as well as supply and demand is often lumped into an area referred to as technical analysis. In more liquid markets, computers have been used to follow some of these trading patterns and find various anomalies to exploit through high-frequency trading. The illiquidity of the credit markets does not allow for such strategies, but studying these technical factors still can give insight into investment opportunities.

Moving averages are a tool to follow trends in data over time and to smooth out short-term spikes in the data. It does this by not just using one individual data point for each entry (e.g,. the yield of an index on a given day), but by also using the average of a group of trailing data for each entry (e.g., the yield for date X/XX/XXXX would use the average of the previous 50 trading days). An example of how this might be used would be to compare the moving average of the prices of a stock for the last 200 days and compare it to the moving average of the last 50 days to see if more recent trends are diverging from longer-term trends. In stocks, it is common to also look at the trading volume along with the price movements. In the credit markets, price movements are not always the best data point to track; at times, relative value measures such as option-adjusted spreads and yields can be more valuable to use.

There are also various moving average calculations designed to give more weight to certain data points than others within a moving average, such as a weighted moving average and an exponential weighted moving average. Most commonly, these adjusted moving averages give more weight to the most recent prices, but weighted moving averages could theoretically be designed to give more weight to price movements on days when there is a higher trading volume or when markets trade down to try to emphasize selected events.

The tracking of inflows and outflows of capital into various asset classes can theoretically be a valuable tool, as these technical flows can influence asset prices. Unfortunately, usually by the time the data is available the flows have already moved and the impact on prices has already occurred. Increasingly, work has been done on trying to track intra- and interday activity in exchange-traded funds (ETFs) to get a sense of flows, but there is considerable noise in this data, especially in the corporate credit markets. Because liquidity of individual securities can be challenged in credit market, ETFs in these markets are often used by tactical investors to get short-term exposure to the asset class and may not

5. Richards J. Heuer Jr., *Psychology of Intelligence Analysis* (Washington, DC: CSI Publications, 2007).

be more broadly indicative of the larger and longer-term flows in and out of the corporate debt asset classes. An arena where more work can be done is to use unsupervised AI to see if there are predictable patterns of capital shifts from one asset class to another based on changes in the relationships in asset class performance, yields, volatility, or some other performance measure.

Regime Recreation and Mean Reversion

Regime recreation is where analysts try to find previous time periods that resemble current events (or expected events) and study what happened in that prior "regime." This is a form of scenario analysis, but it is based on a very specific set of circumstances. This technique has a high-level of subjectivity (and can make up endless chatter on business news channels). You could set a series of parameters that you believe are going to align with the anticipated events and use a program to see which prior period fits this profile the best, or you could just choose the period you think best resembles the expected one. Ideally, you would get information on which factors performed the best and the worst in this prior period and might even be able to run a scenario analysis on how your portfolio would perform in such an environment. However, one has to consider that the makeup of markets changes over time and the knowledge that investors have from these prior regimes may change how they react in the current one.

Mean reversion techniques are not that dissimilar to regime re-creation. In this technique, it is assumed that when a price shock happens, the price will eventually return toward its mean. Proponents of this technique often can point to periods when a year of bad results is followed by a year of very strong results. This technique can also be applied to trend reversion. In other words, if the price of an asset is trending upward at a certain trajectory and then falls off that trajectory, the assumption is that over time it would revert back to that trend, not dissimilar to when correlations breakdown and it has some of the same shortcomings.

Optimization

The concepts of portfolio optimization grew out of modern portfolio theory. The initial idea was to find the investment mix for a portfolio that can maximize the return per unit of risk along an efficient frontier. The original models used volatility of returns as a measure of risk, and this is still common, as portfolio optimization is often run to solve for the best Sharpe ratio.

With increased computing power, optimization techniques can be significantly more varied than just maximizing the Sharpe ratio. You can run optimization programs to try to maximize other measurements such as the information ratio and the Sortino ratio, or to balance maximum drawdown relative to returns. With the increasing popularity of multi-asset credit, portfolio optimization can be used to experiment with the optimal mix of assets to meet the customized needs of an investor.

Factor and Factor Investing

Factor investing has been very popular in the equity markets for some time. It isolates a specific, defining characteristics of an asset and analyzes how assets with that characteristic perform over time relative to others. Ideally, this "factor" can be clearly defined and its performance can be quantified. How the factors are defined and what mix of factors are used is part of what can make each factor strategy unique.

Within equities, some of the common investment factors include: size (e.g., large-cap, mid-cap), growth versus value stocks, and volatility. A stock may have multiple factors (e.g., both large-cap and growth). To do factor investing properly, you need significant data to run testing of how the factor performed over time. You also need to be able to define the factor clearly so that the data sets have minimal noise.

A boom in available computing power may have led to an overexpansion of research on factors. Some of these factors that have been "discovered" through cross-sectional research are quite likely not as meaningful or as investible as others. One research paper stated that from 1980 to 2003 about 84 factors were discovered in equity investing; however, spurred by well-publicized cross-sectional research in equities and the expansion of computing power, the number of factors discovered doubled over the next nine years, and if working papers were included the figure would have been even greater. This was referred to by one researcher as a "zoo of factors." Many of these factors have likely not proven to be helpful to professional investors, and some of the analysis on these factors have been deemed statistically "significant by chance."[6]

So just because you can define a factor does not therefore make it meaningful. There should be enough historical data to support the factor. In credit markets, if the factor is based on bond math, (e.g., price movements based on duration and convexity), you can rationalize having less data to back it up, but if the attraction of the factor is due to data mining, be wary of randomness in the data. The factor performance should make sense in various environments. Also, the factor should not be so carefully selected as to make it overly biased, unrealistic, or un-investible. The factor should also make common sense.

Credit markets can lend themselves to a vast array of factors. As examples, you can define factors by industry groups, by corporate performance, by credit quality, or by issuer size. Furthermore, factors can utilize structural issues such as callability, covenant strength, or coupon. Factors can be very helpful in trying to express a theme within a portfolio and in achieving a certain investment style. Factors are particularly valuable to analyze and manage within a portfolio when trying to create a customized solution for a client that desires certain goals and characteristics. Data science techniques are critical in developing, defining, and back-testing factors that can be used in credit markets

6. Campbell R. Harvey, Yan Liu and Heqing Zhu, ". . . and the Cross-Section of Expected Returns," *Review of Financial Studies*, 29(1), 2016, pp. 5–68.

Passive Investing

In passive investing, the manager is usually trying to mimic the performance of an index. Usually the index is based on market value, so that a database and computing system has to constantly generate orders to match the portfolio relative to the changing market value. Additionally, many passive products are in the form of an ETF, so that the fund has intraday liquidity needs that also have to be managed while maintaining weightings in line with the index. The ETFs also have to factor in the regular inclusion and exclusion of issues in the index it is mimicking. For corporate credit markets, all of this has to be done in asset classes that are much less liquid than the equity or the government bond market and that usually have a vast array of constituents. This requires programs that can take data and generate buy and sell orders rapidly to optimize the portfolio to be aligned with the index.

Data management systems have been built by broker-dealer firms to be able to create and unwind these portfolio optimization trades for passive ETFs. It has also allowed broker-dealers to be able to expand their capability to do large portfolio trades for actively managed accounts, matching a multitude of buy and sell lists together to get a large trade in many issues at the same time.

ETFs within the credit markets have tended to have much higher volatility than the market overall and higher than actively managed funds. However, because of their forced buying and selling, they do appear to have added to the liquidity in the corporate debt markets.

DATA SCIENCE AND INVESTMENT EFFICIENCY

Data science is widely used to make middle office and back-office operations more efficient. Similarly, it can enhance client services and marketing. On the investment side, it can be used to make information flow and execution more efficient. Below, we outline some examples of how it can enhance the investment process by speeding up access to information that can speed the time from idea generation to execution.

Query Systems

Assuming that you have valuable investment data and it is in a usable format, the other necessary step to exploit the data is to easily access it. Not only do you want the analytical algorithms to be able to use the data, but you want the investment team on the frontline to be able to access it too. To do this, the ability to run queries is key.

A good database and well-designed query technology can allow an analyst or a portfolio manager to put in criteria for a data search and a list of options meeting that criteria can be generated. For example, a manager may be looking to reduce exposure to credits in commodity-based industries. If they had a good database and query system, there could be a set of fields where they could enter the criteria they were looking for. The query for possible buys could include:

1. A yield-to-worst of greater than 5% but less than 7%
2. A credit rating between B– to B+
3. A fixed-rate bond structure
4. Duration of less than three years
5. A credit analyst recommendation of "overweight" or higher
6. No commodity sectors

Ideally, the database would produce a sortable list of bonds with various information about each one. A similar process could be set up for the sell-side of the equation, but perhaps item (5) would now read, "a credit analyst recommendation of 'hold' or lower" and item (6) "only include commodity sectors."

There are so many potential factors within corporate credit, it is important that query systems are built so that they can include all of the parameters that might be considered in a search. It also highlights how critical designing data fields and entering the right data is when building data science systems These types of systems are in fairly wide use and are hugely valuable, but they become really empowered when linked with other data science tools, such as the ability to run scenario analysis on how these buys and sells would impact the portfolio.

There can also be automated queries. For example, identifying anomalies and outliers rapidly can be of great value for investors. This could be done each day through entering a query (e.g., a list of bonds that have traded off the most in the last week), but it is more valuable if an automated system could run pre-set sorts—it could be programmed to send an alert if the movement was outside a band of preset parameters.

Research Links

Quality credit research is critical in driving performance within fixed-income markets. Highly functioning database management systems should be able to link research information so that it can reach portfolio management and trading teams efficiently. Likewise, it should give research analysts updates on market prices.

Databases should be linked to research and query systems that are able to search for research recommendations and commentary as easily as it can search for bond prices. Most research teams now have credit-scoring systems and recommendation rankings. In the example in the preceding section, the list of bonds produced by the query should include recent research credit scores, recommendations, and a link to any recent research notes.

The research process can be more automated as well. To make research more efficient, many of the inputs for credit scores can be automated and data can be extracted from various third-party databases. Financial reports can be scanned using natural language processing for key changes in words and terminology and alerts can be sent, the same way news alerts are. With enough data, programs can run relational reports of credit scores and relative value and look for patterns between price movements and credit scores over time. As an example, it could also breakdown relationships between parts of a credit score and yields to see which aspects of a credit score appear to influence market levels the most.

One of the critical features in successfully integrating research into a firmwide database is consistency in how the data is calculated and how it is entered. Credit scores and recommendations, along with other key data, need to be processed and placed in the same format for all credits in the system and for all bonds and loans. With so many critical datapoints in corporate debt markets, this requires a significant investment and may limit how much historical data can be utilized.

Trading Execution

With liquidity and execution costs much more of a concern in credit markets than in many other capital markets, data science can bring considerable value if it can lower transaction costs and quickly analyze if investment ideas are actionable. Some of the systems used by ETFs and broker-dealers were mentioned earlier, but asset managers can gain an advantage by investing and using systems that can analyze which bonds and loans may actually trade based on various characteristics. For example, studies can be run to show what data points are likely to correlate with the ability to trade bonds; these might include data such as how many market makers there are and who the market makers are, the size of the issue, and the regularity of two-sided price quotes.

There has already been significant progress in "scraping" lists of markets offered by broker-dealers to see all of the markets in one place; there has also been improved information on trades that have actually taken place. Electronic trading platforms could improve this information flow and the ability to transact. There have been numerous trading platforms for credit markets introduced, but they are still challenged to win the bulk of the volume in trading. Loans present another array of trading issue as the agent banks tend to still control most of the activity.

It still appears that credit markets are in the fairly early days of the ability to transact. It is likely that more developments in predictive analysis will evolve regarding which bond or loan is actually the most tradable on any given day, at any given hour, and at the best value.

RISK AND PERFORMANCE

The section is focused on the use of data science for performance analysis and risk management. These are not just-backward looking or administrative tools, but can also help guide decisions on portfolio positioning. The more rapidly you can receive performance and risk analysis, the more valuable it is.

Attribution Analysis

One of the most common tools to breakdown performance is attribution analysis. Like many analytical investment tools, the most commonly used attribution model was originally developed for the equity market and is often referred to as Brinson attribution, or BHB attribution.[7] This is a tool to compare a portfolio's return relative to a benchmark, but it can just as easily be used to compare two portfolios of similar or different style. The goal is to see what has driven the differences in performance during a given time period.

The basics of this methodology start by separating the returns by industry and then getting the data for the average weighting (W) of each industry (i) and the return (R) for each industry for the portfolio (p) and the benchmark (b) as well the overall return for the benchmark.

The terms for the equations are the following:

W_{bi} = Weighting of the industry within the benchmark
W_{pi} =Weighting of the industry within the portfolio
$R_b i$ = Return of the industry in the benchmark
R_b = Return of the benchmark
R_{pi} = Return of the industry in the portfolio

The methodology includes separating out three effects:

1. Allocation effect, which measures how the portfolio weighted an industry versus the benchmark. If the industry was overweighted in the portfolio and, within the benchmark, that industry outperformed relative to the broad returns of the benchmark, then this allocation would be viewed as having a positive effect on the portfolio's return. Note that in this allocation effect it uses the return of the benchmark, not the return of the portfolio, this is an area of some debate.

   A simple formula for this is:

   $$\textbf{Allocation effect} = (W_{pi} - W_{bi}) \times (R_b i - R_b)$$

   The right side of the formula takes the "industry return for the benchmark" ($R_b i$) and nets out the overall return for the benchmark as this assumes that the alternative for investing in the industry would be just buying the whole benchmark, so in a sense this is the opportunity cost of investing in the industry.

2. Selection effect measures how well the portfolio chose the investments within a specific industry and quantifies the impact of choosing

7. See Gary P. Brinson, L. Randolph Hood, and Gilbert L. Beebower, "Determinants of Portfolio Performance," *Financial Analysts Journal*, 42(4), 1986, pp. 39–44, and Mark Kritzman, L. Randolph Hood, and Gary P. Brinson, "Determinants of Portfolio Performance: 20 Years Later," *Financial Analysts Journal*, 62(1), 2006, pp. 10–13.

securities that provide different returns than the benchmark. In this equation the weighing for the benchmark is used and the industry excess return for the portfolio (R_{pi}) is used.

A simple formula for this is

$$\textbf{Selection effect} = W_{bi} \times (R_{pi} - R_{bi})$$

3. Interaction effect measures the combined impact, or the portfolio's allocation and selection. This effect is more controversial, and some analysts prefer to leave it out or combine it with selection. Others argue that you should adjust the selection effect and change the right side of the formula to W_{pi} instead of W_{bi} and use a two-factor model. It could be argued that as the interaction effect penalizes a portfolio if it makes good selections but underweights the sector, it is a measure of how well the portfolio understands in which sectors it has an edge and in which sectors it does not, or how well it can maximize its investment selection style.

   A simple formula for this is

$$\textbf{Interaction effect} = (W_{pi} - W_{bi}) \times (R_{pi} - R_{bi})$$

All of these effects are added together to get total attribution for a sector, sometimes referred to as an "active manager" effect.

One aspect of industry attribution is that it assumes that investors make an industry allocation decision first (and that they make that decision relative to the benchmark), and then this is followed by making security selections within that industry. This may not be the case. An investor could determine industry weightings as a random factor based on how many good ideas their analysts have in that sector.

This analysis can also be utilized to isolate many other factors other than just industry selection, and this can enhance its use as a risk management tool. This is particularly valuable in corporate credit markets. An attribution analysis can be run for any number of factors such as credit rating, credit scores, duration, or issuer size, and it can show where the relative risks have been as well as where the relative rewards have come from.

Data science has the potential to improve the value of attribution analysis. Assume an algorithm was designed to scour historical attribution analysis in various periods, not just by industry allocation decisions but across numerous characteristics. The algorithm's goal could be to examine periods where the portfolio outperformed above a certain threshold and to see which categories tended to have the biggest effect on performance. For example, a study could find that when the portfolio outperformed its benchmark by 10% or more, 80% of the time the largest allocation effect occurred in BB-rated long-duration bonds and the biggest selection effect occurred in utilities. This would obviously warrant more work to see how these investments contributed in other performance cycles, but it might lead the portfolio management team to rethink its base case weighting to these investment factors.

Data Science and Risk

While attribution measurements often focus on how to get the best reward, using data to manage risk is equally valuable. The return profile of non-convertible corporate debt is asymmetrically skewed toward the downside as the upside is limited due to maturities and call structures. Therefore, minimizing drawdowns and permanent impairments can be a major differentiator in performance and heightens the importance of risk management when investing in these debt markets.

There are many aspects where data science can be used to monitor thresholds within a portfolio. These risk controls could be items like issuer limits, duration limits, or interest income targets. However, given the strength of computing power and good historical data sets, a risk management system could do more than just monitor these levels. Analyses could be run to help rationalize what the best thresholds are and to run estimates of the increased risk and reward to the portfolio if those limits were raised or lowered. It could also use historical data to analyze what are the probabilities of hitting the existing risk thresholds.

Scenario analysis is another important risk management tool that can give a portfolio manager a better sense of how a portfolio is positioned for certain events. It is somewhat similar to regime recreation, but in this you can change multiple variables. One common risk test is to induce interest rate shocks to the portfolio to see how it performs. This should be done in multiple ways; three common interest rate tests are often referred to as shift, twist, and butterfly.[8] Similarly, there are various scenarios that can be run using value-at-risk type models. These types of models tend to look at historical losses over some period of time and shock the portfolio's prices accordingly. Drawdowns could be analyzed by any number of factors:

Drawdowns by rating category
Drawdowns by issuer
Drawdowns by industry
Drawdowns by seniority and structure
Drawdowns by a credit score
Drawdowns by duration
Drawdowns by issuer size

Risk metrics can be designed to monitor the portfolio for anomalies. For example, if volatility within a sector breaks out of a range, an alert could be sent to review the movements and positioning in that sector. One of the tricky aspects of this for credit is to try to determine what is causing the anomaly. It could be driven by changes in an industry or by a broad move in interest rates; thus the sudden increase in volatility might not be a real change in risk relative to that sector.

8. These movements of the yield curve are denoted as follows: shift = a parallel shift in the yield curve, twist = a steepening or flattening of the yield curve, and butterfly = changes to the curvature of the yield curve.

Risk monitoring, if properly organized, is not just a governor on position limits. With good data and systems, it can be an active tool to improve portfolio construction and understand where the risks exist relative to the potential rewards

Putting It All Together

Many of these tools are designed to produce better decision-making information and to increase the efficiency in finding and executing investment ideas. Whether the idea involves a transaction in a single investment, a repositioning of a portfolio, or a realignment of a multi-asset credit portfolio, good data science can improve the process. Below is a simplified hypothetical flow of how these systems can work.

1. After reviewing data on interest rates and shifting market risk-tolerance, the CIO and strategist teams make a determination to lower duration parameters.
2. A report on the rationale of this decision and how much duration has to change is sent to the portfolio management teams.
3. The report includes a summary of other key data on the portfolio as well (e.g., yield, spread, average credit score, key active industry exposures).
4. Portfolio managers note that they are at the low end of their healthcare and gaming weighting targets but at the high end of auto and retail weighting targets.
5. A query is sent to the system for potential buys in bonds in healthcare and gaming with lower duration targets and sells in auto and retail with higher duration. The query also states what the goal is for the impact of these on the portfolio's overall duration.
6. The system runs different iterations that would involve different amounts of buys and sells to meet the criteria.
7. Using the bonds that meet the query criteria, the system runs a regression based on a number of credit statistics and credit scores relative to the option-adjusted spread and then ranks the selected bonds based on relative value.
8. The system also scrapes trader runs to prioritize names that have the characteristics that give them a high likelihood of being tradable.
9. The sortable list that is sent to the portfolio management team includes potential buys and sells, relative value, credit scores, most recent analyst notes, and expected duration contribution in the portfolio; additionally, the analysts are alerted about the query output and asked if any updates are pending.

10. The report allows the portfolio management team to experiment with buys and sells from the list and immediately see the potential impact on the portfolio for a variety of characteristics.
11. Trades are entered and executed.

WHY DATA SCIENCE IS DIFFERENT IN CREDIT

Many of the quantitative and data-driven techniques that have been developed in finance have their roots in the equity markets. This is important to remember when applying these methods to the credit markets. There are numerous significant differences in how these securities are structured and how these markets act.

Equity is an ownership stake in a corporation, and prices tend to move on the perceived value of that company. Assuming a company does not distribute a huge portion of its earnings to shareholders through dividends, the way to make money when buying an equity is to make other people want to buy it at a higher price. Corporate credit instruments are a contract with a corporation. They pay a stated interest rate, and the principle has to be repaid at a stated date. This means that in the long run, if the company honors its obligations, your return can be calculated based on a yield regardless of whether other investors decide to buy the bonds or not. Of course, in reality, a credit portfolio's performance is not measured during the entire life of a bond, but in shorter increments. However, this difference in how these markets produce returns is important when you utilize data analysis techniques that were developed based on research in the equity markets.

In most corporate credit markets, the bulk of the return is usually from interest income, other than in the convertible bond market. If you are running a shock analysis on an equity portfolio, the time it takes for that shock to occur may not have a huge impact on the absolute return, but for credit if you run the scenario over a short time period or a long period it can make a big difference because of the interest income effect.

Building data sets in credit can be more difficult and costly than in other markets. Most public companies have one share class of equity. However, they may have a multitude of bonds and loans outstanding, and each bond typically has different structures. The differences in seniority, coupon, maturity, call schedules, and covenants can make two bonds issued by the same company each perform very differently in different environments. Not only are there potentially more structural factors to model and consider, but by the nature of having scheduled maturities there is greater turnover in the market constituents than you would see in the equity markets.

Because of the maturity schedules and the interest component fixed income markets have several ways of expressing relative value. While stocks are usually quoted by price, fixed income uses price, various yield measures (e.g., yield to call, yield to maturity, yield to take-out), and also spread, which is measured relative to a "risk-free" fixed-income instrument like U.S. Treasuries or LIBOR.

Imbedded options also cause complexity, in part because they can make return calculations more complex, but also because they vary so much. Loans are almost always callable, and usually with less of a penalty to the issuer than in the bond market. Some bonds have call options and others have non-call structures. Call options have a variety of structures. Additionally, in the high-yield bond market there are often call provisions that can get triggered if an equity offering is completed (i.e., equity clawbacks), and sometimes secured bonds give the issuer the option to call a small percentage of the bonds each year for a period of time at a premium; this is usually a carve-out that is separate from whatever other call protection are in the bonds. There are often change of control puts in investment-grade and below-investment-grade bonds.[9] Then convertible bonds have an imbedded equity option, which gives convertibles a much different potential return profile. While the issuer of the convertible still owes par at maturity, the bond's equity call option can cause it to trade at prices well above where a nonconvertible from the same issuer would trade. Convertibles also often have unique call and put features. All of this not only adds complexity to the credit markets, but also can create significant noise in pricing data, given how many of these structural issues can impact performance.

It has been mentioned several times in this chapter, but it is important to point out again that liquidity is a major difference in corporate credit markets versus equities or rates. Transaction costs have to be considered when managing portfolios in these markets. Many corporate bonds and loans do not trade every day, every week, or sometimes even every month. This also means that pricing data is suspect and that it can be harder to execute any recommendations. Additionally, the liquidity varies among the corporate credit asset classes, and these differences in trading liquidity can send false signals about volatility as a measure of risk. If an asset is seeing less price movement simply because it is not trading, does that really make it less risky? It adds another dimension of difficulty in comparing these asset classes within corporate credit.

In addition to all these hurdles outlined above, corporate credit is different than other fixed income markets because in some ways it is so similar to the equity market. Performance can be impacted by how an individual company performs, what corporate actions they take, and what is happening within an industry. The further you move down the credit spectrum, the less sensitive the corporate debt market is to macro factors and the more sensitive it is to corporate actions and industry trends. So along with all the unique fixed income features that have to be factored into analysis, tools from the equity market must be applied as well.

The turnover of the constituents in corporate credit markets is fairly high. Given the maturity schedule, call options, and corporate actions, there is a fairly active natural flow of entry and exit of constituents in these markets. This can lead to fairly dramatic changes in the characteristic of the markets over time.

9. Some investment-grade bonds are also issued with a pick-up in the stated interest rate if the bonds get downgraded to below investment grade.

A market's exposure to industries and weightings by rating categories can shift meaningfully. In some markets, like high-yield bonds, it can make longer-term time-series analysis very misleading because the characteristics of the market have changed so much over time.

The differences between the asset classes within the credit markets also present challenges and opportunities, particularly for multi-asset credit managers. The difficulty in comparing data on volatility and in using long-term time-series data was outlined above. Additionally, there are difficulties in analyzing relative value between nonconvertible corporate bonds, loans, and convertible bonds. Each of these asset classes tends to have differences in debt ranking, coupon structures, maturity, and embedded options. Each of these markets also tends to be dominated by different industries and corporate ownership structures. This can make cross-asset analysis more difficult, but it also can allow for asset class rotations and thematic investing and can give a multi-asset credit strategy more flexibility to capture better performance in a more varied set of circumstances.

ORGANIZATION AND PLANNING

Designing, building, and integrating data science systems into a credit-focused investment management business requires many things to be successful, not the least of which is a thorough plan and buy-in from many parties within the firm.

The first step is to be clear on your investment identities and style. How your investment strategy and its goals are defined is likely to drive your prioritization and plan. While an investment manager is likely to have one overriding ethos, they may have several strategies or styles. There is no problem with that, but to get the best and most expandable system, those involved in the plan need to have a clear definition of all these styles.

There also has to be open and thoughtful discussion of where the overall business is likely to be in the next three to five years. If certain businesses, styles, or markets are expected to grow and others are not, that may be a factor in how systems are designed and prioritized.

There needs to be a clear definition of the problems you want to address. The firm also needs to determine if the investment in fixing these problems aligns with a reasonable expectation of rewards. Matching the problem with the opportunity can quicken the process of prioritizing projects. This process also has to factor in which projects are the most doable and what the longer-term goal is for the systems. For example, can one project be the building block for another? If the list of potential projects is a long one, it is often helpful to go through an iterative process of prioritization. This should not be an arbitrary decision from one person and should involve all invested parties from system designers to the front-end users.

Assessing the quality of the data you have available is critical. There are numerous questions to be addressed about the data. Is the quality of the data clean, are there gaps in it, are figures correct? Is the data in a form that is easily usable by the systems, and can it be sorted and labeled? Can the data be updated in an efficient manner, and are there sources that are able to supply real-time information for your models so they stay relevant? The decision of what data to use and how it is entered into the system is one area where bias can creep into the process and eventually show up in the analysis; this needs to be guarded against.

For developing internal data, such as credit scores and other thematic identifiers, you must have an exceptionally disciplined approach. The analysts and strategists that are working on creating the data must buy in to the approach. The data fields must be defined and be as consistent as possible across all of the bonds and loans that are entered into the system so that the data is usable. The science improves if the definitions and calculations for each of the data fields is consistent. A matrix for data calculations and entry rules can be extremely helpful in this regard. The more comprehensive the documentation the cleaner the data will be and the more repeatable the process.

A map should be made of who will be touching the systems. This means end-users, managers, risk teams, project managers, programmers, IT teams, among others. They all need to be involved in the project on a regular basis as it evolves. These types of projects do not work well when a person locks themselves in a room and comes out with a plan that they expect everyone to use. It can take longer, but projects work better if there is regular involvement and input along the way, as long as there is a clear decision process when a deadlock occurs. Quite often, it is actually the investment team that avoids involvement in the process; they focus on the markets and the portfolios and take an attitude of "show me when it is done," but then when the final project is presented they may complain that it doesn't help them and it is impractical—thus proving the adage "It is easier to criticize than create."

It may sound trivial, but a schedule of goals and a regular meeting schedule of updates and discussions with the interested parties can solve many problems. An increasingly popular management style for large projects is called Agile and involves relatively short development periods followed by collaborative meetings. This type of development style can help keep the project flexible as roadblocks develop and priorities can shift. It is also important that decisions are documented and circulated to those involved to avoid ambiguity

Deciding on how the project will be measured is a necessary part of the process. There are several aspects of measurement that need to be made clear. Time frames and deadlines are one goal. More importantly, what are the rewards that the project is expected to produce that justify the investment and how can they be measured (e.g., lowering transaction costs, more rapid generation of research updates)? Any project related to improving investment results should consider how the investment goals are measured. For example, are the portfolio returns being measured versus a benchmark or in some other way, or is the priority to have the best absolute total return or best risk-adjusted return?

Modeling and testing are vital, too, because the first technique tried may not be the best. Many data scientists will tell you that in many cases there may be multiple methods that theoretically could be used to address the same problem, and the data science team may want to model and do testing to make sure the project makes sense and they are using the best tools.

An important part of the planning is also an understanding of the expectations for the front end. In what format is the output going to be accessible and usable. It should have some flexibility, because the demands of the end-users almost always change as they actually start using the data.

To be involved in helping to plan data science projects and to use the output you do not need to know how to design and use complex algorithms, nor do you need to be a data scientist or a statistician to exploit these tools as an investor. However, understanding the basics of how they work can help you comprehend what they are capable of. It can be helpful to refresh the benefits of using regression and probability techniques and thinking about the potential for these tools given supercharged computing power. But it is also important to understand their shortcomings. While it is not necessary to become an expert, getting some rudimentary basics of how programs that data scientists commonly use for statistical analysis and AI algorithms (e.g., R and Python) can help improve your understanding of what is involved and what is possible in using data science to make better investment decisions.

All of this is not possible without having a firm-wide commitment to make the investment of money and time. It is also important that management realize it is not a onetime project; implementing data science is an ongoing and evolutionary process. Rushing a system into production that is not properly tested and checked can be damaging to a franchise.

KEY POINTS

- Data science has been utilized in corporate credit markets for some time, but the advances in computer science are creating valuable tools that can drive better investment decisions, increase efficiency, and analyze performance and risk management in ways that can improve portfolio construction.
- Data science tools tend to fall into two categories: descriptive analytics or predictive analytics; both are very valuable to improve decision-making. Both tend to have their roots in regression and probability, and their capabilities can be supercharged with AI algorithms.
- Using data science in corporate credit markets presents unique problems and opportunities. There is significant noise in the data, a lack of homogeneity among the constituents, a vast area of factors impacting performance, and a high level of difficulty to execute investment ideas.
- Defining the process improves the output. In defining goals, it is important to be sure that the cost of the problem you want to fix is balanced against expected rewards.

- Data science should improve investment decision-making. However, it cannot be accepted at face value—testing and applying common sense is key to prevent misusing output, using data that has bias, or relying on statistical conclusions achieved through randomness.
- Despite all the math that is used, investing is not an exact field. Even with advanced data techniques, the best investment models are fallible as human actions cannot always be modeled.

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PART THREE

TREASURY, AGENCY, MUNICIPAL, AND CORPORATE BONDS

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CHAPTER
SEVEN

U.S. TREASURY SECURITIES

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U.S. Treasury securities are direct obligations of the U.S. government issued by the Department of the Treasury. They are backed by the full faith and credit of the U.S. government and are therefore considered to be free of credit risk. Issuance to pay off maturing debt and raise needed funds has created a stock of marketable Treasury securities that totaled $16.7 trillion on December 31, 2019.[1] The creditworthiness and supply of the securities has resulted in a highly liquid, round-the-clock secondary market with high levels of trading activity and narrow bid/ask spreads.

Because of their liquidity, Treasury securities are commonly used to price and hedge positions in other fixed income securities and to speculate on the course of interest rates. The securities' creditworthiness and liquidity also makes them a widespread benchmark for risk-free rates. These same attributes make Treasury securities a key reserve asset of central banks and other financial institutions. Moreover, exemption of interest income from state and local taxes helps make the securities a popular investment asset to institutions and individuals.

As of September 30, 2019, foreign and international investors held 40% of the publicly held Treasury debt.[2] Federal Reserve Banks held an additional 13% of the debt. The remaining public debt was held by mutual funds (13%), pension

We thank Francisco Ruela for his research assistance. Michael Fleming's views expressed in this chapter are his and not necessarily those of the Federal Reserve Bank of New York or the Federal Reserve System.

1. The stock of nonmarketable Treasury securities on the same date totaled $6.5 trillion. Of this, $6.3 trillion was nonpublic debt (held in government accounts), $0.2 trillion was held by private investors in the form of U.S. savings bonds, and $0.1 trillion was held in a special series by state and local governments (Monthly Statement of the Public Debt, www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm).
2. The publicly held debt includes marketable and nonmarketable securities held in nongovernment accounts. Figures are calculated from Table OFS-2 of the *Treasury Bulletin* and the Federal Reserve's H.4.1 statistical release.

funds (7%), depository institutions (5%), state and local governments (4%), insurance companies (1%), and other investors, including individuals (17%).

In this chapter, we discuss U.S. Treasury securities. Our focus is on marketable Treasury securities.

TYPES OF SECURITIES

Treasury securities are issued as either *discount* or *coupon securities*. Discount securities pay a fixed amount at maturity, called *face value* or *par value*, with no intervening interest payments. Discount securities are so called because they are issued at a price below face value with the return to the investor being the difference between the face value and the issue price. Coupon securities are issued with a stated rate of interest, pay interest every six months (for the most part), and are redeemed at par value (or *principal value*) at maturity. Coupon securities are issued at a price close to par value with the return to the investor being primarily the coupon payments received over the security's life.

The Treasury issues securities with original maturities of one year or less as discount securities. These securities are called *Treasury bills*. The Treasury currently issues bills with original maturities of 4 weeks (1 month), 8 weeks (2 months), 13 weeks (3 months), 26 weeks (6 months), and 52 weeks (1 year) as well as cash management bills with various maturities. On December 31, 2019, Treasury bills accounted for $2.4 trillion (14%) of the $16.7 trillion in outstanding marketable Treasury securities, as shown in Exhibit 7-1.

EXHIBIT 7-1

Marketable U.S. Treasury Securities

Issue Type	Security Type	Issues	Amount Outstanding (December 31, 2019)
Treasury bills	discount	cash management, 4-week, 8-week, 13-week, 26-week, 52-week	$2,417 billion
Treasury notes	coupon	2-year, 3-year, 5-year, 7-year, 10-year	$9,929 billion
Treasury bonds	coupon	30-year	$2,379 billion
Treasury inflation-protected securities	coupon	5-year, 10-year, 30-year	$1,507 billion
Floating-rate notes	coupon	2-year	$441 billion

Source: Department of the Treasury, Monthly Statement of the Public Debt (http://www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm) for amounts outstanding.

Securities with original maturities of more than one year are issued as coupon securities. Coupon securities with original maturities of more than 1 year but not more than 10 years are called *Treasury notes*. The Treasury currently issues notes with maturities of 2 years, 3 years, 5 years, 7 years, and 10 years. On December 31, 2019, Treasury notes accounted for $9.9 trillion (60%) of the outstanding marketable Treasury securities.

Coupon securities with original maturities of more than 10 years are called *Treasury bonds*. The Treasury currently issues bonds with maturities of 20 years and 30 years. On December 31, 2019, Treasury bonds accounted for $2.4 trillion (14%) of the outstanding marketable Treasury securities. In the past, the Treasury issued callable bonds. The last callable bond was issued in 1984 and the last callable bond outstanding was called in 2009.

In January 1997, the Treasury began selling *Treasury Inflation-Protected Securities* (TIPS). The principal of these securities is adjusted for inflation using the consumer price index for urban consumers. Semi-annual interest payments are a fixed percentage of the inflation-adjusted principal, and the inflation-adjusted principal is paid at maturity. On December 31, 2019, TIPS accounted for $1.5 trillion (9%) of the outstanding marketable Treasury securities. TIPS are discussed in detail in Chapter 15.

In January 2014, the Treasury began selling *Floating Rate Notes* (FRNs). FRNs are fixed-principal securities but pay varying amounts of interest depending on the course of short-term rates. FRNs have original maturities of two years and make interest payments quarterly, with the rate based on auction rates on 13-week Treasury bills. On December 31, 2019, FRNs accounted for $441 billion (3%) of the outstanding marketable Treasury securities.

THE PRIMARY MARKET

Marketable Treasury securities are sold in the primary market through sealed-bid, *single-price* (or *uniform price*) *auctions*. Each auction is usually announced one or more days in advance by means of a Treasury Department press release. The announcement provides details of the offering, including the offering amount and the term and type of security being offered, and describes some of the auction rules and procedures.

Treasury auctions are open to all entities. Bids must be made in multiples of $100 (with a $100 minimum) and submitted to the Treasury or through an authorized financial institution. Competitive bids must be made in terms of yield and must typically be submitted by 1:00 p.m. eastern time on auction day. Noncompetitive bids must typically be submitted by noon on auction day.[3]

All noncompetitive bids from the public up to $5 million are accepted. The lowest yield (i.e., highest price) competitive bids are then accepted up to the yield

3. Bidding procedures are described in detail on the Bureau of the Public Debt's website at www.treasurydirect.gov/.

required to cover the amount offered (less the amount of noncompetitive bids). The highest yield accepted is often called the *stop-out yield*. All accepted tenders (competitive and noncompetitive) are awarded at the stop-out yield. There is no maximum acceptable yield, and the Treasury does not add to or reduce the size of the offering according to the strength of the bids.

Historically, the Treasury auctioned securities through *multiple-price* (or *discriminatory*) *auctions*. With multiple-price auctions, the Treasury still accepted the lowest-yielding bids up to the yield required to sell the amount offered (less the amount of noncompetitive bids), but accepted bids were awarded at the particular yields bid, rather than at the stop-out yield. Noncompetitive bids were awarded at the weighted-average yield of the accepted competitive bids rather than at the stop-out yield. In September 1992, the Treasury started conducting single-price auctions for the two- and five-year notes. In November 1998 the Treasury adopted the single-price method for all auctions.

Within minutes of the 1:00 p.m. auction deadline, the Treasury announces the auction results. Announced results include the stop-out yield, the associated price, and the proportion of securities awarded to those investors who bid exactly the stop-out yield. For notes and bonds, the announcement includes the coupon rate of the new security. The coupon rate is set to be that rate (in increments of 1/8 of a percent) that produces the price closest to, but not above, par when evaluated at the yield awarded to successful bidders.

Accepted bidders make payment on issue date through a Federal Reserve account or account at their financial institution, or they provide payment in full with their tender. Marketable Treasury securities are issued in book-entry form and held in the commercial book-entry system operated by the Federal Reserve Banks or in other accounts maintained by the Treasury.

Primary Dealers

While the primary market is open to all investors, the *primary government securities dealers* play a special role. Primary dealers are trading counterparties of the Federal Reserve Bank of New York in its implementation of monetary policy. Among their responsibilities, primary dealers are expected to participate consistently in open market operations conducted by the New York Fed's trading desk, provide the desk with insight into market developments, participate competitively in all Treasury auctions, and make markets for the New York Fed on behalf of its foreign official account holders. The dealers must also meet certain minimum capital requirements. The 24 primary dealers as of December 31, 2019, are listed in Exhibit 7-2.

Historically, Treasury auction rules tended to facilitate bidding by the primary dealers. In August 1991, however, Salomon Brothers Inc. admitted deliberate and repeated violations of auction rules. While the rules preclude any bidder from being awarded more than 35% of any issue, Salomon amassed significantly larger positions by making unauthorized bids on behalf of its customers. For the

EXHIBIT 7-2

Primary Government Securities Dealers as of December 31, 2019

Amherst Pierpont Securities LLC	HSBC Securities (USA) Inc.
Bank of Nova Scotia, New York Agency	Jefferies LLC
BMO Capital Markets Corp.	J.P. Morgan Securities LLC
BNP Paribas Securities Corp.	Mizuho Securities USA LLC
Barclays Capital Inc.	Morgan Stanley & Co. LLC
BofA Securities, Inc.	NatWest Markets Securities Inc.
Cantor Fitzgerald & Co.	Nomura Securities International, Inc.
Citigroup Global Markets Inc.	RBC Capital Markets, LLC
Credit Suisse AG, New York Branch	Societe Generale, New York Branch
Daiwa Capital Markets America Inc.	TD Securities (USA) LLC
Deutsche Bank Securities Inc.	UBS Securities LLC.
Goldman Sachs & Co. LLC	Wells Fargo Securities, LLC

Source: Federal Reserve Bank of New York (https://www.newyorkfed.org/markets/primarydealers).

five-year note auctioned on February 21, 1991, for example, Salomon bid for 105% of the issue (including two unauthorized customer bids) and was awarded 57% of the issue. Rule changes enacted later that year allowed any government securities broker or dealer to submit bids on behalf of its customers and facilitated competitive bidding by nonprimary dealers.[4]

Auction Schedule

To minimize uncertainty surrounding auctions, and thereby reduce borrowing costs, the Treasury offers securities on a regular, predictable schedule. Four-, 8-, 13-, and 26-week bills are offered weekly, and 52-week bills are offered every four weeks, as shown in Exhibit 7-3. Four- and 8-week bills are typically announced for auction on Tuesday, auctioned two days later, on Thursday, and issued the following Tuesday. Thirteen- and 26-week bills are typically announced for auction on Thursday, auctioned the following Monday, and issued the following Thursday. Fifty-two-week bills are also typically announced for auction on Thursday, auctioned the following Tuesday, and issued the following Thursday. Cash management bills are issued when required by the Treasury's short-term cash-flow needs, and not on a regular schedule.

4. For further information on the auction violations and subsequent rule changes, see the *Joint Report on the Government Securities Market*, published by the Department of the Treasury, the Securities and Exchange Commission, and the Board of Governors of the Federal Reserve System in January 1992.

EXHIBIT 7-3

Auction Schedule for U.S. Treasury Bills

Issue	Auction Frequency	Offering Amount
Cash management bill	ad hoc	$15–50 billion
4-week bill	weekly	$35–60 billion
8-week bill	weekly	$30–40 billion
13-week bill	weekly	$36–48 billion
26-week bill	weekly	$36–42 billion
52-week bill	every 4 weeks	$26–28 billion

Notes: Auction frequency and offering amount are reported for regularly issued Treasury bills as of 2019. Offering amounts exclude amounts issued to refund maturing securities of Federal Reserve Banks.

Source: Department of the Treasury.

Two-, three-, five-, and seven-year notes are offered monthly, as shown in Exhibit 7-4. Two-, five-, and seven-year notes are usually announced for auction in the second half of the month, auctioned a few days later, and issued on the last day of the month. Three-year notes are usually announced for auction in the first half of the month, auctioned a few days later, and issued on the 15th of the month.

EXHIBIT 7-4

Auction Schedule for U.S. Treasury Notes and Bonds

Issue	Auction Frequency	Offering Amount
2-year note	monthly	$40 billion
3-year note	monthly	$38 billion
5-year note	monthly	$41 billion
7-year note	monthly	$32 billion
10-year note	quarterly	$27 billion
30-year bond	quarterly	$19 billion

Notes: Auction frequency and offering amount are reported for Treasury notes and bonds as of 2019. New 10-year notes and 30-year bonds are auctioned quarterly, with additional amounts of the notes auctioned one and two months later. Offering amounts exclude amounts issued to refund maturing securities of Federal Reserve Banks.

Source: Department of the Treasury.

Ten-year notes and 30-year bonds are issued as a part of the Treasury's *quarterly refunding* in February, May, August, and November. The Treasury holds a press conference on the first Wednesday of the refunding month (or on the last Wednesday of the preceding month) at which it announces details of the upcoming auctions. The auctions then take place the following week, with issuance on the 15th of the refunding month.

While the Treasury seeks to maintain a regular issuance cycle, its borrowing needs change over time. For example, the 2007–09 financial crisis and the government's response increased the Treasury's borrowing needs, resulting in increased issuance and a rising stock of outstanding Treasury securities. As a consequence, the Treasury increased the issuance frequency of some securities, such as the three-year note (from quarterly to monthly), and reintroduced issuance of other securities, including the 52-week bill (in 2008) and the seven-year note (in 2009). More recently, Treasury introduced FRNs (in 2014) and eight-week bills (in 2018), and reintroduced 20-year bonds (in 2020).

In addition to maintaining a regular issuance cycle, the Treasury tries to maintain a stable issue size for issues of a given maturity. Public offering amounts in 2019 were $15–60 billion for bills, $27–40 billion for notes, and $19 billion for the 30-year bond. Issue sizes have also changed in recent years in response to the government's increased funding needs. Issue sizes for two-year notes, for example, rose from $26 billion in 2017 to $40 billion in 2019.

Reopenings

While the Treasury regularly offers new securities at auction, it often offers additional amounts of outstanding securities. Such additional offerings are called *reopenings*. Current Treasury practice is to reopen 10-year notes and 30-year bonds one and two months after their initial issuance. Moreover, shorter-term bills are typically fungible with previously issued and outstanding bills, so that every 13-week bill is a reopening of a previously issued 26-week bill, every fourth 26-week bill is a reopening of a 52-week bill, and every 4-week bill is a reopening of a previously issued 8-week bill. The Treasury also reopens securities on an ad hoc basis from time to time.

Buybacks

To maintain the sizes of its new issues and help manage the maturity of its debt in a time of federal budget surpluses, the Treasury launched a debt buyback program in January 2000. Under the program, the Treasury redeemed outstanding unmatured Treasury securities by purchasing them in the secondary market through reverse auctions. Buyback operations were announced one day in advance. Each announcement contained details of the operation, including the operation size, the eligible securities, and some of the operation rules and procedures.

The Treasury conducted 45 buyback operations between March 2000 and April 2002. Operation sizes ranged from $750 million par to $3 billion par, with all but three between $1 and 2 billion. The number of eligible securities in the operations ranged from 6 to 26, but was more typically in the 10 to 13 range. Eligible securities were limited to those with original maturities of 30 years, consistent with the Treasury's goal of using buybacks to prevent an increase in the average maturity of the public debt.

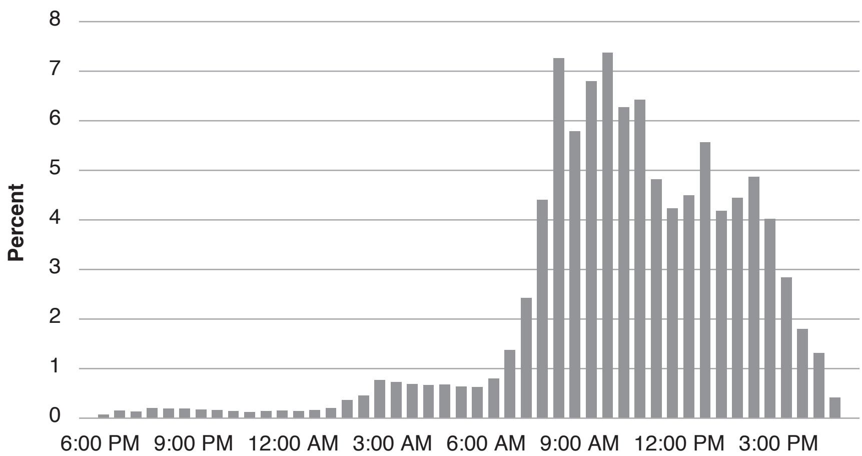
While there have been no buyback operations of meaningful size since 2002, the Treasury has held one or two small-value buyback operations per year since 2014. Such operations are intended to ensure operational readiness of Treasury's buyback infrastructure.

THE SECONDARY MARKET

Secondary trading in Treasury securities occurs in a multiple-dealer over-the-counter market rather than through an organized exchange. Trading takes place around the clock during the week, from the three main trading centers of Tokyo, London, and New York. As shown in Exhibit 7-5, the vast majority of trading takes place during New York trading hours, roughly 7:30 a.m. to 5:00 p.m. eastern time. The primary dealers are the principal market makers, buying and selling securities from customers for their own accounts at their quoted bid and ask prices. In 2019, primary dealers reported daily trading activity in the secondary market that averaged \$594 billion per day.[5]

EXHIBIT 7-5

Trading Volume of U.S. Treasury Securities by Half Hour



Notes: Average half-hourly trading volume as a percent of average daily trading volume for the on-the-run notes and bonds for the January 2010-December 2011 period. Times on the horizontal axis indicate the beginning of intervals (Eastern time).

Source: Calculated from numbers reported in Table 1 and Figure 2 of "The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform," Michael Fleming, Bruce Mizrach, and Giang Nguyen, Journal of Financial Markets, Vol. 40, September 2018, pp. 2-22.

5. Federal Reserve Bank of New York (www.newyorkfed.org/markets/primarydealers.html). As the data is collected from the primary dealers but no other entities, trades between primary dealers are counted twice, and trades between non-primary dealers are not counted at all.

Interdealer Brokers

In addition to trading with their customers, the dealers trade among themselves through *interdealer brokers*. The brokers offer the dealers and certain other financial firms proprietary trading platforms that post the best bid and offer prices of the participating firms, along with the associated quantities bid or offered (minimums are $5 million for bills and $1 million for notes and bonds). The firms execute trades by notifying the brokers (by phone or electronically), who then post the resulting trade price and size. Interdealer brokers thus facilitate information flows in the market while providing anonymity to the trading firms. In compensation for their services, the brokers charge a small fee.

The interdealer market has undergone significant structural change in recent years. Until 1999, nearly all trading in the IDB market for U.S. Treasury securities occurred over the phone via voice-assisted brokers. Voice-assisted brokers provide firms with proprietary electronic screens that post the best bid and offer prices, along with the associated quantities, but trades are executed over the phone. Brokers then post the resulting trade price and size on their screens.

In 1999, Cantor Fitzgerald introduced its fully automated eSpeed (now Nasdaq Fixed Income) electronic trading platform, whereby trades are executed electronically so that buyers are matched to sellers without human intervention. In 2000, BrokerTec, a rival electronic trading platform, began operations. Over the span of a few years, nearly all trading of the most actively traded Treasury securities migrated to these electronic platforms.[6]

Historically, participation on the electronic platforms was limited to government securities dealers. In the mid-2000s, however, the platforms opened to other professional traders, including hedge funds and high-frequency trading firms (HFTs). A 2015 study found that HFTs now account for more than half of trading activity in this segment of the market.[7]

Federal Reserve

The Federal Reserve is another important participant in the secondary market for Treasury securities by virtue of its open market operations, security holdings, and surveillance activities. The Federal Reserve Bank of New York buys and sells Treasury securities through open market operations as one of the tools used to implement the monetary policy directives of the Federal Open Market Committee

6. See Bruce Mizrach and Christopher Neely, "The Transition to Electronic Communications Networks in the Secondary Treasury Market," Federal Reserve Bank of St. Louis *Review* 88, November/December 2006, and Michael J. Barclay, Terrence Hendershott, and Kenneth Kotz, "Automation versus Intermediation: Evidence from Treasuries Going Off the Run," *Journal of Finance* 61 (2006), pp. 2395–2414,

7. "Joint Staff Report: The U.S. Treasury Market on October 15, 2014," U.S. Department of the Treasury, Board of Governors of the Federal Reserve System, Federal Reserve Bank of New York, U.S. Securities and Exchange Commission, and U.S. Commodity Futures Trading Commission. July 13, 2015.

(FOMC). As of September 30, 2019, the Federal Reserve Banks held $2.1 trillion in Treasury securities, or 13% of the publicly held stock. The New York Fed also follows and analyzes the Treasury market and communicates market developments to other government agencies, including the Federal Reserve Board and the Treasury Department.

Trading Activity

While the Treasury market is extremely active and liquid, much of the activity is concentrated in a small number of the roughly 400 issues outstanding. The most recently issued securities of a given maturity, called *on-the-run securities*, are particularly active, accounting for 69% of trading volume.[8] Older issues of a given maturity are called *off-the-run securities*. While nearly all Treasury securities are off-the-run, they account for only 27% of interdealer trading.

The small share of remaining trading occurs in *when-issued securities*. When-issued securities are securities that have been announced for auction but not yet issued. When-issued trading facilitates price discovery for new issues and can serve to reduce uncertainty about bidding levels surrounding auctions. The when-issued market also enables dealers to sell securities to their customers in advance of the auctions, and thereby bid competitively with relatively little risk. While most Treasury market trades settle the following day, trades in the when-issued market settle on the issue date of the new security.

There are also notable differences in trading activity by issue type and maturity, with trading concentrating in the intermediate-term notes. The on-the-run five-year note is the single most traded Treasury security, with average daily volume of $115 billion, followed by the 10- and 2-year issues, with $93 and $52 billion in daily volume, respectively.[9] For on-the-run bills, in contrast, average daily volumes for the 4-, 13-, and 26-week issues are $9 billion, $8 billion, and $6 billion, respectively.

Quoting Conventions for Treasury Bills

The convention in the Treasury market is to quote bills on a discount rate basis. The rate on a discount basis is computed as

$$Y_d = \frac{(F - P)}{F} \times \frac{360}{t}$$

where

8. See Doug Brain, Michiel De Pooter, Dobrislav Dobrev, Michael Fleming, Peter Johansson, Frank Keane, Michael Puglia, Anthony Rodrigues, and Or Shachar, "Breaking Down TRACE Volumes Further," Federal Reserve Bank of New York *Liberty Street Economics*, November 29, 2018.

9. See Doug Brain, Michiel De Pooter, Dobrislav Dobrev, Michael Fleming, Peter Johansson, Frank Keane, Michael Puglia, Anthony Rodrigues, and Or Shachar, "Breaking Down TRACE Volumes Further," Federal Reserve Bank of New York *Liberty Street Economics*, November 29, 2018.

Y_d = the rate on a discount basis
F = the face value
P = the price
t = the number of days to maturity

For example, the 26-week bill auctioned August 1, 2019, sold at a price (P) of \$99.014167 per \$100 face value (F). At issue, the bill had 182 days to maturity (t). The rate on a discount basis is then calculated as

$$Y_d = \frac{\$100 - \$99.014167}{\$100} \times \frac{360}{182} = 1.950\%$$

Conversely, given the rate on a discount basis, the price can be computed as

$$P = F - (F \times Y_d \times \frac{t}{360})$$

For our example,

$$P = \$100 - \left(\$100 \times 1.950\% \times \frac{182}{360}\right) = \$99.014167$$

The discount rate differs from more standard return measures for two reasons: First, the measure compares the dollar return to the face value rather than to the price. Second, the return is annualized based on a 360-day year rather than a 365-day year. Nevertheless, the discount rate can be converted to a bond-equivalent yield (as discussed in Chapter 4), and such yields are often reported alongside the discount rate.

Treasury bill discount rates are typically quoted to two decimal places in the secondary market, so that a quoted discount rate might be 1.18%. For more active issues, the last digit is often split into halves, so that a quoted rate might be 1.175%.

Typical bid–ask spreads for the on-the-run bills are 1.0 basis points, as shown in Exhibit 7-6 A basis point equals one one-hundredth of a percentage point, so that quotes for a one point spread might be 1.18%/1.17%. Spreads vary with market conditions, ranging from 0.5 to about 2.5–3.0 basis points most of the time. A spread of zero (called a "locked market") can also exist in the interdealer market because of the transaction fee paid to the broker who mediates a trade. Bid–ask spreads are typically wider outside of the interdealer market and for less active issues.

Quoting Conventions for Treasury Coupon Securities

In contrast to Treasury bills, Treasury notes and bonds are quoted in the secondary market on a price basis in points where one point equals 1 percent of par.[10] The points are split into units of 32nds, so that a price of 97-14, for example,

10. Notes and bonds are quoted in yield terms in when-issued trading because coupon rates for new notes and bonds are not set until after these securities are auctioned.

EXHIBIT 7-6

Bid–Ask Spreads for U.S. Treasury Bills

Issue	Median Spread	90% Range
4-week bill	1.0 basis points	0.5–3.0 basis points
8-week bill	1.0 basis points	0.5–3.0 basis points
13-week bill	1.0 basis points	0.5–2.5 basis points
26-week bill	1.0 basis points	0.5–2.5 basis points
52-week bill	1.0 basis points	0.5–2.5 basis points

Notes: Statistics for the spread between the best bid and the best offer are reported for the on-the-run bills of each issue. Spreads are reported in discount rate terms in basis points.

Source: Authors' calculations, based on 2019 data from GovPX.

refers to a price of 97 and 14/32 or 97.4375. The 32nds are themselves split by the addition of a plus sign or a number, with a plus sign indicating that half a 32nd (or 1/64) is added to the price and a number indicating how many eighths of 32nds (or 256ths) are added to the price. A price of 97-14+ therefore refers to a price of 97 and 14.5 / 32 or 97.453125, while a price of 97-142 refers to a price of 97 and 14.25 / 32 or 97.4453125. The yield to maturity, discussed in Chapter 4, is typically reported alongside the price.

Typical bid–ask spreads in the interdealer market for the on-the-run coupon securities range from 1 / 256 point for the two-year note to 1/32 point for the 30-year bond, as shown in Exhibit 7-7. A two-year note might thus be quoted as 99-172/99-173 whereas a 30-year bond might be quoted as 95-23/95-24. As with bills, the spreads vary with market conditions, and are usually wider outside of the interdealer market and for less active issues.

EXHIBIT 7-7

Bid–Ask Spreads for U.S. Treasury Notes and Bonds

Issue	Median Spread	90% Range
2-year note	1/256 point	1/256–1/128 point
3-year note	1/128 point	1/128–1/64 point
5-year note	1/128 point	1/128–1/64 point
7-year note	1/64 point	1/64–1/32 point
10-year note	1/64 point	1/64–1/32 point
30-year bond	1/32 point	1/64–1.5/32 point

Notes: Statistics for the spread between the best bid and the best offer in the interdealer broker market are reported for the on-the-run notes and bonds of each issue. Spreads are reported in price terms in points.

Source: Authors' calculations, based on 2019 data from BrokerTec.

ZERO-COUPON TREASURY SECURITIES

Zero-coupon Treasury securities are created from existing Treasury notes and bonds through coupon stripping (the Treasury does not issue them). Coupon stripping is the process of separating the coupon payments of a security from the principal and from one another. After stripping, each piece of the original security can trade by itself, entitling its holder to a particular payment on a particular date. A newly issued 10-year Treasury note, for example, can be split into its 20 semi-annual coupon payments (called *coupon strips*) and its principal payment (called the *principal strip*), resulting in 21 individual securities. As the components of stripped Treasury securities consist of single payments (with no intermediate coupon payments), they are often referred to as zero coupons or zeros, as well as strips.

As they make no intermediate payments, zeros sell at discounts to their face value, and frequently at deep discounts due to their oftentimes long maturities. On December 4, 2019, for example, the closing price for the November 2049 principal strip was just $52.06 (per $100 face value). As zeros have known cash values at specific future dates, they enable investors to closely match their liabilities with Treasury cash flows, and are thus popular with pension funds and insurance companies. Zeros also appeal to speculators because their prices are more sensitive to changes in interest rates than coupon securities with the same maturity date.

The Treasury introduced its *Separate Trading of Registered Interest and Principal Securities* (STRIPS) program in February 1985 to improve the liquidity of the zero-coupon market. The program allows the individual components of eligible Treasury securities to be held separately in the Federal Reserve's book-entry system. Institutions with book-entry accounts can request that a security be stripped into its separate components by sending instructions to a Federal Reserve Bank. Each stripped component receives its own CUSIP (or identification) number and can then be traded and registered separately. The components of stripped Treasury securities remain direct obligations of the U.S. government. The STRIPS program was originally limited to new coupon security issues with maturities of 10 years or longer, but was expanded to include all new coupon issues in September 1997.

Since May 1987, the Treasury has also allowed the components of a stripped Treasury security to be reassembled into their fully constituted form. An institution with a book-entry account assembles the principal component and all remaining interest components of a given security and then sends instructions to a Federal Reserve Bank requesting the reconstitution.

As of December 31, 2019, $331 billion of Treasury notes and bonds were held in stripped form, representing about 3% of the $12.3 trillion in notes and bonds outstanding.[11] There is wide variation across issue types and across issues

11. Figures are from Table V of the Treasury's Monthly Statement of the Public Debt (www.treasurydirect.gov/govt/reports/pd/mspd/mspd.htm).

of a particular type in the rate of stripping. As of December 31, 2019, roughly 14% of bonds were stripped but only 0.1% of notes were stripped. Among individual bond issues, the proportion stripped ranged from 1% to 32%. On a flow basis, securities were stripped at a rate of $27 billion per month in the last quarter of 2019, and reconstituted at a rate of $21 billion per month.

KEY POINTS

- U.S. Treasury securities are debt obligations of the U.S. government issued by the Department of the Treasury.
- Marketable Treasury securities are sold in the primary market through sealed-bid, single-price (or uniform price) auctions.
- Treasury securities are issued as either discount securities (bills) or coupon securities (notes, bonds, TIPS, and FRNs) and are issued as either fixed-principal or inflation-protected securities.
- Secondary trading in Treasury securities occurs in a multiple-dealer over-the-counter market rather than through an organized exchange.
- Treasury securities trade in a highly liquid secondary market, and are used by market participants as a pricing and hedging instrument, risk-free benchmark, reserve asset, and investment asset.
- Zero-coupon Treasury securities are created from existing Treasury notes and bonds through the Treasury's Separate Trading of Registered Interest and Principal Securities (STRIPS) program. Coupon stripping is the process of separating the coupon payments of a security from the principal and from one another.

CHAPTER

EIGHT

AGENCY DEBT SECURITIES

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Head of U.S. Rates Strategy
BofA Securities

Agency debt securities are direct obligations of federal government agencies or government-sponsored enterprises. Federal agencies are entities of the U.S. government, such as the Tennessee Valley Authority (TVA). Government-sponsored enterprises (GSEs) are designed as publicly chartered but privately owned and operated entities, such as the Federal National Mortgage Association (Fannie Mae), the Federal Home Loan Mortgage Corporation (Freddie Mac), the Federal Home Loan Banks (FHLB), and the Farm Credit Banks. Technically, GSEs are instrumentalities of the government that exempt them from certain management laws and regulations that would be applicable to other direct government agencies. However, for the purposes of this chapter, GSEs will frequently be referred to as agencies.

Agency debt securities typically are not backed by the full faith and credit of the U.S. government, as is the case with Treasury securities. Agency debt securities are not considered to be risk-free instruments and trade with some credit risk. Nevertheless, agency debt securities have traditionally been considered to be of strong credit quality due to the fundamentals of their underlying businesses and because of their government affiliation.

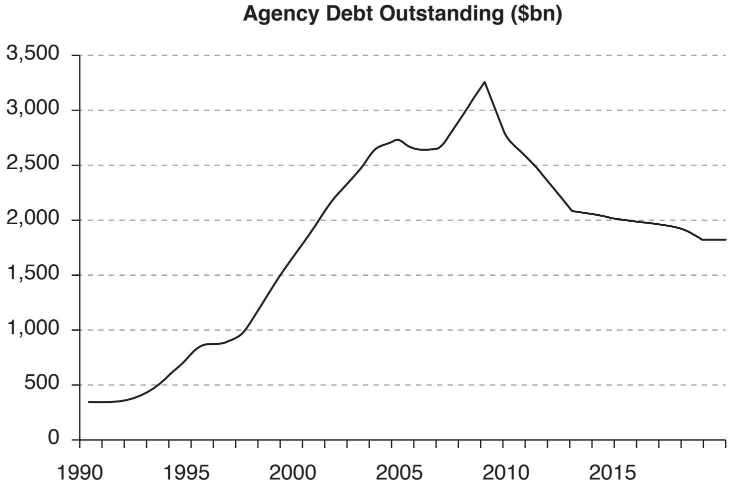
AGENCY DEBT MARKET OVERVIEW

The market for agency debt securities expanded rapidly during the 1990s, primarily due to increased issuance from housing-related agencies (including Fannie Mae, Freddie Mac, and the FHLB) as they grew their retained portfolios and mortgage-related businesses. The agency debt market has declined off its peak totals to nearly $2 trillion by the second quarter of 2020 largely due to limitations imposed on some housing-related GSEs in the wake of the 2008 financial crisis. See Exhibits 8-1 and 8-2.

Mark Cabana's views expressed in this chapter are his and not necessarily those of Bank of America. Mark would like to thank Ralph Axel, Greg Ingrassia, and Scott Stelmach for very helpful comments and Olivia Lima for data assistance.

EXHIBIT 8-1

Agency Debt Outstanding ($ billion)



Source: SIFMA

EXHIBIT 8-2

Agency Debt Outstanding by Issuer ($ billion)

	Fannie Mae	Freddie Mac	FHLB	Farm Credit	Farmer Mac	TVA
2015	389	418	847	242	14	25
2016	329	357	905	258	14	25
2017	277	317	989	265	16	25
2018	232	256	1034	282	16	24
2019	182	283	1026	294	19	22

Source: Created with data obtained from GSE reports.

Credit Quality of Agency Securities

There is a perception among some market participants that the government implicitly backs agency issues and would be reluctant to let an agency default on its obligations. However, there is no explicit government guarantee for most agency securities and the extent of government backing for agency securities is a source of uncertainty for some investors.

Agency securities are perceived to have a government backing due to their legal characteristics and affiliation with the U.S. government. Agencies are granted authority to issue debt from Congress and many have directors that are appointed by the President of the United States. In addition, most agencies have the authority to borrow directly from the Treasury and some agencies have received direct Treasury financing. Many agency securities are also eligible for standard Federal Reserve open market operations.

Despite their relation to the government, agency securities have historically traded at a slight discount to Treasury securities. The pricing difference between agency and Treasury securities has depended partially on the strength of each agency's underlying business, the perceived strength of their government backing, and the liquidity difference between agencies and Treasuries.

Conservatorship and Credit Quality

Fannie Mae and Freddie Mac were placed in a conservatorship run by the Federal Housing Finance Agency (FHFA) in September 2008. Through the conservatorship, the U.S. Treasury Department and the FHFA established Preferred Stock Purchase Agreements (PSPA). The PSPAs were designed to ensure that Fannie Mae and Freddie Mac (1) provide stability to the financial markets, (2) prevent disruptions in the availability of mortgage finance, and (3) protect the taxpayer. The PSPAs have modified over time and there is an expectation these agencies will eventually be removed from conservatorship.

Even after Fannie Mae and Freddie Mac entered conservatorship in September 2008 the government did not provide an explicit guarantee covering their outstanding debentures, but rather increased direct support to each enterprise. This step strengthened government backing for Fannie Mae and Freddie Mac but did not allay investor concerns sufficient to stop their debt spreads from widening during periods of market stress. In 2008 it took nearly $170 billion in direct purchases from the Federal Reserve to contain sharp spread widening stemming from the financial crisis.

Agency Debt Investors

A variety of market participants invest in agency debt. Many investors are attracted to the relatively high credit quality of agency debt, which offers a slightly higher return when compared with Treasury securities while offering the perception of only modestly more credit risk. In addition, agency issues are also attractive to investors because interest income is exempt from state and local taxation for some issuers (including FHLB and Farm Credit Banks).

The composition of agency debt investors largely depends on the tenor of the debt maturity, though asset managers comprise the largest ownership segment of agency debt. For short-term debt that matures in 12 months or less, investment managers and money market mutual funds are the largest holders. For longer-dated debt outstanding, the largest ownership segments tend to include fund managers, central banks, state and local governments, commercial banks, and pension/insurance funds.

TYPES OF AGENCY DEBT SECURITIES

Agency debt securities are issued in a variety of maturities and types to help manage their business financing needs, mitigate interest-rate risk, and expand their respective investor bases.

Short-Dated Agency Securities

Agencies frequently issue securities with relatively short-term tenors of less than one year, often referred to as discount notes. Discount notes are issued at a discount from par with maturities ranging from 1 to 365 days and are priced similar to Treasury bills. Some of the agencies offer regular and predictable discount note supply through established programs with standard announcement and offering dates, including the Federal Home Loan Bank's discount note auctions. Other discount notes issued by the agencies are offered through reverse inquiries from investors.

Longer-Dated Agency Securities

Agencies also offer a wide variety of longer-dated securities with maturities of between 1 and 30 years. Most agency debt is U.S. dollar denominated, although some agencies have issued debt denominated in foreign currencies. Some longer-dated issues are large in size with fixed-rate coupon offerings issued through established programs, such the Federal Home Loan Bank's Global Debt program, Fannie Mae's Benchmark Notes program, and Freddie Mac's Reference Notes program. These programs were established in the late 1990s to create more regular and standardized types of debt with greater liquidity. The programs were also intended to produce a yield-curve for liquid agency securities and thereby appeal to investors that might otherwise purchase Treasury securities. These fixed-rate coupon offerings typically have semiannual coupon payments with principal redeemed only at the security's stated final maturity date.

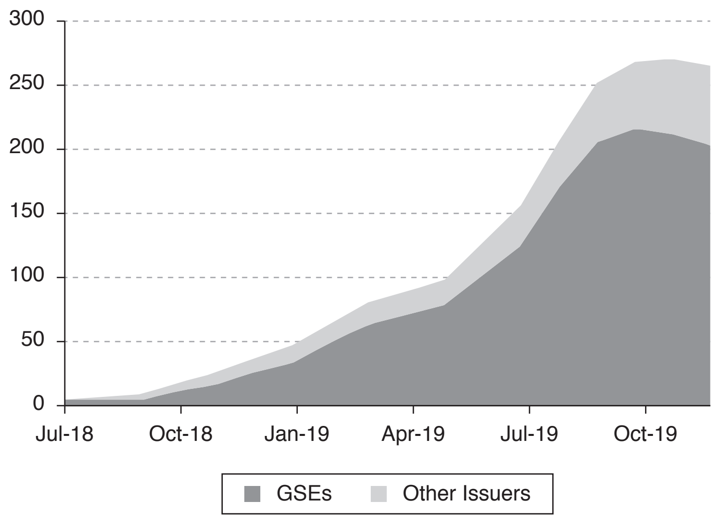
In addition to these programs, agencies also offer smaller longer-dated securities with a variety of characteristics that are frequently referred to as medium-term notes. In the past, agencies have offered medium-term notes with a variety of characteristics, including senior and subordinated hierarchies; callable and putable structures; denominations in U.S. dollars or in other currencies; fixed-rate, floating-rate, indexed, and zero coupons. Some agencies also offer variations on fixed-rate callable securities called "step-up notes," in which the issuer will generally have the choice to call a security on a specific date; if it is not called then the investor's interest rate increases or "steps up." In addition, the FHLB Office of Finance offers a TAP issuance program, in which it issues fixed-rate securities at longer-dated maturities and has the option to continually reopen a security for a three-month period based upon investor demand. Some of these longer-dated security types are discussed in greater detail later in this chapter.

Most longer-dated agency securities generally make semiannual coupon payments and are priced similar to Treasury notes, depending on their various characteristics. Some longer-dated agency securities are also eligible for stripping into principal and interest components through the Federal Reserve Book Entry System.

Agencies also tie their floating-rate notes to a number of different indices, including LIBOR, SOFR, fed funds, Treasury bills, or the prime rate. The agencies have been the most active issuer of SOFR-related floating-rate notes and are widely seen as the most proactive adopter of SOFR-related liabilities. At the end of 2019, the agencies had a little over $200 billion of SOFR floating-rate debt outstanding and comprised 77% of all SOFR-related floating-rate debt outstanding. FHLB has the largest amount of SOFR-linked FRNs outstanding, followed by Fannie Mae and Freddie Mac (see Exhibits 8-3 and 8-4).

EXHIBIT 8-3

SOFR Floating-Rate Debt Outstanding ($ billion)



Source: Created with data obtained from Bloomberg.

EXHIBIT 8-4

GSE SOFR FRN Debt Outstanding by Issuer (Year-end 2019, in $ billion)

FHLBs	Freddie Mac	Fannie Mae	Farm Credit	Farmer Mac
121	56	15	8	0.8

Source: Created with data obtained from Bloomberg.

Callable Securities and Other Tools to Mitigate Interest-Rate Risk

Agencies issue a wide variety of longer-dated securities to better manage the interest-rate and cash-flow risk inherent in their businesses, especially as some relate to securitizing mortgages and purchasing mortgage-backed securities. One of the most notable risks for housing-related GSEs is the unpredictable nature of mortgage prepayment speeds, given that mortgage prepayments tend to vary with the interest-rate environment. Specifically, mortgage prepayment speeds tend to increase in a declining interest-rate environment and decrease in a rising rate environment.

Housing-related agencies partially mitigate this risk by issuing callable debt securities, which have somewhat similar characteristics to mortgage-backed securities. The duration of mortgage-backed and callable debt tends to shorten as interest rates decline due to the increased likelihood that the call options inherent in these structures will be exercised by the mortgage owner or callable debt issuer. By issuing callable debt, GSEs effectively purchase a call option from an investor and compensate the investor by issuing the security at a slightly higher yield when compared to similar noncallable securities.

Callable securities generally have three main characteristics: the maturity date, the lockout period, and the type of call feature. The maturity date is somewhat similar to a noncallable security, which is the latest date on which the security will be retired and principal redeemed assuming the security is not called. The lockout period refers to the amount of time over which a callable security cannot be called by the issuer. For example, a "3 non-call 1-year security" cannot be called for the first year but may be callable at a specific time over the remainder of the security's total three-year life. The call feature is generally one of three types: European-style, in which the call option can only be exercised on a single day at the end of the initial lockout period; Bermudan-style, in which the call option can be exercised on coupon payment dates after the conclusion of the initial lockout period; and, American-style, in which the call option can be exercised at any point after the initial lockout period.

In addition to callable securities, housing-related GSEs also utilize a variety of other tools to help mitigate interest-rate risk, including interest-rate derivatives such as swaps and swaptions. Callable debt and interest-rate derivatives are an important part of housing-related GSE risk management strategies, which have also allowed some GSEs to expand their investor base.

THE PRIMARY MARKET

The agencies use a variety of methods to distribute their securities, including competitive dealer bidding through auctions, issuance allocation to dealers, sales to investors through dealers, and direct sales to investors. The method may differ based on the issuer and the type of debt being offered.

Agencies have a variety of ways to issue short-dated securities, although most offerings are executed through regular discount note auctions or reverse inquiry sales. Housing-related agencies offer programs that provide a regular and predictable supply of short-dated securities to the market through weekly discount note announcements and auctions. Auctions are underwritten by a predetermined group of dealers who participate in the auctions through issuance platforms specific to each of the housing-related agencies. Depending on the agency, these discount note offerings may be conducted through single- or multiple-price auctions.

Agencies also provide discount notes through reverse inquiry offers. In this process, an agency will post rates daily to the public or investor community at which they are willing to issue discount securities. These rates are sometimes referred to as window rates. Dealers will then assist investors in making offers to the issuing agency for a specific amount and tenor near the applicable rate. This process is attractive for both the agency issuer and investor as it allows for a broader range of participants to finance the agencies at short-dated tenors that best meet their investment objectives. However, discount notes issued through the reverse inquiry or window offering process may have nonstandard maturity dates and limited sizes outstanding, which can hinder secondary market liquidity should they be sold by the original investor.

For longer-dated securities, agencies will also use a variety of methods, including syndicated offerings, reopening auctions, or reverse inquiry sales. A common distribution mechanism for agency debt securities is to allocate them among members of a selling group or syndicate of dealers. The syndicate provides market and trading information to the issuing agency before and during the allocation and may support secondary trading in the issue after allocation. In compensation for their services, the syndicate members are offered a concession in the offering or they are able to retain a percentage of the proceeds from the sold securities.

The syndication process is used by some agencies to issue callable and standard fixed-rate coupon offerings. Syndications are most frequently used to issue large fixed-rate coupon offerings such as those issues through the Federal Home Loan Bank's Global Debt program, Fannie Mae's Benchmark Notes program, and Freddie Mac's Reference Notes program. To organize the issuance process among these programs, the U.S. Treasury Department in coordination with the FHFA and the housing-related agencies establish a monthly issuance calendar in which each agency has predetermined days on which it can offer large fixed-rate coupon offerings to investors. The agencies can choose to offer securities on their respective date or pass and wait until their next scheduled issuance date. This monthly calendar coordination ensures that each housing-related agency has the potential to offer coupon securities in relatively large size without interfering with the issuance plans of any other agency. Of note, on these scheduled offering dates, the agencies can also choose to reopen previously issued securities through these established programs. The agencies generally manage the reopening auctions through their internal systems and do not require a dealer syndicate for this process.

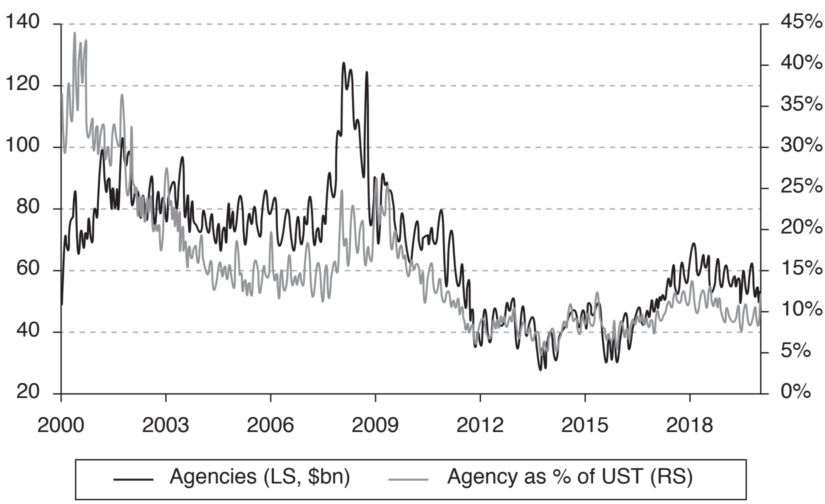
Similar to discount notes, agencies also issue medium-term notes through a reverse inquiry process. Some dealers will post or send daily rates for a variety of security types to underwriting dealers, who then assist investors in making offers to the issuing agency. Agencies frequently issue callable securities through the reverse inquiry process and are able to entertain a wide variety of callable structure reverse inquiries simultaneously, including those with European, American, and Bermudan call options. Agencies will also consider a wide variety of other debt structures through the reverse inquiry process. On any given day, agencies can issue longer-term securities with a variety of different maturities, coupon types, and call features through this process.

THE SECONDARY MARKET

Like Treasury securities, agency securities trade in a multiple-dealer over-the-counter secondary market. Also like Treasury securities, trading among dealers is screen-based, through interdealer brokers. Trading volume is significantly lower than that in the Treasury market, but it is still reasonably high relative to other fixed income markets. Primary dealer trading volumes in agency debt securities averaged 9.5% of U.S. Treasury daily trading volumes from 2010 to 2020 (see Exhibit 8-5).

EXHIBIT 8-5

Agency Debt Trading Volume



Source: Created with data obtained from Federal Reserve.

Secondary market trading activity is also concentrated in agency securities in discount notes. From 2010 to 2020, discount notes averaged 81% of daily primary dealer trading volumes versus longer-term agency securities, which averaged only 19% of such volume. During 2019, daily trading by primary dealers averaged $56 billion per day, with $47 billion in discount notes and $9 billion in longer-dated securities.

AGENCY DEBT ISSUANCE

The quantity of agency debt securities sold in the primary market increased through most of the 1990s and 2000s but has slowly declined since 2008. Agency debt outstanding peaked in 2008 at $3.2 trillion and was only $1.8 trillion at the end of 2019 (see Exhibit 8-1). The decline in agency debt outstanding is related to the conservatorship of Fannie Mae and Freddie Mac, which limits their aggregate indebtedness and required their retained portfolios to decline over time.

Housing-related agencies are the largest issuers of agency debt and total over 80% of all agency-related debt outstanding, including the Federal Home Loan Bank, Freddie Mac, and Fannie Mae. Agency debt outstanding from these three entities totals nearly $1.5 trillion. The FHLB has the largest share of agency debt outstanding at over $1 trillion. The second largest single agency issuer is now Farm Credit and their debt outstanding exceeded that of Fannie Mae and Freddie Mac by the end of 2018.

ISSUING AGENCIES

As mentioned previously, agency securities are direct obligations of federal agencies or GSEs. Federal agencies are entities of the federal government. They include the Export-Import Bank of the United States, the Federal Housing Administration, the Government National Mortgage Association (Ginnie Mae), the TVA, and the Small Business Administration. Historically, a number of federal agencies issued their own debt securities. The TVA still issues its own debt securities and accounts for nearly all the outstanding debt issued directly by federal agencies.

GSEs are privately owned and operated entities chartered by Congress to work toward public policy goals and decrease the cost of funding for certain sectors of the economy. The GSEs are granted certain privileges to help them achieve their public purposes and, in turn, are limited to certain activities. As mentioned, agency debt securities are thought to have an implicit government guarantee and agency security interest income is exempt from state and local taxation for some issuers. The agencies themselves are exempt from state and local income taxes and are also exempt from Securities and Exchange Commission (SEC) registration fees.

The largest GSEs were chartered to provide credit to the housing sector including Fannie Mae, Freddie Mac, and the FHLB. Another set of GSEs was established to provide credit to the agricultural sector, including the Farm Credit Banks, the Farm Credit System Financial Assistance Corporation, and the Federal Agricultural Mortgage Corporation (Farmer Mac).

There are also older GSEs with debt outstanding and other GSEs that have recently been privatized. The Financing Corporation and the Resolution Funding Corporation are GSEs that were established to recapitalize the savings and loan. Another older GSE, the Student Loan Marketing Association (Sallie Mae), was wholly privatized at the end of 2004.

In addition to the agencies and GSEs, there have been some government initiatives that explicitly back types of fixed income securities for public policy purposes. The Temporary Liquidity Guarantee Program (TLGP) was established during the 2008 financial crisis, through which the Federal Deposit Insurance Company (FDIC) guaranteed senior unsecured debt of insured depository institutions issued between October 14, 2008, and June 30, 2009.

The remainder of this section provides a brief overview of each of the agencies, GSEs, and government-backed initiatives that have debt securities outstanding or were recently wound-down. This information is also summarized in Exhibit 8-6.

EXHIBIT 8-6

Summary of Agencies and GSEs

Agency	Purpose	Debt Outstanding ($bn)
FHLB	Provide financial products and services to members and housing associates	1026
Farm Credit	Support rural communities and agriculture with reliable, consistent credit and financial services	294
Freddie Mac	Provide liquidity, stability, and affordability to the U.S. housing market	283
Fannie Mae	Provide liquidity, stability, and affordability to the U.S. housing market	182
TVA	Promote development of Tennessee River and adjacent areas	22
Farmer Mac	Increase the availability and affordability of credit for the benefit of American agriculture and rural communities	19

Source: Created with data obtained from GSE reports.

LARGE, ACTIVE ISSUERS

The largest active issuer today is the Federal Home Loan Bank system. Fannie Mae, Freddie Mac, and the Farm Credit System comprise the next three largest issuers of agency debt.

Federal Home Loan Bank System

The FHLB system was established as a GSE in 1932 to increase credit access for the housing sector by supporting residential mortgage lending and related community investment through its member financial institutions. The FHLB system is composed of 11 regional banks that are privately capitalized and owned as cooperatives by their members. FHLBs provide access to low-cost funding to nearly 7,000 banks, credit unions, insurance companies, and community development financial institutions. FHLBs provide liquidity by raising funds in the global financial markets and then lend that money in the form of "advances" or loans to their member banks and local communities.

The FHFA regulates the FHLB system for mission, as well as safety and soundness issues. Unlike Fannie Mae and Freddie Mac, none of the 11 regional FHLB are in conservatorship.

FHLB debt issuance is conducted through the system's fiscal agent, the Office of Finance. The FHLB Office of Finance sells a variety of debt securities, including discount notes and medium-term notes. Bonds and discount notes issued by the FHLBs are called consolidated obligations. Although each FHLB is primarily liable for its portion of consolidated obligations, each FHLB is also jointly and severally liable with the other FHLBs for the payment of principal and interest on all consolidated obligations.

The FHLBs issue discount notes in maturities ranging from one day to one year, and bonds with maturities of three months to 30 years. The majority of issues are between one and five years. Issue size can range from $10 million to several billion dollars. FHLB debt is sold through a broad, international network of underwriters. Discount notes are offered at fixed tenors of 4, 8, 13, and 26 but can also be offered on reverse inquiry through their discount note window. Consolidated bonds are issued with either fixed-rate coupon payment terms or variable-rate coupon payment terms and can be issued and distributed through directly negotiated or auction formats.

As of year-end 2019, the FHLB Office of Finance had just over $1 trillion in consolidated obligations outstanding. Discount notes outstanding were $404 billion and consolidated bonds outstanding were $622 billion.

Federal National Mortgage Association (Fannie Mae)

Fannie Mae was established in 1938 to develop a secondary market for residential mortgages and was chartered by Congress in 1968 as a private stockholder-owned corporation. Fannie Mae buys home loans from banks and other mortgage lenders in the primary market and holds the mortgages until they mature or issues securities backed by pools of the mortgages. FHFA also regulates Fannie Mae. On September 6, 2008, the Director of the FHFA was appointed conservator of Fannie Mae, at which time the GSE also established the PSPA with the U.S. Treasury Department to ensure the enterprise will maintain a positive net worth.

To finance their businesses, Fannie Mae issues a variety of securities, including discount notes and medium-term notes. Fannie Mae offers benchmark bills with maturities of one year or less that may be auctioned on a weekly basis. Their benchmark note program follows a specific calendar when the issues can be offered typically once or twice a month.

At year-end 2019, Fannie Mae had $182 billion of debt outstanding. Of this debt $27 billion was in short-term debt, $47 billion was in long-term debt maturing within one year, and $108 billion was in longer-term debt beyond one year. Under Fannie Mae's conservatorship their aggregate indebtedness is fixed at $300 billion.

Federal Home Loan Mortgage Corporation (Freddie Mac)

Freddie Mac is a stockholder-owned corporation chartered in 1970 to expand opportunities for homeownership and improve the liquidity of the secondary mortgage market. Freddie Mac purchases mortgage loans from individual lenders and sells securities backed by the mortgages to investors or holds the mortgages until they mature.

FHFA also regulates Freddie Mac. Similar to Fannie Mae, Freddie Mac entered conservatorship overseen by the FHFA in September 2008 and has a PSPA with the U.S. Treasury Department. Under Fannie Mae's conservatorship their aggregate indebtedness is fixed at $300 billion.

Freddie Mac issues a variety of debt securities, including discount notes and medium-term notes. Discount note maturities may range from overnight through one year and are supplemented with reference bills that are auctioned on a predetermined calendar. Medium-term notes are issued in a variety of fixed-rate and variable-rate medium-term notes, including callable and noncallable securities, and zero-coupon securities, with various maturities via an underwriting syndicate of dealers following a yearly issuance calendar.

Freddie Mac had $283 billion of total debt outstanding as of year-end 2019. Of this debt $61 billion was in discount notes, $50 billion was in long-term debt maturing within one year, and $172 billion was in longer-term debt beyond one year.

The Farm Credit System

The Farm Credit System (FCS) is a GSE, established in 1916 to provide credit to the agricultural sector. Farm Credit is a nationwide network of 72 customer-owned financial institutions. Products and services offered by FCS institutions include real estate loans, operating loans, rural home mortgage loans, crop insurance, and various financial services. The FCS and the system's fiscal entity are regulated by the Farm Credit Administration.

The Federal Farm Credit Banks Funding Corporation is the system's fiscal entity, providing funds to system institutions through the issuance of debt securities. The FCS issues discount notes, fixed-rate callable and noncallable securities, and floating-rate notes. In addition, FCS also issues Designated Bonds, which are large, liquid callable and noncallable issues. These bonds are issued through a dealer syndicate and can have 2- to 10-year original maturities.

As of year-end 2019, FCS had $294 billion of debt outstanding. This included $19 billion in discount notes and the remainder in fixed-rate, floating, and designated bonds.

SMALLER, ACTIVE ISSUERS

The Federal Agricultural Mortgage Corporation, and the Tennessee Valley Authority are two other smaller, active issuers.

Federal Agricultural Mortgage Corporation (Farmer Mac)

Farmer Mac is a stockholder-owned corporation chartered in 1988 to promote a liquid secondary market for agricultural real estate and rural housing loans. It does this by buying qualified loans from lenders and grouping the loans into pools against which it issues securities. Farmer Mac thus performs a role for the agricultural mortgage market similar to that performed by Fannie Mae and Freddie Mac for the residential mortgage market. Farmer Mac issues discount notes and medium-term notes, including callable and noncallable securities. As of year-end 2019, Farmer Mac outstanding debt totaled $19 billion with $10 billion in maturities less than one year and $9 billion in tenors greater than one year.

Tennessee Valley Authority

The TVA is a government-owned corporation established in 1933 to promote development of the Tennessee River and adjacent areas. The TVA manages the river system for flood control, navigation, power generation, and other purposes and is the nation's largest public power company.

The TVA issues discount notes as well as longer-term coupon securities, called Power Bonds. Interest and principal on Power Bonds are paid from the proceeds of TVA's power program. TVA outstanding debt included $895 million in short-term debt and over $20 billion in long-term debt as of year-end 2019.

NONACTIVE ISSUERS AND RECENTLY RETIRED GSES

In addition to the issuers discussed above, there are issues outstanding and traded in the market from entities that were previously GSEs and those that are not currently active in the issuance market.

Resolution Funding Corporation

The Resolution Funding Corporation (REFCorp) was established in 1989 as the funding arm of the Resolution Trust Corporation to finance the recapitalization of the savings and loan industry. REFCorp issued $30 billion in debt securities between 1989 and 1991. Interest payments on REFCorp bonds are guaranteed by the U.S. government, and the principal is protected by the purchase of zero-coupon bonds with a face value equal to those of REFCorp bonds. The full $30 billion in issued debt securities was outstanding near the end of 2019.

Financing Corporation

The Financing Corporation (FICO) was established in 1987 to finance the recapitalization of the Federal Savings and Loan Insurance Corporation (FSLIC). Between 1987 and 1989, FICO issued debt obligations with an aggregate principal value of $8.2 billion. Toward the end of 1991, FICO's authority to issue new debt was terminated. The FHLB system provided FICO with initial capital to purchase zero-coupon Treasury securities in order to repay their principal. FICO interest payments are funded by an assessment on FDIC-insured institutions.

FCS Financial Assistance Corporation

The Farm Credit Financial Assistance Corporation was chartered in 1988 to finance the recapitalization of FCS institutions. Between 1988 and 1990, the corporation raised $1.3 billion through the issuance of debt securities, which it provided to system institutions in return for preferred stock. Unlike most GSEs, the debt securities of this corporation were fully guaranteed by the U.S. Treasury. All debt issuance by the corporation has been called or matured, with the last bond maturing in June 2005. The Financial Assistance Corporation's charter was canceled by the FCA as of December 31, 2006.

Student Loan Marketing Association

The Student Loan Marketing Association (Sallie Mae) was a stockholder-owned corporation established in 1972 to increase the availability of student loans. As a GSE, Sallie Mae purchased insured student loans from lenders and made loans to lenders secured by student loans. Sallie Mae was reorganized in 1997 in a step toward privatization and was fully privatized at the end of 2004. As a GSE, Sallie

Mae issued discount notes, medium-term notes, and other debt securities, but no longer has any GSE-related debt outstanding. Sallie Mae was replaced by a publicly held, private sector financial services company named SLM Corporation, which specializes in financing education.

Treasury Liquidity Guarantee Program

The Treasury Liquidity Guarantee Program (TLGP) was announced on October 14, 2008, as an initiative to counter systemic risks in the financial sector by ensuring that financial institutions would be able to roll over maturing wholesale debt. Through the TLGP, the FDIC provided guarantees for a limited amount of newly issued senior unsecured debt of insured depository institutions, most U.S. bank holding companies, and one large nonbank finance company. Debt issued through the TLGP is backed by the full faith and credit of the U.S. government.

Issuers in the TLGP were required to pay a fee to the FDIC that was based on the maturity of the debt and the type of institution that was issuing it. Each participating financial institution was limited to a maximum amount of guaranteed debt that it could issue based on the amount of senior unsecured debt scheduled to expire over a set time period. Guarantees for TLGP-backed senior unsecured debt originally applied to issuance by June 30, 2009, for maturities before June 30, 2012. However, this was extended to issuance by October 31, 2009, for maturities before December 31, 2012.

Issuance through the TLGP was elevated at the start of the program when other forms of corporate debt issuance were limited. During the first six months of the TLGP program $346 billion in term debt was issued from applicable institutions. However, as corporate credit markets improved, credit availability increased, and the FDIC encouraged firms to return to private funding markets, TLGP issuance and amounts outstanding declined. There is limited to no TLGP debt outstanding today.

KEY POINTS

- Agency securities are direct obligations of federal government agencies or GSEs. Agency securities have historically been viewed as having limited credit risk, although they are not risk-free and have at times traded with a notable discount to Treasury securities.
- Agency security issuance and amount outstanding grew in the early 2000s but has declined in recent years due to restrictions from the conservatorship of Fannie Mae and Freddie Mac.
- Federal agencies and GSEs issue a wide variety of debt securities, including discount note securities at tenors less than one year and medium-term notes with numerous structures at maturities greater than one year.

- Agencies use a variety of methods to distribute their securities, including competitive dealer bidding through auctions, issuance allocation to dealers, sales to investors through dealers, and direct sales to investors.
- The vast majority of agency debt issued (mostly concentrated in discount notes) and traded is from the FHLB system, Fannie Mae, Freddie Mac, and Farm Credit.

CHAPTER
NINE

MUNICIPAL BONDS

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The U.S. bond market can be divided into two major sectors: the taxable bond market and the tax-exempt bond market. The former sector includes bonds issued by the U.S. government, U.S. government agencies and sponsored enterprises, and corporations. The tax-exempt bond market is one in which the interest from bonds that are issued and sold is exempt from federal income taxation. Interest may or may not be taxable at the state and local levels. The interest on U.S. Treasury securities is exempt from state and local taxes, but the distinction in classifying a bond as tax exempt is the tax treatment at the federal income tax level.

It should be noted that over the years some taxable municipal bonds have been issued. As an example of the largest issuance program, under the Federal Build America Bond (BABS) program, between 2009 and 2010, almost $190 billion of BABS were issued. Interest on these bonds was federally taxable and the federal government pays a portion of the interest payments to the issuer.

The Federal Reserve Board estimates that the overall size of the municipal bond market as of 2020 was $3.8 trillion. The municipal sector is certainly one of the larger components of the domestic bond market, but it is clearly different from the taxable bond market.

The majority of tax-exempt securities are issued by state and local governments and by their creations, such as "authorities" and special districts. Consequently, the terms *municipal market* and *tax-exempt market* are often used interchangeably. Although not all municipal bonds are tax-exempt securities, most are.

The major motivation for investing in tax-exempt municipal bonds is their tax advantage. The primary owners of municipal bonds are individual investors;

the remainder of the investors consists of mutual funds, commercial banks, and property and casualty insurance companies. Although certain institutional investors such as pension funds have no need for tax-advantaged investments, there have been instances in which such institutional investors have crossed into the municipal bond market to take advantage of higher yields. These investors also have purchased municipal bonds when municipal bonds were expected to outperform taxable bonds. Institutional investors who are natural purchasers of taxable bonds but at times purchase municipal debt are known as *crossover buyers*.

The industry has many new buy-side participants. In addition to the traditional bank trust departments, mutual funds, property and casualty insurance companies, and high-net-worth individuals, buyers now include hedge funds, arbitrageurs, life insurance companies, crossover buyers, and foreign banks, among other relative value buyers. There are now municipal bond exchange-traded funds (ETFs) that cater to investors. Additionally, the Tax Cuts and Jobs Act of 2017 (TCJA) reduced their holdings even more by cutting the corporate tax rate to 21% from 35%.

Traditionally, the household sector has owned the largest portion of the tax-exempt municipal bond market. Another substantial owner has been the mutual fund industry. However, examination of Federal Reserve Board data indicates that there have been three major changes among holders. First, the percentage holdings of commercial banks have dropped significantly since 1986. In general, the Tax Reform Act of 1986 reduced the benefits commercial banks received by owning municipal bonds. Commercial banks responded to this change by reducing their municipal bond holdings and investing in assets that provided greater benefits.Additionally, the Tax Cuts and Jobs Act of 2017 (TCJA) reduced their holdings even more by cutting the corporate tax rate to 21% from 35%.

Households accounted for the next ownership change. In 1990, household ownership of municipal bonds reached a peak of 49% for the 20-year period. However, by the end of September 2019, household ownership was at 46%. If commercial banks and households both decreased their holdings, then other groups had to increase their ownership. Federal Reserve Board data indicate that mutual funds, money market funds, closed-ended funds, and exchange-traded funds dramatically increased their holdings. In 1979, they held only 1% of the municipal market; by the end of September 2019, their combined share was 26.2%.

Insurance companies and personal bank trust accounts have had relatively stable ownership of municipal bonds. Insurance companies typically adjust their holdings of municipal bonds according to profitability and the relative value municipal bonds offer compared with taxable bonds. Trust accounts are relatively stable purchasers of municipal bonds. A typical trust account will purchase bonds near par, collect the tax-exempt income, and hold the bonds to maturity.

It should be noted that when municipal bond yields are attractive compared with taxable bonds, traditional bond buyers, hedge funds, and arbitrageurs are active and at times have become significant participants in the municipal market.

In the past, investing in municipal bonds was considered second in safety only to that of U.S. Treasury securities; however, there have now developed among investors ongoing concerns about the credit risks of municipal bonds. This is true regardless of whether or not the bonds are given investment-grade credit ratings by the commercial rating companies. There are several reasons for this: (1) the financial crisis of several major municipal issuers beginning with the City of New York billion-dollar financial crisis in 1975 and the bankruptcy filing in 1994 of Orange County, California; (2) the federal bankruptcy law (which became effective October 1979) that makes it easier for municipal bond issuers to seek protection from bondholders by filing for bankruptcy; (3) the proliferation of innovative financing techniques and legally untested security structures, highlighted by the default of the Washington Public Power Supply System (WPPSS) in the early 1980s; (4) the cutbacks in federal grant and aid programs that will affect the ability of certain municipal issuers to meet their obligations; and (5) fundamental changes in the American economy that may cause economic hardship for municipal issuers in some regions of the country and thus difficulty in meeting their obligations.

Beginning in December of 2007 when the latest recession began, the well-publicized bond defaults of Vallejo, California, and Harrisburg, Pennsylvania, as well as the budgetary stresses of several large states and cities, highlighted credit concerns about municipal bonds. Vallejo utilized Chapter 9 of the U.S. Bankruptcy Code to avoid paying bondholders. And Harrisburg just didn't appropriate debt service. More recently, the default of Detroit and Puerto Rico bonds added to these concerns.

FEATURES OF MUNICIPAL SECURITIES

In Chapter 1, the various features of fixed income securities were described. These include call and refunding provisions, sinking-fund provisions, and put provisions. Such provisions also can be included in municipal securities. In one type of municipal structure discussed below, a revenue bond, there is a special call feature wherein the issuer must call the entire issue if the facility is destroyed.

Coupon Features

The coupon rate on a municipal issue can be fixed throughout the life of the issue, or it can be reset periodically. When the coupon rate is reset periodically, the issue is referred to as a *floating-rate* or *variable-rate* issue. In general form, the coupon reset formula for a floating-rate issue is

$$\text{Percent of reference rate} \pm \text{spread}$$

Typically, when the reference rate is a municipal index, the coupon reset formula is

$$\text{Reference rate} \pm \text{spread}$$

Reference rates that have been used for municipal issues include the Securities Industry and Financial Markets Association (SIFMA), LIBOR, and Treasury bills.

The coupon rate on a floating-rate issue need not change in the same direction as the reference rate. There are derivative municipal bonds whose coupon rate changes in the opposite direction to the change in the reference rate. That is, if the reference rate increases from the previous coupon reset date, the coupon rate on the issue declines. Such issues are referred to as *inverse floating-rate issues.* Some municipal issues have a fixed coupon rate and are issued at a discount from their maturity value. Issues whose original-issue price is less than its maturity value are referred to as *original-issue discount bonds* (OIDs). The difference between the par value and the original-issue price represents tax-exempt interest that the investor realizes by holding the issue to maturity.

Two types of municipal issues do not distribute periodic interest to the investor. The first type is called a *zero-coupon bond.* The coupon rate is zero, and the original issue price is below the maturity value. Zero-coupon bonds are therefore OIDs. The other type of issue that does not distribute periodic interest is one in which a coupon rate is stated but the coupon is not distributed to the investor. Instead, the interest is accrued, and all interest is paid to the investor at the maturity date along with the maturity value. Later in this chapter we will discuss the important aspects an investor should be aware of when considering the purchase of OIDs in the secondary market.

Maturity Date

The maturity date is the date on which the issuer is obligated to pay the par value. Corporate issuers of debt generally schedule their bonds to mature in one or two different years in the future. Municipal issuers, on the other hand, frequently schedule their bonds to mature serially over many years. Such bonds are called *serial bonds.* It is common for a municipal issue to have 10 or more different maturities.

After the last of the serial maturities, some municipal issues lump together large sums of debt into one or two years—much the way corporate bonds are issued. These bonds, called *term bonds,* have become increasingly popular in the municipal market because active secondary markets for them can develop if the term issue is of sufficient size.

The Legal Opinion

Municipal bonds have legal opinions. The relationship of the legal opinion to the safety of municipal bonds for both general obligation and revenue bonds is threefold. First, bond counsel should check to determine if the issuer is indeed legally able to issue the bonds. Second, bond counsel is to see that the issuer has properly prepared for the bond sale by having enacted the various required ordinances, resolutions, and trust indentures and without violating any other laws and regulations. This preparation is particularly important in the highly technical areas of determining if the bond issue is qualified for tax exemption under federal law and if the issue has not been structured in such a way as to violate federal arbitrage regulations. Third, bond counsel is to certify that the security safeguards and remedies provided for the bondholders and pledged either by the bond issuer or third parties, such as banks with letter-of-credit agreements, are actually supported by federal, state, and local government laws and regulations.

The popular notion is that much of the legal work done in a bond issue is boilerplate in nature, but from the bondholder's point of view, the legal opinions and document reviews should be the ultimate security provisions. The reason is that if all else fails, the bondholder may have to go to court to enforce security rights. Therefore, the integrity and competence of the lawyers who review the documents and write the legal opinions that are usually summarized and stated in the official statements are very important.

It should be noted that by 2020, there were thousands of attorneys in the business. They were located throughout the country and listed in the *The Bond Buyer's* "Red Book" Municipal Marketplace directory of municipal bond attorneys. They presented themselves as being experts in municipal finance law and provided various security structure and tax opinions. Sorting out quality distinctions in their work and who is well grounded in the law, and who is not, is challenging.

TYPES OF MUNICIPAL OBLIGATIONS

The number of municipal bond issuers is remarkable. One estimate places the total at approximately 50,000. Even more noteworthy is the number of different issues. As of 2020, the International Exchange (ICE),[1] provides daily prices for over a million individual issues. The Bloomberg Financial Markets' (Bloomberg) database,[2] as of 2020, contained over 5 million CUSIPS (including matured bonds). Of the 941,698 CUSIP numbers still active, Bloomberg updates them on a regular basis.

The number of different issues to choose from is staggering. Considering all the different types of issuers in the market—states, state agencies, cities, airports, colleges and universities, hospitals, continuing care retirement communities (CCRCs), school districts, toll roads and bridges, public power facilities, seaport facilities, water and sewer authorities, solid waste facilities, and other special purpose districts—the investment choices are overwhelming. Some of the issuers are extremely large and issue billions of dollars of debt. Some are extremely small and may only have \$1 to \$2 million in outstanding debt. Obviously, the characteristics

1. ICE is a securities information provider that specializes in data collection and internally authored evaluations. Data are delivered electronically to financial institutions and authorized redistribution vendors. Fixed income coverage encompasses the municipal and taxable bond markets. Another pricing service is Standard & Poor's Securities Evaluation Service.

2. Bloomberg Financial Markets is a multimedia distributor of information services that combines news, data, and analysis for global financial markets and business. The company's core business is a software network that delivers real-time financial information and links the world's financial markets and financial professionals.

of these issuers and their debt are very different, and both require independent and careful analysis. However, municipal bonds can be categorized into two broad security structures. In terms of municipal bond security structures, there are basically two different types. The first type is the general obligation bond, and the second is the revenue bond.

General Obligation Bonds

General obligation bonds are debt instruments issued by states, counties, special districts, cities, towns, and school districts. They are secured by the issuer's general taxing powers. Usually, a general obligation bond is secured by the issuer's unlimited taxing power. For smaller governmental jurisdictions, such as school districts and towns, the only available unlimited taxing power is on property. For larger general obligation bond issuers, such as states and big cities, the tax revenues are more diverse and may include corporate and individual income taxes, sales taxes, and property taxes. The security pledges for these larger issuers such as states sometimes are referred to as being *full faith and credit obligations*.

Additionally, certain general obligation bonds are secured not only by the issuer's general taxing powers to create monies accumulated in the general fund, but also from certain identified fees, grants, and special charges, which provide additional revenues from outside the general fund. Such bonds are known as being *double barreled* in security because of the dual nature of the revenue sources. Also, not all general obligation bonds are secured by unlimited taxing powers. Some have pledged taxes that are limited as to revenue sources and maximum property-tax millage amounts. Such bonds are known as *limited-tax general obligation bonds*.

Revenue Bonds

The second basic type of security structure is found in a revenue bond. Such bonds are issued for either project or enterprise financings in which the bond issuers pledge to the bondholders the revenues generated by the operating projects financed. Below are examples of the specific types of revenue bonds that have been issued over the years.

Airport Revenue Bonds

The revenues securing airport revenue bonds usually come from either traffic-generated sources—such as passenger charges, landing fees, concession fees, and airline apron-use and fueling fees—or lease revenues from one or more airlines for the use of a specific facility such as a terminal or hangar.

Charter School Bonds

These bonds are for publicly funded private schools that offer more institutional and academic flexibility than local public schools. State-aid funding usually follows the student who goes from a traditional public school to a charter school. Bond proceeds go for capital improvements.

College and University Revenue Bonds

The revenues securing college and university revenue bonds usually include dormitory room rental fees, tuition payments, and sometimes the general assets of the college or university as well.

Continuing Care Retirement Community Bonds

Life care or continuing care retirement community (CCRC) bonds are issued to construct long-term residential facilities for older citizens. Revenues usually are derived from initial lump-sum payments made by the residents and operating revenues.

Higher Education Bonds

Debt is often issued by institutions of higher education to finance the costs of building/renovating facilities or purchasing land for expansion. These bonds are secured by revenues of the given project, student charges, and/or a general obligation of the college or university.

Hospital Revenue Bonds

The security for hospital revenue bonds is usually dependent on federal and state reimbursement programs (such as Medicaid and Medicare), third-party commercial payers (such as Blue Cross and private insurance), health maintenance organizations (HMOs), and individual patient payments.

Industrial Development and Pollution Control Revenue Bonds

Bonds have been issued for a variety of industrial and commercial activities that range from manufacturing plants to shopping centers. They usually are secured by payments to be made by the corporations or businesses that use the facilities.

Land-Secured "Dirt" Bonds

Public infrastructure costs associated with new development projects on raw land are often financed by land-secured bonds, also known as "dirt" bonds. Revenue from the additional tax or assessment placed on the properties benefitting from these improvements is the primary security for the bondholders.

Multifamily Revenue Bonds

These revenue bonds usually are issued for multifamily housing projects for senior citizens and low-income families. Some housing revenue bonds are secured by mortgages that are federally insured; others receive federal government operating subsidies, such as under Section 8, or interest-cost subsidies, such as under Section 236; and still others receive only local property-tax reductions as subsidies.

Public Power Revenue Bonds

Public power revenue bonds are secured by revenues to be produced from electrical operating plants and distribution systems. Some bonds are for a single issuer, who constructs and operates power plants and then sells the electricity. Other public power revenue bonds are issued by groups of public and private investor-owned utilities for the joint financing of the construction of one or more power plants. This last arrangement is known as a *joint power* financing structure. During the past several years, this sector started to undergo the most dramatic changes since electricity was invented. In many states the electric utility industry is transforming to a deregulated industry. In a deregulated environment, customers will have the ability to choose an electric provider; therefore, electric providers will face competition. This means that this sector will experience new and different challenges, and investors will need to analyze this sector differently. Additional risk factors include the different energy sources such as coal, nuclear, hydro, natural gas, and solar.

Public-Private Partnerships (PPPs)

Privatization is a form of municipal financing where a private company pays a large payment to operate, and often build or improve, a governmental asset (e.g., usually toll roads). The purchaser issues debt to help finance this large upfront cost, and the operating revenues are pledged to repay bondholders.

Resource Recovery Revenue Bonds

A resource recovery facility converts refuse (solid waste) into commercially salable energy, recoverable products, and a residue to be landfilled. The major revenues for a resource recovery revenue bond usually are (1) the "tipping fees" per ton paid by those who deliver the garbage to the facility for disposal; (2) revenues from steam, electricity, or refuse-derived fuel sold to either an electrical power company or another energy user; and (3) revenues from the sale of recoverable materials such as aluminum and steel scrap.

Seaport Revenue Bonds

The security for seaport revenue bonds can include specific lease agreements with the benefiting companies or pledged marine terminal and cargo tonnage fees.

Sewer Revenue Bonds

Revenues for sewer revenue bonds come from hookup fees and user charges. For many older sewer bond issuers, substantial portions of their construction budgets have been financed with federal grants.

Single-Family Mortgage Revenue Bonds

Single-family mortgage revenue bonds usually are secured by the mortgages and mortgage loan repayments on single-family homes. Security features vary but can include Federal Housing Administration (FHA), Federal Veterans Administration (VA), and private mortgage insurance.

Sports Complex and Convention Center Revenue Bonds

Sports complex and convention center revenue bonds usually receive revenues from sporting or convention events held at the facilities and, in some instances, from earmarked outside revenues such as local motel and hotel room taxes.

Student Loan Revenue Bonds

Student loan revenue bonds usually are issued by state agencies or not-for-profit organizations and are used for purchasing student loans for higher education. Depending on the security structure, bondholders' payment can include student loan repayments and federal payments.

Tax-Allocation Bonds

These bonds are usually issued to finance the construction of office buildings and other new buildings in formerly blighted areas. They are secured by property taxes collected on the improved real estate.

Tobacco Revenue Bonds

Some tobacco bonds are usually solely secured by revenues in the Master Settlement Agreement (MSA) annually paid to states by cigarette companies.

Toll Road and Gas Tax Revenue Bonds

There are generally two types of highway revenue bonds. The bond proceeds of the first type are used to build such specific revenue-producing facilities as toll roads, bridges, and tunnels. For these pure enterprise-type revenue bonds, the pledged revenues usually are the monies collected through the tolls. The second type of highway bond is one in which the bondholders are paid by earmarked revenues outside toll collections, such as gasoline taxes, automobile registration payments, and driver's license fees.

Tribal Casino Bonds

Native American governments in general finance the construction of their casino gaming facilities by issuing debt. Tribal casino bonds derive their revenues from the gaming operations of these facilities.

Water Revenue Bonds

Water revenue bonds are issued to finance the construction of water treatment plants, pumping stations, collection facilities, and distribution systems. Revenues usually come from connection fees and charges paid by the users of the water systems.

Hybrid and Special Bond Securities

Although having certain characteristics of general obligation and revenue bonds, the following types of municipal bonds have more unique security structures as well.

Refunded Bonds

Although originally issued as either revenue or general obligation bonds, municipals are sometimes *refunded.* A refunding usually occurs when the original bonds are escrowed or collateralized either by direct obligations guaranteed by the U.S. government or other types of securities. The maturity schedules of the securities in the escrow fund are such that they pay when due the bond's maturity value, coupon, and premium payments (if any) on the refunded bonds. Once this cash-flow match is in place, the refunded bonds are no longer secured as either general obligation or revenue bonds. The bonds are now supported by the securities held in the escrow fund. Such bonds, if escrowed with securities guaranteed by the U.S. government, have little if any credit risk. They are the safest municipal bond investments available.

Usually, an escrow fund is an irrevocable trust established by the original bond issuer with a commercial bank or state treasurer's office. Government securities are deposited in an escrow fund that will be used to pay debt service on the refunded bonds. A *pure* escrow fund is one in which the deposited securities are solely direct or guaranteed obligations of the U.S. government, whereas a *mixed* escrow fund is one in which the permitted securities, as defined by the trust indenture, are not exclusively limited to direct or guaranteed U.S. government securities. Other securities that could be placed in mixed escrow funds include federal agency bonds, certificates of deposit from banks, other municipal bonds, and even annuity policies from commercial insurance companies. The escrow agreement should indicate what is in the escrow fund and if substitutions of lower-credit-quality investments are permitted.

Still another type of refunded bond is a *crossover refunded bond.* Typically, proceeds from crossover refunding bonds are used to purchase securities that are placed in an escrow account. Usually, the crossover refunding bonds are secured by maturing principal and interest from the escrowed securities *only until the crossover date,* and the bonds to be refunded continue to be secured by the issuer's own revenues until the crossover date, which is usually the first call date of the bonds to be refunded. On that date, the crossover occurs, and the bonds to be refunded are redeemed from maturing securities in the escrow fund, which could include U.S. government securities or other investments, such as certificates of deposit. In turn, the security for the refunding bonds reverts back to the issuer's own revenues.

Here we focus primarily on the pure escrow-backed bonds, not the mixed escrow or crossover bonds. The escrow fund for a refunded municipal bond can be structured so that the refunded bonds are to be called at the first possible date or a subsequent call date established in the original bond indenture. The call price usually includes a premium of from 1% to 3% above par. This type of structure usually is used for those refundings that either reduce the issuer's interest payment expenses or change the debt maturity schedule. Such bonds are known in the industry as *prerefunded* municipal bonds. Prerefunded municipal bonds usually are to be retired at their first or subsequent respective callable dates, but some escrow funds for refunding bonds have been structured differently. In such refundings, the maturity schedules of the securities in the escrow funds match the regular debt-service requirements on the bonds as originally stated in the bond indentures. Such bonds are known as *escrowed-to-maturity,* or ETM, bonds. It should be noted that under the TCJA, such ETM refundings still can be done though not with tax-exempt bonds. In the secondary market there may be ETM refunded municipal bonds outstanding. However, we note that the investor or trader should determine whether all earlier calls have been legally defeased before purchasing an ETM bond.

Dedicated Tax-Backed and Structured Asset-Backed Bonds

More recently, states and local governments have issued increasing amounts of bonds in which the debt service is to be paid from so-called dedicated revenues such as sales taxes, tobacco settlement payments, fees, and penalty payments. Many are structured to mimic the asset-backed bonds that are common in the taxable market. The "assets" providing the security for the municipal bonds are the "dedicated" revenues instead of credit card receivables, home equity loans, and auto loan repayments that are commonly used to secure the taxable asset-backed bonds.

Insured Bonds

Insured bonds, in addition to being secured by the issuer's revenues, are also backed by insurance policies written by commercial insurance companies. The insurance, usually structured as an insurance contract, is supposed to provide prompt payment to the bondholders if a default should occur. These bonds are discussed in more detail later in this chapter.

Lease-Backed Bonds

Lease-backed bonds usually are structured as revenue-type bonds with annual payments. In some instances the payments may come only from earmarked tax revenues, student tuition payments, or patient fees. In other instances the underlying lessee governmental unit makes annual appropriations from its general fund.

Letter of Credit–Backed Bonds

Some municipal bonds, in addition to being secured by the issuer's cash-flow revenues, also are backed by commercial bank letters of credit. In some instances the letters of credit are irrevocable and, if necessary, can be used to pay the bondholders. In other instances the issuers are required to maintain investment-quality worthiness before the letters of credit can be drawn on.

Moral Obligation Bonds

A moral obligation bond is a security structure usually for some state-issued bonds that indicates that if revenues are needed for paying bondholders, the state legislature involved is legally authorized, although not required, to make an appropriation out of general state tax revenues.

Territorial Bonds

These are bonds issued by U.S. territorial possessions such as Puerto Rico, the Virgin Islands, and Guam. The bonds are tax-exempt throughout most of the country. Also, the economies of these issuers may be influenced by positive special features of the U.S. corporate tax codes that are not available to the states.

Troubled City Bailout Bonds

There are certain bonds that are structured to appear as pure revenue bonds but in essence are not. Revenues come from general-purpose taxes and revenues that otherwise would have gone to a state's or city's general fund. Their bond structures were created to bail out underlying general obligation bond issuers from severe budget deficits. The Chicago Sales Tax Securitization Cooperation Bonds are an example.

Money Market Products

Tax-exempt money market products include notes, commercial paper, variable-rate demand obligations, and a hybrid of the last two products.

Notes

Municipal notes include tax anticipation notes (TANs), revenue anticipation notes (RANs), grant anticipation notes (GANs), and bond anticipation notes (BANs). These are temporary borrowings by states, local governments, and special jurisdictions. Usually, notes are issued for a period of 12 months, although it is not uncommon for notes to be issued for periods of as short as three months and for as long as three years. TANs and RANs (also known as TRANs) are issued in anticipation of the collection of taxes or other expected revenues. These are borrowings to even out the cash flows caused by the irregular flows of income into the treasuries of the states and local units of government. BANs are issued in anticipation of the sale of long-term bonds.

Tax-exempt money market products generally have some type of credit support. This may come in the form of an irrevocable letter of credit, a line of credit, municipal bond insurance policy, an escrow agreement, a bond purchase agreement, or a guaranteed investment contract. With a bond purchase agreement, a bank obligates itself to purchase the debt if the remarketing agent cannot resell the instrument or make a timely payment. In the case of a guaranteed investment contract, either an insurance company or a bank invests sufficient proceeds so that the cash flow generated from a portfolio of supporting assets can meet the obligation of the issue.

Commercial Paper

As with commercial paper issued by corporations, tax-exempt commercial paper is used by municipalities to raise funds on a short-term basis ranging from 1 to 270 days. The dealer sets interest rates for various maturity dates, and the investor then selects the desired date. Thus the investor has considerable choice in selecting a maturity to satisfy investment objectives.

Variable-Rate Demand Obligations

Variable-rate demand obligations (VRDOs) are floating-rate obligations that have a nominal long-term maturity but have a coupon rate that is reset either daily or every seven days. The investor has an option to put the issue back to the trustee at any time with seven days' notice or the same day in the case of a daily VRDO. The put price is par plus accrued interest.

Commercial Paper Mode

The commercial paper mode is customized to meet the cash-flow needs of an investor. As with tax-exempt commercial paper, there is flexibility in structuring the maturity because the remarketing agent establishes interest rates for a range of maturities. Although the instrument may have a long nominal maturity, there is a put provision as with a VRDO. Put periods can range from 1 day to more than 360 days. On the put date, the investor can put back the bonds, receiving principal and interest, or the investor can elect to extend the maturity at the new interest rate and put date posted by the remarketing agent at that time. Thus the investor has two choices when initially purchasing this instrument: the interest rate and the put date. Interest generally is paid on the put date if the date is within 180 days. If the put date is more than 180 days forward, interest is paid semiannually. Some commercial paper dealers market these products under a proprietary name, but most do so simply as money market municipals.

Municipal Derivative Securities

In recent years, a number of municipal products have been created from the basic fixed-rate municipal bond. This has been done by splitting up cash flows of newly issued bonds as well as bonds existing in the secondary markets. These products have been created by dividing the coupon interest payments and principal payments into two or more bond classes, or *tranches*. The resulting bond classes may have far different yield and price volatility characteristics than the underlying fixed-rate municipal bond from which they were created. By expanding the risk/return profile available in the municipal marketplace, institutional investors have more flexibility in structuring municipal bond portfolios either to satisfy a specific asset/liability objective or to make an interest rate or yield-curve bet more efficiently.

The name *derivative securities* has been attributed to these bond classes because they derive their value from the underlying fixed-rate municipal bond. Much of the development in this market has paralleled that of the taxable and, specifically, the mortgage-backed securities market. The ability of investment bankers to create these securities has been enhanced by the development of the municipal swap market.

A common type of derivative security is one in which two classes of securities, a *floating-rate security* and an *inverse floating-rate bond,* are created from a fixed-rate bond. Two types of inverse floaters dominated the market: auction rate securities and the later-developed tender option bond (TOB) product. TOB programs, in various forms, have existed since the beginning to middle 1980s. Widespread use did not occur until the 1990s.

In 2008, when failed auctions occurred, new issuance of auction rate securities ended. Functionally, TOBs are similar to the auction rate product. Both derivatives are inverse floaters. Auction rate floaters, however, were sold primarily to corporations and individuals, whereas TOB floaters are sold to money market funds. Tax-exempt money market funds have a continuous need for tax-exempt interest. This demand provided a stable buying base for the TOB floaters. To take advantage of this money market demand, TOBs feature a liquidity facility, which makes these floating-rate derivatives putable and therefore money market eligible. These liquidity facilities typically last 364 days and are provided by highly rated banks or broker-dealers.

TOBs are created through trusts. Given this structure, certain provisions must exist for the unwinding of a TOB. For example, if the remarketing agent fails to sell out the floating-rate class or the underlying bond falls below a minimum collateral value, a mandatory tender event is triggered. When a mandatory tender event occurs, the liquidity provider pays the floater holder par plus accrued interest. The trustee simultaneously terminates the trust and liquidates the bonds. The proceeds from this sale are used to first pay par plus accrued interest to the liquidity provider and then any accrued fees. Finally, the inverse floating-rate investor receives the residual value.

Several proprietary programs have been developed to market and sell plain vanilla TOBs, which are used by mutual bond funds, insurance companies, *and crossover buyers*. Additionally, at times TOBs are used in more exotic combination trades by a few Wall Street structured products areas.

THE COMMERCIAL CREDIT RATING OF MUNICIPAL BONDS

Of the municipal bonds that were rated by a commercial rating company in 1929 and plunged into default in 1932, 78% had been rated double-A or better, and 48% had been rated triple-A. Since then, the ability of rating agencies to assess the creditworthiness of municipal obligations has evolved to a level of general industry acceptance and respectability. In most instances, they adequately describe the financial conditions of the issuers and identify the credit-risk factors. However, a small but significant number of relatively recent instances have caused market participants to reexamine their reliance on the opinions of the rating agencies.

As examples, the troubled bonds of the Washington Public Power Supply System (WPPSS) and Orange County, California, should be mentioned. Two major commercial rating companies, Moody's and Standard & Poor's, gave their highest ratings to the WPPSS bonds in the early 1980s. Moody's gave the WPPSS Projects 1, 2, and 3 bonds its very highest credit rating of Aaa and the Projects 4 and 5 bonds its rating of Al. This latter investment-grade rating is defined as having the strongest investment attributes within the upper medium grade of creditworthiness. Standard & Poor's also had given the WPPSS Projects 1, 2, and 3 bonds its highest rating of AAA and Projects 4 and 5 bonds its rating of A. While these high-quality ratings were in effect, WPPSS sold more than $8 billion in long-term bonds. By 1990, more than $2 billion of these bonds were in default.

Orange County, California, also had very strong credit ratings before its filing for bankruptcy protection on December 6, 1994. This would be the largest municipal bankruptcy filing in U.S. history. The Orange County debacle was unique. The county's problem was not caused by local economic problems, like Philadelphia's crisis in the early 1990s, nor was it caused by budget problems, like New York City's situation in 1975. Orange County's problem was created by the county Treasurer–Tax Collector's investment strategy for the Orange County Investment Pool. The investment pool was highly leveraged and contained a large percentage of inverse floaters. As interest rates rose in 1994, the value of the investments decreased, and the institutions that provided the financial leverage decided to terminate those financial agreements. The problem was that if the investment pool were liquidated, the amount of assets would be insufficient to cover all the loans. Since the pool did not have sufficient assets to cover its debt, the county chose to seek the safety of bankruptcy protection.

The county's voluntary bankruptcy filing was unprecedented. It was a signal to investors that the county did not necessarily intend to repay all its obligations. In most other cases of severe financial hardship, the municipalities tried to meet all their obligations and did not even suggest that they might wish not to fulfill their obligations. What troubled most investors was that Orange County was a vibrant and economically strong area and in all likelihood could fulfill its obligations. This created a different situation for investors and brought the question of an issuer's ability to pay versus its willingness to pay. This was something that municipal investors rarely, if ever, questioned before Orange County.

Another area investors rarely questioned prior to Orange County was the investment strategies that were being used to manage operating fund investments and other state and local investment funds or pools. It was a common perception that state and local government finance officials invested conservatively and followed policies that emphasized safety of principal and maintenance of liquidity. Immediately following the onset of the Orange County debacle, large investors started to question state and local officials on their investment policies and their use of financial leverage and derivative securities. Because Orange County received high-quality credit ratings prior to its problems, investors started to question the reliability of the commercial credit-rating agencies.

The Washington Public Power Supply System and Orange County, California, are the more notable issuers that had high-quality ratings prior to their problems, but they are not isolated instances. In fact, since 1975, all the major municipal defaults in the industry initially had been given investment-grade ratings by Moody's and Standard & Poor's. Of course, it should be noted that in the majority of instances, ratings of the commercial rating companies adequately reflect the condition of the credit. However, unlike 40 years ago, when the commercial rating companies would not rate many kinds of revenue bond issues, today they seem to view themselves as assisting in the capital formation process.

After criticism by some public officials on the federal and state levels, we note that in 2009 the rating agencies recalibrated their ratings upward on many general obligation and essential service revenue bonds. They argued that municipal bond issues should have higher ratings relative to corporate bonds because of historical default rates and recovery levels. This resulted in higher ratings on many municipal bonds.

More recently, highly visible defaults in 2013 and 2014 of $9.5 billion of Detroit's municipal bonds, followed by the defaults in 2014, 2015, and 2016 of $57.2 billion of Puerto Rico municipal bonds, drew increased attention to the reliability of credit ratings on municipal bonds.

Today, many large institutional investors, underwriters, and traders use the ratings of the commercial rating agencies as starting points and rely on their own in-house municipal credit analysts for determining the creditworthiness of municipal bonds. However, other investors do not perform their own credit-risk analysis but instead rely entirely on credit-risk ratings by Moody's, Standard & Poor's, and Fitch. In this section we discuss the rating categories of these three commercial rating companies.

Moody's Investors Service

The municipal bond rating system used by Moody's grades the investment quality of municipal bonds in a nine-symbol system that ranges from the highest investment quality, which is Aaa, to the lowest credit rating, which is C. The respective nine alphabetical ratings and their definitions are found in Exhibit 9-1. Moody's, like the other credit rating agencies, sometimes attaches an "outlook" designation such as "Positive," "Negative," or "Stable" to the bond rating. Moreover, the term "Watch" is designated for a rating change within the next year or so.

Municipal bonds in the top four categories (Aaa, Aa, A, and Baa) are considered to be of investment-grade quality. Speculative or noninvestment grade ratings incorporate the five lower rating grade categories (Ba, B, Caa, Ca, and C). Additionally, bonds in the Aa through Caa categories are refined by numeric modifiers 1, 2, and 3, with 1 indicating the top third of the rating category, 2 the middle third, and 3 the bottom third.

The municipal note rating system used by Moody's is designated by investment-grade categories of Moody's Investment Grade (MIG), and one speculative grade category; SG as shown in Exhibit 9-2.

Moody's also provides credit ratings for tax-exempt commercial paper. These are promissory obligations not having an original maturity in excess of nine months. Moody's uses three designations, all considered to be of investment grade, and one speculative grade category for indicating the relative repayment capacity of the rated issuers, as shown in Exhibit 9-3.

EXHIBIT 9-1

Moody's Municipal Bond Ratings

Rating	Definition
Aaa	Highest quality, minimal credit risk
Aa	High quality, very low credit risk
A	Upper medium grade, low credit risk
Baa	Moderate credit risk
Ba	Speculative elements, substantial credit risk
B	Speculative, high credit risk
Caa	Poor standing, very high credit risk
Ca	Highly speculative, in or near default
C	In default with no recovery expected

EXHIBIT 9-2

Moody's Municipal Note Ratings*

Rating	Definition
MIG 1	Excellent Protection
MIG 2	Strong quality
MIG 3	Acceptable quality
SG	Speculative Grade

*A short issue having a demand feature (i.e., payment relying on external liquidity and usually payable on demand rather than fixed maturity dates) is differentiated by Moody's with the use of the symbols *VMIG1* through *VMIG3*, and *VSG*.

EXHIBIT 9-3

Moody's Tax-Exempt Commercial Paper Ratings

Rating	Definition
Prime 1 (P-1)	Superior capacity for repayment
Prime 2 (P-2)	Strong capacity for repayment
Prime 3 (P-3)	Acceptable capacity for repayment
NP	Not Prime Grade

Standard & Poor's

The municipal bond rating system used by Standard & Poor's grades the investment quality of municipal bonds in a 10-symbol system that ranges from the highest investment quality, which is AAA, to the lowest credit rating, which is D.[3] Bonds within the top four categories (AAA, AA, A, and BBB) are considered by Standard & Poor's as being of investment-grade quality. The respective 10 alphabetical ratings and definitions are shown in Exhibit 9-4.

Standard & Poor's also uses a plus (+) or minus (−) sign to show relative standing within the rating categories ranging from AA to CCC.

The municipal note rating system used by Standard & Poor's grades the investment quality of municipal notes in a four-symbol system that ranges from highest investment quality, SP-1, to the lowest credit rating, D. Notes within the top three categories (i.e., SP-1, SP-2, and SP-3) are considered by Standard & Poor's as being of investment-grade quality. The respective ratings and summarized definitions are shown in Exhibit 9-5.

Standard & Poor's also rates tax-exempt commercial paper. The tax-exempt commercial paper rating categories are shown in Exhibit 9-6.

Fitch

The third rating company is Fitch. The alphabetical ratings and definitions used by Fitch are given in Exhibit 9-7. Plus (+) and minus (−) signs are used with a

EXHIBIT 9-4

Standard & Poor's Municipal Bond Ratings

Rating	Definition
AAA	Highest rating; extremely strong security
AA	Very strong security
A	Somewhat more susceptible to adverse economic effects than two above categories
BBB	Adequate capacity but adverse economic conditions more likely to weaken capacity
BB	Lowest degree of speculation; risk exposure
B	Speculative; risk exposure
CCC	Speculative; major risk exposure
CC	Highly vulnerable to nonpayment
C	Bankruptcy petition may be filed
D	Bonds in default with interest and/or repayment of principal in arrears

3. www.standardandpoors.com. Standard & Poor's Global Ratings, February 25, 2020.

EXHIBIT 9-5

Standard & Poor's Municipal Note Ratings

Rating	Definition
SP-1	Strong capacity to pay principal and interest. Those issues determined to possess overwhelming safety characteristic will be given a plus (+) designation.
SP-2	Satisfactory capacity to pay principal and interest.
SP-3	Speculative capacity to pay principal and interest.
D	Default

EXHIBIT 9-6

Standard & Poor's Tax-Exempt Commercial Paper Ratings

Rating	Definition
A-1+	Extremely strong degree of safety
A-1	Strong degree of safety
A-2	Satisfactory degree of safety
A-3	Adequate degree of safety
B	Speculative capacity for timely payment
C	Doubtful capacity for payment
D	Used when principal or interest payments are not made on the due date

EXHIBIT 9-7

Fitch Municipal Bond Ratings

Rating	Definition
AAA	Highest credit quality
AA	Very high credit quality
A	High credit quality
BBB	Good
BB	Speculative
B	Highly speculative
CCC	Substantial credit risk
CC	Very high levels of credit risk
C	Exceptionally high levels of credit risk
D	Default

rating to indicate the relative position of a credit within the rating category.[4] Plus and minus signs are not used for the AAA category.

Additionally, Fitch assigns ratings for obligations that are due up to 36 months. The rating scale has three investment grade symbols, F1 (the highest), F2, and F3. There are two speculative scales, B and C. There is a rating RD for an entity that has defaulted on one or more of its financial commitments, although it is meeting other financial obligations. Lastly, D indicates a broad-based default event for an entity, or the default of a short-term obligation.

A fourth and smaller rating agency is Kroll Bond Rating Agency (KBRA).

MUNICIPAL BOND INSURANCE

Using municipal bond insurance was considered for many years one way to help reduce credit risk within a portfolio. Because of this, it had great appeal to retail investors. Insurance on a municipal bond was an agreement by an insurance company to pay debt service that is not paid by the bond issuer. Municipal bond insurance contracts insure the payment of debt service on a municipal bond to the bondholder. That is, the insurance company promised to pay the issuer's obligation to the bondholder if the issuer did not do so.

The insurance usually was for the life of the issue. If the trustee or investor had not had his bond paid by the issuer on its due date, he notified the insurer and presented the defaulted bond and coupon. Under the terms of the insurance contract, the insurer generally was obligated to pay sufficient monies to cover the value of the defaulted insured principal and coupon interest when they came due.

Because it was believed that municipal bond insurance reduced the credit risk for the investor, the marketability of certain municipal bonds was greatly expanded. Municipal bonds that benefited most from the insurance would include lower-quality bonds, bonds issued by smaller governmental units not widely known in the financial community, bonds that had a sound although complex and difficult-to-understand security structure, and bonds issued by infrequent local government borrowers who do not have a general market following among investors.

Of course, a major factor for an issuer to obtain bond insurance was that its creditworthiness without the insurance was substantially lower than what it would be with the insurance. That is, the interest cost savings were only of sufficient magnitude to offset the cost of the insurance premium when the underlying creditworthiness of the issuer was lower. The major group of bond insurers are "monoline" companies that were primarily in the business of insuring financial securities, including municipal bonds. Almost all the companies that insured municipal bonds could be characterized as monoline in structure.

While for many years until 2008, the majority of insured bonds were with the monoline insurers—most of whom had AAA ratings from all three major

4. Fitch Ratings Definitions, February 2020.

agencies, and captured 47% of the new issue market—this dramatically changed. With massive defaults in their taxable books of insured bonds, they were rapidly downgraded and faced insolvency. As of 2020, there were mainly two monoline insurers writing business in the financial guaranty insurance sector: Assured Guaranty (rated double A by both Moody's and S&P) and Build America Mutual (BAM) rated double A by S&P. Market share was 6%.

VALUATION METHODS

The traditional method for evaluating municipal bonds is relatively straightforward. First, an investor determines the maturity of the bond, considers the offered price (discount, par, or premium), evaluates any call features or sinking funds, and then considers credit quality. If it is a premium bond and callable, then the investor places more emphasis on the call dates. If the bond is callable and sells at a discount, then the calls are not much of a factor, and the bond is valued using its maturity date. Basically, the investor is determining the relative attractiveness of the bond based on a yield-to-worst calculation. The credit quality is quantified, and the appropriate yield premium for the specific credit quality is added to the base yield-to-worst calculation. Because investors do not perform an option-adjusted spread (OAS) analysis, the yield premium that is applied is a nominal yield premium. The benchmark yields that are used to value the bonds come from a variety of sources, such as yield levels from the primary market, trading levels of similar bonds in the secondary market, and benchmark (triple-A GO, generic sector, state-specific) interest-rate curves.

An investor interested in purchasing a municipal bond must be able to compare the promised yield on a municipal bond with that of a comparable taxable bond. Employing the yield computed with traditional approaches, the following general formula is used to determine the *equivalent taxable yield* for a tax-exempt bond:

$$\text{Equivalent taxable yield} = \frac{\text{tax} - \text{exempt yield}}{(1 - \text{marginal tax rate})}$$

For example, suppose that an investor in the 40% marginal tax bracket is considering the acquisition of a tax-exempt bond that offers a tax-exempt yield of 6%. The equivalent taxable yield is 10%, as shown below:

$$\text{Equivalent taxable yield} = \frac{0.06}{(1 - 0.40)} = 0.10 = 10\%$$

When computing the equivalent taxable yield, the traditionally computed yield-to-maturity is not the tax-exempt yield if the issue is selling below par (i.e., selling at a discount) because only the coupon interest is exempt from federal income taxes. Instead, the yield-to-maturity after an assumed capital gains tax is computed and used in the numerator of the formula.

The yield-to-maturity after an assumed capital gains tax is calculated in the same manner as the traditional yield-to-maturity. However, instead of using the redemption value in the calculation, the net proceeds after an assumed tax on any capital gain are used.

There is a major drawback in employing the equivalent taxable yield formula to compare the relative investment merits of a taxable and tax-exempt bond. Recall from the discussion in Chapter 4 that the yield-to-maturity measure assumes that the entire coupon interest can be reinvested at the computed yield. Consequently, taxable bonds with the same yield-to-maturity cannot be compared because the total dollar returns may differ from the computed yield. The same problem arises when attempting to compare taxable and tax-exempt bonds, especially because only a portion of the coupon interest on taxable bonds can be reinvested, although the entire coupon payment is available for reinvestment in the case of municipal bonds. The total return framework that should be employed to compare taxable and tax-exempt bonds is discussed in Chapter 4.

The traditional method of evaluating a municipal bond leaves much to be desired. The basic problem is that the call risk is not analyzed properly. The yield-to-worst calculation ignores the fact that interest rates can change in the future, and the actual timing of the cash flows may not be the same as what was projected. If an investor evaluates a bond to its maturity date, then this investor will be surprised if the bonds are called several years earlier. Conversely, if the investor evaluates a bond to a specific call date and the bond is not called, then this investor will realize a stream of cash flows that is different from what was anticipated. The result of the traditional methodology is that most callable municipal bonds are priced too richly, and the cost of noncallable bonds with extra convexity is cheap. This is especially true for longer-dated bonds. More information about OAS analysis can be found in Chapter 36.

TAX PROVISIONS AFFECTING MUNICIPALS

Federal tax rate levels affect municipal bond values and strategies employed by investors. There are three provisions in the Internal Revenue Code that investors in municipal securities should recognize. These provisions deal with the tax treatment of OIDs, alternative minimum tax, and the deductibility of interest expense incurred to acquire municipal securities. Moreover, there are state and local taxes about which an investor must be aware.

Tax Treatment of Original-Issue Discount Bonds

When purchasing OIDs in the secondary market, investors should analyze the bond carefully owing to the complex tax treatment of OIDs. Few investors think about tax implications when investing in municipal debt. After all, the interest earned on most municipal bonds is exempt from federal taxes. If investors do think about taxes, they probably think about selling bonds at a higher price than the original tax cost. Most investors believe that this would create a capital gain and absent this situation there should be no tax impact. Sounds straightforward, but the municipal world isn't simplistic. Several years ago the marketplace was introduced to the Revenue Reconciliation Act of 1993, and since then investing in municipals has become more complex. Currently, profit from bonds purchased in the secondary market after April 30, 1993, could be free from any tax implications or taxed at the capital gains rate, ordinary income rate, or a combination of the two rates. To understand this situation, it is essential to understand the rule of de minimus.

In basic terms, the *rule of de minimu*s states that a bond is to be discounted up to 0.25% from the face value for each remaining year of a bond's life before it is affected by ordinary income taxes. This price is commonly referred to as the "market discount cutoff price." If the bond is purchased at a market discount but the price is higher than the market discount cutoff price, then any profits will be taxed at the capital gains rate. If the purchase price is lower than the market discount cutoff price, then any profits may be taxed as ordinary income or a combination of the ordinary income rate and the capital gains rate. The exact tax burden depends on several factors.

The rule of de minimus is especially complicated for OID bonds. For these bonds, a revised issue price must be calculated, as well as the market discount cutoff price. The revised issue price does change over time because the OID must be accreted over the life of the bond. The rule of de minimus does not apply to the OID segment, but it does apply to the market discount segment. The market discount segment is equal to the purchase price (secondary market price) minus the revised issue price. If an OID bond is purchased in the secondary market at a price greater than the revised issue price, the bond is considered to have an acquisition premium, and the rule of de minimus does not apply. If the OID bond is purchased at a price below the revised issue price and above the market discount cutoff price, then the OID bond is purchased at a market discount, and any profits will be taxed at the capital gains rate. Finally, if the purchase price of the OID bond is lower than the market discount cutoff price, then any profits may be taxed as ordinary income or a combination of the ordinary income rate and the capital gains rate. The OID topic is complicated. More specific details can be found in the Internal Revenue Service (IRS) Publications.

Alternative Minimum Tax

Alternative minimum taxable income (AMTI) is a taxpayer's taxable income with certain adjustments for specified tax preferences designed to cause AMTI to approximate economic income. For individuals, a taxpayer's liability is the greater of (1) the tax computed at regular tax rates on taxable income and (2) the tax computed at a lower rate on AMTI. This parallel tax system, the alternative minimum tax (AMT), is designed to prevent taxpayers from avoiding significant tax liability as a result of taking advantage of exclusions from gross income, deductions, and tax credits otherwise allowed under the Internal Revenue Code.

Under TCJA, corporations are not subject to the AMT.

One of the tax preference items that must be included is certain tax-exempt municipal interest. As a result of the AMT, the value of the tax-exempt feature is reduced. However, the interest of some municipal issues is not subject to the AMT. Under the current tax code, tax-exempt interest earned on all private activity bonds issued after August 7, 1986, must be included in AMTI. There are two exceptions. First, interest from bonds that are issued by 501(c)(3) organizations (i.e., not-for-profit organizations) is not subject to AMTI. The second exception is interest from bonds issued for the purpose of refunding if the original bonds were issued before August 7, 1986. The AMT does not apply to interest on governmental or nonprivate activity municipal bonds. An implication is that the issues subjected to the AMT will trade at a higher yield than those exempt from AMT.

Deductibility of Interest Expense Incurred to Acquire Municipals

Some investment strategies involve the borrowing of funds to purchase or carry securities. Ordinarily, interest expense on borrowed funds to purchase or carry investment securities is tax deductible. There is one exception that is relevant to investors in municipal bonds. The IRS specifies that interest paid or accrued on "indebtedness incurred or continued to purchase or carry obligations, the interest on which is wholly exempt from taxes," is not tax deductible. It does not make any difference if any tax-exempt interest is actually received by the taxpayer in the taxable year. In other words, interest is not deductible on funds borrowed to purchase or carry tax-exempt securities.

Special rules apply to commercial banks. At one time, banks were permitted to deduct all the interest expense incurred to purchase or carry municipal securities. Tax legislation subsequently limited the deduction first to 85% of the interest expense and then to 80%. The 1986 tax law eliminated the deductibility of the interest expense for bonds acquired after August 6, 1986. The exception to this nondeductibility of interest expense rule is for *bank-qualified issues*. These are tax-exempt obligations sold by small issuers after August 6, 1986, and purchased by the bank for its investment portfolio.

An issue is bank-qualified if (1) it is a tax-exempt issue other than private activity bonds, but including any bonds issued by 501(c)(3) organizations, and (2) it is designated by the issuer as bank-qualified and the issuer or its subordinate entities reasonably do not intend to issue more than $10 million of such bonds. A nationally recognized and experienced bond attorney should include in the opinion letter for the specific bond issue that the bonds are bank-qualified.

State and Local Taxes

The tax treatment of municipal bonds varies by state. There are three types of taxes that can be imposed: (1) an income tax on coupon income, (2) a tax on realized capital gains, and (3) a personal property tax.

Many states levy an individual income tax. Coupon interest from obligations by in-state issuers is exempt from state individual income taxes in most states. A few states levy individual income taxes on coupon interest whether the issuer is in state or out of state.

State taxation of realized capital gains is often ignored by investors when making investment decisions. In many states, a tax is levied on a base that includes income from capital transactions (i.e., capital gains or losses). In many states in which coupon interest is exempt if the issuer is in state, the same exemption will not apply to capital gains involving municipal bonds.

Some states levy a personal property tax on municipal bonds. The tax resembles more of an income tax than a personal property tax. Before 1995, some state and local governments levied this tax on residents who owned municipal bonds where the issuer of the bond was located outside the investor's home state. While residents owning municipal bonds where the issuer was located within the investor's home state's boundaries were exempt from such tax, this tax was declared unconstitutional by the U.S. Supreme Court because it violated the federal commerce clause by favoring in-state businesses over out-of-state businesses. The determining case was *Fulton Corporation* v. *Janice H. Faulkner, Secretary of Revenue of North Carolina,* No. 94-1239 (U.S. S.C. Feb. 21, 1996). After the court ruled on this case, many state and local governments that levied a similar tax repealed the tax or chose not to collect it.

In determining the effective tax rate imposed by a particular state, an investor must consider the impact of the deductibility of state taxes on federal income taxes. Moreover, in some states, *federal* taxes are deductible in determining state income taxes. It should be noted that under TCJA, the state and local tax deduction was limited to a combination of $10,000 for income, sales, and property taxes.

YIELD RELATIONSHIPS WITHIN THE MUNICIPAL BOND MARKET

In this section, we briefly look at some important yield relationships within the municipal bond market.

Differences Within an Assigned Credit Rating

Bond buyers primarily use the credit ratings assigned by the commercial rating companies, Standard & Poor's, Moody's, and Fitch, as a starting point for pricing an issue. The final market-derived bond price is determined by the assigned credit rating and adjustments by investors to reflect their own analysis of creditworthiness and perception of marketability. For example, insured municipal bonds—when they were a dominant factor in the market—tended to have yields that were substantially higher than noninsured superior-investment-quality municipal bonds, even though most insured bonds were given triple-A ratings by the commercial rating companies. Additionally, many investors have geographic preferences among bonds despite identical credit quality and otherwise comparable investment characteristics.

Differences Between Credit Ratings

With all other factors constant, the greater the credit risk perceived by investors, the higher the return expected by investors. The spread between municipal bonds of different credit quality is not constant over time. Reasons for the change in spreads are (1) the outlook for the economy and its anticipated impact on issuers, (2) federal budget financing needs, and (3) municipal market supply-and-demand factors. During periods of relatively low interest rates, investors sometimes increase their holdings of issues of lower credit quality in order to obtain additional yield. This narrows the spread between high-grade and lower-grade credit issues. During periods in which investors anticipate a poor economic climate, there is often a "flight to quality" as investors pursue a more conservative credit-risk exposure. This widens the spread between high-grade and lower-grade credit issues.

Another factor that causes shifts in the spread between issues of different quality is the temporary oversupply of issues within a market sector. For example, a substantial new issue volume of high-grade state general obligation bonds may tend to decrease the spread between high-grade and lower-grade revenue bonds. In a weak market environment, it is easier for high-grade municipal bonds to come to market than for weaker credits. Therefore, it is not uncommon for high grades to flood weak markets at the same time that there is a relative scarcity of medium- and low-grade municipal bond issues.

Differences Between In-State and General Market

Bonds of municipal issuers located in certain states (e.g., New York, New Jersey, California, Arizona, Maryland, and Pennsylvania) usually yield considerably less than issues of identical credit quality that come from other states that trade in the "general market." There are three reasons for the existence of such spreads. First, states often exempt interest from in-state issues from state and local personal income taxes. Interest from out-of-state issues is generally not exempt. Consequently, in states with high income taxes (e.g., New York and California), strong investor demand for in-state issues will reduce their yields relative to bonds of issues located in states in which state and local income taxes are not important considerations (e.g., Illinois and Wisconsin). Of course, it should be noted that bonds of Puerto Rico and other U.S. territorial governments are also exempt from state and local taxation, and enjoy these yield advantages. Second, in some states, public funds deposited in banks must be collateralized by the bank accepting the deposit. This requirement is referred to as "pledging." Acceptable collateral for pledging typically will include issues of certain in-state issuers. For those qualifying issues, pledging tends to increase demand (particularly for the shorter maturities) and reduce yields relative to nonqualifying comparable issues. The third reason is that investors in some states exhibit extreme reluctance to purchase issues from issuers outside their state or region. In-state parochialism tends to decrease relative yields of issues from states in which investors exhibit this behavior.

Differences Between Maturities

One determinant of the yield on a bond is the number of years remaining to maturity. As explained in Chapter 3, the yield-curve depicts the relationship at a given point in time between yields and maturity for bonds that are identical in every way except maturity. When yields increase with maturity, the yield-curve is said to be *normal* or *have a positive slope.* Therefore, as investors lengthen their maturity, they require a greater yield. It is also possible for the yield-curve to be *inverted,* meaning that long-term yields are less than short-term yields. If short, intermediate, and long-term yields are roughly the same, the yield-curve is said to be *flat*.

In the taxable bond market, it is not unusual to find all three shapes for the yield-curve at different points in the business cycle. However, in the municipal bond market, the yield-curve typically is normal or upward-sloping. Consequently, in the municipal bond market, long-term bonds generally offer higher yields than short- and intermediate-term bonds.

PRIMARY AND SECONDARY MARKETS

The municipal market can be divided into the primary market and the secondary market. The primary market is one in which all new issues of municipal bonds are sold for the first time. The secondary market is the market in which previously issued municipal securities are traded.

Primary Market

A substantial number of municipal obligations are brought to market each week. A state or local government can market its new issue by offering bonds publicly to the investing community or by placing them privately with a small group of investors. When a public offering is selected, the issue usually is underwritten by investment bankers or municipal bond departments of commercial banks. Public offerings may be marketed by either competitive bidding or direct negotiations with underwriters. When an issue is marketed via competitive bidding, the issue is awarded to the bidder submitting the best bid.

Most states mandate that general obligation issues be marketed through competitive bidding, but generally this is not required for revenue bonds. Usually state and local governments require a competitive sale to be announced in a recognized financial publication, such as *The Bond Buyer,* which is the trade publication for the municipal bond industry. *The Bond Buyer* also provides information on upcoming competitive sales and most negotiated sales, as well as the results of previous weeks.

The sale of bonds by issuers, both competitively and through negotiation, has become more efficient and software based. Two companies offer this service for competitive bond sales. One is Ipreo, which also provides a software platform for negotiated bond sales. The other is the Grant Street Group, which focuses on competitive sales in the municipal market.

Secondary Market

Municipal bonds are traded in the over-the-counter markets supported by municipal bond dealers across the country. Markets are maintained on smaller issuers (referred to as *local credits*) by regional brokerage firms, local banks, and some of the larger Wall Street firms. Larger issuers (referred to as *general market names*) are supported by the larger brokerage firms and banks, many of which have investment banking relationships with these issuers. There are brokers who serve as intermediaries in the sale of large blocks of municipal bonds among dealers and large institutional investors. Additionally, beginning in 2000, bonds in the secondary market, as well as some new issue competitive and negotiated bond issues, began to be auctioned and sold over the Internet by large and small broker-dealers to institutional and individual investors.

In the municipal bond markets, an odd lot of bonds is $5,000 or less in par value for retail investors. For institutions, anything below $1 million in par value is considered an odd lot. Dealer spreads depend on several factors. For the retail investor, the spread can range from as low as one-quarter of one point ($12.50 per $5,000 of par value) on large blocks of actively traded bonds to three points ($150 per $5,000 of par value) for odd-lot sales of an inactive issue. For retail investors, the typical commission should be between 1 and 3 points. For institutional investors, the dealer spread rarely exceeds one-half of 1 point ($25 per $5,000 of par value).

The convention for both corporate and Treasury bonds is to quote prices as a percentage of par value, with 100 equal to par. Municipal bonds, however, generally are traded and quoted in terms of yield (yield-to-maturity or yield-to-call). The price of the bond in this case is called a *basis price.* Certain long-maturity revenue bonds are exceptions. A bond traded and quoted in dollar prices (actually, as a percentage of par value) is called a *dollar bond.*

It should be noted that many institutional investors, for trading and bond purchasing purposes, price bonds off the MMD scale. This is a daily index of generic AAA's prices covering the full yield-curve provided by Thomson Municipal Market Data and available to subscribers over the Internet. Also, the Municipal Securities Rulemaking Board (MSRB) in Washington, DC, reports on a daily basis for no charge actual trades and prices of specific bonds in its EMMA site.[5]

5. www.MSRB.org.

BOND INDEXES

The major provider of total return-based indexes to institutional investors is Bloomberg. Investors use the Bloomberg Barclays Municipal Bond index (formerly Barclays and before that the Lehman Brothers Municipal Bond index) to measure relative total return performance and enhance a fund manager's ability to outperform the market. Lehman began publishing municipal indexes in January of 1980 and by 2020 Bloomberg compiles returns and statistics on more than 2,500 benchmarks. They are broad-based performance measures for the tax-exempt bond market. Similar to all bond indexes provided by Bloomberg, the municipal indexes are rules based and market value weighted. As of 2020, the Bloomberg Barclays Municipal Bond Index contained more than 55,000 bonds with a market value of about $1.2 trillion. To be included in the index, bonds must have a minimum credit rating of Baa/BBB. They must have an outstanding par value of at least $7 million and be part of a transaction of $75 million or greater. The bonds must have been issued after December 31, 1990, and have a remaining maturity of at least one year.

In addition to investment-grade indexes, Bloomberg offers total return benchmarks for the noninvestment-grade tax-exempt market. To ensure statistically significant, representative benchmarks for the lower capitalized states, Bloomberg provides state-specific municipal benchmarks with reduced liquidity requirements.

Many investors use Bloomberg indexes as performance measures for a given market or market segment. The benchmarks are also employed to identify and quantify portfolio bets versus the general market and/or a given peer group.

Indexes also are used to identify relative value opportunities as well as a proxy for the outstanding market. Given the consistent methodologies, the Bloomberg indexes are used often when comparing tax-exempt and taxable fixed income markets.

In addition to the Bloomberg indexes, ICE data services publishes a number of the ICE Merrill Lynch municipal bond indexes. Their product is the ICE US Broad Municipal Index which tracks the performance of more than 58,000 investment-grade tax-exempt municipal bonds. *The Bond Buyer,* the trade daily newspaper, publishes weekly yield indexes.

There are also two services that in the afternoon of each trading day make available generic scales for different maturities and credit ratings. As noted, one is provided by Thomson Municipal Market Data, known in the industry as the MMD scale. The other is by Municipal Market Advisors (MMA).

OFFICIAL STATEMENT

An official statement describing the issue and issuer is prepared for new offerings. Often a preliminary official statement is issued prior to the final official statement. These statements are known as the OS and POS. These statements provide potential investors with a wealth of information. The statements contain basic information about the amount of bonds to be issued, maturity dates, coupons, the use of the bond proceeds, the credit ratings, a general statement about the issuer, and the name of the underwriter and members of the selling group. Much of this information can be found on the cover page or the first few pages of the official statement. It also contains detailed information about the security and sources of payments for the bonds, sources and uses of funds, debt-service requirements, relevant risk factors, issuer's financial statements, a summary of the bond indenture, relevant agreements, notice of any known existing or pending litigation, the bond insurance policy specimen (if insured), and the form of opinion of bond counsel. The official statement contains most of the information an investor will need to make an informed and educated investment decision.

REGULATION OF THE MUNICIPAL SECURITIES MARKET

As an outgrowth of abusive stock market practices, Congress passed the Securities Act of 1933 and the Securities Exchange Act of 1934. The 1934 act created the Securities and Exchange Commission (SEC), granting it regulatory authority over the issuance and trading of *corporate* securities. Congress specifically exempted municipal securities from both the registration requirements of the 1933 act and the periodic reporting requirements of the 1934 act. However, antifraud provisions did apply to offerings of or dealings in municipal securities.

The exemption afforded municipal securities appears to have been due to (1) the desire for governmental comity, (2) the absence of recurrent abuses in transactions involving municipal securities, (3) the greater level of sophistication of investors in this segment of the securities markets (i.e., institutional investors dominated the market), and (4) the fact that there were few defaults by municipal issuers. Consequently, from the enactment of the two federal securities acts in the early 1930s to the early 1970s, the municipal securities market can be characterized as relatively free from federal regulation.

In the early 1970s, however, circumstances changed. As incomes rose, individuals participated in the municipal securities market to a much greater extent. As a result, public outcries over selling practices occurred with greater frequency. For example, in the early 1970s, the SEC obtained seven injunctions against 72 defendants for fraudulent municipal trading practices. According to the SEC, the abusive practices involved both disregard by the defendants as to whether the particular municipal bonds offered to individuals were in fact appropriate investment vehicles for the individuals to whom they were offered, and misrepresentation—failure to disclose information necessary for individuals to assess the credit risk of the municipal issuer, especially in the case of revenue bonds. Moreover, the financial problems of some municipal issuers, notably New York City, made market participants aware that municipal issuers have the potential to experience severe and bankruptcy-type financial difficulties.

Congress passed the Securities Act Amendment of 1975 to broaden regulation in the municipals market. The legislation brought brokers and dealers in the municipal securities market, including banks that underwrite and trade municipal securities, within the regulatory scheme of the Securities Exchange Act of 1934. In addition, the legislation mandated that the SEC establish a 15-member (now 21-member) Municipal Securities Rulemaking Board (MSRB) as an independent, self-regulatory agency whose primary responsibility is to develop rules governing the activities of banks, brokers, and dealers in municipal securities. Rules adopted by the MSRB must be approved by the SEC. The MSRB has no enforcement or inspection authority. This authority is vested with the SEC, the National Association of Securities Dealers, and certain regulatory banking agencies such as the Federal Reserve banks. The Securities Act Amendment of 1975 does *not* require that municipal issuers comply with the registration requirement of the 1933 act or the periodic-reporting requirement of the 1934 act. There have been, however, several legislative proposals to mandate financial disclosure. Although none has been passed, there is clearly pressure to improve disclosure. Even in the absence of federal legislation dealing with the regulation of financial disclosure, underwriters began insisting on greater disclosure as it became apparent that the SEC was exercising stricter application of the antifraud provisions. Moreover, underwriters recognized the need for improved disclosure to sell municipal securities to an investing public that has become much more concerned about credit risk by municipal issuers. On June 28, 1989, the SEC formally approved the first bond disclosure rule, effective January 1, 1990. The following paragraphs summarize its contents. The rule applies to all new issue municipal securities offerings of $1 million or more. Exemptions have been added for securities offered in denominations of $100,000 or more, if such securities

- Are sold to no more than 35 "sophisticated investors"
- Have a maturity of nine months or less
- Are variable-rate demand instruments

Before bidding on or purchasing an offering, underwriters must obtain and review official statements that are deemed final by the issuer, with the omission of no more than the following information:

- Offering price
- Interest rate
- Selling compensation
- Aggregate principal amount
- Principal amount per maturity
- Delivery dates
- Other terms or provisions required by an issuer of such a security to be specified in a competitive bid, ratings, other terms of the securities depending on such matters, and the identity of the underwriters

The underwriters shall contract with an issuer or its designated agent to receive copies of a final official statement within seven business days after any final agreement to purchase, offer, or sell any offering and in sufficient time to accompany any confirmation that requests payment from any customer.

Except for competitively bid offerings, the underwriters shall send, no later than the next business day, to any potential customer, on request, a single copy of the most recent preliminary official statement, if any.

Underwriters are required to distribute the final official statement to any potential customer, on request, within 90 days, or 25 days if the final official statement is available from a repository.

The *Dodd-Frank Wall Street Reform and Consumer Protection Act*, signed into law on July 21, 2010, requires that municipal advisers be subject to SEC registration and MSRB oversight.

Material Event Disclosure Under SEC Rule 15c2-12

The first phase of the implementation of amendments to Rule 15c2-12, which took effect on July 3, 1995, required dealers to determine that issuers before issuing new municipal bonds made arrangements to disclose in the future financial information *at least* annually as well as notices of the occurrence of any of 11 "material event notices" as specified in the rule. By the beginning of 2020, the amended rule increased the material event notices to 16. Also by 2020, the annual report and notices of material events are filed with the Municipal Securities Rulemaking Board (MSRB), in an electronic format as prescribed by the MSRB. The MSRB designated its Electronic Municipal Market Access system (EMMA), found at http://emma.msrb.org, as the repository for such disclosure filings.

The second phase went into effect on January 1, 1996, and required dealers to have in-house procedures in place to provide reasonable assurance that they will receive prompt notice of any material event notices that are required to be disclosed by the issuers.

The Governmental Accounting Standards Board

The Governmental Accounting Standards Board (GASB) is a nonprofit organization that sets generally accepted accounting standards (GAAP) for state and local governments. Providing detailed guidelines and established in 1984, for many years it has improved financial reporting standards in reports of state and local governments that are used by analysts, auditors, and other users. By improving the transparency of state and local government accounting, it helps prevent issuers from obfuscating budget deficits and long-term liabilities that in the past had resulted in budgetary disasters and bond defaults. The Web address is http://gasb.org.

The National Federation of Municipal Analysts

The National Federation of Municipal Analysts (NMFA) was established in 1983, and by 2020 had a membership of more than 1,000 municipal professionals, drawing in part from the institutional investors in municipal bonds who advocated increased and timely information for investors. By 2020, its committees have developed detailed disclosure guidelines and risk factors in municipal securities ranging from specific credit sectors to swap structures. They are recommended for municipal bond issuers to use in providing ongoing financial and operating information to investors. The Web address is www.nfma.org.

KEY POINTS

- The majority of tax-exempt securities are issued by state and local governments and by their creations. Most outstanding municipal bonds are tax-exempt securities, meaning that the interest income is exempt from federal income taxes. Consequently, the major motivation for investing in tax-exempt municipal bonds is their tax advantage. The state and local income tax treatment of interest income from municipal bonds varies.
- In terms of municipal bond security structures, there are basically two different types: general obligation bonds (secured by the issuer's general taxing powers) and revenue bonds (issued for either project or enterprise financings in which the bond issuers pledge to the bondholders the revenues generated by the operating projects financed). There are bonds with security structures that have certain characteristics of general obligation and revenue bonds. These hybrid and special bond securities include refunded bonds, dedicated tax-backed and structured asset-backed bonds, insured bonds, lease-backed bonds, letter of credit–backed bonds, moral obligation bonds, and territorial bonds. Municipal money market products include notes, commercial paper, variable-rate demand obligations, and commercial paper mode.
- Municipal bonds are assigned credit ratings by commercial rating agencies (Moody's, Standard & Poor's, and Fitch) just like corporate bonds. Some investors do not perform their own credit-risk analysis, but instead rely entirely on credit-risk ratings assigned. Large institutional investors, underwriters, and traders tend to use ratings as a starting point in evaluating a municipal credit and then rely on their own in-house municipal credit analysts for determining the creditworthiness of municipal bonds.
- As in other sectors of the bond market, yield measures such as yield to maturity and yield to call are computed. In comparing a tax-exempt

municipal bond yield to that of a comparable taxable yield, the taxable equivalent yield is computed.

- Tax considerations in investing in tax-exempt municipal bonds include original issue discount embedded in an issue, the alternative minimum tax, deductibility of interest expense incurred to acquire a municipal bond, and treatment of interest income at the state and local tax levels.
- Bloomberg is the major provider of total return–based municipal bond indexes that are used by institutional investors. The Bloomberg Municipal Bond Index is used to measure relative total return performance. The Bloomberg indexes are available for a given market or market segment within the municipal bond market. Thomson Municipal Market Data and Municipal Market Advisors are two services that in the afternoon of each trading day make available generic scales for different maturities and different credit ratings in the municipal bond market.
- An official statement (OS) describing the issue and the issuer is prepared for new offerings. Typically a preliminary official statement (POS) is issued prior to the final official statement.

CHAPTER
TEN

CORPORATE BONDS

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In its simplest form, a corporate bond is a debt instrument that obligates the issuer to pay a specified percentage of the bond's par value on designated dates (the coupon payments) and to repay the bond's par or principal value at maturity. Failure to pay the interest and/or principal when due (and to meet other of the debt's provisions) in accordance with the instrument's terms constitutes legal default, and court proceedings can be instituted to enforce the contract. Bondholders as creditors have a prior legal claim over common and preferred shareholders as to both the corporation's income and assets for cash flows due them and may have a prior claim over other creditors if liens and mortgages are involved. This legal priority does not insulate bondholders from financial loss. Indeed, bondholders are fully exposed to the firm's prospects as to the ability to generate cash flow sufficient to pay its obligations.

Corporate bonds usually are issued in denominations of $1,000 and multiples thereof. In common usage, a corporate bond is assumed to have a par value of $1,000 unless otherwise explicitly specified. A security dealer who says that she has five bonds to sell means five bonds each of $1,000 principal amount. If the promised rate of interest (coupon rate) is 6%, the annual amount of interest on each bond is $60, and the semiannual interest is $30.

Although there are technical differences between bonds, notes, and debentures, we will use Wall Street convention and call fixed income debt by the general term—*bonds*. Therefore, practically speaking, it is motivated bond investors who examine covenant compliance and bring alleged violations to the trustee's attention.

THE CORPORATE TRUSTEE

The promises of corporate bond issuers and the rights of investors who buy them are set forth in great detail in contracts generally called *indentures*. If bondholders were handed the complete indenture, some may have trouble understanding the legalese and have even greater difficulty in determining from time to time if the corporate issuer is keeping all the promises made. Further, it may be practically difficult and expensive for any one bondholder to try to enforce the indenture if those promises are not being kept. These problems are solved in part by bringing in a *corporate trustee* as a third party to the contract. The indenture is made out to the corporate trustee as a representative of the interests of bondholders; that is, the trustee acts in a fiduciary capacity for investors who own the bond issue.

A corporate trustee is a bank or trust company with a corporate trust department and officers who are experts in performing the functions of a trustee. The corporate trustee must, at the time of issue, authenticate the bonds issued; that is, keep track of all the bonds sold, and make sure that they do not exceed the principal amount authorized by the indenture. It must obtain and address various certifications and requests from issuers, attorneys, and bondholders about compliance with the covenants of the indenture. These covenants are many and technical, and they must be watched during the entire period that a bond issue is outstanding. We will describe some of these covenants in subsequent pages.

It is very important that corporate trustees be competent and financially responsible. To this end, there is a federal statute known as the Trust Indenture Act that generally requires a corporate trustee for corporate bond offerings in the amount of more than $5 million sold in interstate commerce. The indenture must include adequate requirements for performance of the trustee's duties on behalf of bondholders; there must be no conflict between the trustee's interest as a trustee and any other interest it may have, especially if it is also a creditor of the issuer; and there must be provision for reports by the trustee to bondholders. If a corporate issuer has breached an indenture promise, such as not to borrow additional secured debt, or fails to pay interest or principal, the trustee may declare a default and take such action as may be necessary to protect the rights of bondholders.

However, it must be emphasized that the trustee is paid by the debt issuer and can only do what the indenture provides. The indenture may contain a clause stating that the trustee undertakes to perform such duties and only such duties as are specifically set forth in the indenture, and no implied covenants or obligations shall be read into the indenture against the trustee. Trustees often are not required to take actions such as monitoring corporate balance sheets to determine issuer covenant compliance, and in fact, indentures often expressly allow a trustee to rely upon certifications and opinions from the issuer and its attorneys. The trustee is generally not bound to make investigations into the facts surrounding documents delivered to it, but it may do so if it sees fit. Also, the trustee is usually under no obligation to exercise the rights or powers under the indenture at the request of bondholders unless it has been offered reasonable security or indemnity.

The terms of bond issues set forth in bond indentures are always a compromise between the interests of the bond issuer and those of investors who buy bonds. The issuer always wants to pay the lowest possible rate of interest and wants its actions bound as little as possible with legal covenants. Bondholders want the highest possible interest rate, the best security, and a variety of covenants to restrict the issuer in one way or another. As we discuss the provisions of bond indentures, keep this opposition of interests in mind and see how compromises are worked out in practice. A more detailed description of covenants is provided in Chapter 40 where credit analysis is covered.

SOME BOND FUNDAMENTALS

Bonds can be classified by a number of characteristics, which we will use for ease of organizing this section.

Bonds Classified by Issuer Type

The five broad categories of corporate bonds sold in the United States based on the type of issuer are public utilities, transportations, industrials, banks and finance companies, and international or Yankee issues. Finer breakdowns are often made by market participants to create homogeneous groupings. For example, public utilities are subdivided into telephone or communications, electric companies, gas distribution and transmission companies, and water companies. The transportation industry can be subdivided into airlines, railroads, and trucking companies. Like public utilities, transportation companies often have various degrees of regulation or control by state and/or federal government agencies. Industrials are a catchall class, but even here, finer degrees of distinction may be needed by analysts. The industrial grouping includes manufacturing and mining concerns, retailers, and service-related companies. Even the Yankee or international borrower sector can be more finely tuned. For example, one might classify the issuers into categories such as supranational borrowers (International Bank for Reconstruction and Development and the European Investment Bank), sovereign issuers (Canada, Australia, and the United Kingdom), and foreign municipalities and agencies.

Corporate Debt Maturity

A bond's maturity is the date on which the issuer's obligation to satisfy the terms of the indenture is fulfilled. On that date, the principal is repaid with any premium and accrued interest that may be due. However, as we shall see later when discussing debt redemption, the final maturity date as stated in the issue's title may or may not be the date when the contract terminates. Many issues can be retired prior to maturity. The maturity structure of a particular corporation can be accessed using the Bloomberg function DDIS.

Interest Payment Characteristics

The three main interest payment classifications of domestically issued corporate bonds are straight-coupon bonds, zero-coupon bonds, and floating-rate, or variable-rate, bonds. Floating-rate issues are discussed in Chapter 14, and the other two types are examined below.

However, before we get into interest-rate characteristics, let us briefly discuss bond types. We refer to the interest rate on a bond as the *coupon*. This is technically wrong because bonds issued today do not have coupons attached. Instead, bonds are represented by a certificate, similar to a stock certificate, with a brief description of the terms printed on both sides. These are called *registered bonds*. The principal amount of the bond is noted on the certificate, and the interest-paying agent or trustee has the responsibility of making payment by check to the registered holder on the due date. Years ago bonds were issued in *bearer* or coupon form, with coupons attached for each interest payment. However, the registered form is considered safer and entails less paperwork. As a matter of fact, the registered bond certificate is on its way out as more and more issues are sold in *book-entry* form. This means that only one master or global certificate is issued. It is held by a central securities depository that issues receipts denoting interests in this global certificate.

Straight-coupon bonds have an interest rate set for the life of the issue, however long or short that may be; they are also called *fixed-rate bonds*. Most fixed-rate bonds in the United States pay interest semiannually and at maturity. For example, consider a 4.75% bond due 2033 issued in July 2013. This bond carries a coupon rate of 4.75% and has a par amount of $1,000. Accordingly, this bond requires payments of $23.75 each January 15 and July 15, including the maturity date of July 15, 2033. On the maturity date, the bond's par amount is also paid. Bonds with annual coupon payments are uncommon in the U.S. capital markets but are the norm in continental Europe.

Interest on corporate bonds is based on a year of 360 days made up of twelve 30-day months. The corporate calendar day-count convention is referred to as 30/360.

Most fixed-rate corporate bonds pay interest in a standard fashion. However, there are some variations of which one should be aware. Most domestic bonds pay interest in U.S. dollars. However, starting in the early 1980s, issues were marketed with principal and interest payable in other currencies, such as the Australian, New Zealand, or Canadian dollar or the British pound. Generally, interest and principal payments are converted from the foreign currency to U.S. dollars by the paying agent unless it is otherwise notified. The bondholders bear any costs associated with the dollar conversion. Foreign currency issues provide investors with another way of diversifying a portfolio, but not without risk. The holder bears the currency, or exchange-rate, risk in addition to all the other risks associated with debt instruments.

There are a few issues of bonds that can participate in the fortunes of the issuer over and above the stated coupon rate. These are called *participating* *bonds* because they share in the profits of the issuer or the rise in certain assets over and above certain minimum levels. Another type of bond rarely encountered today is the *income bond.* These bonds promise to pay a stipulated interest rate, but the payment is contingent on sufficient earnings and is in accordance with the definition of available income for interest payments contained in the indenture. Repayment of principal is not contingent. Interest may be cumulative or noncumulative. If payments are cumulative, unpaid interest payments must be made up at some future date. If noncumulative, once the interest payment is past, it does not have to be repaid. Failure to pay interest on income bonds is not an act of default and is not a cause for bankruptcy. Income bonds have been issued by some financially troubled corporations emerging from reorganization proceedings.

Zero-coupon bonds are, just as the name implies, bonds without coupons or an interest rate. Essentially, zero-coupon bonds pay only the principal portion at some future date. These bonds are issued at discounts to par; the difference constitutes the return to the bondholder. The difference between the face amount and the offering price when first issued is called the *original-issue discount* (OID). The rate of return depends on the amount of the discount and the period over which it accretes to par.

Zeros were first publicly issued in the corporate market in the spring of 1981 and were an immediate hit with investors. The rapture lasted only a couple of years because of changes in the income tax laws that made ownership more costly on an after-tax basis. Also, these changes reduced the tax advantages to issuers. However, tax-deferred investors, such as pension funds, could still take advantage of zero-coupon issues. One important risk is eliminated in a zero-coupon investment—the reinvestment risk. Because there is no coupon to reinvest, there isn't any reinvestment risk. Of course, although this is beneficial in declining-interest-rate markets, the reverse is true when interest rates are rising. The investor will not be able to reinvest an income stream at rising reinvestment rates. Investors tend to find zeros less attractive in lower-interest-rate markets because compounding is not as meaningful as when rates are higher. Also, the lower the rates are, the more likely it is that they will rise again, making a zero-coupon investment worth less in the eyes of potential holders.

In bankruptcy, a zero-coupon bond creditor can claim the original offering price plus the accretion that represents accrued and unpaid interest to the date of the bankruptcy filing, but not the principal amount of $1,000. Zero-coupon bonds have been sold at deep discounts, and the liability of the issuer at maturity may be substantial. The accretion of the discount on the corporation's books is not put away in a special fund for debt retirement purposes. There are no sinking funds on most of these issues. One hopes that corporate managers invest the proceeds properly and run the corporation for the benefit of all investors so that there will not be a cash crisis at maturity. The potentially large balloon repayment creates a cause for concern among investors. Thus it is most important to invest in higher-quality issues so as to reduce the risk of a potential problem.

If one wants to speculate in lower-rated bonds, then that investment should throw off some cash return.

Finally, a variation of the zero-coupon bond is the *deferred-interest bond* (DIB). These bonds generally have been subordinated issues of speculative-grade issuers, also known as *junk issuers*. Most of the issues are structured so that they do not pay cash interest for the first five years. At the end of the deferred-interest period, cash interest accrues and is paid semiannually until maturity, unless the bonds are redeemed earlier. The deferred-interest feature allows newly restructured, highly leveraged companies and others with less-than-satisfactory cash flows to defer the payment of cash interest over the early life of the bond. Barring anything untoward, when cash interest payments start, the company will be able to service the debt. If it has made excellent progress in restoring its financial health, the company may be able to redeem or refinance the debt rather than have high interest outlays.

An offshoot of the deferred-interest bond is the *pay-in-kind (PIK) debenture*. With PIKs, cash interest payments are deferred at the issuer's option until some future date. Instead of just accreting the original-issue discount as with DIBs or zeros, the issuer pays out the interest in additional pieces of the same security. The option to pay cash or in-kind interest payments rests with the issuer, but in many cases the issuer has little choice because provisions of other debt instruments often prohibit cash interest payments until certain indenture or loan tests are satisfied. The holder just gets more pieces of paper, but these at least can be sold in the market without giving up one's original investment; PIKs, DIBs, and zeros do not have provisions for the resale of the interest portion of the instrument. An investment in this type of bond, because it is issued by speculative-grade companies, requires careful analysis of the issuer's cash-flow prospects and ability to survive.

SECURITY FOR BONDS

Investors who buy corporate bonds prefer some kind of security underlying the issue. Either real property (using a mortgage) or personal property may be pledged to offer security beyond that of the general credit standing of the issuer. In fact, the kind of security or the absence of a specific pledge of security is usually indicated by the title of a bond issue. However, the best security is a strong general credit that can repay the debt from earnings.

Mortgage Bond

A mortgage bond grants the bondholders a first-mortgage lien on substantially all its properties. This lien provides additional security for the bondholder. As a result, the issuer is able to borrow at a lower rate of interest than if the debt were unsecured. A debenture issue (i.e., unsecured debt) of the same issuer almost surely would carry a higher coupon rate, other things equal. A *lien* is a legal right to sell mortgaged property to satisfy unpaid obligations to bondholders. In practice, foreclosure of a mortgage and sale of mortgaged property are unusual. If a default occurs, there is usually a financial reorganization on the part of the issuer, in which provision is made for settlement of the debt to bondholders. The mortgage lien is important, though, because it gives the mortgage bondholders a very strong bargaining position relative to other creditors in determining the terms of a reorganization.

Often first-mortgage bonds are issued in series with bonds of each series secured equally by the same first mortgage. Many companies, particularly public utilities, have a policy of financing part of their capital requirements continuously by long-term debt. They want some part of their total capitalization in the form of bonds because the cost of such capital is ordinarily less than that of capital raised by sale of stock. Thus, as a principal amount of debt is paid off, they issue another series of bonds under the same mortgage. As they expand and need a greater amount of debt capital, they can add new series of bonds. It is a lot easier and more advantageous to issue a series of bonds under one mortgage and one indenture than it is to create entirely new bond issues with different arrangements for security. This arrangement is called a *blanket mortgage*. When property is sold or released from the lien of the mortgage, additional property or cash may be substituted or bonds may be retired in order to provide adequate security for the debtholders.

When a bond indenture authorizes the issue of additional series of bonds with the same mortgage lien as those already issued, the indenture imposes certain conditions that must be met before an additional series may be issued. Bondholders do not want their security impaired; these conditions are for their benefit. It is common for a first-mortgage bond indenture to specify that property acquired by the issuer subsequent to the granting of the first-mortgage lien shall be subject to the first-mortgage lien. This is termed the *after-acquired clause.* Then the indenture usually permits the issue of additional bonds up to some specified percentage of the value of the after-acquired property, such as 60%. The other 40%, or whatever the percentage may be, must be financed in some other way. This is intended to ensure that there will be additional assets with a value significantly greater than the amount of additional bonds secured by the mortgage. Another customary kind of restriction on the issue of additional series is a requirement that earnings in an immediately preceding period must be equal to some number of times the amount of annual interest on all outstanding mortgage bonds including the new or proposed series (1.5, 2, or some other number). For this purpose, *earnings* usually are defined as earnings before income tax. Still another common provision is that additional bonds may be issued to the extent that earlier series of bonds have been paid off.

One seldom sees a bond issue with the term *second mortgage* in its title. The reason is that this term has a connotation of weakness. Sometimes companies get around that difficulty by using such words as *first and consolidated, first and refunding,* or *general and refunding mortgage bonds.* Usually this language means that a bond issue is secured by a first mortgage on some part of the issuer's property but by a second or even third lien on other parts of its assets. A general and refunding mortgage bond is generally secured by a lien on all the company's property *subject* to the prior lien of first-mortgage bonds, if any are still outstanding.

Collateral Trust Bonds

Some companies do not own fixed assets or other real property and so have nothing on which they can give a mortgage lien to secure bondholders. Instead, they own securities of other companies; they are *holding companies,* and the other companies are *subsidiaries*. To satisfy the desire of bondholders for security, they pledge stocks, notes, bonds, or whatever other kinds of obligations they own. These assets are termed *collateral* (or personal property), and bonds secured by such assets are *collateral trust bonds*. Some companies own both real property and securities. They may use real property to secure mortgage bonds and use securities for collateral trust bonds. As an example, consider the 10.375% Collateral Trust Bonds due 2018 issued by National Rural Utilities. According to the bond's prospectus, the securities deposited with the trustee include mortgage notes, cash, and other permitted investments.

The legal arrangement for collateral trust bonds is much the same as that for mortgage bonds. The issuer delivers to a corporate trustee under a bond indenture the securities pledged, and the trustee holds them for the benefit of the bondholders. When voting common stocks are included in the collateral, the indenture permits the issuer to vote the stocks so long as there is no default on its bonds. This is important to issuers of such bonds because usually the stocks are those of subsidiaries, and the issuer depends on the exercise of voting rights to control the subsidiaries.

Indentures usually provide that, in event of default, the rights to vote stocks included in the collateral are transferred to the trustee. Loss of the voting right would be a serious disadvantage to the issuer because it would mean loss of control of subsidiaries. The trustee also may sell the securities pledged for whatever prices they will bring in the market and apply the proceeds to payment of the claims of collateral trust bondholders. These rather drastic actions, however, usually are not taken immediately on an event of default. The corporate trustee's primary responsibility is to act in the best interests of bondholders, and their interests may be served for a time at least by giving the defaulting issuer a proxy to vote stocks held as collateral and thus preserve the holding company structure. It also may defer the sale of collateral when it seems likely that bondholders would fare better in a financial reorganization than they would by sale of collateral.

Collateral trust indentures contain a number of provisions designed to protect bondholders. Generally, the market or appraised value of the collateral must be maintained at some percentage of the amount of bonds outstanding. If collateral value declines below the minimum percentage, additional collateral must be provided by the issuer. There is almost always provision for withdrawal of some collateral, provided other acceptable collateral is substituted.

Collateral trust bonds may be issued in series in much the same way that mortgage bonds are issued in series. The rules governing additional series of bonds require that adequate collateral must be pledged, and there may be restrictions on the use to which the proceeds of an additional series may be put. All series of bonds are issued under the same indenture and have the same claim on collateral.

Since 2005, an increasing percentage of high-yield bond issues have been secured by some mix of mortgages and other collateral on a first, second, or even third lien basis. These secured high yield bonds have very customized provisions for issuing additional secured debt and there is some debate about whether the purported collateral for these kinds of bonds will provide greater recoveries in bankruptcy than traditional unsecured capital structures over an economic cycle.

Equipment Trust Certificates

The desire of borrowers to pay the lowest possible rate of interest on their obligations generally leads them to offer their best security and to grant lenders the strongest claim on it. Many years ago, the railway companies developed a way of financing purchase of cars and locomotives, called *rolling stock,* that enabled them to borrow at just about the lowest rates in the corporate bond market.

Railway rolling stock has for a long time been regarded by investors as excellent security for debt. This equipment is sufficiently standardized that it can be used by one railway as well as another. And it can be readily moved from the tracks of one railroad to those of another. There is generally a good market for lease or sale of cars and locomotives. The railroads have capitalized on these characteristics of rolling stock by developing a legal arrangement for giving investors a legal claim on it that is different from, and generally better than, a mortgage lien.

The legal arrangement is one that vests legal title to railway equipment in a trustee, which is better from the standpoint of investors than a first-mortgage lien on property. A railway company orders some cars and locomotives from a manufacturer. When the job is finished, the manufacturer transfers the legal title to the equipment to a trustee. The trustee leases it to the railroad that ordered it and at the same time sells *equipment trust certificates* (ETCs) in an amount equal to a large percentage of the purchase price, normally 80%. Money from the sale of certificates is paid to the manufacturer. The railway company makes an initial payment of rent equal to the balance of the purchase price, and the trustee gives that money to the manufacturer. Thus the manufacturer is paid off. The trustee collects lease rental money periodically from the railroad and uses it to pay interest and principal on the certificates. These interest payments are known as dividends. The amounts of lease rental payments are worked out carefully so that they are enough to pay the equipment trust certificates. At the end of some period of time, such as 15 years, the certificates are paid off, the trustee sells the equipment to the railroad for some nominal price, and the lease is terminated.

Railroad ETCs usually are structured in serial form; that is, a certain amount becomes payable at specified dates until the final installment. For example, a $60 million ETC might mature $4 million on each June 15 from 2014 through 2028. Each of the 15 maturities may be priced separately to reflect the shape of the yield curve, investor preference for specific maturities, and supply-and-demand considerations. The advantage of a serial issue from the investor's point of view is that the repayment schedule matches the decline in the value of the equipment used as collateral. Hence principal repayment risk is reduced. From the issuer's side, serial maturities allow for the repayment of the debt periodically over the life of the issue, making less likely a crisis at maturity due to a large repayment coming due at one time.

The beauty of this arrangement from the viewpoint of investors is that the railroad does not legally own the rolling stock until all the certificates are paid. In case the railroad does not make the lease rental payments, there is no big legal hassle about foreclosing a lien. The trustee owns the property and can take it back because failure to pay the rent breaks the lease. The trustee can lease the equipment to another railroad and continue to make payments on the certificates from new lease rentals.

This description emphasizes the legal nature of the arrangement for securing the certificates. In practice, these certificates are regarded as obligations of the railway company that leased the equipment and are shown as liabilities on its balance sheet. In fact, the name of the railway appears in the title of the certificates. In the ordinary course of events, the trustee is just an intermediary who performs the function of holding title, acting as lessor, and collecting the money to pay the certificates. It is significant that even in the worst years of a depression, railways have paid their equipment trust certificates, although they did not pay bonds secured by mortgages. Although railroads have issued the largest amount of equipment trust certificates, airlines also have used this form of financing.

Debenture Bonds

While bondholders prefer to have security underlying their bonds, all else equal, most bonds issued are unsecured. These unsecured bonds are called *debentures.* With the exception of the utilities and structured products, nearly all other corporate bonds issued are unsecured.

Debentures are not secured by a specific pledge of designated property, but this does not mean that they have no claim on the property of issuers or on their earnings. Debenture bondholders have the claim of general creditors on all assets of the issuer not pledged specifically to secure other debt. And they even have a claim on pledged assets to the extent that these assets have value greater than necessary to satisfy secured creditors. In fact, if there are no pledged assets and no secured creditors, debenture bondholders have first claim on all assets along with other general creditors.

These unsecured bonds are sometimes issued by companies that are so strong financially and have such a high credit rating that to offer security would be superfluous. Such companies simply can turn a deaf ear to investors who want security and still sell their debentures at relatively low interest rates. But debentures sometimes are issued by companies that have already sold mortgage bonds and given liens on most of their property. These debentures rank below the mortgage bonds or collateral trust bonds in their claim on assets, and investors may regard them as relatively weak. This is the kind that bears the higher rates of interest.

Even though there is no pledge of security, the indentures for debenture bonds may contain a variety of provisions designed to afford some protection to investors. Sometimes the amount of a debenture bond issue is limited to the amount of the initial issue. This limit is to keep issuers from weakening the position of debenture holders by running up additional unsecured debt. Sometimes additional debentures may be issued a specified number of times in a recent accounting period, provided that the issuer has earned its bond interest on all existing debt plus the additional issue.

If a company has no secured debt, it is customary to provide that debentures will be secured equally with any secured bonds that may be issued in the future. This is known as the *negative-pledge clause.* Some provisions of debenture bond issues are intended to protect bondholders against other issuer actions when they might be too harmful to the creditworthiness of the issuer. For example, some provisions of debenture bond issues may require maintaining some level of net worth, restrict selling major assets, or limit paying dividends in some cases. However, the trend in recent years, at least with investment-grade companies, is away from indenture restrictions.

Subordinated and Convertible Debentures

Many corporations issue *subordinated debenture bonds*. The term *subordinated* means that such an issue ranks after secured debt, after debenture bonds, and often after some general creditors in its claim on assets and earnings. Owners of this kind of bond stand last in line among creditors when an issuer fails financially.

Because subordinated debentures are weaker in their claim on assets, issuers would have to offer a higher rate of interest unless they also offer some special inducement to buy the bonds. The inducement can be an option to convert bonds into stock of the issuer at the discretion of bondholders. If the issuer prospers and the market price of its stock rises substantially in the market, the bondholders can convert bonds to stock worth a great deal more than what they paid for the bonds. This conversion privilege also may be included in the provisions of debentures that are not subordinated. Convertible securities are discussed in Chapters 38 and 39.

The bonds may be convertible into the common stock of a corporation other than that of the issuer. Such issues are called *exchangeable bonds.* There are also issues indexed to a commodity's price or its cash equivalent at the time of maturity or redemption.

Guaranteed Bonds

Sometimes a corporation may guarantee the bonds of another corporation. Such bonds are referred to as *guaranteed bonds.* The guarantee, however, does not mean that these obligations are free of default risk. The safety of a guaranteed bond depends on the financial capability of the guarantor to satisfy the terms of the guarantee, as well as the financial capability of the issuer. The terms of the guarantee may call for the guarantor to guarantee the payment of interest and/or repayment of the principal. A guaranteed bond may have more than one corporate guarantor. Each guarantor may be responsible for not only its pro rata share but also the entire amount guaranteed by the other guarantors.

ALTERNATIVE MECHANISMS TO RETIRE DEBT BEFORE MATURITY

We can partition the alternative mechanisms to retire debt into two broad categories—namely, those mechanisms that must be included in the bond's indenture in order to be used and those mechanisms that can be used without being included in the bond's indenture. Among those debt retirement mechanisms included in a bond's indenture are the following: call and refunding provisions, sinking funds, maintenance and replacement funds, and redemption through sale of assets. Alternatively, some debt retirement mechanisms are not required to be included in the bond indenture (e.g., fixed-spread tender offers).

Call and Refunding Provisions

Many corporate bonds contain an embedded option that gives the issuer the right to buy the bonds back at a fixed price either in whole or in part prior to maturity. The feature is known as a *call provision.* The ability to retire debt before its scheduled maturity date is a valuable option for which bondholders will demand compensation ex-ante. All else equal, bondholders will pay a lower price for a callable bond than an otherwise identical option-free (i.e., straight) bond. The difference between the price of an option-free bond and the callable bond is the value of the embedded call option.

Conventional wisdom suggests that the most compelling reason for corporations to retire their debt prior to maturity is to take advantage of declining borrowing rates. If they are able to do so, firms will substitute new, lower-cost debt for older, higher-cost issues. However, firms retire their debt for other reasons as well. For example, firms retire their debt to eliminate restrictive covenants, to alter their capital structure, to increase shareholder value, or to improve financial/managerial flexibility. There are two types of call provisions included in corporate bonds—a fixed-price call and a make-whole call. We will discuss each in turn.

Fixed-Price Call Provision

With a standard fixed-price call provision, the bond issuer has the option to buy back some or all of the bond issue prior to maturity at a fixed price. The fixed price is termed the *call price*. Normally, the bond's indenture contains a call-price schedule that specifies when the bonds can be called and at what prices. The call prices generally start at a substantial premium over par and decline toward par over time such that in the final years of a bond's life, the call price is usually par.

In some corporate issues, bondholders are afforded some protection against a call in the early years of a bond's life. This protection usually takes one of two forms. First, some callable bonds possess a feature that prohibits a bond call for a certain number of years. Second, some callable bonds prohibit the bond from being refunded for a certain number of years. Such a bond is said to be *nonrefundable*. Prohibition of refunding precludes the redemption of a bond issue if the funds used to repurchase the bonds come from new bonds being issued with a lower coupon than the bonds being redeemed. However, a refunding prohibition does not prevent the redemption of bonds from funds obtained from other sources (e.g., asset sales, the issuance of equity, etc.). Call prohibition provides the bondholder with more protection than a bond that has a refunding prohibition that is otherwise callable.[1]

Make-Whole Call Provision

In contrast to a standard fixed-price call, a make-whole call price is calculated as the present value of the bond's remaining cash flows subject to a floor price equal to par value. The discount rate used to determine the present value is the yield on a comparable-maturity Treasury security plus a contractually specified *make-whole call premium.* These notes are redeemable at any time either in whole or in part at the issuer's option. The redemption price is the greater of (1) 100% of the principal amount plus accrued interest or (2) the make-whole redemption price, which is equal to the sum of the present value of the remaining coupon and principal payments discounted at the Treasury rate plus 10 basis points. The spread of 10 basis points is the aforementioned make-whole call premium. Thus the make-whole call price is essentially a floating call price that moves inversely with the level of interest rates.

1. There are, of course, exceptions to a call prohibition, such as sinking funds and redemption of the debt under certain mandatory provisions.

The Treasury rate is calculated in one of two ways. One method is to use a constant-maturity Treasury (CMT) yield as the Treasury rate. CMT yields are published weekly by the Federal Reserve in its statistical release H.15. The maturity of the CMT yield will match the bond's remaining maturity (rounded to the nearest month). If there is no CMT yield that exactly corresponds with the bond's remaining maturity, a linear interpolation is employed using the yields of the two closest available CMT maturities. Once the CMT yield is determined, the discount rate for the bond's remaining cash flows is simply the CMT yield plus the make-whole call premium specified in the indenture.

Another method of determining the Treasury rate is to select a U.S. Treasury security having a maturity comparable with the remaining maturity of the make-whole call bond in question. This selection is made by a primary U.S. Treasury dealer designated in the bond's indenture. An average price for the selected Treasury security is calculated using the price quotations of multiple primary dealers. The average price is then used to calculate a bond-equivalent yield. This yield is then used as the Treasury rate.

Make-whole call provisions were first introduced in publicly traded corporate bonds in 1995. Bonds with make-whole call provisions are now issued routinely for bonds issued in the investment-grade market, while bonds with fixed-price call provisions are generally used for bonds issued in the high-yield market.

The primary advantage from the firm's perspective of a make-whole call provision relative to a fixed-price call is a lower cost. Since the make-whole call price floats inversely with the level of Treasury rates, the issuer will not exercise the call to buy back the debt merely because its borrowing rates have declined. Simply put, the pure refunding motive is virtually eliminated. This feature will reduce the upfront compensation required by bondholders to hold make-whole call bonds versus fixed-price call bonds.

Sinking-Fund Provision

Term bonds may be paid off by operation of a *sinking fund.* These last two words are often misunderstood to mean that the issuer accumulates a fund in cash, or in assets readily sold for cash, that is used to pay bonds at maturity. It had that meaning many years ago, but too often the money supposed to be in a sinking fund was not all there when it was needed. In modern practice, there is no fund, and *sinking* means that money is applied periodically to redemption of bonds before maturity. Corporate bond indentures require the issuer to retire a specified portion of an issue each year. This kind of provision for repayment of corporate debt may be designed to liquidate all of a bond issue by the maturity date, or it may be arranged to pay only a part of the total by the end of the term.

The issuer may satisfy the sinking-fund requirement in one of two ways. A cash payment of the face amount of the bonds to be retired may be made by the corporate debtor to the trustee. The trustee then calls the bonds pro rata or by lot for redemption. Bonds have serial numbers, and numbers may be selected randomly for redemption. Owners of bonds called in this manner turn them in for redemption; *interest payments stop at the redemption date.* Alternatively, the issuer can deliver to the trustee bonds with a total face value equal to the amount that must be retired. The bonds are purchased by the *issuer* in the open market. This option is elected by the issuer when the bonds are selling below par. A few corporate bond indentures, however, prohibit the open-market purchase of the bonds by the issuer.

Many electric utility bond issues can satisfy the sinking-fund requirement by a third method. Instead of actually retiring bonds, the company may certify to the trustee that it has used unfunded property credits in lieu of the sinking fund. That is, it has made property and plant investments that have not been used for issuing bonded debt. For example, if the sinking-fund requirement is $1 million, it may give the trustee $1 million in cash to call bonds, it may deliver to the trustee $1 million of bonds it purchased in the open market, or it may certify that it made additions to its property and plant in the required amount, normally $1,667 of plant for each $1,000 sinking-fund requirement. In this case it could satisfy the sinking fund with certified property additions of $1,667,000.

The issuer is granted a special call price to satisfy any sinking-fund requirement. Usually, the sinking-fund call price is the par value if the bonds were originally sold at par. When issued at a price in excess of par, the sinking-fund call price generally starts at the issuance price and scales down to par as the issue approaches maturity.

There are two advantages of a sinking-fund requirement from the bondholder's perspective. First, default risk is reduced because of the orderly retirement of the issue before maturity. Second, if bond prices decline as a result of an increase in interest rates, price support may be provided by the issuer or its fiscal agent because it must enter the market on the buy side in order to satisfy the sinking-fund requirement. However, the disadvantage is that the bonds may be called at the special sinking-fund call price at a time when interest rates are lower than rates prevailing at the time of issuance. In that case, the bonds will be selling above par but may be retired by the issuer at the special call price that may be equal to par value.

Usually, the periodic payments required for sinking-fund purposes will be the same for each period. Gas company issues often have increasing sinking-fund requirements. However, a few indentures might permit variable periodic payments, where the periodic payments vary based on prescribed conditions set forth in the indenture. The most common condition is the level of earnings of the issuer. In such cases, the periodic payments vary directly with earnings. An issuer prefers such flexibility; however, an investor may prefer fixed periodic payments because of the greater default risk protection provided under this arrangement.

Many corporate bond indentures include a provision that grants the issuer the option to retire more than the amount stipulated for sinking-fund retirement. This option, referred to as an *accelerated sinking-fund provision,* effectively reduces the bondholder's call protection because, when interest rates decline, the issuer may find it economically advantageous to exercise this option at the special sinking-fund call price to retire a substantial portion of an outstanding issue.

Sinking fund provisions have fallen out of favor for most companies, but they used to be fairly common for public utilities, pipeline issuers, and some industrial issues. Finance issues almost never include a sinking fund provision. There can be a mandatory sinking fund where bonds have to be retired or, as mentioned earlier, a nonmandatory sinking fund in which it may use certain property credits for the sinking-fund requirement. If the sinking fund applies to a particular issue, it is called a *specific sinking fund.* There are also *nonspecific sinking funds* (also known as *funnel, tunnel, blanket,* or *aggregate sinking funds*), where the requirement is based on the total bonded debt outstanding of an issuer. Generally, it might require a sinking-fund payment of 1% of all bonds outstanding as of year-end. The issuer can apply the requirement to one particular issue or to any other issue or issues. Again, the blanket sinking fund may be mandatory (where bonds have to be retired) or nonmandatory (whereby it can use unfunded property additions).

Maintenance and Replacement Funds

Maintenance and replacement fund (M&R) provisions first appeared in bond indentures of electric utilities subject to regulation by the Securities and Exchange Commission (SEC) under the Public Holding Company Act of 1940. It remained in the indentures even when most of the utilities were no longer subject to regulation under the act. The original motivation for their inclusion is straightforward. Property is subject to economic depreciation, and the replacement fund ostensibly helps to maintain the integrity of the property securing the bonds. An M&R differs from a sinking fund in that the M&R only helps to maintain the value of the security backing the debt, whereas a sinking fund is designed to improve the security backing the debt. Although it is more complex, it is similar in spirit to a provision in a home mortgage requiring the homeowner to maintain the home in good repair.

An M&R requires a utility to determine annually the amounts necessary to satisfy the fund and any shortfall. The requirement is based on a formula that is usually some percentage (e.g., 15%) of adjusted gross operating revenues. The difference between what is required and the actual amount expended on maintenance is the shortfall. The shortfall is usually satisfied with unfunded property additions, but it also can be satisfied with cash. The cash can be used for the retirement of debt or withdrawn on the certification of unfunded property credits. While the retirement of debt through M&R provisions is not as common as it once was, M&Rs are still relevant, so bond investors should be cognizant of their presence in an indenture.

Redemption Through the Sale of Assets and Other Means

Because mortgage bonds are secured by property, bondholders want the integrity of the collateral to be maintained. Bondholders would not want a company to sell a plant (which has been pledged as collateral) and then to use the proceeds for a distribution to shareholders. Therefore, release-of-property and substitution-of-property clauses are found in most secured bond indentures.

As an illustration, Texas–New Mexico Power Co. issued \$130 million in first-mortgage bonds in January 1992 that carried a coupon rate of 11.25%. The bonds were callable beginning in January 1997 at a call price of 105. Following the sale of six of its utilities, Texas–New Mexico Power called the bonds at par in October 1995, well before the first call date. As justification for the call, Texas–New Mexico Power stated that it was forced to sell the six utilities by municipalities in northern Texas, and as a result, the bonds were callable under the eminent domain provision in the bond's indenture. The bondholders sued, stating that the bonds were redeemed in violation of the indenture. In April 1997, the court found for the bondholders, and they were awarded damages, as well as lost interest. In the judgment of the court, while the six utilities were under the threat of condemnation, no eminent domain proceedings were initiated.

Tender Offers

In addition to those methods specified in the indenture, firms have other tools for extinguishing debt prior to its stated maturity. At any time a firm may execute a tender offer and announce its desire to buy back specified debt issues. Firms employ tender offers to eliminate restrictive covenants or to refund debt. Usually the tender offer is for "any and all" of the targeted issue, but it also can be for a fixed dollar amount that is less than the outstanding face value. An offering circular is sent to the bondholders of record stating the price the firm is willing to pay and the window of time during which bondholders can sell their bonds back to the firm. If the firm perceives that participation is too low, the firm can increase the tender offer price and extend the tender offer window. When the tender offer expires, all participating bondholders tender their bonds and receive the same cash payment from the firm.

Tender offers have been executed using a fixed spread as opposed to a fixed price.[2] In a fixed-spread tender offer, the tender offer price is equal to the present value of the bond's remaining cash flows either to maturity or the next call date if the bond is callable. The present-value calculation occurs immediately after the tender offer expires. The discount rate used in the calculation is equal to the yield-to-maturity on a comparable-maturity Treasury or the associated CMT yield plus the specified fixed spread. Fixed-spread tender offers eliminate the exposure to interest-rate risk for both bondholders and the firm during the tender offer window.

2. See Steven V. Mann and Eric A. Powers, "Determinants of Bond Tender Premiums and the Percentage Tendered," *Journal of Banking and Finance*, March 2007, pp. 547–566.

CREDIT RISK

All corporate bonds are exposed to credit risk, which includes *credit default risk* and *credit-spread risk.*

Measuring Credit Default Risk

Any bond investment carries with it the uncertainty as to whether the issuer will make timely payments of interest and principal as prescribed by the bond's indenture. This risk is termed *credit default risk* and is the risk that a bond issuer will be unable to meet its financial obligations. Institutional investors have developed tools for analyzing information about both issuers and bond issues that assist them in accessing credit default risk. These techniques are discussed in later chapters. However, most individual bond investors and some institutional bond investors do not perform any elaborate credit analysis. Instead, they rely largely on bond ratings published by the major rating agencies that perform the credit analysis and publish their conclusions in the form of ratings. The three major nationally recognized statistical rating organizations (NRSROs) in the United States are Fitch Ratings, Moody's, and Standard & Poor's. These ratings are used by market participants as a factor in the valuation of securities on account of their independent and unbiased nature.

The ratings systems use similar symbols, as shown in Exhibit 10-1. In addition to the generic rating category, Moody's employs a numerical modifier of 1, 2, or 3 to indicate the relative standing of a particular issue within a rating category. This modifier is called a *notch*. Both Standard & Poor's and Fitch use a plus (+) and a minus (–) to convey the same information. Bonds rated triple B or higher are referred to as *investment-grade bonds.* Bonds rated below triple B are referred to as *non-investment-grade bonds* or, more popularly, *high-yield bonds* or *junk bonds.*

Credit ratings can and do change over time. A *rating transition table,* also called a *rating migration table,* is a table that shows how ratings change over some specified time period. Exhibit 10-2 presents a hypothetical rating transition table for a one-year time horizon. The ratings beside each of the rows are the ratings at the start of the year. The ratings at the head of each column are the ratings at the end of the year. Accordingly, the first cell in the table tells that 93.20% of the issues that were rated AAA at the beginning of the year still had that rating at the end. These tables are published periodically by the three rating agencies and can be used to access changes in credit default risk.

Measuring Credit-Spread Risk

The *credit-spread* is the difference between a corporate bond's yield and the yield on a comparable-maturity benchmark Treasury security or the swap rate. Credit spreads are so named because the presumption is that the difference in yields is due primarily to the corporate bond's exposure to credit risk. This is misleading,

EXHIBIT 10-1

Corporate Bond Credit Ratings

Fitch	Moody's	S&P	Summary Description
			Investment Grade
AAA	Aaa	AAA	Gilt edged, prime, maximum safety, lowest risk, and when sovereign borrower considered "default-free"
AA+	Aa1	AA+	
AA	Aa2	AA	High-grade, high credit quality
AA–	Aa3	AA–	
A+	A1	A+	
A	A2	A	Upper-medium grade
A–	A3	A–	
BBB+	Baa1	BBB+	
BBB	Baa2	BBB	Lower-medium grade
BBB–	Baa3	BBB–	
			Speculative Grade
BB+	Ba1	BB+	
BB	Ba2	BB	Low grade; speculative
BB–	Ba3	BB–	
B+	B1		
B	B	B	Highly speculative
B–	B3		
			Predominantly Speculative, Substantial Risk or in Default
CCC+		CCC+	
CCC	Caa	CCC	Substantial risk, in poor standing
CC	Ca	CC	May be in default, very speculative
C	C	C	Extremely speculative
		CI	Income bonds—no interest being paid
DDD			
DD			Default
D	D	D	

however, because the risk profile of corporate bonds differs from Treasuries on other dimensions; namely, corporate bonds are less liquid and often have embedded options.

Credit-spread risk is the risk of financial loss or the underperformance of a portfolio resulting from changes in the level of credit spreads used in the marking

EXHIBIT 10-2

Hypothetical One-Year Rating Transition Table

Rating at Start of Year	*Rating at End of Year*								
	AAA	**AA**	**A**	**BBB**	**BB**	**B**	**CCC**	**D**	**Total**
AAA	93.20	6.00	0.60	0.12	0.08	0.00	0.00	0.00	100
AA	1.60	92.75	5.07	0.36	0.11	0.07	0.03	0.01	100
A	0.18	2.65	91.91	4.80	0.37	0.02	0.02	0.05	100
BBB	0.04	0.30	5.20	87.70	5.70	0.70	0.16	0.20	100
BB	0.03	0.11	0.61	6.80	81.65	7.10	2.60	1.10	100
B	0.01	0.09	0.55	0.88	7.90	75.67	8.70	6.20	100
CCC	0.00	0.01	0.31	0.84	2.30	8.10	62.54	25.90	100

to market of a fixed income product. Credit spreads are driven by both macro-economic forces and issue-specific factors. Macro-economic forces include such things as the level and slope of the Treasury yield curve, the business cycle, and consumer confidence. Correspondingly, the issue-specific factors include such things as the corporation's financial position and the future prospects of the firm and its industry.

One method used commonly to measure credit-spread risk is *spread duration*. Spread duration is the approximate percentage change in a bond's price for a 100 basis point change in the credit-spread assuming that the Treasury rate is unchanged. For example, if a bond has a spread duration of 3, this indicates that for a 100 basis point change in the credit-spread, the bond's price should change by approximately 3%. Spread duration is discussed in Chapter 53.

EVENT RISK

In recent years, one of the more talked-about topics among corporate bond investors is *event risk*. Over the last couple of decades, corporate bond indentures have become less restrictive, and corporate managements have been given a free rein to do as they please without regard to bondholders. Management's main concern or duty is to enhance shareholder wealth. As for the bondholder, all a company is required to do is to meet the terms of the bond indenture, including the payment of principal and interest. With few restrictions and the optimization of shareholder wealth of paramount importance for corporate managers, it is no wonder that bondholders became concerned when merger mania and other events swept the nation's boardrooms. Events such as decapitalizations, restructurings, recapitalizations, mergers, acquisitions, leveraged buyouts, and share repurchases, among other things, often caused substantial changes in a corporation's capital structure, namely, greatly increased leverage and decreased equity. Bondholders' protection was sharply reduced and debt quality ratings lowered, in many cases to speculative-grade categories. Along with greater risk came lower bond valuations. Shareholders were being enriched at the expense of bondholders. It is important to keep in mind the distinction between event risk and headline risk. Headline risk is the uncertainty engendered by the firm's media coverage that causes investors to alter their perception of the firm's prospects. Headline risk is present regardless of the veracity of the media coverage.

In reaction to the increased activity of leveraged buyouts and strategic mergers and acquisitions, some companies incorporated "poison puts" in their indentures. These are designed to thwart unfriendly takeovers by making the target company unpalatable to the acquirer. The poison put provides that the bondholder can require the company to repurchase the debt under certain circumstances arising out of specific designated events such as a change in control. Poison puts may not deter a proposed acquisition but could make it more expensive. Many times, in addition to a designated event, a rating change to below investment grade must occur within a certain period for the put to be activated. Some issues provide for a higher interest rate instead of a put as a designated event remedy.

At times, event risk has caused some companies to include other special debt-retirement features in their indentures. An example is the *maintenance of net worth clause* included in the indentures of some lower-rated bond issues. In this case, an issuer covenants to maintain its net worth above a stipulated level, and if it fails to do so, it must begin to retire its debt at par. Usually the redemptions affect only part of the issue and continue periodically until the net worth recovers to an amount above the stated figure or the debt is retired. In other cases, the company is required only to *offer to redeem* a required amount. An offer to redeem is not mandatory on the bondholders' part; only those holders who want their bonds redeemed need do so. In a number of instances in which the issuer is required to call bonds, the bondholders may elect not to have bonds redeemed. This is not much different from an offer to redeem. It may protect bondholders from the redemption of the high-coupon debt at lower interest rates. However, if a company's net worth declines to a level low enough to activate such a call, it probably would be prudent to have one's bonds redeemed.

Protecting the value of debt investments against the added risk caused by corporate management activity is not an easy job. Investors should analyze the issuer's fundamentals carefully to determine if the company may be a candidate for restructuring. Attention to news and equity investment reports can make the task easier. Also, the indenture should be reviewed to see if there are any protective covenant features. However, there may be loopholes that can be exploited by sharp legal minds. Of course, large portfolios can reduce risk with broad diversification among industry lines, but price declines do not always affect only the issue at risk; they also can spread across the board and take the innocent down with them. This happened in the fall of 1988 with the leveraged buyout of RJR Nabisco, Inc. The whole industrial bond market suffered as buyers and traders withdrew from the market, new issues were postponed, and secondary market activity came to a standstill. The impact of the initial leveraged buyout bid announcement on yield spreads for RJR Nabisco's debt to a benchmark Treasury increased from about 100 to 350 basis points. The RJR Nabisco transaction showed that size was not an obstacle. Therefore, other large firms that investors previously thought were unlikely candidates for a leveraged buyout were fair game. The spillover effect caused yield spreads to widen for other major corporations. This phenomenon was repeated in the mid-2000s with the buyout of large, investment grade public companies such as Alltel, First Data, and Hilton Hotels.

HIGH-YIELD BONDS

As noted, high-yield bonds are those rated below investment grade by the ratings agencies. These issues are also known as *junk bonds*. Despite the negative connotation of the term *junk,* not all bonds in the high-yield sector are on the verge of default or bankruptcy. Many of these issues are on the fringe of the investment-grade sector.

Types of Issuers

Several types of issuers fall into the less-than-investment-grade high-yield category. These categories are discussed below.

Original Issuers

Original issuers include young, growing concerns lacking the stronger balance sheet and income statement profile of many established corporations but often with lots of promise. Also called *venture-capital situations* or *growth or emerging market companies,* the debt is often sold with a story projecting future financial strength. From this we get the term *story bond.* There are also the established operating firms with financials neither measuring up to the strengths of investment-grade corporations nor possessing the weaknesses of companies on the verge of bankruptcy. Subordinated debt of investment-grade issuers may be included here. A bond rated at the bottom rung of the investment-grade category (Baa and BBB) or at the top end of the speculative-grade category (Ba and BB) is referred to as a "businessman's risk."

Fallen Angels

"Fallen angels" are companies with investment-grade-rated debt that have come on hard times with deteriorating balance sheet and income statement financial parameters. They may be in default or near bankruptcy. In these cases, investors are interested in the workout value of the debt in a reorganization or liquidation, whether within or outside the bankruptcy courts. Some refer to these issues as "special situations." Over the years, they have fallen on hard times; some have recovered, and others have not.

Restructurings and Leveraged Buyouts

These are companies that have deliberately increased their debt burden with a view toward maximizing shareholder value. The shareholders may be the existing public group to which the company pays a special extraordinary dividend, with the funds coming from borrowings and the sale of assets. Cash is paid out, net worth decreased, and leverage increased, and ratings drop on existing debt. Newly issued debt gets junk-bond status because of the company's weakened financial condition.

In a leveraged buyout (LBO), a new and private shareholder group owns and manages the company. The debt issue's purpose may be to retire other debt from commercial and investment banks and institutional investors incurred to finance the LBO. The debt to be retired is called *bridge financing* because it provides a bridge between the initial LBO activity and the more permanent financing.

Unique Features of Some Issues

Often actions taken by management that result in the assignment of a non-investment-grade bond rating result in a heavy interest-payment burden. This places severe cash-flow constraints on the firm. To reduce this burden, firms involved with heavy debt burdens have issued bonds with *deferred coupon structures* that permit the issuer to avoid using cash to make interest payments for a period of three to seven years. There are three types of deferred-coupon structures: (1) deferred-interest bonds, (2) step-up bonds, and (3) payment-in-kind bonds.

Deferred-interest bonds are the most common type of deferred-coupon structure. These bonds sell at a deep discount and do not pay interest for an initial period, typically from three to seven years. (Because no interest is paid for the initial period, these bonds are sometimes referred to as "zero-coupon bonds.") *Step-up bonds* do pay coupon interest, but the coupon rate is low for an initial period and then increases ("steps up") to a higher coupon rate. Finally, *payment-in-kind (PIK) bonds* give the issuers an option to pay cash at a coupon payment date or give the bondholder a similar bond (i.e., a bond with the same coupon rate and a par value equal to the amount of the coupon payment that would have been paid). The period during which the issuer can make this choice varies from five to ten years.

Sometimes an issue will come to market with a structure allowing the issuer to reset the coupon rate so that the bond will trade at a predetermined price.[3] The coupon rate may reset annually or even more frequently, or reset only one time over the life of the bond. Generally, the coupon rate at the reset date will be the average of rates suggested by two investment banking firms. The new rate will then reflect (1) the level of interest rates at the reset date and (2) the credit-spread

3. Most of the bonds have a coupon reset formula that requires the issuer to reset the coupon so that the bond will trade at a price of $101.

the market wants on the issue at the reset date. This structure is called an *extendible reset bond.*

Notice the difference between an extendible reset bond and a typical floating-rate issue. In a floating-rate issue, the coupon rate resets according to a fixed spread over the reference rate, with the index spread specified in the indenture. The amount of the index spread reflects market conditions at the time the issue is offered. The coupon rate on an extendible reset bond, in contrast, is reset based on market conditions (as suggested by several investment banking firms) at the time of the reset date. Moreover, the new coupon rate reflects the new level of interest rates and the new spread that investors seek.

The advantage to investors of extendible reset bonds is that the coupon rate will reset to the market rate—both the level of interest rates and the credit-spread—in principle keeping the issue at par value. In fact, experience with extendible reset bonds has not been favorable during periods of difficulties in the high-yield bond market. The sudden substantial increase in default risk has meant that the rise in the rate needed to keep the issue at par value was so large that it would have insured bankruptcy of the issuer. As a result, the rise in the coupon rate has been insufficient to keep the issue at the stipulated price.

Some speculative-grade bond issues grant the issuer a limited right to redeem a portion of the bonds during the noncall period if the proceeds are from an initial public stock offering. Called "clawback" provisions, they merit careful attention by inquiring bond investors. The provision appears in the vast majority of new speculative-grade bond issues, and sometimes allow even private sales of stock to be used for the clawback. The provision usually allows 35% of the issue to be retired during the first three years after issuance, at a price of par plus one year of coupon. Investors should be forewarned of clawbacks because they can lose bonds at the point in time just when the issuer's finances have been strengthened through access to the equity market. Also, the redemption may reduce the amount of the outstanding bonds to a level at which their liquidity in the aftermarket may suffer.

DEFAULT RATES AND RECOVERY RATES

We now turn our attention to the various aspects of the historical performance of corporate issuers with respect to fulfilling their obligations to bondholders. Specifically, we will look at two aspects of this performance. First, we will look at the default rate of corporate borrowers. From an investment perspective, default rates by themselves are not of paramount significance; it is perfectly possible for a portfolio of bonds to suffer defaults and to outperform Treasuries at the same time, provided the yield spread of the portfolio is sufficiently high to offset the losses from default. Furthermore, because holders of defaulted bonds typically recover some percentage of the face amount of their investment, the *default loss rate* is substantially lower than the default rate. Therefore, it is important to look at default loss rates or, equivalently, *recovery rates.*

Default Rates

A default rate can be measured in different ways. A simple way to define a default rate is to use the issuer as the unit of study. A default rate is then measured as the number of issuers that default divided by the total number of issuers at the beginning of the year. This measure gives no recognition to the amount defaulted nor the total amount of issuance. The rationale for ignoring dollar amounts is that the credit decision of an investor does not increase with the size of the issuer. The second measure is to define the default rate as the par value of all bonds that defaulted in a given calendar year divided by the total par value of all bonds outstanding during the year. Edward Altman, who has performed extensive analyses of default rates for speculative-grade bonds, measures default rates in this way. We will distinguish between the default-rate statistic below by referring to the first as the *issuer default rate* and the second as the *dollar default rate*.

With either default-rate statistic, one can measure the default for a given year or an average annual default rate over a certain number of years. Researchers who have defined dollar default rates in terms of an average annual default rate over a certain number of years have measured it as

$$\frac{\text{Cumulative \$ value of all defaulted bonds}}{\text{Cumulative \$ value of all issuance} \times \text{weighted avg. no. of years outstanding}}$$

Alternatively, some researchers report a cumulative annual default rate. This is done by not normalizing by the number of years. For example, a cumulative annual dollar default rate is calculated as

$$\frac{\text{Cumulative \$ value of all defaulted bonds}}{\text{Cumulative \$ value of all issuance}}$$

There have been several excellent studies of corporate bond default rates. We will not review each of these studies because the findings are similar.

Recovery Rates

There have been several studies that have focused on recovery rates or default loss rates for corporate debt. Measuring the amount recovered is not a simple task. The final distribution to claimants when a default occurs may consist of cash and securities. Often it is difficult to track what was received and then determine the present value of any noncash payments received.

MEDIUM-TERM NOTES

Medium-term notes (MTNs) are debt instruments that differ primarily in how they are sold to investors. Akin to a commercial paper program, they are offered continuously to institutional investors by an agent of the issuer. MTNs are registered with the Securities and Exchange Commission under Rule 415 ("shelf registration") which gives a corporation sufficient flexibility for issuing securities on a continuous basis. MTNs are also issued by non-U.S. corporations, federal agencies, supranational institutions, and sovereign governments.

One would suspect that MTNs would describe securities with intermediate maturities. However, it is a misnomer. MTNs are issued with maturities of 9 months to 30 years or even longer. For example, in 1993, Walt Disney Corporation issued bonds through its medium-term note program with a 100-year maturity, a so-called century bond. MTNs can perhaps be more accurately described as highly flexible debt instruments that can easily be designed to respond to market opportunities and investor preferences.

As noted, MTNs differ in their primary distribution process. Most MTN programs have two to four agents. Through its agents, an issuer of MTNs posts offering rates over a range of maturities: for example, 9 months to one year, one year to 18 months, 18 months to two years, and annually thereafter. Many issuers post rates as a yield spread over a Treasury security of comparable maturity.

Relatively attractive yield spreads are posted for maturities that the issuer desires to raise funds. The investment banks disseminate this offering rate information to their investor clients. When an investor expresses interest in an MTN offering, the agent contacts the issuer to obtain a confirmation of the terms of the transaction. Within a maturity range, the investor has the option of choosing the final maturity of the note sale, subject to agreement by the issuing company. The issuer will lower its posted rates once it raises the desired amount of funds at a given maturity.

Structured medium-term notes or simply *structured notes* are debt instruments coupled with a derivative position (options, forwards, futures, swaps, caps, and floors). For example, structured notes are often created with an underlying swap transaction. This "hedging swap" allows the issuer to create structured notes with interesting risk/return features desired by a swath of fixed income investors.

KEY POINTS

- A bond's indenture includes the promises of corporate bond issuers and the rights of investors. The terms of bond issues set forth in bond indentures are always a compromise between the interests of the bond issuer and those of investors who buy bonds.
- The classification of corporate bonds by type of issuer include public utilities, transportations, industrials, banks and finance companies, and international or Yankee issues.
- The three main interest payment classifications of domestically issued corporate bonds are straight-coupon bonds (fixed-rate bonds), zero-coupon bonds, and floating-rate bonds (variable-rate bonds).

- Either real property (using a mortgage) or personal property may be pledged to offer security beyond that of the general credit standing of the issuer. In fact, the kind of security or the absence of a specific pledge of security is usually indicated by the title of a bond issue. However, the best security is a strong general credit that can repay the debt from earnings.
- A mortgage bond grants the bondholders a first-mortgage lien on substantially all its properties and as a result the issuer is able to borrow at a lower rate of interest than if the debt were unsecured.
- Some companies do not own fixed assets or other real property and so have nothing tangible on which they can give a mortgage lien to secure bondholders. To satisfy the desire of bondholders for security, they pledge stocks, notes, bonds, or whatever other kinds of obligations they own and the resulting issues are referred to as collateral trust bonds.
- Debentures are not secured by a specific pledge of designated property and therefore bondholders have the claim of general creditors on all assets of the issuer not pledged specifically to secure other debt. Moreover, debenture bondholders have a claim on pledged assets to the extent that these assets have value greater than necessary to satisfy secured creditors. In fact, if there are no pledged assets and no secured creditors, debenture bondholders have first claim on all assets along with other general creditors.
- Owners of subordinated debenture bonds stand last in line among debt creditors when an issuer fails financially.
- For a guaranteed bond there is a third party guaranteeing the debt but that does not mean a bond issue is free of default risk. The safety of a guaranteed bond depends on the financial capability of the guarantor to satisfy the terms of the guarantee, as well as the financial capability of the issuer.
- Debt retirement mechanisms included in a bond's indenture are call and refunding provisions, sinking funds, maintenance and replacement funds, redemption through sale of assets, and tender offers.
- All corporate bonds are exposed to credit risk, which includes credit default risk and credit-spread risk.
- Credit ratings can and do change over time and this information is captured in a rating transition table, also called a rating migration table.
- Credit-spread risk is the risk of financial loss or the underperformance of a portfolio resulting from changes in the level of credit spreads used in the marking to market of a fixed income product. One method used commonly to measure credit-spread risk is spread duration which is the approximate percentage change in a bond's price for a 100 basis point change in the credit-spread assuming that the Treasury rate is unchanged.

- The three types of issuers that comprise the less-than-investment-grade high-yield corporate bond category are original issuers, fallen angels, and restructuring and leveraged buyouts.
- Often actions taken by management that result in the assignment of a noninvestment-grade bond rating result in a heavy interest payment burden. To reduce this burden, firms involved with heavy debt burdens have issued bonds with deferred coupon structures that permit the issuer to avoid using cash to make interest payments for a period of three to seven years. There are three types of deferred-coupon structures: deferred-interest bonds, step-up bonds, and payment-in-kind bonds.
- From an investment perspective, default rates by themselves are not of paramount significance because a portfolio of bonds could suffer defaults and still outperform Treasuries at the same time. This can occur if the yield spread of the portfolio is sufficiently high to offset the losses from default. Furthermore, because holders of defaulted bonds typically recover some percentage of the face amount of their investment, the default loss rate is substantially lower than the default rate. Therefore, it is important to look at default loss rates or, equivalently, recovery rates.
- A default rate can be measured in term of the issuer default rate and the dollar default rate.

CHAPTER
ELEVEN

LEVERAGED LOANS

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A *leveraged loan* is a loan made to a company whose credit rating is speculative grade. That is, the borrower has a credit rating that is below BBB-/Baa3. When reference is made to "loans" by market participants, typically it means (1) loans that are broadly syndicated (to 10 or more bank and nonbank investors), (2) senior secured loans that are at the top-most rank in the borrower's capital structure, and (3) large loans to large companies.

For below investment-grade companies, leveraged loans are a key component of their capital structure. Historically, the typical company raising capital in the leveraged finance space has relied on the loan market for a large portion of their overall funding, with about two-thirds of the total coming from the loan market and about one-third coming from the high-yield bond market. Worth noting, there can be meaningful variations from this two-third/one-third rule of thumb, and these tend to occur during and in the wake of significant market disruptions such as the Global Financial Crisis of 2008–2009.

In terms of the use of proceeds, corporate borrowers utilize the capital from a leveraged loan for various purposes, but by far the two most prevalent uses are to fund mergers and acquisitions and to refinance existing debt. Together these two purposes have accounted for about 80% of leveraged loan usage over time, with close to (although not quite) an even split between these two uses.

With regard to the total par amount of leveraged loans outstanding, the most commonly cited number by market participants is $1.2 trillion, and market outstandings have been hovering at this level in recent years. That said, this figure represents *index-eligible* leveraged loans rather than all leveraged loans outstanding, and to be index-eligible a number of hurdles, such as time until maturity, must be met.

The index-eligible universe is important, as these are the loans that market participants tend to trade, but just as important is that $1.2 trillion underestimates the size of the actual leveraged loan market meaningfully. According to a recent study completed by the Bank of England the size of the leveraged loan market without index constraints is approximately $2.2 trillion, or around 80% larger than the index-eligible universe.[1] Clearly the leveraged loan market is very large and important to issuers.

SYNDICATED BANK LOANS

Leveraged loans have been syndicated and sold to nonbank institutional investors since the late 1980s, but institutional investors only became a meaningful factor in the marketplace in the mid-1990s. Here we describe various facets of the leveraged loan market.

A leveraged loan is one form of a *syndicated loan*. A syndicated loan is a single loan with a single set of terms but multiple lenders, each providing a portion of the funds. The advantage of the syndication of a loan from a borrower's perspective is that (1) it allows a corporation to negotiate loan terms once, while at the same time having access to multiple lenders, and (2) it avoids conflicts in priority from arising that might otherwise occur if the borrower serially negotiated loans. All lenders in the syndicate share equally in rights under the credit agreement.

Typically, a syndicated loan is arranged by a commercial or investment bank—referred to as the *arranger*, also called the *mandated lead arranger*[2]—and that entity advises the borrower on the type of facility (as described later, a revolving line of credit and/or term loan); negotiates the terms of the loan, including pricing; and manages the structuring of the credit agreement. The arranger prepares an information memo or bank book. The document, which is confidential and made available to qualified banks and accredited investors only, provides information about the borrower, the borrower's industry, loan terms, and the borrower's financial projections. For administering the loan on a daily basis, an *agent* is appointed. It is the agent that is responsible for monitoring the borrower to assure compliance with the terms of the loan.

After the credit agreement and a security agreement are finalized, the required documents are filed with the relevant legal jurisdictions. However, the credit agreement may be amended for a variety of reasons. It could be for a minor change, such as a waiver of a specific covenant. Such changes may merely require a majority vote to do so. At the other extreme, it could involve more complex changes such as changes in the interest rate, term of the facility, or the security for the loan. More complex changes may require unanimous consent.

One amendment type worth noting in particular is the "amend-to-extend." The bankruptcy process tends to be very expensive for all stakeholders in a

1. https://www.bankofengland.co.uk/bank-overground/2019/how-large-is-the-leveraged-loan-market
2. Actually, there is often more than one arranger in a transaction despite the reference to a singular party in this chapter.

company, including lenders. In part due to these high costs, modifying the terms of a loan (i.e., amend-to-extend) may be a more beneficial option for all involved (including lenders) than the bankruptcy process. Not surprisingly the number of amend-to-extend and covenant relief amendments tends to rise when business conditions for leveraged loan borrowers soften and the chance of bankruptcy rises.

For example, during the Global Financial Crisis of 2008–2009 and the period immediately following, we saw a multifactor jump in the amount of amend-to-extend and covenant relief amendments when compared to the long-term average. Worth noting is that while there has been an increase in amend-to-extend activity in the wake of the Covid-19 crisis of 2020, there is uncertainty among market participants about the extent to which activity will ultimately rise because there had been more loans with soft covenants (i.e., covenant lite) issued prior to the crisis. Said differently, there simply aren't as many covenants to amend.

Loans may be underwritten or done on a best-efforts basis. In an *underwritten deal*, any portion of the loan that is not subscribed for by other banks or investors the arranger must take onto its books (and thus fund). In contrast, in a *best-efforts deal* the arranger does not guarantee the placement of the entire amount to other banks or investors. Instead, the pricing or the size may be adjusted. A variant of the best-efforts arrangement involves the use of *market flex language* wherein borrowers typically give arrangers the flexibility to adjust loan terms and loan pricing (i.e., increase the spread over the reference benchmark) to ensure that the loan would be fully subscribed. A *reverse market flex*, in contrast, tightens the spread in response to oversubscription or other market conditions.

LOAN STRUCTURE

In practice, there is often not just one loan that is arranged. Instead, a credit agreement often calls for a *revolving line of credit* and one or more term loans (term loan A, term loan B, and so on). In some credit agreements, the revolving line of credit can be drawn upon by the borrower, who is then permitted to convert the amount drawn into a term loan.

Leveraged loans can be classified under the credit agreement as pro rata loans and institutional loans. *Pro rata loans* are distributed to banks, and usually include the revolving line of credit and term loans that mature in three to five years. As the name suggests, *institutional loans* are distributed to nonbank institutional investors and typically include term loans maturing in five to seven years. Institutional loans now represent the significant component of new loan issues. To put the evolution (from banks to nonbank investors) into perspective, it is estimated that a single type of institutional investor—collateralized loan obligations (CLOs)—now have approximately $0.8 trillion of exposure to the leveraged loan market, well in excess of overall bank exposure (estimates range from $0.4 trillion to $0.67 trillion).[3]

3. Bank of England Financial Stability Report, November 2018, Issue No 44; Bank Overground, January 25 2019.

LOAN TERMS

The loan credit agreement sets forth the loan's terms. There are three forms: (1) representations and warranties made by the borrower, (2) affirmative covenants, and (3) negative covenants.

Leveraged loans commonly contain covenants or requirements that must be satisfied by borrowers. The two most common are maintenance requirements and incurrence requirements. These requirements are specified in the form of tests. Basically, *maintenance requirements* are regular reviews of various operating performance measures, such as leverage, interest coverage, and so on. It is not necessary for there to be any particular corporate action in order to "trigger" a review of these operating measures. An *incurrence requirement* is a review of specific operating measures relative to predetermined levels after an issuer has taken an action that triggers a review. Examples of actions that can trigger a review are share repurchases, divestitures, and special dividends. There are five purposes served by this process:[4]

1. *Preservation of collateral:* The borrower represents that the lenders have a legal, valid, and enforceable security interest in the pledged collateral. Typically, this means not only the borrower's existing assets at the time of the loan's closing, but also assets subsequently acquired by the borrower. There are loans where only specific assets are pledged as collateral.
2. *Appropriation of excess cash flow:* In the absence of restrictions, a borrower could take out a loan, sell its assets, distribute the proceeds from the sale of the assets and the proceeds of the loan(s) to the equity holders, and thereby create an empty corporate shell with no assets for the lenders. To prevent this, excess cash flow from the borrower's ordinary and extraordinary business activities—defined as cash flow minus cash expenses, required dividends, debt repayments, capital expenditures, and changes in working capital—is required to be used to prepay loans.
3. *Control of business risk:* Lenders become disadvantaged when a borrower's business becomes riskier and the risk that borrowers will make business decisions to benefit equity holders at the expense of lenders increases.[5] Management of the borrowing firm can increase risk by taking on riskier investment projects, taking on more debt, and acquiring other firms, among other actions. Loan terms are imposed to prevent this practice. In the case of taking on more debt, this may be prohibited even if the priority of the new debt ranking is subordinate to the loan.

4. For a more detailed description, see Chapter 3 in Stephen Antczak, Douglas Lucas, and Frank J. Fabozzi, *Leveraged Finance: Concepts, Methods, and Trading of High-Yield Bonds, Loans, and Derivatives* (Hoboken, NJ: John Wiley & Sons, 2009).

5. Financial economists refer to this as one of the costs of financial distress.

4. *Performance requirements:* Performance measures used by lenders include ratios such as coverage ratios, leverage ratios, and liquidity ratios, as well as dollar amounts, such as tangible net worth, maximum capital expenditures, and cash-flow/net worth requirements. These measures can be calculated based on financial statement items (prepared under generally accepted accounting principles) or lender-specified calculations. If these measures are violated, the loan becomes due and payable immediately.
5. *Reporting requirements:* For purposes of monitoring the borrower, the lender will require that the borrower periodically furnish specified documents and reports. These include not only documents required by government regulatory agencies but also internal reports such as budgets and projections and accounts-receivable analysis, as well as third-party non-filing reports such as appraisals for certain assets.

The pricing of a loan (i.e., the loan's spread) depends in large part on four factors: (1) the credit quality/rating of the borrower, (2) the size of the loan(s), (3) the supply of and demand for new issues in the loan market, and (4) investor risk appetites in general.[6]

Obviously, the lower the borrower's credit rating, the greater the loan's spread all other factors equal. The second factor relates to the balance or imbalance between the amount of loans that are being brought to market and the credit appetite of buyers (i.e., banks and institutional lenders). The size of the loan can result in a higher or lower spread. On the one hand, the larger the loan size, the higher the spread needed to clear the market. On the other hand, for trading purposes a larger loan size can work to decrease the spread because investors believe that larger loans tend to trade better in the secondary market due to greater familiarity with the issuer.[7] Lastly, greater investor risk appetites, even in markets other than the leveraged loan market, tend to lower loan spreads. For example, if spreads in the high-yield bond market decline, loans may appear attractive on a relative basis. Investors may shift funds from the bond market to the loan market as a result.

RECOVERY RATES

The textbook description of the position of a creditor in the case of a bankruptcy is that the priority of creditors as set forth in the original lending agreements will be respected by the courts. However, a good number of empirical studies have clearly demonstrated that in the case of a Chapter 11 bankruptcy, the absolute

6. For other factors influencing a loan's attractiveness, see Chapter 3 in Antczak, Lucas, and Fabozzi, *Leveraged Finance: Concepts, Methods, and Trading of High-Yield Bonds, Loans and Derivatives.*
7. Antczak, Lucas, and Fabozzi, *Leveraged Finance: Concepts, Methods, and Trading of High-Yield Bonds, Loans and Derivatives,* p. 63.

priority rule is typically violated. That is, senior creditors may not be paid in full before junior creditors and even equity owners receive some form of payment. There are a good number of economic reasons as to why the absolute priority rule may be violated. These reasons relate to the direct and indirect costs associated with the negotiations among the creditors and equity claimants. The bottom line, however, is that the recovery rates for the various levels of creditors is an empirical issue.

Fortunately, studies of recovery rates confirm that despite the high risk of a violation of the absolute priority rule in practice, the senior claim of bank loan lenders on the assets of the borrower, as measured by recovery rates, is higher than that for other creditors. In a comprehensive study by Moody's of about 3,500 defaulted loans and bonds issued by more than 700 nonfinancial U.S. corporations, the ultimate recovery rates were higher for loans in comparison to bonds.[8] More specifically Moody's found that the average recovery rate for defaulted loans was 81% of par value; the average recovery rate for defaulted bonds was only 39% of par value. Moreover, the Moody's study reported that loan recovery rates have a right-skewed distribution, while bond recovery rates have a left-skewed distribution.

Another way to look at recovery rates is using post-default trading prices as a proxy for recovery rather than the ultimate recovery levels. Based on a broad sample of issuer-weighted, post-default trading prices, the average recovery for first lien loans is about 70% of par value. In comparison, Moody's found that the average recovery rate for the same time period is about 40% of par value for corporate bonds.

It is important to keep in mind that the previously mentioned ultimate recovery rates are all expressed in percentage terms of par value. As such, loans trading at a discount to par are exposed to relatively muted risk (versus a par-priced loan) in the event of a default. In fact, leveraged loans trading at a discount can actually have a positive return profile in the event of default.

For example, in secondary market trading many leveraged loans were priced in the $60s during the depths of the Global Financial Crisis, and many were trading in the $70s during the more recent Covid-19 crisis (2020). Assume the average 81% recovery rate of par value and the simplified profit calculation (recovery – purchase price + coupon income = profit). Given these assumptions, an investor that purchased a typical loan during the depths of the financial crisis would have made a *minimum profit of 17%* if a default occurred ($81 – $69 + $0 = $12, and $12/$69 = 17%).

8. Moody's *Ultimate Recovery Database: Special Comment*, April 2007. The method for measuring recovering varies from study to study. Some studies use a loan's or bond's post-default trading level as a proxy for its recovery rate. In the Moody's study, the discounted actual amount received by the holder of a given piece of debt at the resolution of a credit event was used.

SECONDARY MARKET

Leveraged loans are private contracts and as a result, prior to 1987, little public information was available about them. This stifled secondary market trading. In 1987 the Loan Pricing Corporation (LPC) began publishing information on global syndicated loans.

In 1995, the Loan Syndication and Trading Association (LSTA) was created as an industry association whose goal was to foster the development of a more liquid and transparent secondary market. It was done so by establishing market practices and procedures for settlement and operations. For example, the LSTA publishes model credit agreement provisions and a document covering the principles for the communications and use of confidential information by loan market participants.

LSTA and Standard & Poor's (S&P) joined forces to create secondary market indexes. Market indexes play an important role for all asset classes for several reasons, such as measuring the performance of an asset class for purposes of making asset allocation decisions and evaluating the performance of managers. In the leverage loan market, the S&P/LSTA U.S. Leveraged Loan 100 is the primary index.[9] This index measures the performance of 100 of the largest institutional leveraged loans (on a market-weighted basis) drawn from term loans included in the S&P/LSTA Leveraged Loan Index (LLI). To be included in the LLI itself the term loan must meet a series of criteria, such as being a senior secured first-lien facility, having a minimum initial term of one year, having a minimum initial spread of 125 basis points over LIBOR, and be denominated in U.S. dollars, among others. The loans included are selected by a set of rules specified by S&P's index committee.

There are two methods by which loans in the secondary market change hands: by assignment or by participation. In the case of an *assignment*, the buyer becomes the lender of record with all related rights and powers. An assignment typically requires the borrower's consent for the exchange to take place. In contrast, if the exchange is accomplished via *participation*, although the buyer receives the right to repayment, the original lender remains the lender of record. It is therefore the responsibility of the lender of record to collect the amount due from the borrower and then pay that amount to the participant. The borrower's consent is usually not required in the case of a participation. However, the buyer bears a greater credit risk in the case of a participation because there is not a contractual link between the borrower and the participant. As a result, if the original lender becomes insolvent, the participant may have no recourse.

As noted earlier the importance of nonbank institutional investors within the leveraged finance market has increased over time. But with the proliferation of exchange-traded funds (ETFs) in recent years a new trend has emerged, and

9. For more details about this index, see "S&P/LSTA U.S. Leveraged Loan 100" published by Standard & Poor's; available at www.SPindices.com.

that is that the leveraged loan investor base has become even more inclusive and now "everyday" individual investors have at least some access to the market.

With regard to the trading characteristics of leveraged loan ETFs, in Exhibit 11-1 we examine select details of a benchmark leveraged loan ETF (ticker BKLN) and compare these details to a benchmark high-yield bond ETF (HYG). First, we see that as of June 2020 the market capitalization of the leveraged loan ETF was $6.5 billion, which represents a fair amount of access to the loan market for everyday investors. With regard to risk and return, the data shows that leveraged loans in ETF format offer less yield than their high-yield bond counterparts (4.98% vs. 5.36%), but are less volatile, have less downside risk, and are less actively traded. Essentially, the ETFs mirror the trading relationships between leveraged loans and high-yield bonds that exist in the cash market.

EXHIBIT 11-1

Trading Profile of Select Leveraged Finance ETFs

Characteristic	BKLN	HYG	Difference
Yield (%)	4.98	5.36	–0.38
Avg. Trading Vol (shares, mm)	8.5	31.2	–22.7
Standard Dev (%)	0.06	0.4	–0.34
Market Cap ($ bn)	6.5	11.8	–5.3
52-Week High ($)	22.92	88.53	–
52-Week Low ($)	17.06	67.52	–

As of June 2020; data from NASDAQ and Invesco and Blackrock manager fact sheets.

KEY POINTS

- A leveraged loan is a loan made to a company whose credit rating is below investment-grade (below BBB-/Baa3). When a reference is made to "loans" by market participants it typically means (1) loans that are broadly syndicated (to 10 or more bank and nonbank investors), (2) senior secured loans that are at the top-most rank in the borrower's capital structure, and (3) larger loans to larger companies.
- A leveraged loan is a syndicated loan with a single set of terms but multiple lenders, each providing a portion of the funds. The advantage of the syndication of a loan from a borrower's perspective is that it (1) allows a corporation to negotiate loan terms only once yet gain access to multiple lenders and (2) avoids possible conflicts in priority if

the borrower serially negotiated loans; all lenders in the syndicate share equal rights under the credit agreement.

- Leveraged loans can be classified as (1) pro rata loans that are distributed to banks and usually include the revolving line of credit and shorter maturity term loans, and (2) institutional loans that are distributed to nonbank institutional investors and typically include longer-maturity term loans.
- Leveraged loans commonly contain covenants or requirements that must be satisfied by borrowers. The two most common are (1) maintenance requirements, or regular reviews of operating measures, and (2) incurrence requirements, a review of specific operating measures after an issuer has taken an action to trigger a review. Purposes of such loan terms include (1) preservation of collateral, (2) appropriation of excess cash flow, (3) control of business risk, (4) performance requirements, and (5) reporting requirements.
- Studies of recovery rates confirm that the senior claim of bank loan lenders on the assets of the borrower, as measured by recovery rates as a percentage of par value, is higher than that for other creditors. It is important to keep in mind that such recovery rates are expressed in percentage terms of par value so that loans trading at par are exposed to greater loss than those trading under par in the event of a default. Worth noting is that recovery rates tend to vary meaningfully by year.
- There are two methods by which loans in the secondary market change hands: (1) by assignment, in which the buyer becomes the lender of record with all related rights and powers and (2) by participation, in which the buyer receives the right to repayment but the original lender remains the lender of record. In the case of a participation, the buyer bears a greater credit risk since there is no contractual link between the borrower and the participant.
- The proliferation of exchange-traded funds (ETFs) in recent years has increased access to the leveraged loan market. When comparing various trading characteristics of benchmark high-yield bond and leveraged loan ETFs we find similar relationships to those that exist in the high-yield and leveraged loan cash markets—loans tend to offer less yield and lower upside potential, but by various metrics tend to have less risk.

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CHAPTER
TWELVE

STRUCTURED NOTES AND CREDIT-LINKED NOTES

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Structured notes and credit-linked notes are debt instruments that provide customized interest or principal payments that depend on the performance of a specified reference asset, market price, index, interest rate, or some other market quantity. They enable investors to express a view on the future performance of the reference item as part of their investment management program or protect their other assets against adverse changes in the value of the underlying item as part of their risk management program. A structured note combines a conventional fixed-rate or floating-rate note with an embedded derivative instrument, such as an option or a swap, which links the payments on the note to the reference item. A credit-linked note (CLN) is a particular form of structured note in which the derivative instrument is a credit default swap or some other form of credit derivative.

Structured notes and CLNs provide investors with investment opportunities that they might find difficult or expensive to access in other ways—for example, because of transaction costs, regulatory restrictions, or other market frictions. Generally, any derivative instrument can be structured either as a stand-alone financial instrument, such as a swap or a forward, or it can be attached to a conventional note to form a structured note. Structured notes have been issued regularly at least since the mid-1980s. They emerged as an important instrument in the early 1990s when financial engineers regularly began crafting new forms of structured notes—including, in particular, CLNs—by attaching derivative instruments to medium-term notes in the United States, Europe, and Asia. According to Bloomberg L.P., the average annual volume of structured notes issued between 2015 and 2019 across the globe was $140 billion with 8,258 issues. The new issue volume of structured notes outside the United States accounts for, on average, 75% of the global volume of structured notes issued during the period. Exhibit 12-1 reports the volume of issuance and the number of structured note issues across the globe as well as in the United States between 2010 and 2019.

EXHIBIT 12-1

The Volume of Issuance and the Number of Structured Note Issues Between 2010 and 2019

	Global[1]		United States[2]		
Period	Volume (USD in Billions)	Number of Issues	Volume (USD in Billions)	Number of Issues	% of Global Volume[3]
2010	456.7	11,206	261.9	4,631	43%
2011	352.2	10,020	176.0	3,585	50%
2012	289.8	9,145	133.7	3,118	54%
2013	232.8	7,757	98.6	1,950	58%
2014	211.1	8,438	67.7	2,192	68%
2015	173.6	8,400	68.1	2,525	61%
2016	163.0	8,530	58.2	2,407	64%
2017	116.9	7,770	25.1	1,309	79%
2018	108.8	7,970	19.9	872	82%
2019	138.5	8,622	14.9	760	89%

Notes:

[1] Includes all structured notes issued across the globe.

[2] Includes structured notes denominated in U.S. dollars and belonging to the categories "Domestic MTN," "Global," "Private Placement," "U.S. Domestic," or "Yankee" based on Bloomberg's criteria.

[3] Percentage represents the proportion of the structured notes issued outside the U.S.

Data obtained from Bloomberg, L.P.

CLNs have been very popular since the mid-1990s, soon after the credit derivatives market first began to develop. The volume of CLNs issued in the U.S. market increased from $2.5 billion in 2000 to $12.9 billion in 2007, according to Bloomberg L.P. However, the global financial crisis that started in late 2007 caused a significant reduction in the volume of CLN issuance. According to Bloomberg L.P., the average annual volume of CLNs issued between 2015 and 2019 across the globe was $50 billion with 4,155 issues. The new issue volume of CLNs outside the United States accounts for, on average, 99.4% of the global volume of CLNs issued during the period. Exhibit 12-2 reports the volume of issuance and the number of CLN issues across the globe as well as in the United States between 2010 and 2019.

Exhibit 12-2 probably understates the use of CLNs in the United States. CLNs are often used in the U.S. CDS market because they are a form of funded credit derivative, which provides collateral that backs up the CDS protection seller's obligation to pay the protection buyer if a credit event occurs. This usage of the structure is not fully reflected in the issuance statistics in Exhibit 12-2.

EXHIBIT 12-2

The Volume of Issuance and the Number of CLN Issues Between 2010 and 2019

	Global[1]		United States[2]		
Period	Volume (USD in Billions)	Number of Issues	Volume (USD in Billions)	Number of Issues	% of Global Volume[3]
2010	45.6	2,681	0.2	23	99.6%
2011	49.5	3,099	1.0	41	98.0%
2012	68.3	3,802	0.3	22	99.6%
2013	69.0	3,762	0.0	7	100.0%
2014	65.0	3,905	0.4	13	99.4%
2015	47.4	3,584	0.8	12	98.3%
2016	47.1	3,686	0.2	10	99.7%
2017	45.0	3,955	0.2	12	99.6%
2018	40.7	4,387	0.1	9	99.7%
2019	68.8	5,161	0.1	6	99.8%

Notes:

[1] Includes all CLNs issued across the globe.

[2] Includes CLNs denominated in U.S. dollars and belonging to the categories "Domestic MTN," "Global," "Private Placement," "U.S. Domestic," or "Yankee" based on Bloomberg's criteria.

[3] Percentage represents the proportion of the CLNs issued outside the U.S.

Data obtained from Bloomberg, L.P.

STRUCTURED NOTES

A structured note combines a debt security or a certificate of deposit (CD) with a derivative instrument. It is a hybrid security that contains an embedded derivative instrument, which transforms the interest payments or the principal payments (or both) by making at least some of these payments contingent on a specified reference asset, market price, index, interest rate, or some other market quantity. Often, the derivative instrument is designed to provide the investor with financial exposure to a particular underlying asset class, such as equities, commodities, currencies, or interest rates. The term *structured* refers to incorporating a derivative into the structure of the note to give the reconfigured note the desired financial properties. Adding the contingency feature alters the risk/return profile of the (structured) note to suit the investment preferences of investors.

Instead of making the traditional interest payments that are either fixed in amount or tied to a specified floating-rate index, many structured notes pay interest in amounts that are determined by some formula tied to the movement of a stock price or index, a bond or loan price, a commodity price, a foreign exchange rate, or some other financial variable. Some structured notes are designed to have relatively conservative risk/return profiles so as to be useful in reducing portfolio risk, whereas others are designed to have more aggressive risk/return profiles—for example, by leveraging returns so as to provide the possibility for substantial gain or loss. The nature and design of the embedded derivative instrument determines the structured note's risk/return profile.

Characteristics of Structured Notes

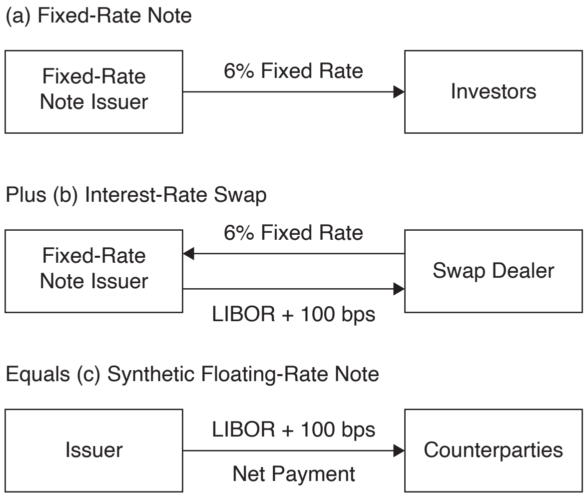
Although a floating-rate note is not considered a structured note, the relationship between a fixed-rate note and a floating-rate note can be used to illustrate the distinguishing characteristic of a structured note, which is the packaging of a derivative with a conventional senior unsecured note or a CD. Start with a 10-year note that pays a 6% fixed rate annually. Add a 10-year fixed-for-floating interest-rate swap in which the note issuer pays LIBOR plus 100 basis points quarterly and receives 6% annually. Exhibit 12-3 illustrates the resulting debt service stream. The package combining the 6% note and the swap is equivalent to a floating-rate note paying LIBOR plus 100 basis points. A floating-rate note could thus be characterized as a structured note that combines a conventional fixed-rate note and a conventional pay-floating-receive-fixed interest-rate swap. (Similarly, this basic relationship implies that a fixed-rate note could be characterized as a conventional floating-rate note plus a conventional pay-fixed-receive-floating interest-rate swap.) This simple intuition underlies all structured notes, which differ in their complexity owing to the nature of the derivative instrument(s) employed in structuring the note.

Most structured notes are issued as medium-term notes (MTNs). MTNs are usually issued under a firm's shelf-registration program, which permits the issuer to register an inventory of securities that may be sold for three years after the registration statement's effective date. Having registered securities available allows the issuer to design and make an offering of previously registered securities in a short period of time without the need to first file a separate registration statement with the SEC. This flexibility allows issuers to respond quickly to changes in market conditions by designing and offering structured notes opportunistically to take advantage of favorable funding opportunities.

Another advantage of MTNs is their flexibility in design, which can benefit both issuers and investors. By combining MTNs with derivatives, issuers can

EXHIBIT 12-3

A Floating-Rate Note Can Be Characterized as a Combination of a Fixed-Rate Note and an Interest-Rate Swap



reduce their financing costs, while investors can satisfy their specific investment needs. Investors seek to satisfy their investment needs through reverse inquiry: They contact an investment bank to request notes with specific characteristics that may not be available currently in the market. Based on an investor's view concerning future market conditions, such as future movements in interest rates, currency exchange rates, commodity prices, or other market variables, investors and issuers can customize structured notes to reflect the investors' specific views on the market. Consequently, structured notes can be issued with a range of embedded options, including call options, put options, swaps, caps, floors, or collars.

Investors prefer to have an MTN issuer of high-investment-grade quality so as not to incur significant credit risk. Structured note investors target specific financial risks they are willing to incur, and they are willing to take on issuer credit risk only if that risk is the specific one they have targeted. CLNs, discussed later in this chapter, are a form of structured note that offers such an opportunity.

The structured note issuer usually is not willing to take on the added financial risk associated with the embedded derivative. When selling a structured note, the issuer typically simultaneously enters into one or more derivative transactions to hedge this risk by transforming the cash flows that the issuer is obligated to make to investors. These derivative transactions allow the issuer to eliminate its exposure to the risks arising from the customization of the structured notes. Returning to our floating-rate note example, the issuer who sells a floating-rate MTN that pays LIBOR plus a premium can simultaneously enter into an interest-rate swap transaction in which it pays a fixed rate of interest and receives LIBOR from a swap counterparty. By combining a floating-rate note and a swap transaction, the issuer is able to create a synthetic fixed-rate note and eliminate its floating-rate risk exposure because the floating-rate payments are offsetting.

Issuing structured notes can enable a firm to reduce its financing costs when the purchasers of the structured notes are willing to pay a premium (accept a reduced yield) in exchange for the investment opportunity. They may be willing to pay a premium when similar investment opportunities are not currently available, possibly due to investment restrictions. For example, suppose an institutional investor that is not permitted to purchase stand-alone non-U.S. currency options has a view that the Australian dollar is going to appreciate significantly relative to the U.S. dollar over the next five years. It cannot buy Australian dollar call options, but it might be able to purchase a structured note that will pay an increased redemption amount at maturity if the Australian dollar has appreciated above some specified threshold. This contingent payment structure embeds a call option on the Australian dollar in the structured note, as illustrated in Exhibit 12-4. The institutional investor is willing to pay for the embedded call option by accepting a lower coupon rate on the structured note than it would require for a plain vanilla fixed-rate note of the same maturity for the same issuer.

Suppose the structured note issuer does not wish to be exposed to Australian dollar foreign exchange risk. It can purchase a matching call option on the Australian dollar from an options dealer (possibly the same dealer who created the structured note) and finance the option premium through the dealer—for example, by paying the dealer 90 basis points per year. If the annual option premium payment is less than the differential in yield between the structured note and an otherwise identical conventional note, then this difference in payments reduces the firm's funding cost, as illustrated in Exhibit 12-5. The issuer saves 10 basis points (6.00% to 5.90%) in this example.

Structured European Medium-Term Notes

When an MTN is issued outside the United States, particularly in the Euromarket, the product is called a Euro-MTN. Euro-MTNs are not subject to national regulations, such as SEC registration requirements. An issuer of Euro-MTNs typically maintains a standardized single document that can be tailored to suit almost any Euro-MTN issue and provides flexibility in the size, currency, and contingent structure of the offering. Similar to MTNs issued in the U.S. market, structured Euro-MTNs can provide an issuer with the opportunity to reduce its funding costs by crafting structured notes opportunistically.

The maturity of Euro-MTNs are typically less than five years, and the ratings on Euro-MTNs are typically higher than MTNs issued in the U.S. market because of the greater credit sensitivity of Euro-MTN investors. The Euro-MTN market is more diverse than the U.S. MTN market, mostly because it has a broader range of currency denominations and a more international mix of borrowers and investors.

EXHIBIT 12-4

Structured Note with an Embedded Foreign Exchange Call Option

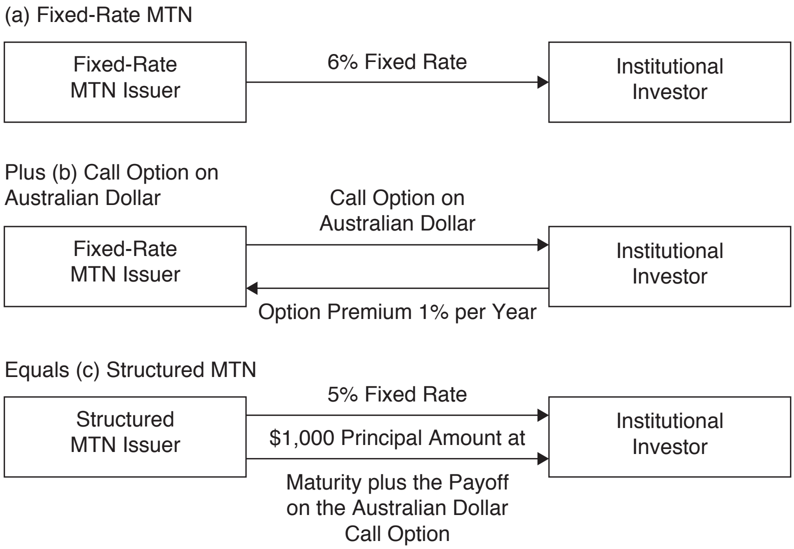
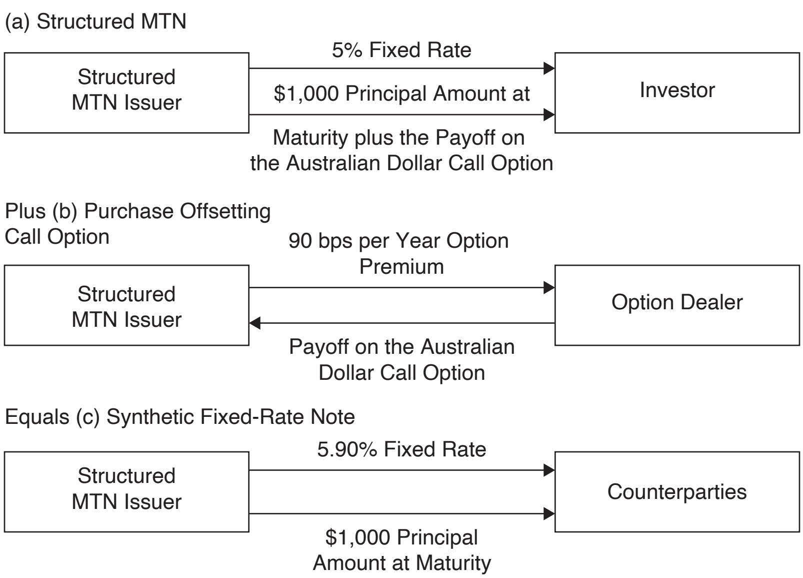


EXHIBIT 12-5

Structured Note Issuer Reduces Its Funding Cost When It Enters into an Offsetting Derivative Transaction That Costs Less Than the Value It Receives for Including the Embedded Call Option in the Structured MTN



Types of Structured Notes

Structured notes have been designed to provide exposure to a wide range of financial risks, such as changes in interest rates, foreign exchange rates, stock prices, the value of market indices, commodity prices, and credit quality. A few examples will illustrate the rich variety of structured MTNs.

Inverse Floating-Rate Notes

A floating-rate note is structured to facilitate taking a view on the future direction of interest rates. Inverse floating-rate notes (IFRNs) reverse the direction of the bet on interest rates. They can also be structured so as to leverage the bet. In particular, IFRNs have a coupon reset formula in which LIBOR is subtracted from a fixed percentage rate. As LIBOR increases (decreases), the coupon payment on an IFRN decreases (increases). By design, investors in IFRNs generally expect interest rates to fall and are therefore bullish on bond prices. For this reason, IFRNs have also become known as *bull floaters*.

If an investor expects interest rates to fall, the investor can approach an investment bank for an opportunity to purchase a structured note, issued by an investment-grade company, with coupon payments that move inversely to LIBOR. The investment bank then communicates this interest to prospective note issuers to whom it proposes an IFRN transaction. If an issuer agrees to the proposed transaction, it would then issue the IFRNs to satisfy the investor's demand.

Exhibit 12-6 provides an example of an IFRN. An IFRN can be created by adding an interest-rate swap to a fixed-rate MTN. For example, if the issuer combines a 7% fixed-rate note and a fixed-for-floating interest-rate swap that pays 7% fixed and receives LIBOR, the resulting structured note pays interest at a rate equal to 14% minus LIBOR. The coupon rate on the IFRN varies inversely with LIBOR.

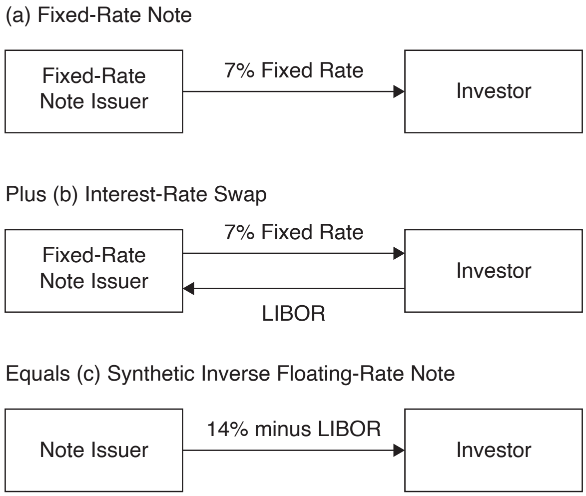
IFRNs have a very long duration. When interest rates drop, the coupon rate on the notes increases and the discount rate at which the stream of debt service payments is valued decreases, which magnifies the price increase. The opposite occurs when interest rates rise. Consequently, the IFRN exhibits much greater price sensitivity in response to interest rate changes than even a conventional fixed-rate note of the same maturity. As Exhibit 12-6 suggests, an IFRN has a duration that is roughly double the duration of a comparable fixed-rate note.

The issuer's objective in issuing structured notes is to reduce its funding cost by satisfying an investor's demand for a particular structure without incurring undue additional risk. If the issuer of IFRNs does not want to pay floating-rate interest, which will fluctuate inversely to market interest rates, but rather, wants to fix its interest payments, then it must hedge this risk. To protect itself against the IFRN's heightened interest-rate risk, the IFRN issuer can simultaneously enter into an offsetting interest-rate swap transaction to pay floating and receive fixed.

Suppose it can issue three-year IFRNs that pay 13.75% minus LIBOR with a semiannual reset. The 25-basis-point saving versus the coupon in Exhibit 12-6 might reflect the reduction in yield purchasers are willing to accept in return for

EXHIBIT 12-6

An Inverse Floating-Rate Note Can Be Characterized as a Combination of a Fixed-Rate Note and an Interest-Rate Swap



the IFRN investment opportunity. An interest rate floor is included in the IFRN to prevent a negative coupon rate if LIBOR rises above 13.75%. The swap does not have such a feature, but the IFRN issuer can offset the IFRN floor by purchasing a cap contract. Thus, the IFRN issuer can hedge its IFRN risk exposure by entering into a swap transaction in which it receives a fixed rate of 7% semiannually for three years and pays LIBOR and simultaneously purchasing a cap contract that pays the excess above the strike rate if LIBOR rises above 13.75%. Suppose the cap contract costs 10 basis points per year. Exhibit 12-7 illustrates the effect of the hedging transactions. As a result of issuing the IFRN and entering into the swap and purchasing the cap contract, the issuer creates a synthetic fixed-rate note paying a 6.85% coupon rate. Its cost of arranging three-year fixed-rate funding is 6.85%, which represents a saving of 15 basis points (6.85% versus 7%).

Leveraged Inverse Floating-Rate Notes

An IFRN can be leveraged by adding another interest-rate swap. This structure results in a coupon rate that is equal to some fixed rate minus some multiple of the reference rate. Exhibit 12-8 illustrates the structure of a leveraged inverse floating-rate note (leveraged IFRN). In this particular example, two interest-rate swaps are embedded in the structured note. As a result, a multiple of two is applied to LIBOR, and the coupon rate of the leveraged IFRN declines twice as fast as the coupon of the IFRN in Exhibit 12-6 as LIBOR rises. The leveraged IFRN pays interest at the rate of 21% minus two times LIBOR.

EXHIBIT 12-7

An Issuer of an Inverse Floating-Rate Note Can Offset Its Interest-Rate Risk by Entering into an Offsetting Interest-Rate Swap and Purchasing a Cap Contract

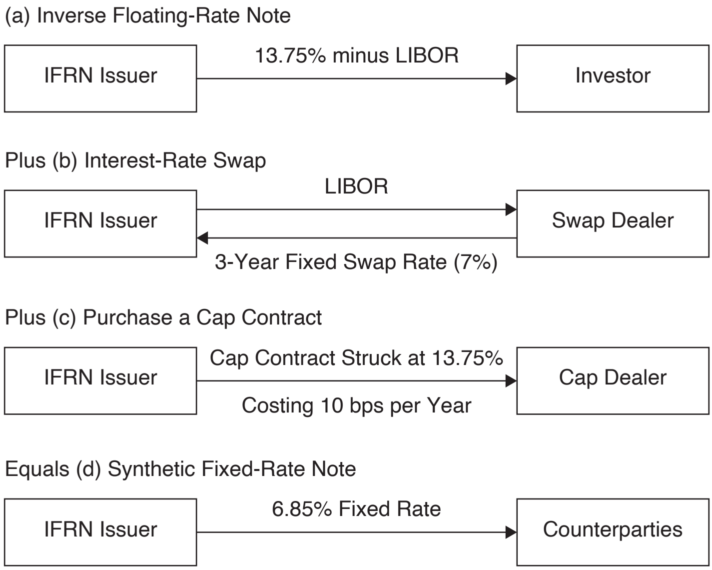
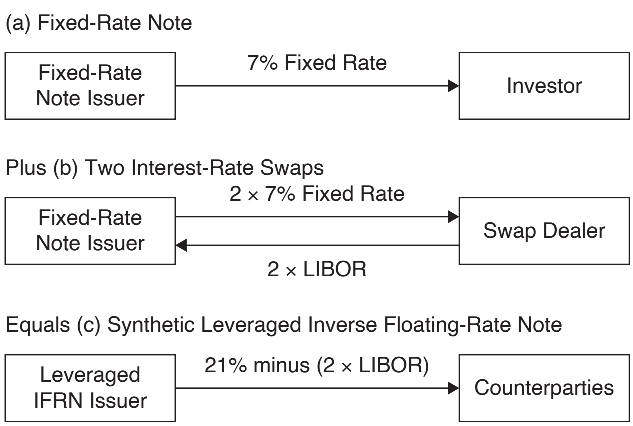


EXHIBIT 12-8

A Leveraged Inverse Floating-Rate Note Created by Combining a Fixed-Rate Note and Two Interest-Rate Swaps



Range Floating-Rate Notes

A range floating-rate note enables the issuer and investors to take a particular view on future interest rate volatility. Range floating-rate notes make interest payments only when the specified interest rate, usually a short-term interest rate such as three-month LIBOR, stays within the stated range. For instance, suppose an issuer sells a range floating-rate note that accrues interest during the first two interest periods at a rate equal to three-month LIBOR plus 100 basis points on those days when three-month LIBOR is between 3% and 4%. The range typically steps up in subsequent periods. If three-month LIBOR is outside the specified range, no interest accrues that day. Therefore, the investor profits if short-term interest rates rise in a gradual and predictable pattern and stay within the specified range. At the same time, the investor bears the risk that LIBOR rises or falls outside of the specified range. In return, the investor is compensated for this risk by receiving a greater spread over LIBOR than a conventional floating-rate note of the same issuer would provide.

An issuer of range floaters could simultaneously enter into an interest-rate swap transaction to hedge its floating interest-rate risk exposure. For example, suppose the issuer enters into an interest-rate swap that pays 6% fixed and receives floating-rate payments that mirror the coupon payments on the structured note, which is three-month LIBOR plus 100 basis points when LIBOR is within the specified range, as in the previous example. As a result of the combined transactions, the issuer of the range floater locks in a financing rate of 6%, which is beneficial if its cost of conventional fixed-rate funding for that maturity exceeds 6%.

Yield Curve Accrual Notes

A yield curve accrual note accrues interest at an above-market fixed annual rate but only when the slope of the yield curve is within a specified range. The slope of the yield curve is defined by the difference between specified long-term and short-term interest rates, such as the difference between the 30-year constant maturity Treasury (CMT) rate and the 2-year CMT rate. No interest accrues on days when the slope is zero or negative; that is, the yield curve is flat or inverted. Often, the notes initially pay the above-market rate for a year or two, and the accrual feature starts at the end of this period. The issuer is usually given the option to redeem the notes prior to maturity or there may be an automatic call. The total rate of return is capped by the fixed annual rate.

A similar structure offers a leveraged play on the slope of the yield curve. Leveraged yield curve–linked notes initially pay interest at an above-market fixed rate for one or two years before switching to paying a floating rate. This floating rate is equal to a multiple, typically between two and five times, of the slope of the yield curve at the beginning of the quarterly interest period. The interest rate is capped, and the minimum rate is zero (if the yield curve is flat or inverted).

Currency-Linked Notes

A currency-linked note is a structured note in which payments are linked to the performance of a specified foreign exchange rate or a basket of currencies. Investors are able to capitalize on their view of the likely movement of the exchange rate. One of the most popular types of currency-linked notes combines a fixed-rate note with an embedded currency call or put option. The issuer pays (receives) an option premium to (from) investors in the form of an enhanced (reduced) coupon rate if it is long (short) the embedded option. At maturity, if the currency option remains out-of-the-money, the issuer repays the par amount to the investor. If the option is in-the-money, the principal repayment amount is enhanced or reduced according to the type of option and its moneyness.

For example, suppose a financial institution wants to issue a structured note that will provide a hedge against a possible fall in the value of the Japanese yen relative to the U.S. dollar. It can sell investors a Japanese-yen-linked U.S. dollar–denominated structured note for \$10 million with an embedded long yen put option that specifies a strike rate set equal to the spot yen–dollar exchange rate of, say, ¥90/\$1 at the time of issue. This put option on yen can be viewed equivalently as a call option on the U.S. dollar. The note pays the par amount in dollars at maturity if the option is out-of-the-money (Japanese yen remains above—equivalently, the U.S. dollar remains below—¥90/\$1). At maturity, if the Japanese yen has weakened (equivalently, the U.S. dollar has strengthened) to ¥95/\$1, then the payment is reduced by \$0.53 million (= \$10 million × (90 – 95)/95). Thus, the financial institution pays—and the investors receive—\$9.47 million. The \$0.53 million saving would offset part of the foreign exchange loss on the assets the financial institution had hedged by issuing the currency-linked note. Conversely, non-U.S. investors who believe that the Japanese yen would strengthen relative to the U.S. dollar—equivalently, that the U.S. dollar might weaken against the Japanese yen—could express that view by taking the other side of the transaction.

As with other structured notes, an issuer of a currency-linked note that is not interested in the currency option for hedging or investment purposes, but is merely acting as a conduit, can hedge itself by taking an offsetting position in the option. If the issuer of the currency-linked note in the preceding example, which is the buyer of a currency put option, were instead merely acting as a conduit, it could hedge itself by selling an identical (or substantially similar) yen put option to neutralize its risk exposure to changes in the yen-dollar exchange rate.

Equity-Linked Notes

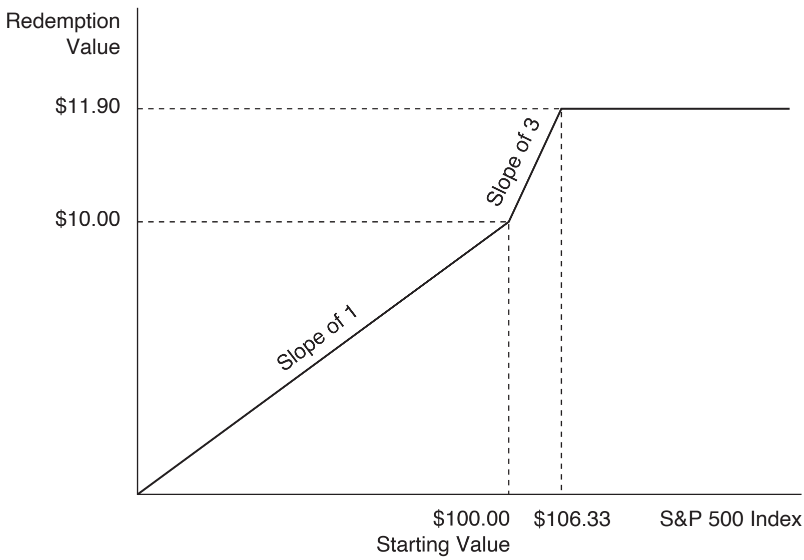
Equity-linked notes are structured by combining a note with an equity derivative. The payments on an equity-linked note are principally determined by the return on the underlying equity derivative, which could be a single stock, a basket of stocks, or an equity index.

One structure combines a non-interest-bearing note and an equity call option. On the maturity date, an investor receives the par value of the note plus a variable return based on the percentage change in the underlying equity derivative. Specifically, the final payout is calculated as the initial investment times the gain or loss in the underlying stock or equity index times a note-specific participation rate. For instance, if the gain on the underlying stock or equity index is 30% during the investment period and the participation rate is 90%, the investor receives 1.27 times the amount she invested. If the note provides principal protection (a floor rate of return of zero) and the underlying equity declines or remains unchanged during the investment period, then the investor simply receives the original amount she invested.

Many equity-linked notes build in leverage by increasing the participation rate to two or three times the percentage change in the benchmark index. For example, suppose a highly rated bank holding company originates accelerated return notes (ARNs) linked to the S&P 500 Index. Its broker-dealer subsidiary will market the notes to its retail customers who want to take a view on the performance of the S&P 500 over the next 14 months. The face amount of each note is $10. The ARNs do not pay interest; the only payment is at maturity. The notes have a 3× participation rate subject to a 19% total return cap. If the ending value of the S&P 500 exceeds the starting value, the ARN holder gets her $10 back plus the product of $10 times the participation rate (3×) times the percentage return on the S&P 500 subject to a cap of $11.90 ($10 plus a 19% return). If the ending value is less than or equal to the starting value, the amount the ARN holder gets back is reduced by the percentage drop in the S&P 500. Exhibit 12-9 shows the payoff on an ARN at maturity. Note that if the S&P 500 fell to zero, so would the payoff on the ARN; the ARN's value would be wiped out.

EXHIBIT 12-9

Payoff on an ARN at Maturity



Equity-linked notes can also be interest-bearing. In that case, the participation rate is reduced to reflect the income provided by the interest payments. As with other structured notes, an issuer of an equity-linked note can hedge its risk exposure—in this case, by simultaneously purchasing an equity call option to hedge its exposure to a rise in the price of the specified stock or equity index. Issuers of equity-linked notes have typically been broker-dealers or highly rated financial institutions with a broker-dealer subsidiary, who can structure these hedges relatively cheaply.

Commodity-Linked Notes

Commodity-linked notes are created by combining a note with a commodity derivative. Commodities that have served as the underlying for such securities include crude oil, natural gas, gasoline, copper, lead, or precious metals. The payments on a commodity-linked note are determined by the performance of the underlying commodity or a specified basket of commodities. Interest or principal payments or both can be commodity-linked.

One structure combines a non-interest-bearing note and a commodity call option. At maturity, an investor receives the par value of the non-interest-bearing note plus a variable return based on the percentage change in the price of the underlying commodity component. If the note provides principal protection and the price of the underlying commodity declines or remains unchanged during the investment period, then the investor simply receives the original amount she invested.

As with equity-linked notes, commodity-linked notes can also be interest-bearing, and the issuer of the notes can hedge its risk exposure by simultaneously entering into an offsetting commodity derivative transaction.

Risks of Structured Notes

Issuers of structured notes and investors face a variety of risks in addition to the risk that is specific to the embedded derivative instrument. These risks are in addition to the risks due to changes in interest rates and price risk due to the remaining time to maturity.

Credit Risk

A structured note is typically a senior unsecured note. An investor does not have a security interest in (or any other access to) the underlying assets. Because a structured note combines an unsecured note and a derivative instrument that an investment bank creates to satisfy an investor's desire for exposure to a specific risk, payments of interest and principal are subject to the note issuer's credit risk. An investor is exposed to the risk of a change in the note issuer's credit ratings or a change in the credit spread of the issuer's senior unsecured notes, which affects the required rate of return on the issuer's conventional notes. An investor bears the risk that the issuer might default on the note. Investors try to control this risk by limiting their structured note purchasers to notes issued by high-grade issuers, such as the parent company of a major bank, a major broker-dealer, or government-sponsored enterprises Freddie Mac and Fannie Mae before they encountered financial distress.

Structured notes are also issued by banking institutions in the form of CD bank deposits. When issued in the United States, their principal (but not any unrealized gain) is insured up to the permitted limit by the Federal Deposit Insurance Corporation, which is an agency of the U.S. government.

It has been more common, however, for investment banks to issue structured notes. Because of the risk of issuer default, it is possible for a structured note to become worthless even when the embedded derivative is in-the-money. This counterparty risk is well illustrated by the collapse of Lehman Brothers in September 2008, which resulted in Lehman Brothers structured notes becoming worthless even when the underlying derivatives had positive returns. In effect, the default risk trumped the risks and returns inherent in the embedded derivative instrument and nullified the specific bet that the issuer and the investors were trying to make when the structured notes were issued.

Market Risk

By design, an investment in a structured note carries additional market risks on top of the risks that a traditional note carries because of the embedded derivative instrument. A structured note is created for investors who are seeking to profit by taking on specific market risks. Depending on future market conditions, such as interest-rate movements, stock price movements, or commodity price movements, losses on a structured note could be magnified. Market risks can be quantified with financial models, such as an interest-rate term structure model or an option pricing model, so that the degree of market risk can be quantified and priced into the structured note price.

The price at which a particular structured note could be sold prior to maturity will depend on several market-related factors that are difficult to assess, which can cause the sale price to be substantially less than the purchase price. These factors include (1) changes in the value of the underlying asset or index, (2) the volatility of the underlying asset or index, and (3) changes in the dividend rate on the underlying asset or index.

The secondary market price of a structured note will also be adversely affected by the inclusion of the issuer's hedging profits and the agent's commissions in the issue price. These transaction costs will not be reflected in the secondary market price. Consequently, the secondary market price will tend to be less, and possibly significantly less, than the purchase price.

Liquidity Risk

The markets for structured notes are generally less liquid than those for conventional senior unsecured notes. There may be no secondary market for a particular structured note. Structured note issuers typically do not commit to make markets in the notes they issue. Most structured notes are rarely traded after issuance. An investor in a structured note should be prepared to hold it to maturity. Due to the limited liquidity, structured notes often have a short maturity between one and three years to compensate.

One of the reasons for the market illiquidity is that because a structured note is customized to satisfy the specific needs of an original investor, there is a smaller number of potential investors who might be willing to buy the structured note (and make the same customized bet) in the secondary market. Another reason for the market illiquidity is that the issue sizes are generally smaller and the transaction costs are usually higher than for standardized notes. Consequently, to value a structured note, one needs to take into account not only the credit risk of the issuer, but also the particular risk/return profile customized to the investor. Pricing accuracy can be another concern with structured notes. Because structured notes are rarely traded after issuance, their prices are usually calculated with a financial model. In that case, the accuracy of the valuation depends to a large extent on whether the underlying derivative is modeled correctly.

As a result, when an investor intends to sell structured notes before they mature, it may not be easy to sell them at a reasonable price within a reasonable time frame. For instance, if interest rates move in the opposite direction to an investor's expectation when he purchased a structured note, the investor may want to sell the structured note but not be able to find a market for it. As another example, when an investor's view on the direction of interest rates proves to be correct but the interest rate underlying the structured note (such as the interest rate in an inverse floater) changed earlier than expected, the investor may want to sell the structured note before the maturity date to take advantage of current market conditions and lock in her profit. Because structured notes are thinly traded securities, the spread between the market bid and ask prices may be wide; the size of the spread would reduce the profit realized on the structured note investment.

Early Redemption Risk

Many structured notes give the issuer the discretion to redeem the notes prior to maturity or automatically redeem the notes early based on the performance of the underlying asset or index. The issuer is likely to use this discretion when interest is accruing faster than on conventional notes of the same maturity and credit rating. The early redemption stops the accrual of interest at the favorable rate and forces the investor to reinvest the redemption proceeds at a less attractive yield.

Systemic Risk

Systemic risk refers to the risk associated with a broad market disruption within the financial market system, as opposed to being limited to an individual security or a particular market segment. By design, structured notes are more exposed to systemic risk than conventional notes because the payments on structured notes are often tied to the conditions in the derivative markets for foreign exchange, equities, or commodities. Any disruptions or problems in the underlying derivative market would magnify the structured note holder's risk exposure to that market and compound her risk exposure to disruptions or problems in the fixed income market. Structured notes typically provide that the calculation of the final payment on the maturity date will be postponed if any of the specified market disruption events occurs on that date.

Why Do Investors Buy Structured Notes?

Investors buy structured notes when the risk/return profile of the security matches their investment needs and the investment opportunity is not otherwise available as cheaply (or at all) in the capital market.

Enhanced Yield

Investors in structured notes typically hope to realize an above-market rate of return. This enhanced yield opportunity might entail an above-market coupon payment if the underlying interest rate moves in the investor's favor in exchange for incurring the risk of receiving interest at a floating rate. This floating rate might be very low or even zero for long periods of time. Alternatively, the potential for enhanced yield might be tied to the performance of a specified benchmark with a single payment at maturity in exchange for foregoing coupon payments and assuming the risk that the payment at maturity might be less than the face amount and possibly even zero. The payoff at maturity is often capped.

Administrative Efficiency

Compared with separate transactions consisting of notes and derivative instruments, which could be complex and costly, purchasing a structured note makes the process simple and reduces administrative costs, such as the cost of maintaining margin or the cost of rolling over shorter-term derivative contracts. At least partially offsetting this benefit, the purchase price usually includes the agent's commission and the issuer's hedging profit, which can increase the investment cost significantly.

Diversification and Hedging

Structured notes facilitate investors diversifying their investment portfolios into new products and new security types and possibly new markets. For example, an investor can diversify his interest rate risk exposure by purchasing a structured note with an embedded derivative based on a different asset class. The embedded derivative can serve a useful hedging purpose, as in the example earlier in the chapter of a financial institution that issued a structured currency-linked note containing a Japanese yen put option to protect against a fall in the value of the Japanese yen relative to the U.S. dollar. Inflation-protection structured notes pay a coupon tied to a benchmark inflation index, which provides the investor with a hedge against inflation.

Customization and Managing Risk Exposure

Because structured notes are customized to conform to investors' views on the interest rate, stock price, exchange rate, or commodity price reflected in the underlying derivative instrument, investors are able to adjust the risk/return profiles of their investment portfolios. Through a reverse inquiry, an investor is able to request notes with specific characteristics, which may not be available currently in the market.

Some structured notes are created to minimize risk exposure by providing principal protection, while others are created to maximize returns with or without principal protection. In any case, the derivative components of the structured notes allow the products to be aligned with any particular investor's market view or economic forecast and to suit the investor's risk tolerance. Moreover, leverage can be built into structured notes, as with leveraged inverse floaters, which can enhance expected returns—but also investment risk—as compared with a direct investment in the underlying assets. Therefore, investors are able to manage risks appropriate to their risk/return profiles in line with their views on the market.

Principal-Protected Structured Notes

A principal-protected structured note (PPN) is a structured note that guarantees the return of at least 100% of invested capital (a floor rate of return of zero), regardless of market conditions, as long as the notes are held to maturity. On the maturity date, barring a default by the issuer, investors receive payments consisting of the original principal amount plus any gains from the underlying assets. Because a PPN is a structured note combined with downside protection, investors in PPNs exchange more certain yet potentially lower returns for more uncertain and potentially larger returns. The return from investing in a PPN depends on the value of the embedded option at maturity. With many PPNs, there is no periodic payment of interest during the investment period, and just a single payment is made at maturity.

Its name suggests that a PPN guarantees the repayment of 100% of invested principal. However, this assurance does not mean that there is zero downside risk, because the issuer might default. Typically, an investment bank or a bank holding company serves as the issuer and is therefore responsible for paying the contingent principal amount at maturity. Therefore, evaluating the financial condition and creditworthiness of the issuer is an important step in deciding whether to purchase a PPN. Credit risk can be significant, which materializes when the issuer defaults. An investor can reduce its principal repayment risk by investing in a structured CD that qualifies for deposit insurance.

The Impact of the Lehman Brothers Bankruptcy

The Lehman Brothers collapse in September 2008 has affected virtually all areas of the financial markets in some way, but particularly the structured products market, because a large number of products were linked to Lehman Brothers' credit. One of the more significant products was the Lehman Brothers PPNs.

The Lehman Brothers PPNs were issued as hybrid financial instruments, constructed from a combination of stocks, bonds, currencies, commodities, and derivatives, which were sold to retail investors as low-risk and safe investments. UBS, one of the largest sellers of structured notes, and other brokerage firms sold Lehman Brothers structured notes to retail investors with principal protection effectively guaranteed by Lehman Brothers. Following the Lehman Brothers bankruptcy in September 2008, however, the guarantee of principal protection became meaningless, and the PPNs became essentially worthless.

Before the Lehman Brothers collapse, investment banks were able to sell PPNs to investors easily because investors were convinced that the PPNs would guarantee principal repayment even when the underlying investments did not produce a positive return. However, the Lehman Brothers bankruptcy rudely awakened retail investors to the risk of possible credit loss and generated a substantial amount of litigation in which investors asserted that the PPN guarantee had been misrepresented because the investors' principal was not truly protected in all events.

This negative experience highlights the need to warn investors properly concerning the risks of investing in structured notes. It also highlights the problem inherent in every derivatives contract: a counterparty default will undermine the upside opportunity or downside protection investors thought they were getting when they purchased the structured notes.

CREDIT-LINKED NOTES

Broadly defined, a CLN is a structured note with at least some of its payments dependent on the occurrence of a defined credit event, such as a specified entity's default, a change in a specified entity's credit rating, or a change in a specified debt instrument's credit spread. CLNs have grown in importance with the development of the market for credit default swaps (CDS) because like CDS, CLNs provide attractive opportunities for managing credit risk exposure. At its simplest, a CLN is a form of collateralized CDS.

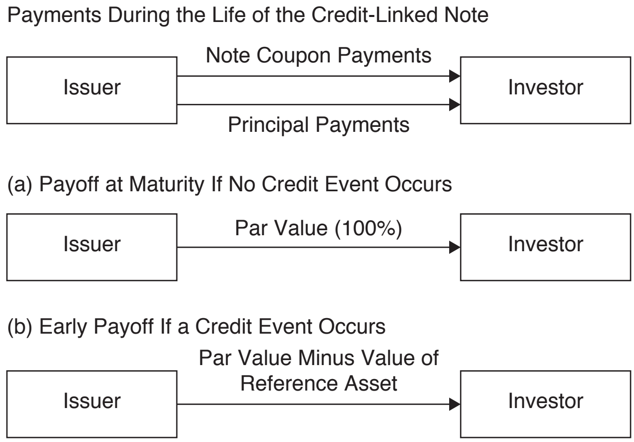
Characteristics of Credit-Linked Notes

Typically, a CLN is a combination of a conventional note and a CDS. A CLN is often issued by either a very strong credit, such as a high-grade bank or a government-sponsored enterprise, or a special-purpose bankruptcy-remote trust that is a counterparty to the CDS. A total return swap or a credit forward contract can also be used in this structure. A CLN allows the issuer to transfer a particular credit risk exposure to the purchaser of the CLN. In this structure, the issuer (seller) of the CLN is the protection buyer, and the investor (purchaser) of the CLN is the protection seller, who ultimately bears the credit risk.

As shown in Exhibit 12-10, if a credit event occurs, the CLN is redeemed early. The redemption amount is reduced below the face amount according to the reduced value of the underlying reference asset, such as a bond or a bank loan that falls in value due to the credit event's occurrence. If no credit event occurs during the life of the CLN, then the full principal amount of the note is paid to the investors at maturity.

EXHIBIT 12-10

Payoffs on a Credit-Linked Note



CLNs are attractive to issuers who want to hedge against a credit default or a rating downgrade, which would adversely affect the value of one of their investments. They are able to customize the terms of the credit protection contract to satisfy their credit risk protection objectives. On the other hand, investors purchase CLNs with the objective of enhancing the yield they receive on their note investment. Investors find CLNs attractive because they are able to gain access to the credit market, which might be unavailable to them otherwise.

A CLN normally adjusts the principal repayment to pay off on the credit derivative instrument embedded within the note. For example, suppose an investor purchased a five-year CLN at a credit spread of 200 basis points that would repay \$1,000 at maturity or \$1,000 minus the payoff if a credit event occurs before the CLN matures. The investor has sold a put option to the issuer of the note and in return receives a higher coupon. Suppose that the reference bond's credit spread is 100 basis points and a credit event occurs that causes the price of the reference asset to fall to 80. The issuer of the CLN pays 100 basis points per year for the put option (200 – 100 basis points). The holder of the CLN would receive \$800 (80% of \$1,000) per \$1,000 face amount following the credit event. The single payment is equivalent to receiving \$1,000 and simultaneously paying off \$200 on the put option.

Funded Credit Derivative

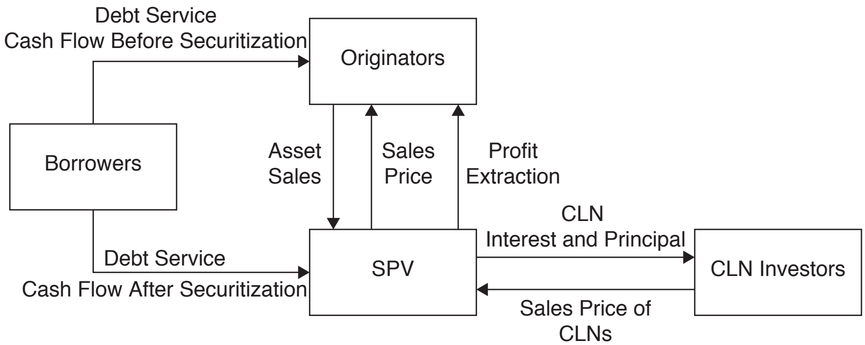
CLNs have gained in popularity because they provide credit protection like CDSs, but entail less risk of contract default. CLNs are a form of funded credit derivative. The investor in the CLN, the protection seller, pays cash to the protection buyer—the full purchase price of the CLN—to purchase the CLN. If a credit event occurs, the protection buyer's repayment obligation decreases, and the protection buyer returns less cash to the protection seller than if no credit event had occurred. In contrast, with CDS, the protection buyer must collect the cash payment from the protection seller, if there is cash settlement, or the protection seller must obtain the bond or loan obligation from the protection buyer and sell it in the market, if there is physical settlement. A CLN thus involves less contract default risk than a CDS written by the same protection seller.

SPV Structure

CLNs have been issued by large financial institutions. This unfunded structure exposes CLN investors to the financial institution's default risk. Alternatively, the CLNs can be issued through a funded structure in which a bankruptcy-remote special-purpose vehicle (SPV) is created to hold high-quality financial assets and issue the CLNs. This structure, which is illustrated in Exhibit 12-11, insulates CLN investors from the risk of issuer default because the SPV's assets are selected so as to generate sufficient cash flows to service the CLNs. The funded CLN structure thus limits the investor's default risk exposure to the reference obligation specified in the CLN, which was the purpose for creating the CLN in the first place.

EXHIBIT 12-11

Structure of a Credit-Linked Note



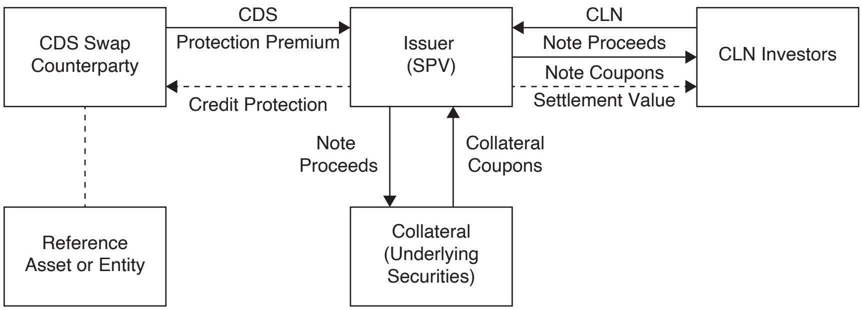
Combining Credit-Linked Notes and Credit Default Swaps

An issuer can design structured products combining CLNs and CDSs to meet both the issuer's and the investors' requirements. Exhibit 12-12 illustrates the combined structure of CLN and CDS, which is designed to fund the CDS obligation and to provide higher returns for an investor who is willing to take on the corresponding credit risk. The CLNs are issued by an SPV, which holds the collateral securities (also known as the *underlying securities*). The SPV uses the proceeds from issuing the CLNs to purchase the pre-agreed collateral securities.

They are normally risk-free securities, such as Treasury bills. The SPV grants a security interest in the collateral to secure the SPV's future performance under the CLN contract. The cash flow from these high-quality securities is used to pay the interest and principal on the CLNs as long as no credit event occurs. In this structure, the SPV buys credit protection on a single reference asset or entity by entering into a CLN and paying the ongoing premium, which is included in the CLN interest rate. The CLN investors sell the credit protection and receive the premium; they have the credit risk exposure to the reference asset or entity.

EXHIBIT 12-12

CLN and CDS Structure on a Single Reference Name



At the same time, the SPV simultaneously enters into a CDS agreement with a highly rated swap counterparty. In this swap agreement, the SPV sells credit protection on the same reference asset or entity underlying the CLNs and, in return, receives the CDS premium. Through the combined CLN and CDS structure, the SPV has a neutral credit risk position with respect to the reference asset or entity.

The coupon rate on the CLN is a spread over LIBOR and is funded by the collateral securities and the fee generated by selling protection in the CDS transaction. The SPV's payment on the CLN is linked to the performance of the reference asset or entity. If a specified credit event[1] involving the reference asset or entity occurs, there are three options to settle the CLN and the CDS. First, under the recovery-linked option, a third party sells the reference assets into the market, and the SPV distributes the realized proceeds to the CLN investors to settle the CLN. At the same time, the third party sells the underlying collateral securities and distributes the proceeds to the swap counterparty to settle the CDS. Second, under the physical delivery option, the CDS swap counterparty delivers the reference assets to the SPV and the SPV delivers them to the CLN investors,

1. Credit events typically include bankruptcy, payment default, repudiation, and restructuring.

and the SPV also delivers the underlying collateral securities to the CDS swap counterparty. Third, under the binary option, a specified cash payment is negotiated among the SPV, the CDS counterparty, and the CLN investors at the outset of the transactions. The SPV makes that cash payment to the CDS counterparty if a credit event occurs. It then deducts it from the principal amount owed to the CLN investors and repays the net amount to the CLN investors.

Reference Obligation Is Emerging Market Sovereign Debt

In the case of CLNs, in which the reference obligation is an emerging market debt obligation, the SPV also may need to enter into an interest-rate swap or a currency swap to reduce interest-rate risk and to tailor the required cash flows of the CLN to the cash flows of the collateral. The resulting package is a CLN that performs similarly to a sovereign bond. Such CLNs are bought by investors who seek an increase in yield as compared with what a comparable sovereign bond would offer and who do not need liquidity during the life of the CLN.

Credit-Sensitive Notes

A conventional corporate bond can be viewed as a package consisting of a long Treasury note and a short position in a CDS, with the credit event defined as an actual default with immediate payment. (Alternatively, one can assume the immediate sale of the note in the event default occurs and ignore the optionality inherent in the flexibility to time the sale of the defaulted note.) In a conventional corporate bond, part of the coupon payment (the credit spread) can be viewed as the CDS premium. The size of the coupon payment depends on the credit quality of the bond at the date of issue, but normally does not change if the credit quality of the bond subsequently changes. Credit-sensitive notes provide for variation in the size of the coupon if the issuing firm's credit quality changes.

A credit-sensitive note is a fixed- or floating-rate note on which the interest rate is adjusted in response to a change in the issuer's credit rating. The coupon rate adjusts inversely to the change in the note's credit rating. If the issuer is downgraded by a credit rating agency, the credit-sensitive note pays a higher coupon rate to compensate investors for the additional credit risk. In this structure, the investors are short a credit spread forward agreement.

Consider the following example with the indicated credit ratings and spreads:

Credit Rating	Credit Spread
AA	100 bps
A	125 bps
BBB	150 bps
BB	200 bps

An investor buys a single-A-rated note paying 125 bps over Treasuries. If the credit rating rises to AA, the investor receives 25 bps less per year in interest. If the credit rating falls to BBB, the investor receives 25 bps more per year in interest. Thus, a credit-sensitive note is a form of structured note, which provides a built-in hedge against changes in the issuer's credit quality. It thus provides protection against the moral hazard risk fixed income investors face.

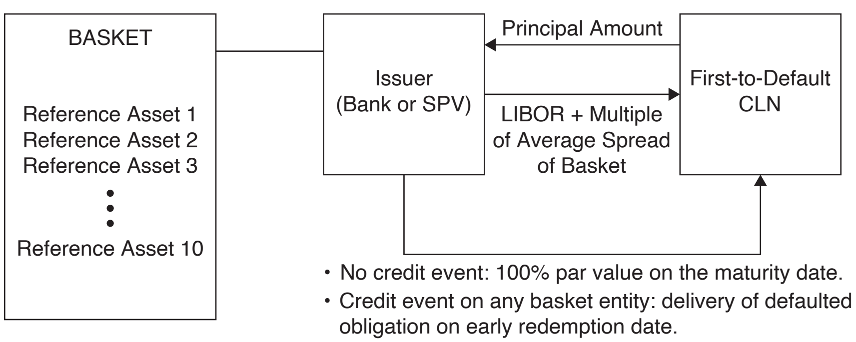
First-to-Default Credit-Linked Notes

A standard CLN is issued with reference to one specific bond or loan. A basket credit-linked note is a CLN that is linked to more than one reference entity. In a first-to-default CLN, an investor sells credit protection on a basket of assets, and the payment occurs upon whichever entity in the basket is the first to default. The coupon payment on the first-to-default CLN is LIBOR plus a multiple of the average spread for the reference entities in the basket of assets. As soon as a credit event occurs on any of the reference assets, the CLN matures.

Exhibit 12-13 illustrates a typical first-to-default CLN structure. Suppose an issuer sells a first-to-default CLN at par with three years to maturity, which is linked to a basket of 10 reference assets with a face value of $10 million. An investor who purchases the note pays $10 million to the issuer at the closing. The issuer will pay interest during the life of the note and will repay the $10 million at maturity, subject to there being no credit event. The CLN investor takes a credit position equal to $10 million notional in each reference entity. The first time a credit event occurs on any asset in the basket, the issuer redeems the CLN by delivering to the CLN investor $10 million face amount of the reference asset that experienced the credit event. Typically, the actual redemption amount is determined by the market value, not by the recovery value, of the reference obligation at the time the credit event is verified.

EXHIBIT 12-13

Structure of a First-to-Default Credit-Linked Note



A first-to-default CLN investor faces the same type of credit risk exposure on default as with a standard CLN, namely, the reduced recovery rate on the defaulted credit. Because a first-to-default CLN involves multiple assets in the basket, rather than a single asset as in a standard CLN, it can reduce the investor's default risk exposure as compared with a single-name CLN through credit risk diversification. The CLN investor obtains default risk exposure to a basket of reference entities, which can be diversified across industries and also across credit rating categories. This diversification benefit is greater the lower are the pairwise correlations among the returns on the reference entities in the basket.

Emerging Market Credit-Linked Notes

Emerging market CLNs are structured notes that are tied to the creditworthiness of a relatively lower-rated sovereign credit. To compensate emerging market CLN investors for taking on greater counterparty credit risk as well as liquidity risk, they are typically paid more than the underlying debt yield. For example, an investment bank issues a $10 million 10-year 9.5% note linked to Turkish government debt when Turkish government bonds of the same maturity pay 9%.

Emerging market CLNs are efficient investment instruments for investors who are not able to trade the underlying bonds of the countries for any reason, such as transaction costs, investment regulations, or other market frictions. They are attractive to emerging market fixed income investors who believe that a particular sovereign credit rating is likely to be upgraded and who want an investment opportunity that enables them to express that view.

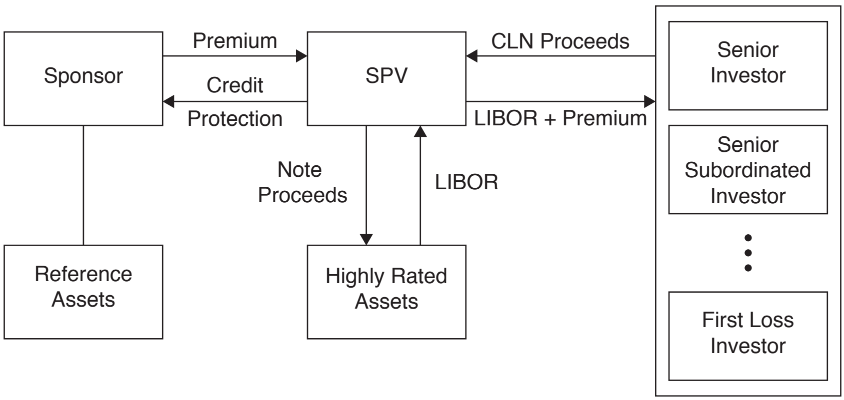
Synthetic CDO Credit-Linked Notes

Synthetic collateralized debt obligations (SCDOs) are a form of CDO that invests in CDSs or other assets to gain exposure to a fixed income portfolio. Unlike a CDS, which typically references a single asset, an SCDO references a portfolio of assets. This portfolio is securitized by issuing notes that are divided into tranches. The SCDO notes are typically prioritized sequentially as to their default risk exposure to the underlying portfolio. They also typically have a sequential amortization structure; the most senior notes are scheduled to be fully repaid first, the next most senior notes are scheduled to be fully repaid next, and so on. Accordingly, when payments are made, they flow first to the most senior notes, thus amortizing them more quickly than the subordinated notes. Investors in the SCDO tranches are able to take on credit risk in accordance with their risk tolerances by purchasing a particular note tranche.

Sponsors may combine SCDOs and CLNs to reduce counterparty risk. Like other CLN structures, an SPV is created to provide a bankruptcy-remote depository for the high-quality assets that are purchased with the CLN proceeds. Exhibit 12-14 illustrates a hybrid structure that combines SCDOs and CLNs in a fully funded structure. The SPV sells credit protection to the sponsor; this credit protection is ultimately provided by the CLN investors. If a credit event occurs involving any of the reference assets, the payments to the CLN investors are reduced according to the repayment priorities of their respective notes. The first loss CLN investors suffer the initial loss up to the full amount of their principal before more senior CLNs are affected.

EXHIBIT 12-14

Funded SCDO: SCDO Combined with CLNs



SCDO transactions can also be structured as a hybrid that blends the funded and unfunded structures. A single, highly rated investor purchases the most senior tranche in the form of an unfunded CDS, whereas the rest of the liability structure is divided into a series of funded CLN tranches, which are purchased by various investors according to their relative risk tolerances. The funded portion of this SCDO structure would mirror the structure illustrated in Exhibit 12-14.

KEY POINTS

- Structured notes and CLNs provide customized interest or principal payments that depend on the performance of a specified reference asset, market price, index, interest rate, foreign exchange rate, commodity price, or some other market quantity.
- A structured note combines a conventional senior unsecured fixed- or floating-rate note with an embedded derivative instrument. A CD can be used in the structure in place of the note to provide principal protection.
- A CLN is a particular form of structured note in which the derivative instrument is a credit default swap or some other form of credit derivative.

- The issuer's objective in issuing structured notes is to reduce its funding cost by satisfying an investor's demand for a particular structure without incurring undue additional risk.
- Investors buy structured notes when the risk/return profile of the security matches their investment needs and the investment opportunity is not otherwise available as cheaply (or at all) in the capital market.

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CHAPTER

THIRTEEN

COMMERCIAL PAPER

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The trillion-dollar market for commercial paper (CP) is in some ways like the market for Treasury bills. Like a Treasury bill, the typical CP issue is a short-term, unsecured, pure-discount instrument that simply pays its principal amount at maturity. And while CP is a private instrument and therefore not risk-free, the realized default rate has been very low, such that years go by with no defaults at all. So, the securities themselves are similar and have overlapping investor clienteles. However, unlike Treasury bills, CP can be a fragile source of funding, and this fragility necessitates an infrastructure around the CP market that includes the banking system, and occasionally necessitates government intervention as well.

This chapter begins with a description of the security, the relevant regulation and statistics on pricing, and issuance and outstandings over time, followed by a discussion of fragility risk and the infrastructure that addresses it. The chapter ends with an overview of policy interventions that supported the CP market after the sudden contractions in September 2008 and March 2020.

This chapter focuses on the CP market in the United States. Other economies, notably the European Union and Japan, have robust CP markets that operate similarly, though there are some points of departure that are beyond the scope of this chapter.

PAYMENT SCHEDULE AND PRICE QUOTATION

Most CP is issued on a pure discount basis, with only a principal payment at maturity. Pure-discount CP has the same payment schedule as Treasury bills and accordingly is also quoted on a discount-rate basis, so if the price today of CP paying F in n days is P, this is quoted as a discount rate of $d = [(F - P)/F](360/n)$. Coupon-paying CP is generally issued at par, and therefore quoted via its coupon rate, if it is fixed-rate, or its spread over a floating benchmark, if it is floating-rate.

PRIMARY AND SECONDARY MARKETS

CP issuers sell any maturity on any business day, and they do this either directly with their own sales force, or, more likely, indirectly through dealers. This contrasts with the Treasury, whose bills are issued and repaid only on Tuesdays and Thursdays and are placed through auctions. Direct issuers enjoy direct interaction with their investors, which could be useful if, for example, an issuer wants to broaden its investor base, or gauge demand for a different quantity or maturity of its paper, or calm a nervous market. Issuers selling instead through dealers enjoy the low fees prevalent in today's market, and benefit from the dealers' contacts with the investor community.

Once placed, CP is unlikely to come back to the market. If it does, the most likely buyer would be the dealer that placed it, or if the CP was directly placed, the issuer itself. One reason the original seller makes the best market for the paper it places is as a favor to its customers, whose liquidity needs might change. Another is to avoid competing with the investor at selling the same paper. Also, investors shopping around the CP they bought could unnerve the market, potentially sparking a run that the issuer would like to avoid. But because the original seller's goodwill for investors who return the product can run out, and because its capacity to repurchase can shrink in bad times, there is no guarantee of liquidity before maturity.

REGULATORY TREATMENT

The short maturity of CP implies high turnover that amplifies issuance volume. In 2019, for example, the issuance volume supporting the outstanding balance of around $1 trillion was approximately $20 trillion. This means that one basis point of issuance cost is $2 billion per year. CP issuers therefore benefit greatly from low regulatory frictions in general, and from relief from registration requirements in particular. This relief generally comes from one of two sections of the Securities Act of 1933, the sections known as 3(a)(3) and 4(a)(2).

The particular requirements of 3(a)(3) and 4(a)(2), established over the years by enforcement actions and no-action letters, are too extensive to catalog here, but there are a few important highlights. CP issued under 3(a)(3) can finance only "current transactions," so, for example, it can finance inventory but not long-horizon capital projects, and its credit quality has to meet the Federal Reserve's high standards for collateral. It has to be issued in a size and manner that is unfit for the general public, and with no more than nine months to maturity at issuance. CP issued instead under 4(a)(2) does not have to finance current transactions or have credit quality high enough for the Federal Reserve or mature within nine months. The main downside of 4(a)(2) is a tight restriction on resale after issuance. Issuers do not have to choose just one of these two sections, they can, for example, issue paper up to nine months maturity under 3(a)(3) and longer paper under 4(a)(2).

The Federal Reserve's issuance volume statistics show that CP is issued in a size unfit for the general public. In 2019 the average dollar volume of CP issued per day was $79.8 billion, and the average number of transactions underlying this volume was 3,960, implying an average transaction size of $20 million, which is impractical for the general public.

ISSUERS

CP issuers divide into several groups. The issuers of asset-backed commercial paper (ABCP) are the special-purpose vehicles (SPVs) that pay creditors from the cash flows collected from their portfolios of financial assets such as auto loans or trade receivables. The operating companies issuing CP divide on the one hand into financial and nonfinancial issuers, and on the other into domestic and non-U.S. issuers. The domestic issuers subdivide into those with domestic versus non-U.S. parents. Exhibit 13-1 reports the CP outstanding from each group of issuers as of the end of 2019, as reported by the Federal Reserve, and shows only a quarter of all CP, $252 billion in total, coming from nonfinancial issuers, indicating the difficulty an investor might face in diversifying out of the financial industry. In contrast, the $544 billion of CP from non-U.S. issuers and issuers with non-U.S. parents indicates that international diversification may be easier.

EXHIBIT 13-1

CP Outstanding at the End of 2019, by Issuer Type as Reported by the Federal Reserve, in $BB

Issuer Type	CP Outstanding
ABCP	$254.4
Nonfinancial Domestic	$194.4
Nonfinancial Foreign	$57.8
Financial Domestic, U.S. Owned	$50.7
Financial Domestic, Foreign Bank Parent	$119.5
Financial Domestic, Foreign Nonbank Parent	$44.7
Financial Foreign Bank	$183.3
Financial Foreign Other	$139.1

The $255 billion of ABCP outstanding in 2019 is far below its $1,218 billion peak. ABCP was an important part of the "shadow banking system" before the 2007–2009 Global Financial Crisis, financing the warehousing of mortgages before securitization, the securitizations themselves, and portfolios of securities backed by securitizations. Outstanding ABCP grew by $562 billion over the three years ending August 8, 2007, and then shed half that amount in seven weeks as suspicions grew about the collateral. The CP market as a whole shrank by half from its 2007 peak to the end of 2019.

INVESTORS

The short maturity of CP means both low duration and high liquidity. These attributes, combined with the generally high credit quality of CP, make it appealing to short-term investment pools, that is, managed portfolios where investors earn interest while parking their cash. An important class of such portfolios is money-market mutual funds (i.e., money funds), in particular, those that are designated Prime funds because they invest in the whole range of money-market instruments with minimal credit risk, including CP of sufficiently high quality. Historically money funds were the largest bid for CP, holding 46% of the market in 2009. However, their importance shrank in 2016 with the reform that reduced the appeal of prime funds relative to money funds restricted to government securities, in part by requiring prime but not government funds to consider redemption gates and fees during market stress. By the end of 2019, money funds held just 23% of the market, the same percentage held by nonfinancial corporations, which had been the biggest CP clientele before money funds started in the 1970s. One contributor to the reemergence of this clientele is large, cash-rich firms that used to invest in CP indirectly through money funds deciding post-reform to invest directly. Additional important investor types include insurance companies, pension funds, state and local governments, and mutual funds other than money funds.[1]

DEFAULT RISK MEASUREMENT AND REALIZATION

Evaluating the credit risk of CP is akin to evaluating the risk of longer-term debt, though the short maturity can change the focus of the evaluation. Credit-rating agencies, most notably Moody's, S&P, and Fitch, rate CP programs alongside longer-term debt and represent the change of focus with different lettering systems. At S&P the investment-grade CP ratings run from A1 down to A3, at Moody's from P1 to P3, and at Fitch from F1 to F3. CP with the top ratings (i.e., A1/P1/F1) is known as tier one or top tier, and CP one notch down at A2/P2/F2 is known as tier two or second tier. There is little reference to the small amount of CP below second tier.

CP ratings are not as important as they once were. This is because the regulation governing money funds (17 CFR § 270.2a-7 (i.e., *2a-7*)), no longer references credit ratings as it once did. Instead, 2a-7(a)(11)(i) now requires the board of a money fund to determine that a security presents minimal credit risk to the fund. Apropos of the backup credit lines discussed below, 2a-7(a)(11)(i)(B)

1. Statistics on CP ownership by investor clientele are from the Federal Reserve's "Flow of Funds," Table L209.

specifically directs the fund's board to consider the issuer's sources of liquidity when gauging whether the risk of an issuer's CP is minimal.

The credit risk of CP rarely ends in credit loss. In its retrospective on CP defaults through Q2 2017,[2] Moody's reports just nine defaulting issuers since 2000 that were rated at least P2 a year before: five in 2000/1, four in 2008, and none in the 8.5 years that followed. This low rate, which Moody's summarizes as a 0.02% probability of default over a 180-day horizon for P1 paper and 0.03% probability for P2 paper, is often attributed to the "orderly exit" mechanism that benefits from the backup lines.

If default does occur, recovery depends on the CP's place in the capital structure, which in the case of CP issued by an operating company is at the senior unsecured level. In the case of ABCP, recovery depends specifically on the receivables held by the SPV, following the repayment waterfall in the prospectus, as the creditors would generally not have legal recourse back to the entity sponsoring the SPV.

CP RATES

As a short-maturity, privately issued, and unsecured obligation, CP is a close match to interbank lending, so LIBOR is the natural benchmark for CP rates. The average CP rate for a tenor tracks LIBOR for the tenor very closely, outside of market disruptions. Consequently, the morning LIBOR fixing is generally a useful reference for issuers and investors to negotiate pricing. Also, the coupons of floating-rate CP can be defined as a fixed spread relative to the LIBOR tenor that matches the frequency of coupon resets.

Another important benchmark for CP rates is the Overnight Index Swap (OIS) rate. In an OIS transaction, say, for 30 days, one side pays the floating overnight rate, and the other pays a fixed rate for 30 days. Profits and losses are settled along the way with daily margin payments, thereby largely insulating each side of the swap from the other side's credit risk. This insulation distinguishes the OIS rate from the LIBOR rate, which reflects the credit risk of the banking system. Consequently, the OIS rate represents the current funding cost for a given maturity without reference to risks specific to the banking sector.

The main benchmark for risk pricing within the CP market is the credit spread between the two top tiers, which the Federal Reserve reports for nonfinancial issuers. The median spread is around 25 basis points, though it fluctuates over time—for example, falling to single digits in the months before the Global Financial Crisis and then spiking over 600 basis points in the depth of the crisis.

CP trades at a discount to Treasuries that reflects not only the credit-risk difference and the different uses of CP versus Treasury collateral, but also a

2. *Default and Recovery Rates of Corporate Commercial Paper Issuers, 1972–2017 H1*, Moody's Investor Service, April 23, 2018.

taxation difference. Both CP and Treasury interest are taxed at the federal level, but interest from Treasury securities is not taxed at the state level, whereas interest from CP and other private money-market instruments *is* taxed at the state level. The impact of this difference varies with the substantial variation in the applicable tax rates across states.

MATURITY DISTRIBUTION

The Federal Reserve reports the average maturity of outstanding CP to be 60 days, but behind this average is a wide distribution of individual maturities offered on any one day. The Federal Reserve data show that most issuance volume rolls over the shortest maturities, with over 60% of issuance below five days to maturity. The share of very short maturities fluctuates over time and tends to spike at tense moments. Two of the biggest spikes, in September 2008 and March 2020, occasioned the Federal intervention discussed below.

One lesson from the maturity distribution is that the 270-day maturity limit under 3(a)(3) is not particularly binding. Only 8% of all paper is longer than 80 days at issuance. One reason for the scarcity of longer paper is that the Federal Reserve requires CP to be both high quality and no more than 90 days to maturity to be acceptable as collateral, and this acceptability can be important to some CP investors.

BACKUP LINES

Financing with CP resembles financing with a revolving bank line, but it brings a new risk the borrower must address. A revolving line allows borrowing up to a limit, if the borrower stays out of default, and specifies the rate paid on the amount borrowed and the unused line fee paid on the remainder. A borrower can instead go around the bank straight to investors by issuing CP, running a balance by repaying old CP with new CP, and taking the balance down by repaying it from a different source, but by doing so it invites a new risk that economists call *fragility risk*. This is the risk of a sudden and crippling loss of funding due to the same coordination problem that drives bank runs. A CP investor who thinks that other CP investors will not roll their old CP into new CP may easily conclude that he should not roll over either, because the issuer's financial strain from funding the departures could make it a bad risk. The investor could conclude this even if he thinks the issuer is solvent to begin with, due to the damage the strain would cause. All debt finance brings some amount of rollover risk; what's special about CP is that, due to the short maturity, rollover is always imminent, so the capital structure is always fragile unless the issuer finds a way to manage this risk.

CP issuers do not have direct access to banks' defenses against fragility risk, but they can pay for indirect access. Banks have two main lines of defense: deposit insurance and their access to loans from the lender of last resort, the

Federal Reserve System.[3] Deposit insurance discourages runs by showing depositors they will be fine, up to the insurance limit, whether the bank survives or not. Access to the Fed shows depositors that the bank can raise funds through borrowing rather than through solvency-reducing fire sales. CP issuers generally have neither deposit insurance nor access to the Fed, but they can effectively rent access to them by arranging *backup* lines of credit. Before selling CP, the issuer can arrange a credit line that it then takes down only to repay maturing CP when investors will not roll over. By paying the unused line fee on this backup line, the CP issuer rents indirect access to the bank's deposit insurance, since the bank can raise and then loan insured deposits when the issuer's uninsured CP investors leave, and also indirect access to the Fed, since the bank can borrow from the Fed to loan to the issuer.

To perfect this indirect access to defenses against fragility risk, the CP issuer has to stay current with the covenants of its loan contract. The low risk tolerance of CP investors, combined with the short maturity, makes it likely that the issuer will be current when the line is needed. That is, there is little demand for CP with above-minimal credit risk, but an issuer that had minimal risk at issuance can see a rise in its risk and still comply at maturity with the ratio tests and other restrictions in the loan contract. This means the issuer likely still has the line when demand for its CP shrinks, provided its risk does not increase too rapidly. And even if its risk does increase rapidly, loan covenants tend to be written in terms of backward-looking quantities such as realized earnings, rather than forward-looking quantities such as anticipated earnings, so the borrower can be compliant even when its prospects worsen significantly. Banks can limit their exposure to the resulting risk by requiring borrowers to pay down their lines with whatever money they raise next, so that the line is just a bridge to the next source of long-term funding. They can also keep down the term of the line agreement in the first place, and regulatory capital requirements encourage the use of 364-day terms.[4]

The hybrid strategy of issuing CP while retaining an untouched backup line is the industry standard practice.[5] The backup line is sometimes known as a *liquidity facility*, and it will be detailed in the Private Placement Memorandum that lays out the CP program to potential investors. Both investors and rating agencies will likely require the issuer to commit in this memorandum to keep its issuance below the limit of the backup line. Because backup lines have historically allowed issuers to exit CP without default, except in extreme circumstances, they are said to facilitate the "early exit mechanism" that has kept the risk of CP low.

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3. See Douglas W. Diamond and Philip H. Dybvig, "Bank Runs, Deposit Insurance, and Liquidity," *Journal of Political Economy* 91(3), 1983, pp. 401–419.

4. The key issue is the credit conversion factor applied to the unused portion of the line. See *Federal Register*, October 11, 2013, pp. 62083, 62091 and 62182.

5. For more analysis of the history and role of backup lines, see Charles Calomiris, "Is the Discount Window Necessary? A Penn-Central Perspective," *Federal Reserve Bank of St. Louis Review* (May 1994), pp. 31–55.

While the backup line has helped keep CP risk low, it is not a credit guarantee. The backup-line provider commits to advance funds for paying down the paper if the issuer is not in default with the loan agreement, but it does not commit to pay down the paper if the issuer fails. A commitment to pay down the paper would be a *letter of credit* (LOC), which is a different product that issuers can buy. The clientele for LOCs includes issuers who are unwilling or unable to publicize the information investors need to do their diligence, but are willing to reveal the information in confidence to an LOC provider. Once an issuer buys an LOC, investors can refocus their diligence on the LOC provider.

REGULATORY RESPONSES TO CRISES

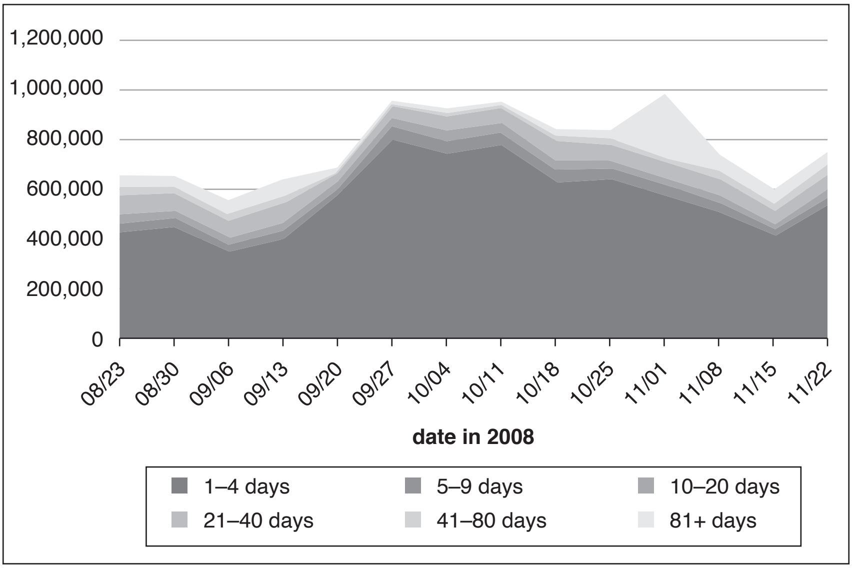
The pressure on the CP market from sudden contractions can be more than the backup-line escape valve can relieve. Banks may be unprepared for many lines to be drawn at once, and the borrowers taking down the lines may have no prospects for paying them down with something else, so that the lines are bridges to nowhere. Furthermore, CP investors may experience contractions of their own, since the economic forces destabilizing investment in CP can destabilize investment in short-term investment pools that buy CP. For these reasons and others, regulators responded to the major market breaks of September 2008 and March 2020 with suites of policy interventions designed to relieve pressure with targeted liquidity. The interventions closest to the CP market are the Commercial Paper Funding Facility (CPFF) in 2008 and 2020, the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF) in 2008, the Money Market Fund Liquidity Facility (MMLF) in 2020, and the Temporary Guarantee Program for Money Market Mutual Funds (the *Temporary Guarantee*) in 2008.

The CPFF is the most direct intervention in the CP market. The Federal Reserve facilitates the purchase of CP directly from issuers, and bears the credit risk, by making loans to an SPV against CP collateral which the SPV buys directly from issuers. In both 2008 and 2020, the Fed targeted the CPFF at the effect of the disruption by limiting purchases from an issuer to the amount the issuer had outstanding before the disruption, and targeted at rollover risk by buying paper at the longer end of CP maturity, with all purchases at 90 days. One difference between the two versions is how the CPFF handled credit risk. The 2008 version bought only top-tier paper, though the pricing distinguished ABCP from other paper. The CPFF bought ABCP at a discount rate equal to the three-month OIS plus 300 basis points, whereas for regular unsecured CP the rate was OIS plus 200 basis points. The later version bought both top-tier paper and second-tier paper, *if* it had been top-tier when the crisis hit, and the discount rates were OIS plus 100 basis points for top tier and OIS plus 200 basis points for second tier.

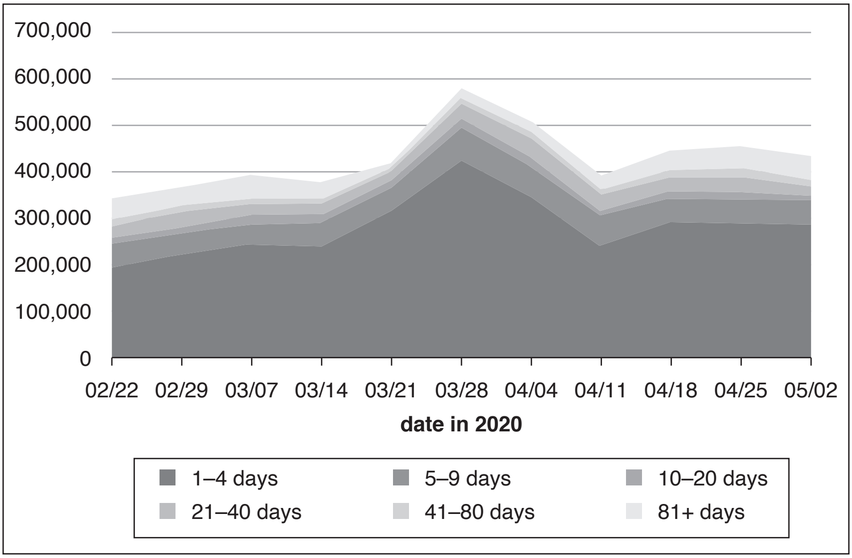
The success of the CPFF at relieving pressure is apparent from the two panels in Exhibit 13-2, which break out CP issuance volume, as reported by the Federal Reserve, by initial maturity in the weeks around the onset of the 2008 (panel a) and 2020 (panel b) crises. In both cases, long-maturity issuance shrinks,

EXHIBIT 13-2

Commercial Paper Volume (in $MM)



Panel A: By Days to Maturity Around Lehman Bankruptcy on 9/15/2008



Panel B: By Days to Maturity Around 2020 Onset of the COVID-19 Pandemic and short-maturity issuance expands as the crisis sets in, and then longer issuance expands rapidly when the CPFF starts buying. In 2008, the CPFF started buying on October 27, and issuance of 81+ day paper grew 686% from the week ending October 25 to the week ending November 1. In 2020, the CPFF started buying on April 14, and issuance of 81+ day CP grew 54% from the week ending April 11 to the week ending April 18.

The AMLF in 2008 and the MMLF in 2020 both offered a liquid secondary market for the CP held by money funds, allowing them to shrink as necessary without the fire sales that can trigger runs, and also allowing them to buy longer-dated securities that they might have to sell to shrink later. The AMLF targeted ABCP holdings in particular, reflecting the prominent role of securitizations in that crisis, whereas the MMLF was open to the whole range of securities in the funds' investible universe. The MMLF launched March 23, 2020, and reached its $54 billion peak holding of money-market securities on April 8. The AMLF launched September 22, 2008, just a week after the Lehman bankruptcy, and reached a peak holding of $146 billion of ABCP on October 8. It worked in tandem with the Temporary Guarantee, which insured money funds' shares and thereby slowed their CP sales by slowing their outflows. The Temporary Guarantee appears to have been very successful slowing outflows, in that over $300 billion flowed out of prime money funds in the five days between the Lehman bankruptcy and the onset of the program, and then flows stabilized when the guarantee began.[6]

KEY POINTS

- Commercial paper is an unsecured, short-term obligation, usually issued in pure-discount form.
- There is little secondary market for commercial paper, outside of selling it back to the dealer or issuer that initially sold it. This may not be a dependable source of liquidity, especially in crisis times.
- Commercial paper issuers face fragility risk, which they manage by arranging backup credit lines for repaying maturing paper when investors do not roll over.
- Commercial paper default has been very rare, due in part to the low risk tolerance of investors and the availability of backup lines.
- In severe market breaks, the federal government has intervened to support the commercial paper market by supporting investors and by buying paper directly from issuers.

6. See Eric Rosengren, *Money Market Mutual Funds and Stable Funding*, Federal Reserve Bank of Boston, September 27, 2013.

CHAPTER
FOURTEEN

FLOATING-RATE SECURITIES

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Under the rubric of floating-rate securities, or simply *floaters,* there are several different types of securities with an essential feature in common: coupon interest can vary over the instrument's life. Floaters, which were first introduced into the European debt market and issued in the United States in the early 1970s, are now issued in every sector of the bond market—government, agency, corporate, municipal, mortgage, and asset-backed—in the United States and in markets throughout the world. Although a floater's coupon formula may depend on a wide variety of economic variables (e.g., foreign exchange rates or commodity prices), a floater's coupon payments usually depend on the level of a money market interest rate (e.g., the London Interbank Offered Rate, or LIBOR, the Secured Overnight Financing Rate, Treasury bills). A floater's coupon rate can be reset semiannually, quarterly, monthly, or weekly. The term *adjustable rate* or *variable rate* typically refers to securities with coupon rates reset not more than annually or based on a longer-term interest rate. However, this is a distinction without a difference, and we will refer to both floating-rate securities and adjustable-rate securities as "floaters."

In this chapter we will discuss the general features of floaters and present some illustrations of the major product types. Most market participants use "spread" or margin measures (e.g., adjusted simple margin or discount margin) to assess the relative value of a floater. We will briefly describe these measures and note their limitations. Finally, we discuss several popular portfolio strategies that employ floaters.

GENERAL FEATURES OF FLOATERS AND MAJOR PRODUCT TYPES

A floater is a debt security whose coupon rate is reset at designated dates based on the value of some designated reference rate. The coupon formula for a pure floater (i.e., a floater with no embedded options) can be expressed as follows:

$$\text{Coupon rate} = \text{reference rate} \pm \text{quoted margin}$$

The quoted margin is the adjustment (in basis points) that the issuer agrees to make to the reference rate. For example, consider a floating-rate note issued by Ford Motor Credit Co, LLC, April 2018 at a rate of 3-month LIBOR + 123.5 basis points (bps) and a price of par. At the time Ford was rated BBB/Baa1. As of February 2020, Ford is downgraded to BBB-/Ba1 and we expect the discount margin (explained later) to reflect the downgrade. In fact, the February 2020 discount margin is wider than issue (163 bps vs. 123.5). As a result, the new price of the floater is now $98.861, over a 1-point decrease from new issue.

As noted, the reference rate is the interest rate or index that appears in a floater's coupon formula, and it is used to determine the coupon payment on each reset date within the boundaries designated by embedded caps and/or floors. The four most common reference rates are LIBOR, Treasury bill yields, prime rates, and domestic certificate of deposit (CD) rates, and they appear in the coupon formulas of a wide variety of floating-rate products. Other reference rates are used in more specialized markets such as the markets for mortgage-backed securities and the municipal market. For example, the most common reference rates for adjustable-rate mortgages (ARMs) or collateralized mortgage obligation (CMO) floaters include (1) the one-year Constant Maturity Treasury Rate (i.e., one-year CMT), (2) the 11th District Cost of Funds (COFI), (3) the six-month LIBOR, and (4) the National Monthly Median Cost of Funds Index. In the municipal market, the reference rate for floaters is often a Treasury rate or the prime rate. Alternatively, the reference rate could be a municipal index. A popular municipal index is the Bond Buyer 20 bond index. A floater often imposes limits on how much the coupon rate can float. Specifically, a floater may have a restriction on the maximum coupon rate that will be paid on any reset date. This is called a *cap*. Consider a floater issued by Federal Home Bank that matured on October 20, 2006. The coupon formula was three-month LIBOR plus 75 basis points with a cap of 3.75%. If the three-month LIBOR at a coupon date reset was 3.25%, then the coupon formula would suggest the new coupon rate would be 4%. However, the cap restricted the maximum coupon rate to 3.75%. Needless to say, a cap is an unattractive feature from the investor's perspective, but an important one to the borrower.

In contrast, a floater also may specify a minimum coupon rate called a *floor*. Suppose a floater delivers quarterly coupon payments with a coupon formula of the three-month LIBOR plus 12.5 basis points with a floor of 4.25%. Thus, if the three-month LIBOR ever fell below 4.125%, the coupon rate would remain at 4.25%.

A floor is an attractive feature from the investor's perspective. When a floater possesses both a cap and a floor, this feature is referred to as a *collar.* Thus, a collared floater's coupon rate has a maximum value and a minimum value.

While a floater's coupon rate typically moves in the same direction as the reference rate, there are floaters whose coupon rate changes in the opposite direction from the change in the reference rate. These floaters are referred to as *inverse floaters* or *reverse floaters.* A general formula for an inverse floater is

$$K - L \times (\text{reference rate})$$

From the formula, it is easy to see that as the reference rate goes up (down), the coupon rate goes down (up). As an example, consider an inverse floater issued by a large bank. This issue delivered quarterly coupon payments according to the formula

$$18\% - 2.5 \times (\text{three-month LIBOR})$$

In addition, this inverse floater has a floor of 3% and a cap of 15.5%. Note that for this inverse floater, the value for L (called the *coupon leverage*) in the coupon reset formula is 2.5. Assuming that neither the cap rate nor the floor rate is binding, this means that for every one basis point change in the three-month LIBOR, the coupon rate changes by 2.5 basis points in the opposite direction.[1]

There is a wide variety of floaters that have special features that may appeal to certain types of investors. For example, some issues provide for a change in the quoted margin (i.e., the spread added to or subtracted from the reference in the coupon reset formula) at certain intervals over a floater's life. These issues are called *stepped-spread floaters* because the quoted margin can either step to a higher or lower level over time. Consider Abu Dhabi Commercial Bank's floater due in May 2016. From its issuance in May 2006 until May 2011, the coupon formula was three-month LIBOR plus 60 basis points. Thereafter, until maturity, the quote margin "steps up" to 90 basis points.

A *range note* is a floater where the coupon payment depends on the number of days that the specified reference rate stays within a preestablished collar. For instance, Barclay's Bank issued a range note in November 2006 (due in November 2016). For every day during the quarter that the three-month LIBOR was between 3% and 9%, the investor earned the three-month LIBOR plus 155 basis points. Interest would accrue at 0% for each day that the three-month LIBOR was outside this collar.

There are also floaters whose coupon formula contains more than one reference rate. A *dual-indexed floater* is one such example. The coupon rate formula is typically a fixed percentage plus the difference between two reference rates. For example, Swedbank Hypotek issued a floater that matures in August 2015 whose coupon formula is the following:

$$(\text{20-year yen swap rate}) - (\text{2-year yen swap rate}) + 40 \text{ basis points}$$

In addition, the issue has a floor of 0.1%.

1. When L is greater than 1, the security is referred to as a *leveraged inverse floater.*

Although the reference rate for most floaters is an interest rate or an interest rate index, numerous kinds of reference rates appear in coupon formulas. This is especially true for structured notes. Potential reference rates include movements in foreign exchange rates, the price of a commodity (e.g., gold), movements in an equity index (e.g., the Standard & Poor's 500 Index), or an inflation index (e.g., CPI). Financial engineers are capable of structuring floaters with almost any reference rate.

CALL AND PUT PROVISIONS

Just like fixed-rate issues, a floater may be *callable.* The call option gives the issuer the right to buy back the issue prior to the stated maturity date. The call option may have value to the issuer sometime in the future for two basic reasons. First, market interest rates may fall so that the issuer can exercise the option to retire the floater and replace it with a fixed-rate issue. Second, the required margin decreases so that the issuer can call the issue and replace it with a floater with a lower quoted margin.[2] The issuer's call option is a disadvantage to the investor because the proceeds received must be reinvested either at a lower interest rate or a lower margin. Consequently, an issuer who wants to include a call feature when issuing a floater must compensate investors by offering a higher quoted margin.

For amortizing securities (e.g., mortgage-backed and some asset-backed securities) that are backed by loans that have a schedule of principal repayments, individual borrowers typically have the option to pay off all or part of their loan prior to the scheduled date. Any additional principal repayment above the scheduled amount is called a *prepayment.* The right of borrowers to prepay is called the *prepayment option.* Basically, the prepayment option is analogous to a call option. However, unlike a call option, there is not a call price that depends on when the borrower pays off the issue. Typically, the price at which a loan is prepaid is its par value.

Floaters also may include a *put provision* that gives the security holder the option to sell the security back to the issuer at a specified price on designated dates. The specified price is called the *put price.* The put's structure can vary across issues. Some issues permit the holder to require the issuer to redeem the issue on any coupon payment date. Others allow the put to be exercised only when the coupon is adjusted. The time required for prior notification to the issuer or its agent varies from as little as four days to as long as a couple of months. The advantage of the put provision to the holder of the floater is that if after the issue date the margin required by the market for a floater to trade at par rises above the issue's quoted margin, the investor can force the issuer to redeem the

2. The required margin is the spread (either positive or negative) the market requires as compensation for the risks embedded in the issue. If the required margin equals the quoted margin, a floater's price will be at par on coupon reset dates.

floater at the put price and then reinvest the proceeds in a floater with the higher quoted margin.

SPREAD MEASURES

There are several yield spread measures or margins that are used routinely to evaluate floaters. The four margins commonly used are spread for life, adjusted simple margin, adjusted total margin, and discount margin. All these spread measures are available on Bloomberg's Yield Analysis (YA) screen.

Spread for Life

When a floater is selling at a premium/discount to par, a potential buyer of a floater will consider the premium or discount as an additional source of dollar return. *Spread for life* (also called *simple margin*) is a measure of potential return that accounts for the accretion (amortization) of the discount (premium) as well as the constant index spread over the security's remaining life.

Adjusted Simple Margin

The *adjusted simple margin* (also called *effective margin*) is an adjustment to spread for life. This adjustment accounts for a one-time cost-of-carry effect when a floater is purchased with borrowed funds. Suppose that a security dealer has purchased $10 million of a particular floater. Naturally, the dealer has a number of alternative ways to finance the position—borrowing from a bank, repurchase agreement, etc. Regardless of the method selected, the dealer must make a one-time adjustment to the floater's price to account for the cost of carry from the settlement date to next coupon reset date.

Adjusted Total Margin

The *adjusted total margin* (also called *total adjusted margin*) adds one additional refinement to the adjusted simple margin. Specifically, the adjusted total margin is the adjusted simple margin plus the interest earned by investing the difference between the floater's par value and the carry-adjusted price.[3]

Discount Margin

One common method of measuring potential return that employs discounted cash flows is *discount margin.* This measure indicates the average spread or margin over the reference rate the investor can expect to earn over the security's life

3. When the floater's adjusted price is greater than 100, the additional increment is negative and represents the interest foregone.

given a particular assumed path that the reference rate will take to maturity. The assumption that the future levels of the reference rate are equal to today's level is the current market convention. The procedure for calculating the discount margin is as follows:

1. Determine the cash flows assuming that the reference rate does not change over the security's life.
2. Select a margin (i.e., a spread above the reference rate).
3. Discount the cash flows found in (1) by the current value of the reference rate plus the margin selected in (2).
4. Compare the present value of the cash flows as calculated in (3) with the price. If the present value is equal to the security's price, the discount margin is the margin assumed in (2). If the present value is not equal to the security's price, go back to (2) and select a different margin.

For a floater selling at par, the discount margin is simply the quoted margin. Similarly, if the floater is selling at a premium (discount), then the discount margin will be below (above) the quoted margin.

Practitioners use the spread measures presented above to gauge the potential return from holding a floater. Much like conventional yield measures for fixed income securities, the yield or margin measures discussed here are, for the most part, relatively easy to calculate and interpret. However, these measures reflect relative value only under several simplifying assumptions (e.g., reference rates do not change).

One of the key difficulties in using the measures described in this chapter is that they do not recognize the presence of embedded options. As discussed, there are callable/putable floaters and floaters with caps and/or floors. However, the recognition of embedded options is critical to valuing floaters properly. If an issuer can call an issue when presented with the opportunity and refund at a lower spread, the investor must then reinvest at the lower spread. With this background, it should not be surprising that sophisticated practitioners value floaters using arbitrage-free binomial interest rate trees and Monte Carlo simulations. These models are designed to value securities whose cash flows are interest-rate-dependent.

PRICE VOLATILITY CHARACTERISTICS OF FLOATERS

The change in the price of a fixed-rate security when market rates change occurs because the security's coupon rate differs from the prevailing rate for new comparable bonds issued at par. Thus, an investor in a 10-year, 7% coupon bond purchased at par, for example, will find that the bond's price will decline below par if the market requires a yield greater than 7% for bonds with the same risk and maturity. By contrast, a floater's coupon resets periodically, thereby reducing its sensitivity to changes in rates. For this reason, floaters are said to be more "defensive" securities. This does not mean, of course, that a floater's price will not change.

Factors That Affect a Floater's Price

A floater's price will change depending on the following factors:

1. Time remaining to the next coupon reset date
2. Changes in the market's required margin for that specific issuer
3. Whether or not the cap or floor is reached, or is close to being reached

We will discuss the impact of each of these factors in the following sections.

Time Remaining to the Next Coupon Reset Date

The longer the time to the next coupon reset date, the more a floater behaves like a fixed-rate security, and the greater is a floater's potential price fluctuation. Conversely, the shorter the time between coupon reset dates, the smaller is the floater's potential price fluctuation.

To understand why this is so, consider a floater with five years remaining to maturity whose coupon formula is the one-year Treasury rate plus 50 basis points, and the coupon is reset today when the one-year Treasury rate is 5.5%. The coupon rate will remain at 6% for the year. One month hence, an investor in this floater effectively would own an 11-month instrument with a 6% coupon. Suppose that at that time the market requires a 6.2% yield on comparable issues with 11 months to maturity. Then our floater would be offering a below-market rate (6% versus 6.2%). The floater's price must decline below par to compensate the investor for the submarket yield. Similarly, if the yield that the market requires on a comparable instrument with a maturity of 11 months is less than 6%, the floater will trade at a premium. For a floater in which the cap is not binding and for which the market does not demand a margin different from the quoted margin, a floater that resets daily will trade at par.

Changes in the Market's Required Margin

At the initial offering of a floater, the issuer will set the quoted margin based on market conditions so that the security will trade near par. Subsequently, if the market requires a higher/lower margin, the floater's price will decrease/increase to reflect the current margin required. We shall refer to the margin that is demanded by the market as the "required margin." For example, consider a floater whose coupon formula is the one-month LIBOR plus 40 basis points. If market conditions change such that the required margin increases to 50 basis points, this floater would be offering a below-market margin. As a result, the floater's price will decline below par value. By the same token, the floater will trade above its par value if the required margin is less than the quoted margin—less than 40 basis points in our example.

The required margin for a particular issue depends on (1) the margin available in competitive funding markets, (2) the credit quality of the issue, (3) the presence of any embedded call or put options, and (4) the liquidity of the issue. An alternative source of funding to floaters is a syndicated loan. Consequently, the required margin will be driven, in part, by margins available in the syndicated loan market.

The portion of the required margin attributable to credit quality is referred to as the "credit spread." The risk that there will be an increase in the credit spread required by the market is called *credit-spread risk*. The concern for credit-spread risk applies not only to an individual issue but also to a sector or the economy as a whole. For example, credit spreads may increase due to a financial crisis (e.g., a stock market crash) while the individual issuer's condition and prospects remain essentially unchanged.

A portion of the required margin reflects the call risk if the floater is callable. Because the call feature imposes hazards on the investor, the greater the call risk, the higher is the quoted margin at issuance, other things equal. After issuance, depending on how interest rates and required margins change, the perceived call risk and the margin required as compensation for this risk will change accordingly. In contrast to call risk owing to an embedded call option, a put provision provides benefits to the investor. If a floater is putable at par, all else the same, its price should trade at par near the put date.

Finally, a portion of the quoted margin at issuance will reflect the issue's perceived liquidity. *Liquidity risk* is the threat of an increase in the required margin due to a perceived deterioration in an issue's liquidity. Investors in nontraditional floater products are particularly concerned with liquidity risk.

Whether or Not the Cap or Floor Is Reached

For a floater with a cap, once the coupon rate as specified by the coupon formula rises above the cap rate, the floater then offers a below-market coupon rate, and the floater will trade at a discount. The floater will trade more and more like a fixed-rate security the further the capped rate is below the prevailing market rate. Simply put, if a floater's coupon rate does not float, it is effectively a fixed-rate security and will assume the duration risk of a fixed-rate bond. *Cap risk* is the risk that the floater's value will decline because the cap is reached.

The situation is reversed if the floater has a floor. Once the floor is reached, all else equal, the floater will trade either at par value or at a premium to par if the coupon rate is above the prevailing rate offered for comparable issues.

Duration of Floaters

We have just described how a floater's price will respond to a change in the required margin, holding all other factors constant. As explained in Chapter 5, the measure used by market participants to quantify the sensitivity of a security's price to changes in interest rates is called *duration*. A security's duration tells us the approximate percentage change in its price for a 100 basis point change in rates. The procedure of computing a security's duration was explained in Chapter 5.

Two measures are employed to estimate a floater's sensitivity to each component of the coupon formula. *Index duration* is a measure of the floater's price sensitivity to changes in the reference rates holding the quoted margin constant. Correspondingly, *spread duration* measures a floater's price sensitivity to a change in the "quoted margin" or "spread" assuming the reference rate remains unchanged.

Price Volatility of an Inverse Floater

An inverse floater can be created by acquiring a fixed-rate security and splitting it into a floater and an inverse floater. The fixed-rate security from which the floater and inverse floater are created is called the *collateral*. The interest paid to the floater investor and inverse floater investor must be such that it is equal to the interest rate paid on the collateral.

Because valuations are additive (i.e., the value of the collateral is the sum of the floater and inverse floater values), durations (properly weighted) are additive as well. Accordingly, the duration of the inverse floater is related in a particular fashion to the duration of the collateral and the duration of the floater. Specifically, the duration of an inverse floater will be a multiple of the duration of the collateral from which it is created.

To understand this, suppose that a 30-year fixed-rate bond with a market value of \$100 million is split into a floater and an inverse floater with market values of \$80 million and \$20 million, respectively. Assume also that the duration of the collateral (i.e., the 30-year fixed-rate bond) is 8. Given this information, we know that for a 100 basis point change in required yield the collateral's value will change by approximately 8%, or \$8 million (8% times \$100 million). Since the floater and inverse floater are created from the collateral, the combined change in value of the floater and the inverse floater must be \$8 million for a 100 basis point change in required yield. The question becomes how do we partition the change in value between the floater and inverse floater. If the duration of the floater is small, as explained earlier, then the inverse floater must experience the full force of the \$8 million change in value. For this to occur, the duration of the inverse floater must be approximately 40. A duration of 40 will mean a 40% change in the inverse floater's value for a 100 basis point change in required yield and a change in value of approximately \$8 million (40% times \$20 million).

Effectively, the inverse floater is a leveraged position in the collateral. That is, ownership of an inverse floater is equivalent to buying the collateral and funding it on a floating-rate basis, where the reference rate for the borrowing is equal to the reference rate for the inverse floater. Accordingly, the duration of the inverse floater is a multiple of the duration of the collateral.

PORTFOLIO STRATEGIES

Several portfolio strategies have been employed using floaters. These include (1) basic asset/liability management strategies, (2) risk arbitrage strategies, (3) betting on changes in the required margin, and (4) arbitrage between fixed- and floating-rate markets using asset swaps. We will briefly describe each of these strategies in turn.

Asset/liability management strategies can be explained most easily using depository institutions. These institutions typically borrow short term, and their objective is to lock in a spread over their short-term funding costs. Not surprisingly, one obvious way to accomplish this objective is to invest in floating-rate products. Naturally, this strategy is not without risks. The floater's coupon rate likely will be capped, whereas the short-term funding may not be. This is known as *cap risk*. Further, the floater's reference rate may not be the same as the reference rate for funding. If this is the case, the institution is exposed to *basis risk*.

Risk arbitrage strategies using floaters are not arbitrage in the true sense of the term. One example of this type of strategy involves money managers using leverage (via repurchase agreements) to invest in agency adjustable-rate pass-through securities that earn a higher spread over their borrowing rate. Of course, this is not a "risk-free" transaction. Like before, the manager likely will be exposed to cap risk if the floater's coupon is capped while the funding rate is not. The manager also may be exposed to basis risk if the two reference rates are mismatched. Finally, there is *price risk* if the floater's risk changes for the worse, and the floater must be sold prior to maturity. In this case, the quoted margin will no longer compensate the investor for the security's risks, and the floater will sell at a discount to par. No informed investor believes that a risk arbitrage strategy is a reliable source of spread income.

Investors also can speculate on whether a floater's required margin will change. When a floater is issued, the quoted margin contained in the coupon formula will be set so that the floater will be priced at or near par. After the floater enters the secondary market, the quoted margin for a standard floater does not change. Thus, if the floater's risk does not change and the compensation demanded by the market does not change either, the floater's price will be par on every coupon reset date. In this case, the quoted margin offered by the security and quoted margin required by the market (called the *required margin*) are the same. If conditions change such that the required spread is greater than (less than) the quoted margin, the floater will trade at discount (premium) to par. Given this background, one obvious strategy money managers pursue is betting on a change in the required margin for a single issue or a sector.

Lastly, some money managers arbitrage between floaters and fixed-rate securities using a so-called asset swap. An asset-based swap transaction involves the creation of synthetic security via the purchase of an existing security and the simultaneous execution of a swap.

DEMISE OF LIBOR

As a result of the LIBOR scandals that ensued during the Global Financial Crisis, regulators have demanded a move from a survey-based index such as LIBOR to an observable market-based index.

Since the early 1970s, the London Interbank Offered Rate (LIBOR) has served as the benchmark reference rate for government and corporate bonds, mortgages, loans, and other types of financial instruments. While LIBOR has served as an important barometer for global financial markets, the methodology for calculating LIBOR rates is outdated. Each day the Intercontinental Exchange Administration (IBA) receives the funding rates from a group of large banks, called panel banks, and this data is averaged, adjusted, and reported. Of greater concern are the scarcity in underlying transactions and a reduction in the number of panel banks reporting transactions since the Global Financial Crisis in 2008. Consequently, the IBA has relied more heavily on "expert judgment" to determine the appropriate rate, making LIBOR a less reliable benchmark. As a result, in 2014, the Federal Reserve assigned the Alternative Reference Rate Committee (ARCC) the task of recommending an alternative benchmark rate to replace LIBOR.

The ARCC ultimately selected the Secured Overnight Funding Rate (SOFR) as the new benchmark interest rate for all dollar-denominated loans and securities. While LIBOR is partially subject to "expert judgment," SOFR is derived from transactions in the overnight repo markets, making it a daily rate as opposed to LIBOR, which has varying terms ranging from one day to one year. The end of 2021 marks the formal retirement of LIBOR. However, slight differences between the two rates create complexities in the adoption of SOFR that make this deadline subject to change. For one, LIBOR represents the unsecured rate at which banks lend to one another, and as such, it includes a credit-risk premium. SOFR, in contrast, is based on the repo financing of U.S. Treasuries, essentially making it a risk-free rate. Second, SOFR is an overnight rate only, not a rate of multiple maturities. For treasurers who currently borrow at one month, three months, etc., the shift from a fixed LIBOR rate to a daily SOFR rate presents operational challenges.

That said, the transition to SOFR is already underway, with some domestic financial institutions issuing securities and contracts that reference SOFR. Ultimately, the standard use of SOFR by central clearinghouses for derivative products will mark a tipping point in the broader adoption of SOFR as the new benchmark rate.

KEY POINTS

- A floater is a debt security whose coupon rate is reset at designated dates based on the value of some designated reference rate. The coupon formula for a floater with no embedded options is the reference rate plus or minus the quoted margin.

- Typically, a floater imposes a cap or maximum interest coupon rate; a floater also may specify a floor or minimum coupon. A collared floater has both a cap and a floor.
- Inverse floaters or reverse floaters are floaters whose coupon rate moves in the opposite direction from the change in the reference rate.
- The different types of floaters include stepped-spread floaters, range notes, and dual-indexed floaters. Although the reference rate for most floaters is an interest rate or an interest rate index, numerous kinds of reference rates appear in coupon formulas.
- A floater may be callable or prepayment. Floaters also may include a put provision.
- Yield spread measures or margins that are commonly used routinely to evaluate floaters are spread for life, adjusted simple margin, adjusted total margin, and discount margin.
- The price of a floater depends on (1) the time remaining to the next coupon reset date, (2) changes in the market's required margin, and (3) whether or not the cap or floor is reached.
- Index duration is a measure of the floater's price sensitivity to changes in the reference rates holding the quoted margin constant. Spread duration measures a floater's price sensitivity to a change in the "quoted margin" or "spread" assuming the reference rate remains unchanged.
- An inverse floater is effectively a leveraged position in the collateral because the position is economically equivalent to buying the collateral and funding it on a floating-rate basis, where the reference rate for the borrowing is equal to the reference rate for the inverse floater.
- The duration of an inverse floater is a multiple of the duration of the collateral.
- Portfolio strategies using floaters include (1) basic asset/liability management strategies, (2) risk arbitrage strategies, (3) betting on changes in the required margin, and (4) arbitrage between fixed- and floating-rate markets using asset swaps.

CHAPTER

FIFTEEN

INFLATION-LINKED BONDS

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Inflation is the key driver of investment performance. It determines how much each dollar of return is worth, and it dictates asset returns themselves. Consider the 37-year period from 1983 to 2020, a period marked by falling inflation. Falling raw materials prices allowed corporate margins to expand. Simultaneously, falling interest rates had a positive impact on the price-to-earnings multipliers being applied to those expanded corporate earnings. The result was doubly explosive equity returns. For different reasons, the inflation-adjusted returns of bonds similarly were favorably affected by falling inflation during this period. The opposite happens during bouts of rising inflation. The 17-year inflationary period from 1966 to 1983 represented one of the worst investment climates in modern history for equities and bonds.

In the late 1990s, investors found a weapon that effectively offsets this threat to stable and predictable investment returns—and that weapon and its incorporation into twenty-first-century fixed income markets is the subject matter of this chapter.

Treasury Inflation-Protected Securities (TIPS)[1] are bonds that promise to protect and grow investors' purchasing power. The U.S. Treasury delivers on this promise by adjusting the principal of TIPS based on changes in the consumer price index (CPI).[2] It repays the bondholders' principal in an amount that exactly maintains the purchasing power of their original investment, as

I wish to thank my clients, colleagues, industry contacts, and many friends for their contributions, insight, and support.

1. United States Secretary of the Treasury Robert Rubin coined the term *TIPS* in 1996, before the official launch of "Treasury Inflation-Indexed Securities" (TIIS) in January 1997. Market participants have gravitated to a generic use of the acronym *TIPS* to refer to all forms of inflation-linked bonds, singular and plural. For clarity, this chapter will do the same. Other terms sometimes used to describe this class of bonds include *inflation-linked bonds, IPBS, TIIS, linkers,* and *real-return bonds.*
2. The Bureau of Labor Statistics, a professionally staffed economics-oriented agency of the U.S. Department of Labor, is responsible for gathering and reporting price changes at the consumer level. The CPI series used to calculate TIPS is the non-seasonally adjusted Consumer Price Index for all Urban Consumers (CPI-U) or more simply the non-seasonally adjusted version of the CPI used to calculate "headline inflation." See the discussion about the CPI later in this chapter.

EXHIBIT 15-1

Schematic Cash Flow of TIPS (10-Year)

	Purchase	First Annual Coupon	Interim Annual Coupon	Last Annual Coupon	Principal	Return (per Annum) %
Date	1/15/Year 0	1/15/Year 1	1/15/Year 5	1/15/Year 10	1/15/Year 10	1/15/Year 10
Real $ Cash Flow	(1,000)	20.00	20.00	20.00	1,000	2.00
CPI (Base = 200)	200.0	206.0	231.8	268.7	268.7	3.00
Indexed Principal	1,000	1,030	1,159	1,343	1,343	(na)
Nominal $ Cash Flow	(1,000)	20.60	23.18	26.87	1343.50	5.06

defined by the CPI. In addition, the U.S. Treasury pays interest in an amount that also maintains the purchasing power of the stream of semiannual interest payments by calculating coupon payments based on the CPI-indexed principal amounts. (See Exhibit 15-1.)

The U.S. Treasury launched the TIPS program in 1997, and through the end of the first quarter of 2020 had outstanding over $1,525 billion of the securities according to the Securities Industry and Financial Markets Association (SIMFA). SIIFMA also reports that during the first two months of 2020, an average of $19.65 billion of these securities traded each day. Since the 1940s, at least 15 governments and numerous corporations have issued similarly structured securities. In the United Kingdom, inflation-indexed securities account for more than 20% of government bonds outstanding. For clarity, we will focus our discussion on the U.S. Treasury TIPS and introduce substantive differences of other TIPS where appropriate.

TIPS are best known as a defensive hedge against the fear of inflation, but they offer tactical and strategic advantages as well. Tactically, investors are attracted to the opportunity TIPS afford to speculate on changes in inflation and real interest rates. Strategically, individual and institutional investors with long-term objectives are attracted to TIPS fixed real yield, low correlation to traditional financial assets, and muted volatility. They sense TIPS will help them to achieve their long-term investment goals and reduce risk in the process.

The unique characteristics of TIPS qualify them as a fundamental asset class, as are equities, traditional bonds, and cash. TIPS have relatively high correlation with one-another and modest correlation with other asset classes. As a whole, they form a large, investable, and easily benchmarked universe.

In addition to TIPS' inflation appeal, their novelty and scope, just over two decades after their introduction into the United States, can attest to their importance as an investment instrument. This chapter has two goals; the first and most important is to expose market participants to this important often not well understood investment instrument. The second is to provide portfolio managers with a comprehensive examination of the investment qualities that make TIPS unique.

We begin with the mechanics of TIPS cash flows. We explore real yield and real duration, two measures that are analogous to a nominal bond's yield to maturity and effective duration. The marketplace section narrates a brief history of TIPS, including their trading characteristics. The valuation and performance section presents a framework and evaluates the TIPS market through early 2020 in the context of that framework. The investors section discusses how professional managers and institutions are using TIPS within portfolios and in asset/liability management. The issuers section introduces the suppliers of TIPS and explains why they use the prevailing structures. We then address common investor concerns, specifically on taxes and deflation.

MECHANICS AND MEASUREMENT

How TIPS Work

The merit of TIPS is that while the principal and interest repaid to investors fluctuates based on the level of the CPI, the purchasing power of each payment is fixed. As a consequence, the *real yield* of TIPS (the growth in purchasing power that a hold-to-maturity investor will earn) is fixed. The assumptions corresponding to Exhibit 15-1 are described below:

- Issuance date of January 15 of Year 1
- Issuance price of $100.00
- 10-year maturity
- 2% real coupon paid annually,
- 3% annualized inflation rate, and
- $1000 original face

If the CPI for the TIPS issuance date is 200.0 and the CPI for a coupon date one year later is 206.0, year-over-year inflation would be reported as 3.00%. The TIPS' adjusted principal would be 1.03 times its original value, or $1,030 per $1,000 of "original face."

This indexed principal is used to calculate the coupon paid. In other words, the Treasury calculates the amount of each coupon payment, *after the principal has been adjusted for inflation.* This exhibit shows that the compounding effect of a 2% real annual coupon with a 3% inflation rate results in a *nominal* cash-flow annualized return of 5.06%.

The calculations of actual Treasury TIPS cash flows and returns are only somewhat more complicated. TIPS pay interest semiannually at one-half their stated annual coupon rate. The inflation-indexed principal is accrued daily throughout a month, based on a straight-line interpolation between the two most recent monthly CPI figures reported prior to the settlement month. And lastly, Treasury uses a rather arcane rounding procedure for interim and final calculations.

The Consumer Price Index (CPI)

The specific CPI series used for TIPS indexation is the Non-Seasonally Adjusted, All-Urban Consumer Price Index (NSA CPI-U), and it is reported monthly. Unlike the seasonally adjusted series, the NSA CPI-U is not subject to revision. One consequence of using the NSA CPI-U is that the series includes predictable seasonal fluctuations in inflation. For example, each December when inflation typically is muted by year-end price cutting and inventory liquidations, the NSA CPI-U index tends to fall slightly below its trend growth rate, whereas in certain other months it tends to rise slightly above the underlying trend.

The CPI report that measures the price level in a given month, for example, May, typically is reported on or near the 15th of the following month, in this case June. The two-week hiatus between June 15 and July 1 when the TIPS accruals begin allows for potential delays in the official release of the CPI and eliminates the need to calculate day counts across month-end. The last daily accrual occurs on July 31, about seven weeks after the CPI is reported. Thus the May CPI is fully incorporated into the August 1 TIPS principal.

This relatively quick 15-day turnaround of CPI reports into TIPS indexation is often described as a three-month lag because the May (month 5) CPI is fully incorporated into the TIPS by August 1 (month 8). To calculate the TIPS principal for any settlement date other than the first of a month, for example, July 10, calculate as follows:

1. Find the TIPS principal that applies to July 1; this is based on the April NSA CPI-U report (month 7 – 3 = month 4).
2. Find the TIPS principal that applies to August 1; this is based on the May NSA CPI-U report (month 8 – 3 = month 5).
3. Divide 9, the number of days accrual (the 10th day of the month – the 1st day of the month) by 31 (the number of days in that month).
4. Linearly interpolate by adding 9/31 of the difference between the July 1 and August 1 TIPS' principal values to the July 1 value.

Real Frame of Reference, Real Yield, Nominal Yield, and Break-Even Inflation Rate

Real Frame of Reference

A nominal frame of reference looks at investments in terms of dollars, without regard for any change in purchasing power of those dollars. In contrast, a real frame of reference takes into account the loss of purchasing power due to inflation. Put another way, it calculates how many bushels of wheat, baskets of apples, or more generally, the standard of living to which a given dollar amount corresponds. If it costs 100 "real dollars" to purchase a basket of consumer goods in the Year 0, in Year 20, 100 "real dollars" will still purchase that same "basket."

Any investment can be described from either a *real* or *nominal* frame of reference. To directly compare the expected returns of any two investments, one must choose either a real or a nominal frame of reference. For example, in *Stocks for the Long Run,* 1998, Jeremy Siegel describes equities from 1926 through 1997 as having generated *either* a 7.2% real return *or* a 10.6% nominal return.

Ideally, the frame of reference would be dictated by one's goals, but in practice, the choice is heavily influenced by the characteristics of the investment instrument. For instance, conventional bonds are described easily in a *nominal* frame of reference because they have fixed *nominal* coupons and principal. TIPS, on the other hand, are described more easily within a *real* frame of reference because they have fixed *real* coupons and principal. Not surprisingly, TIPS' *real* yield, *real* duration, and other real characteristics are relatively intuitive and as easy to calculate as a nominal bond's yield to maturity, effective duration, and other nominal characteristics.

Real Yield

The real yield of a TIPS bond represents the annualized growth rate of purchasing power earned by holding the security to maturity. Real yield can be calculated easily on a standard bond calculator by entering the TIPS quoted market price, coupon rate, and maturity date. The calculator does not know the bond is a TIPS or that the price and coupon rate are *real.* It is the user's responsibility to interpret the result as the "real yield."[3]

The *real* yield of a *nominal* bond is more difficult to calculate because it can be precisely determined only with the benefit of hindsight. In practice, when analysts speak of a nominal bond's real yield, they may be (1) referring to its "current" real yield (approximated by subtracting the current year-over-year inflation from the bond's nominal yield), (2) "guesstimating" the nominal bond's "expected" real yield based on expectations of future inflation, or (3) speaking of historical realized real yields on bonds that have matured.

Nominal Yield

The opposite situation occurs with nominal yields. While the nominal yield of a conventional bond is determined easily, the nominal yield of TIPS is more difficult to pin down. The nominal yield realized by holding TIPS to maturity depends on the average level and trajectory of inflation over the bond's lifetime. Ignoring the trajectory of the inflation rate, and focusing only on the average level of inflation, the realized nominal yield can be approximated as

$$\text{TIPS realized nominal yield} = (1 + \text{real yield}) \times (1 + \text{inflation}) - 1$$

3. Two phenomena that could cause a minor difference in TIPS quoted real yield from the TIPS realized real yield are (1) real reinvestment rate of coupon cash flows and (2) the time lag between the applicable date for the CPI and the applicable date for TIPS indexing.

Break-Even Inflation Rate

The break-even inflation rate is the rate that results in the holder of a TIPS "breaking even" with the holder of a nominal bond. Using the preceding equation, the nominal yield of the TIPS can be set to equal the nominal yield of the conventional bond. Solving the equation for the break-even inflation rate gives

$$\text{Break-even inflation rate} \\ = (1 + \text{conventional nominal yield}) / (1 + \text{TIPS real yield}) - 1$$

If the conventional bond's nominal yield is 7% and the TIPS real yield is 4% (both expressed in simple annualized terms), the break-even inflation rate is 2.88%. For most purposes, approximating the preceding equation as the simple difference between the two bonds' yields, 3%, is appropriate—and general industry practice.

The 2008 episode is instructive for a different reason. During this period there was rampant deleveraging of financial balance sheets, a sharp contraction in output, a breakdown of the payment system, and fear that monetary policy would be unsuccessful at managing away deflationary inflation expectations. Though it is common to see graphs of 10-year break-even inflation rates reflect this dramatic drop in inflation expectations toward zero, these rates dramatically understate the actual extent of deflationary expectations. In particular, 10-year TIPS are "newly issued" and as such have a "deflation put," struck at-the-money at time of issuance, embedded within them. It is therefore virtually impossible, regardless of how deflationary the outlook is, to observe negative break-even inflation rates on newly issued 10-year TIPS. Off-the-run TIPS, on the other hand, which may have previous positive inflation accruals included in their market value, can lose this principal, and therefore can be, and were, priced at negative inflation break-evens during late 2008 and early 2009.

Although the break-even inflation rate may be useful to assess market inflation expectations or to gauge break-even requirements for narrowly constrained fixed income investors, it may overstate or understate the risk-adjusted break-even inflation rate applicable to long-term strategies. In particular, the riskier nominal bonds may embody inflation risk premiums. Researchers have estimated the embedded inflation risk premium in nominal bonds to be between 0.50% and 1.0%.[4]

Because TIPS pay in real dollars, exhibit low volatility, and have a low correlation with other assets, at least part of such inflation risk premiums should not be embodied in TIPS yields. Therefore, the risk-adjusted break-even inflation rate for TIPS equals the calculated break-even inflation rate minus the inflation risk

4. Citing the tremendous supply of TIPS, the illiquidity of TIPS, and the substantial exposure that TIPS have to changes in real interest rates, Lucas and Quek suggest that a part of (or the entire) "inflation-risk premium" may be offset. See Gerald Lucas and Timothy Quek, "Valuing and Trading TIPS," Chapter 9 in John Brynjolfsson and Frank J. Fabozzi (eds.), *Handbook of Inflation Indexed Bonds* (New Hope, PA: Frank J. Fabozzi Associates, 1999). For a more detailed discussion of implied break-evens and risk-premiums, see the seminal work on expectations and markets by M. Harrison and D. Kreps, "Martingales and Multiperiod Securities Markets," *Journal of Economic Theory* (1979), pp. 381–408.

premium. This means an investor can advantageously use TIPS even when his expected inflation rate equals the calculated break-even inflation rate. Such an investor will gain by lowering overall portfolio risk or from "reallocating" the risk capacity created into other sectors.

Real and Effective Duration

Real Duration

Duration is the measure of a bond's market-value sensitivity to changes in yields—real *or* nominal. The preceding section describing real and nominal frames of reference and real and nominal yields is pivotal to any discussion of duration. By definition, the *real* duration of TIPS is the percentage change in its market value associated with a 1.0% change in its *real* yield. For example, if the market value (MV) of TIPS is $1,000 and the market values associated with a 0.50% decrease and a 0.50% increase in the TIPS real yield are $1,051 and $951, respectively, the TIPS real duration is 10. In order to center the calculation at current yield levels, the 1.0% change in the definition is applied equally as a 0.50% decrease and a 0.50% increase in yield.

Algebraically, the formula for TIPS real duration is

$$100 \times [\text{MV(real yield} + 0.50\%) - \text{MV(real yield} - 0.50\%)]/\text{MV(real yield)}$$

Not surprisingly, the TIPS duration formula is identical to that of a nominal bond (excepting the frame of reference). It follows that TIPS' duration can be calculated using a standard bond calculator. As with the calculation for real yield, it is the user's responsibility to remember that the result is the TIPS' *real* duration. (Using real duration within a dedicated TIPS portfolio is discussed in a later section.)

As relevant as real duration is to TIPS' portfolio managers, it is critical to understand that TIPS' real duration does not quantify the exposure of TIPS to changes in nominal yields. First, the correlation of real yields with nominal yields historically has tended to be less than 100%—real duration measures sensitivity to phenomena that may affect nominal bonds in an opposite way or not at all. Second, real yields tended to be significantly less volatile than nominal yields—so any given "real duration" tended to correspond with significantly less portfolio volatility than the same "nominal duration." Recently this has not been the case. Perhaps this is due to extremely high levels of confidence in the Federal Reserve's ability to successfully and perpetually target a stable inflation rate near 2%. Correlations between real and nominal yields have been high, and TIPS yield have been almost as, or more volatile than, nominal yields.

Effective Duration

To compare TIPS' risk with that of nominal bonds so that they may be included within a conventional bond portfolio, a manager needs a measure of TIPS' sensitivity to changes in *nominal* interest rates. The method for determining market-value change of TIPS as a function of nominal-yield change is the "effective duration" calculation. The limitation is that since this calculation must infer a change in real yield from the hypothetical change in nominal yield, the measure is statistical rather than deterministic.

Initially, this dilemma caused more than a few managers to conclude that the risk exposure of TIPS could not be managed within the context of a conventional fixed income portfolio. But it was soon realized that in the 1980s, for example, mortgage-backed securities overcame similar concerns. The calculation of effective duration for mortgages calls for an inference that a change in nominal Treasury yield will result in a change in the underlying yield of mortgage cash flows.

Similar to TIPS, yields underlying mortgage pricing are not perfectly correlated with Treasury yields. In fact, during the deflationary scares in the summer of 1998 and fall of 2008, mortgage prices dramatically underperformed what naive calculations of mortgage effective durations would have predicted. For brief periods, as Treasury yields fell, mortgage yields actually rose. Nonetheless, effective duration is used broadly to determine a mortgage's value change as a function of nominal-yield change. It is incumbent on fixed income managers to manage the remaining mortgage basis risk.

Although crude, the best metric we have found for converting TIPS' real yield into "effective duration" is to apply a 75% multiplicative factor to TIPS' real durations. This approach is often described as a "75% yield beta"—a reference to the second coefficient (beta) of a linear regression of change in real yield against a change in nominal yield. Like mortgages, TIPS' effective duration should be used only as a loose metric for nominal interest-rate exposure because substantial risk (basis risk) remains.

Occasionally, nominal yields fall, and TIPS' real yields rise, meaning that TIPS experience negative effective durations. Conversely, occasionally, nominal yields rise, and real yields rise even more, meaning TIPS experience capital losses greater than what their *ex-ante* effective durations predict. It is incumbent on managers, who use TIPS, therefore to manage the basis risk that TIPS embody beyond their modest effective duration.

For example, the regression results of the weekly change in 10-year TIPS' real yield as a function of changes in the 10-year nominal bond's yield for year 2010 had a highly statistically significant slope of 0.56 and an R-squared of 0.47. This slope indicates that historically the "yield beta" over that period, at 56.51%, has been lower than the 75%. The regression result will vary (as a function of the time period chosen to calculate the individual change), the time period included in the study, the securities chosen, and perhaps most important, the economic environment.

TIPS' real duration measures risk as it relates to change in real yield, and TIPS' effective duration measures risk as it relates to changes in nominal yield. Two broader measures of TIPS' risk are volatility and relative volatility. Volatility is simply the standard deviation of TIPS' prices (or returns). It varies over time and across maturities as a function of the calculation period and measurement interval.

Relative volatility is a measure of TIPS' volatility as a fraction of the volatility of another instrument such as a nominal bond having a comparable maturity. In the period leading up to May 2011, the TIPS bond exhibited about one-third the price volatility of a comparable-maturity nominal Treasury bond.

MARKETPLACE

A Brief History of TIPS

TIPS are such a fundamental economic instrument that they predate nominal bonds and even coins. In essence, the buyer of these bonds is simply "storing" (and earning a return on) a current basket of goods she will consume in the future.

In ancient Mesopotamia, warehouse receipts referencing quantities of grains and other goods were traded in a secondary market and were in some ways preferred to the currency of the day.[5] These receipts "were" TIPS. They could be traded, and on maturity, their value would be redeemed in the form of a "real basket" of consumer goods.

In the United States, TIPS date back to the birth of the nation. In 1780, the state of Massachusetts created debt colorfully inscribed as follows:

> Both Principal and Interest to be paid in the then current Money of said State, in a greater or less Sum, according as Five Bushels of CORN, Sixty-eight Pounds and four–seventh Parts of a Pound of BEEF, Ten Pounds of SHEEP'S WOOL, and Sixteen Pounds of SOLE LEATHER shall then cost, more or less than One Hundred Thirty Pounds current money, at the then current Prices of Said Articles.[6]

Since World War II, more than 15 countries have issued TIPS, or, more generally, inflation-linked bonds (ILBs). ILBs are not just issued by countries experiencing runaway inflation. Countries often issue ILBs as they are embarking on successful disinflationary initiatives. For example, in Iceland from 1949 to 1954, inflation averaged over 15% per year. In 1955, the year following the introduction of their ILBs, Iceland's recorded inflation rate fell to zero.[7]

Quotation and Settlement

In the United States, TIPS are quoted on a "real clean" basis—as distinguished from a "nominal dirty" basis. Fractions of a dollar are quoted as units of 1/32.

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5. Glyn Davies, *A History of Money* (Cardiff: University of Wales Press, 1994).
6. Willard Fisher, "The Tabular Standard in Massachusetts History," *Quarterly Journal of Economics* (May 1913), p. 454.
7. *Statistical Abstract of Iceland,* Table 12.5, p. 150.

In this instance, "real" implies that U.S. TIPS' prices are quoted on the basis of 100 *inflation-adjusted* units of principal. The quoted price 95-20 can be interpreted as 95 and 20/32 real dollars, meaning that the investor is paying 95.625% of the *indexed* principal amount. While this may seem intuitive, it is not the only way to quote TIPS' prices. If prices were quoted on a *nominal* basis, as they are in the U.K. linker market, this same purchase would be quoted as 101.512 (95.625 × 1.06157 = the real price times the index ratio). Similarly, to calculate the clean settlement price, which necessarily is paid in "nominal dollars," multiply the real price by the index ratio.

Clean means that the quoted TIPS' price does not include the accrued-interest amount that the buyer of a TIPS bond owes the seller. Just as with nominal bonds, the TIPS' buyer must compensate the seller for coupon income that has been earned but not yet paid since the last coupon payment. Parties therefore can calculate the settlement proceeds by multiplying real accrued interest by the index ratio and adding the result to the clean settlement price. In practice, a computer algorithm can be used to incorporate prescribed rounding procedures.

Canadian and French TIPS are quoted similarly to U.S. TIPS, except, of course, local inflation indexes are referenced.

The U.K. linker market is quoted on a "nominal clean price" basis, and therefore, some U.K. linkers trade at prices above $200 per $100 original face. This is so because the country's retail price index (RPI) has more than doubled since the Bank of England began issuing these bonds in the early 1980s.

In Australia and New Zealand, ILBs typically are quoted and traded on a "real yield" basis.

Liquidity

The common metrics of liquidity are turnover, bid-ask spread, and transactional size. TIPS are less liquid than conventional coupon Treasuries, but as measured by the bid-ask spread associated with transacting $50 million, they are more liquid than most corporate bonds, nonagency mortgage pass-through bonds, and even some agency debentures. TIPS are significantly more liquid than other inflation hedges such as real estate, precious metal contracts, natural gas partnerships, timberland deeds, and collectable possessions.

VALUATION AND PERFORMANCE DYNAMICS

As with any bond, the holding-period return of a TIPS bond is the sum of its yield and capital gains. For TIPS, changes in real yield determine capital gains. Thus perhaps the most important question for investors evaluating TIPS is: "What direction are real yields heading?"

Over the long term we believe that real yields in the United States should remain at levels below 2.0%. Historically and comparatively, even a 2.0% real return for a riskless instrument is high. Over the past 70 years, long-term Treasury bonds have realized real yields of just above 2% and short-term Treasury bills just below 1%, with both averages concealing significant volatility in real return. During 1999, real yields on long-term nominal Treasuries averaged about 3.5% and Treasury bills 2.5%. Following the 2008 debt crisis "new normal" lower growth dynamics in the developed world depress real yields beyond 2025.

Determinants of Inflation and the Taylor Rule for Real Yields

Professor John Taylor of Stanford University presents a compelling thesis that there is an immutable link between the sustainable real economic growth rate and the sustainable real federal funds rate. "The Taylor rule" argues that over the long term, the real federal funds rate should average the long-term real economic growth rate of the economy, which he estimated to be about 2%. If the monetary authority maintains the real federal funds rate above this for an extended period of time, the inflation rate will diverge toward deflation. If the authority maintains the real federal funds rate below this, the result ultimately will be hyperinflation.[8]

But in 2008 a different risk faced policymakers—the possibility of structural debt deflation. Paraphrasing Fed Chairman Ben Bernanke, we have to be mindful that the risks and costs of deflation may be as great as the risks and costs of inflation.

Despite unprecedented monetary and fiscal stimulus, inflation had been nowhere to be seen through early 2020. This opened the door for residual "Modern Monetary Theory" which delinks monetary policy from inflation, and forces even traditional economists to revisit their assumptions. Regardless, monetary policy should be relatively easy during the next decade. The Fed likely will manage a funds rate that averages at most 2.0% above inflation and substantially less than the 4% above inflation experienced during the 1980s, 1990s, and 2000s. The possibility of negative nominal interest rates in the United States is real, and an actuality elsewhere.

INVESTORS

Tactical Use (Within Fixed Income Portfolios)

There are times when economic fundamentals, financial market dynamics, or simply structure will result in TIPS performing exceptionally well or, as in 1999, less badly relative to other investments. All investors can benefit from understanding how to evaluate and purchase TIPS for tactical gain.

In electing to own TIPS for tactical purposes within a fixed income portfolio, an investor may make a relative valuation assessment by comparing them with debt instruments with similar credit, effective duration, and liquidity. After the investment decision is made, the investor must diligently manage the tracking risk, that is, non–fixed income risk, associated with introducing tactical allocation to TIPS.

8. Taylor's equations suggest that in periods of high inflation, high real rates may be temporarily called for.

International Relative Value Opportunities

The international market for ILBs is currently larger than the U.S. TIPS market. We believe that all global ILBs belong to the same asset class. Tactical opportunities exist in all these markets because no region is immune from ebbs and flows in the global supply and demand for capital. To some extent, ILBs from different countries are interchangeable.

However, there are nuances that differentiate ILBs from one another. International ILBs provide investors with avenues to exploit a variety of currencies, monetary policies, and other local phenomena. These tactical opportunities can be reduced to perspectives regarding absolute global real yield levels, inflation rates, and intercountry differences from these global averages. Exhibit 15-2 reports ancillary data for nine of the larger government issuers of ILBs.

The first and second columns entitled "Market Cap" and "Real Yield" should be of particular interest because they report, respectively, the size and a long-term measure of relative value. Modified duration is simply the sensitivity issues holdings to changes in real yields. Real yield incorporates the return of real principal and the interim real income that an ILBs' holder will earn.

There are potential international risks not included in Exhibit 15-2 that can affect real yields. The first is the credit profile of the particular issuing country. To the extent that government issuers rarely default on debt instruments denominated in their own currencies, credit risk is low. A second factor is issuance. If a country issues more inflation-indexed supply than domestic and global strategic ILBs investors need, yields are likely to rise until sufficient international tactical investors are attracted.

ILBs can be used tactically within equity and cash portfolios as well. Conceptually, the motivation is similar. In the United Kingdom investors often

EXHIBIT 15-2

Data for Nine of the Larger Issuers of Inflation-Linked Bonds

Country	Market Cap (Billions$)	Real Yield (%)	Modified Duration (Yrs)
US	685.1	1.05	7.90
UK	408.0	0.58	15.86
France	228.9	1.23	8.30
Italy	146.3	2.74	8.52
Germany	62.1	0.64	5.22
Japan	56.1	1.06	5.59
Canada	52.9	1.18	16.11
Sweden	40.3	1.02	7.81
Australia	18.1	2.54	8.61

Source: Barclays Capital Global Inflation Linked Monthly, March 2011.

allocate out of equities into ILBs as a defensive tactic—much as U.S. equity managers reallocate defensively into utility stocks to protect against violent market declines.

Strategic Use

Strategic allocations are more deliberate than tactical ones and ultimately speak to the inherent investment qualities of ILBs. ILBs can play a significant role within such top-down strategic allocations. Enduring investor goals, such as matching liabilities, diversifying risks, controlling downside exposures, and achieving real return objectives, typically drive these strategic allocations. In contrast, bottom-up valuation, market timing, and other opportunistic considerations rarely are important aspects of the strategic decision-making process.

Investors typically make strategic asset allocations among the fundamental asset classes: equities, bonds, cash, and inflation hedges. Unadvisedly, some investors opt for finer gradations using more unwieldy sets of narrowly defined asset classes such as large-capitalization, midcap, small-cap equities, and government bonds at the top-level of their asset allocation framework.

Typically, the thread that holds the elements of an asset class together is that each element's returns are driven primarily by common fundamental phenomena. Simply, correlations between members of the same asset class will be high, whereas correlations between assets that are members of different asset classes will be low.

For ILBs, inflation and real global interest rate are the identifying fundamental phenomena that drive returns. Thus it is reasonable that all ILBs (Treasury, international, agency, and corporate) comprise a distinct asset class, separate from equities, (nominal) bonds, and cash. Real estate, commodities, and certain other "inflation hedges" also fall into this inflation-hedging asset class.

There are three general situations that warrant a strategic reallocation into ILBs. First, portfolio managers looking for higher returns without increased risk may investigate moving out of low-risk assets such as cash. Second, those motivated toward preserving past gains might consider a defensive allocation out of higher-risk assets such as equities or real estate. Importantly, a defensive allocation will tend to decrease or eliminate shortfall probability dramatically. (Shortfall probability is the likelihood that a portfolio will fall below a minimum acceptable threshold.) And third, ILBs can be used strategically in an asset/liability management context.

Asset/Liability Management (ALM)

Asset/liability management is closely related to asset allocation. Traditionally, asset allocation studies do not explicitly incorporate liabilities. They tend to focus on increasing absolute levels of return through allocations to higher-returning assets or through diversification of assets, thereby reducing risk calculated without regard to liabilities.

ALM studies focus on reducing the mismatch between assets and liabilities. Traditionally, researchers have studied ALM in a conventional nominal frame of reference where the exposure of assets and liabilities to conventional yield changes is compared and to some extent matched. Liabilities are assumed to be nominal liabilities even when they are in fact inflation-sensitive.

The large-scale introduction of TIPS by the U.S. Treasury has given asset-liability managers the ability to measure and manage both assets and liabilities that are predominantly real. This is a reprieve for the many investors discussed later.

Investors are not limited to choosing between asset allocation or asset-liability management. The two can be combined into a framework generally termed *surplus management*—optimizing the return and risk of surplus (assets net of liabilities). Although developed at one asset management firm in the 1970s, this framework comes into and out of favor periodically.

Risk/Return Optimization

The novelty of ILBs as an asset class in the United States poses challenges for strategic users of the securities. In particular, to include ILBs in a standard nominal Markowitz mean-variance optimization, the analyst must input appropriate expected return, variance, and correlation data for ILBs as well as other assets (or liabilities) included in the optimization.

Although conceptually inputs for such optimizations are forward-looking, practitioners usually rely heavily on historical data. Since U.S. TIPS have existed since 1997, correlation matrices are built using asset class returns from 1997 forward or from pro forma estimates of TIPS returns prior to 1997. Although most optimization models function in a nominal frame of reference, some practitioners appropriately implement them in a real frame of reference.

Managing Dedicated ILB Portfolios Using Real Duration

After a ILBs allocation has been determined, an implementation strategy must be executed. For this, an investor chooses between active or passive management. In either case, real duration is a useful metric of exposure because it measures the allocation's relative sensitivity to changes (parallel shifts) in the real yield curve.

To construct an ILB portfolio, the practitioner needs first to choose a target "real duration" for the portfolio and then to devise a variety of candidate portfolio structures. The candidate portfolios might include a bulleted portfolio having all its ILBs close to the target duration and a barbell portfolio with a combination of longer and shorter ILBs weighted to achieve the target duration.

To select the most advantageous portfolio structure from those with the same real duration, the practitioner need only concern herself with the exposure to changes in the general real yield curve slope of the various candidate portfolios. This is so because the candidate portfolios have the same real yield duration, so their response to parallel shifts will be very similar.

A recent development in the management of TIPS portfolios is increased demand for "break-even" structuring. Typical TIPS portfolios embody inflation protection by locking in to maturity the real yield of instruments owned. Break-even structuring involves selling similar maturity fixed-rate Treasuries, futures, or paying fixed on interest-rate swaps. This in essence nullifies the real yield and real duration of TIPS, leaving the holder with the inflation indexation of the TIPS held. Of course, realized inflation will need to equal or exceed the inflation which is priced into the nominal market in order to profit from this strategy. In essence this strategy become attractive when (1) real yields are low, so that not much is being given up and (2) the investor believes that inflation will rise more than what the Treasury market has priced in, or that certain risks are associated with inflation that the investor particularly wants to hedge.

Investor Types: Pension Plans, Endowments, Foundations, and Individuals

Defined-benefit pension plans have both retired-lives and active-lives liabilities. Although ILBs as assets may match the active-life portion of these plans extremely well, plan sponsors typically do not rely exclusively on ILBs to back their active-lives liabilities. Instead, they reach for higher expected returns by using other asset classes with higher risk and return qualities. Given that ILBs and the active-lives liabilities are both linked to inflation,[9] sponsors realize that to reach for higher returns, they take on some risk of underperformance in inflationary environments. In addition to generic asset allocations, pension plans may use ILBs to protect a surplus, to offset substantial equity risk exposure, or to reduce the variability of annual funding requirements. Defined-contribution pension plans and their participants also may benefit from the inclusion of ILBs as described separately below.

Endowments, foundations, and other eleemosynary organizations also may have return objectives that are formulated in *real* terms. Typically their goal is to generate a 5% or higher real return on their investment portfolio. (The IRS generally requires that 5% of a charitable foundation's assets be spent on the delivery of charitable services each year—so a 5% real return, net of expenses and contributions, is required to maintain the foundation's inflation-adjusted size.)

Establishing a real-return target for investment performance makes sense for these organizations. Educational or charitable programs, whether they involve physical infrastructure or services, often are budgeted for using inflation-adjusted dollars. Implicitly, such goals, objectives, and plans represent real liabilities.

9. More specifically, active-lives liabilities are tied to increases in wages of employees. The pension plans may prescribe that an employee's retirement benefit is a fixed annuity, with each monthly payment being a fraction of employees' highest annual income. This income level is in turn not explicitly but generally highly correlated with the CPI.

This suggests that eleemosynaries employ ILBs as a core pillar in their investment strategy. ILBs will not generally achieve 5% returns in isolation, but they go a long way toward engineering out much of the downside risk of return distributions. With the downside risk truncated, more aggressive use of a higher-returning (riskier) asset can be used. As of this writing, eleemosynaries generally have used ILBs only at the margin.

Individuals save primarily to provide for retirement needs and secondarily for children's education, bequeathment, and other goals. Younger individuals may be relatively immune to the damage that inflation can cause in the context of such liabilities. They hold a large proportion of their "wealth" in the intangible real asset known as *human capital* (future earning power). As individuals age, the proportion of their real assets typically decrease as their financial assets increase—leaving those in their late 40s and older relatively vulnerable to the inflationary erosion of retirement living standards.

ISSUERS

Although corporations and agencies can and do issue ILBs, governments are by far the largest issuers. By issuing ILBs, government officials make clearer their commitment to maintaining a low level of inflation. A government's willingness to assume the financial risk of inflation is a powerful signal to the marketplace regarding future policy. Donald T. Brash, governor of the Reserve Bank of New Zealand, characterized this attitude in a speech following New Zealand's introduction of these securities:

> The only "cost" to Government is that, by issuing inflation-adjusted bonds, it foregoes the opportunity of reducing, through inflation, the real cost of borrowing . . . Since [the New Zealand] Government has no intention of stealing the money invested by bondholders, foregoing the right to steal through inflation hardly seems a significant penalty.[10]

How can an investment instrument that makes so much sense for investors, as described in preceding sections, also be advantageous to the issuer? Brash's quote provides one example of how investors gain while the issuer forfeits something it considered worthless to begin with. Next we discuss the U.S. Treasury rationale for issuing TIPS.

U.S. Treasury's Rationale

A goal of the Clinton administration was to reduce the future interest burden of the Treasury's debt. Balancing the budget was the main target of this policy, but

10. Donald T. Brash, "Monetary Policy and Inflation-Adjusted Bonds," an address to the New Zealand Society of Actuaries, April 12, 1995.

a secondary objective took aim at "bond market vigilantes." The administration recognized that because of the "maturity premium" inherent in longer-term debt, rolling over a 3-year bond ten times likely would incur less interest cost than issuing a single 30-year bond. One of the most important programs Treasury embarked on during this administration was a deliberate effort to reduce the average maturity of outstanding debt.

TIPS Program

The TIPS program was instituted in this spirit. Like floating-rate debt, TIPS have long *stated* but short *effective* maturities, reducing the "rollover risk" inherent in short-term debt. Additionally, TIPS explicitly provide market-based inflation forecasts for use by the Fed. TIPS reduce the expected cost of financing a government's debt because they are conceptually free of the inflation risk premium built into nominal long-term bond yields. Normally one might conclude that by relieving bond investors of this risk, the Treasury implicitly absorbs a burden or risk equal in magnitude. This is not the case here, however.

By reducing nominal debt and increasing inflation-indexed (real) debt, the Treasury has in effect changed the structure of its liabilities to better match its only asset—its authority to tax. Put another way, the Treasury is the ideal issuer of inflation-indexed debt.

The issuance of TIPS improves taxpayer welfare by eliminating the 0.5% to 1.0% inflation risk premium that researchers believe is embedded in nominal bond yields. At the margin, investors are indifferent to accepting lower yields versus living with the higher risk of nominal debt—so conceptually they are no better or worse off. The elimination of this inflation risk premium is therefore a true welfare gain. In practice, the welfare gains of issuing TIPS have been split between issuers and the investors.

Moral Hazard

The government is both the issuer of TIPS (Department of Treasury) and publisher of the CPI (BLS, Department of Labor). The inherent ambiguity in measuring the CPI creates a moral hazard because the government can directly control the economic value of its liability. Fortunately, several factors mitigate the risk of the government publishing statistics that are not scientifically based.

First, professional integrity, a strong institutional infrastructure, and influential political constituencies combine to preclude the government from manipulating the CPI. Second, any confiscation of value through index distortions would be perceived by the financial community as an erosion of credibility or, if blatant, tantamount to default. Since the issuance process is a repeated game of substantial proportion, such an erosion of credibility would have long-term repercussions on future debt issuance and other government promises that would greatly outweigh any apparent short-term economic or political benefits.

International Issuers

The ILB market in the United Kingdom is large and well developed, comprising about 20% of outstanding debt. Additionally, Canada, Australia, France, Italy, and Sweden have issued ILBs in large enough quantities to ensure reasonable market liquidity as well.

While each of these countries shares the basic inflation-protection concept with their U.S. cousins, differences include market size, trading liquidity, time lag associated with the inflation indexation, taxation, day-count conventions, and quotation conventions. These differences substantially influence both observed quoted real yields and "true" real yields available to investors.

All the ILBs issued by these six governments, together with those issued by the U.S. Treasury, make up a performance benchmark of liquid global inflation bonds known as of April 2011 the *Barclays Capital Global Inflation-Linked Bond Index.*

Corporate Issuers and CPI Floaters

In addition to the U.S. Treasury and non-U.S. government issuers, U.S. corporations, agencies, and municipalities have issued inflation-indexed bonds. Two of the earliest corporate issuers were the Tennessee Valley Authority and Salomon Brothers. Their inflation-indexed bonds were virtually identical in structure to U.S. Treasury TIPS. Other issuers, including Nationsbank, Toyota Motor Credit, the Student Loan Marketing Association (SLMA), and the Federal Home Loan Bank (FHLB), have chosen to structure their bonds as CPI floaters.

A CPI floater is a hybrid between TIPS and a conventional floating-rate note (FRN). Like a TIPS, its return is closely linked to CPI inflation. Like a conventional floating-rate note, its principal is fixed in size. The coupon rate of a CPI floater fluctuates and is typically defined as the CPI inflation rate plus a fixed-percentage margin.

OTHER ISSUES

Taxation

U.S. TIPS are taxed similarly to zero-coupon bonds. They incur a tax liability on phantom income (income earned but not paid). This does not mean that investors in TIPS pay more taxes or that they pay taxes sooner than holders of nominal bonds. In fact, if inflation, nominal yields, and tax rates are constant, the cash-flow profile of taxes paid and payments received on TIPS is comparable with those of nominal bonds (assuming reinvestment of the excess coupon). In practice, many taxpayers hold TIPS in tax-exempt accounts (401(k)s, etc.) or within mutual funds (which are generally required to distribute taxable income).

Deflation Protection

Questions naturally arise regarding how TIPS would behave in a deflationary environment (one where prices are literally falling). Applying CPI indexation, the current adjusted principal value would be less than the prior adjusted principal value. This would affect semiannual interest payments accordingly.

Extending this premise, it is certainly possible for the adjusted principal value to fall below the original principal value—and therefore for coupon payments to be calculated on a shrinking base. Note that they would still be positive and almost equal to their original size. For example, even after 10 years of 1% deflation and a resulting price level that was 10% lower than when it started, the semiannual coupon payments on a $1,000 TIPS would still be about $18 (rather than $20 originally). The final principal repayment would be treated even more favorably.

In particular, *the Treasury has guaranteed that for the maturity payment of principal (and only the maturity payment), the investor will not receive less than the original principal amount.*

In such deflationary circumstances, in order to maintain acceptable nominal returns, the Treasury would in effect be paying a higher real return than initially promised. The Treasury decided that the regulatory, institutional, and psychological benefits of providing this guarantee would facilitate distribution of the bonds to an extent that more than justifies the theoretical contingent cost to the government.

This government guarantee of 100% principal return distinguishes TIPS from all other inflation hedges.

KEY POINTS

- The inflation indexed bond market has existed for centuries in various forms, but blossomed in 1997 when the U.S. Treasury introduced Treasury Inflation-Protected Securities or TIPS, and in years since as investors have adopted them strategically.
- The market real yield on TIPS can be subtracted from the market nominal yield of similar maturity fixed-rate Treasuries to arrive at the “break-even inflation rate.”
- A broad range of investors incorporated TIPS into their asset allocations in order to lock in fixed real yields, while protecting their principal from erosion of purchasing power.
- Investors utilize a “break-even” structure in determining their allocations to TIPS. This involves hedging out the relatively low real yields currently priced by the market in order to profit more directly from a rise in inflation, which may or may not be accompanied by rising real yields.

CHAPTER

SIXTEEN

NON-U.S. SOVEREIGN BONDS

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Sovereign bonds refer to bonds issued by the central government of a country. In most countries, the sovereign bond sector the largest sector of the bond market and is considered to be the debt within a country that has the lowest default risk because central governments borrow in a currency whose value they control. Central governments can do so by printing more money to satisfy their obligations to bondholders. In this chapter, the market for non-U.S. sovereign bonds and the debt instruments issues are described. The next chapter provides comprehensive coverage of bonds issued by central governments of developing countries.

SIZE OF THE SOVEREIGN BOND MARKET

Exhibit 16-1 shows the amount of central bank debt securities outstanding for 30 countries as of the third quarter of 2018 as reported by the Bank for International Settlement (BIS). The total amount of central bank debt outstanding was almost US$23.9 trillion. For some reason, Japan was not included in the data provided by the BIS. As of early 2019, the BIS did report that the debt was roughly US$12.8 trillion. Therefore, total debt securities issued by the 30 countries was about US$36.7 trillion and the total debt securities issued by the 29 countries excluding the United States was US$23.4 trillion.

Investors can be domiciled in the country where the central government has issued the bond, or they can be foreign investors. Within each of these groups, we distinguish between financial entities (banks, contractual savings entities, and

Parts of this chapter draw from Frank J. Fabozzi and Francesco A. Fabozzi, *Bond Markets, Analysis, and Strategies* (Cambridge, MA: MIT Press, 2021).

collective investment funds) and nonfinancial entities (nonfinancial firms and individual retail investors). Financial entities are key players in the sovereign debt market. Commercial banks invest in government securities for a variety of reasons. They use these securities to meet liquid asset requirements, manage their interest rate risk, and provide collateral for certain transactions (e.g. repurchase agreements). The contractual saving entities include pension funds and life insurance companies. Their mission is to fund a liability structure. Since their liabilities are long-term, they are important buyers of longer-term maturity government securities. Collective investment funds—including bond mutual funds and money market funds—are active participants across the entire yield curve.

TYPES OF SECURITIES ISSUED

Central governments can issue different types of debt instruments. Exhibit 16-1 shows the amount outstanding by type of instrument (fixed rate, floating rate, and inflation linked). Most sovereign borrowers issue bonds with a fairly wide range of maturities. This allows investors to have a benchmark yield that can be used in the pricing of other debt instruments issued in a country. Governments routinely issue two types of securities. The first is a discount security that pays a single cash flow at the maturity date with the difference between the maturity value and the purchase price being the interest the investor receives. Most sovereign debt issued with an original maturity of one year or less are issued as discount securities. The second type is a coupon security that is issued with a stated rate of interest and make interest payments periodically. The interest payments can be made semiannually or annually. In many European countries interest payments are made annually. Sovereign debt with an original maturity of greater than one year is issued generally issued as coupon securities. From Exhibit 16-1, it can be seen that the most common type of instrument is a one that pays a fixed rate.

Sovereigns can also issue two types whose payments are not fixed: floating-rate securities and inflation-adjusted securities. Floating-rate securities are securities whose interest payments change periodically according to a predetermined coupon formula. The coupon formula includes a reference rate (benchmark interest rate) adjusted with a spread.[1]

Inflation-adjusted securities, also referred to as "linkers," adjust the payments (either coupon or principal) to investors for some measure of the country's rate of inflation.[2] There are different designs that can be used for linkers. The reference rate that is a proxy for the inflation rate some consumer price index (CPI). In the United Kingdom, for example, the index used is the Retail Prices Index (All Items), or RPI. In France, there are two linkers with two different indexes: the French CPI (excluding tobacco) and the Eurozone's Harmonised Index of Consumer Prices (HICP) (excluding tobacco). In the United States, it is the

1. Floating-rate securities are discussed in more detail in Chapter 14.
2. Inflation protection securities are discussed in more detail in Chapter 15.

EXHIBIT 16-1

Central Government Debt Securities Outstanding in Billions of U.S. Dollars as of the Fourth Quarter of 2018

	Amounts Outstanding, in Billions of U.S. Dollars				
	Total	Domestic Currency			Foreign Currency
		Fixed Rate	Floating Rate	Inflation Linked	
All countries	23,897.7	19,737.3	1,222.1	2,834.2	104.1
Argentina	99.7	17.4	7.2	20.7	54.4
Australia	373.7	348.2	0.0	25.6	0.0
Belgium	402.4	393.4	2.4	0.0	6.5
Brazil	1,405.1	520.5	493.7	386.8	4.2
Canada	406.4	371.1	0.0	35.2	0.0
Chile	. . .	. . .	. . .	. . .	. . .
Chinese Taipei	181.5	181.5	0.0	0.0	0.0
Colombia	90.3	59.5	0.0	30.8	0.0
Czech Republic	61.5	53.3	8.2	0.0	0.0
Germany	1,333.0	1,200.4	21.7	76.0	34.8
Hong Kong SAR	17.8	15.4	0.0	2.4	0.0
Hungary	61.9	44.0	6.1	9.4	2.4
India	789.5	764.0	25.3	0.2	. . .
Indonesia	158.3	154.6	3.5	0.0	0.3
Israel	128.9	66.0	10.3	52.6	0.0
Korea	600.3	591.9	0.0	8.4	0.0
Malaysia	178.2	178.2	0.0	0.0	0.0
Mexico	299.3	63.9	149.4	86.1	0.0
Peru	29.9	29.0	0.0	0.9	0.0
Philippines	81.6	79.9	1.1	. . .	0.5
Poland	166.9	119.8	45.9	1.2	0.0
Russia	104.1	75.9	24.6	3.6	0.0
Saudi Arabia	81.3	56.8	24.5	. . .	0.0
Singapore	84.2	84.2	0.0	0.0	0.0
South Africa	146.5	107.9	0.0	38.6	. . .
Spain	1,044.1	982.8	0.0	61.3	0.0
Thailand	132.8	132.8	0.0	0.0	0.0
Turkey	110.8	70.0	14.3	25.6	0.9
United Kingdom	2,059.5	1,503.3	0.0	556.2	0.0
United States	13,268.0	11,471.6	383.8	1,412.6	0.0

Source: Table C2, *BIS Statistical Bulletin*, Bank for International Settlements, September 2019.

Consumer Price Index—Urban, Non-Seasonally Adjusted (denoted by CPI-U) as calculated by the U.S. Bureau of Labor Statistics.[3]

Given the reference rate, the design of a linker can be such that over time the principal and/or the coupon income are adjusted for inflation between the date of issuance and the payment date of a cash flow. The most commonly used design for a linker today calls for adjusting both the principal and the coupon interest. Before maturity, prices for trades in the secondary market are adjusted similarly. The inflation adjustment is usually done with a lag. This structure is used in the United States for its linker (TIPS) where there is a three-month lag in the CPI-U.

A small part of the central government securities markets is exchange rate-linked government debt, also referred to as principal exchange-rate-linked (PERL) government debt. The structure of this debt instrument is that the principal depends on the exchange rate between the U.S. dollar and some exchange rate, typically the exchange rate between the two exchange rates; one of the rates is that of the issuing country.

The denomination of the payments can in be any currency, not just the local currency. Central governments will assess their local economic conditions and internal political developments in making the decision as to the currency in which they will denominate their bonds. For example, oil-producing countries such as Mexico, Chile, and Columbia facing low oil prices have issued denominated in euros and other non-U.S. dollars.

PRIMARY MARKET FOR SOVEREIGN DEBT

There are a number of distribution methods in use in the primary sovereign debt markets. Typically, central governments are active in the primary market at the beginning of the calendar year.[4] This is the case because the minister of finance of countries begin address their country's funding requirements. During the calendar year, the ministers of finance monitor the global capital markets to identify opportunities to obtain more cost-effective funding.

The three primary distribution methods are (1) auctions, (2) syndications/underwriting, and (3) tap sales. For countries with well-developed markets, the primary distribution method is an auction, which has proven to be more

3. The CPI-U is the most widely followed and perhaps the most understood inflation index among alternative choices such as the Gross Domestic Product (GDP) deflator and the Personal Consumption Expenditure (PCE) deflator. Changes in the CPI-U represent the average change in prices facing urban consumers for a fixed basket of goods and services. This group of urban consumers represents about 87% of the total U.S. population. The Treasury reserves the right to substitute an alternative price index under the following circumstances: (1) the CPI-U is discontinued; (2) the CPI-U is altered materially to the detriment of the investor and/or the security; (3) the CPI-U is altered by legislation or executive order in a manner harmful to the investor and/or the security.

4. Eli Whitney Debevoise II, Neil M. Goodman, and Carlos A. Pelaez, "The Current State of the Sovereign Bond Market," Arnold & Porter, May 2, 2017. Available at https://www.arnoldporter.com/en/perspectives/publications/2017/05/the-current-state-of-the-sovereign-bond-market.

transparent and cost effective than other selling methods. In developing markets, other methods such as syndication, underwriting, and tap sales are used.

Auctions

Many sovereigns use either a single-price auction (also called a uniform price auction) or a multiple price auction (also called a discriminatory auction) for all marketable securities it issues. In a multiple price auction, competitive bidders state the amount of the securities desired and the yields they are willing to accept. The yields are then ranked from lowest to highest (which is equivalent to arranging the bids from the highest price to the lowest price). Starting from the lowest yield bid, all competitive bids are accepted until the amount to be distributed to the competitive bidders is completely allocated. The highest yield accepted by the sovereign is called the "stop yield," and bidders at that yield are awarded a percentage of their total tender offer. The single-price auction proceeds in the same fashion except that all accepted bids are filled at the highest yield of accepted competitive tenders.

The frequency of auctions is a function of the debt management practices of the government and the desire to promote a liquid secondary market. Short-term securities, such as bills, are usually auctioned weekly. In most countries, the day of the week for the auction is fixed. Longer-term coupon securities, such as notes and bonds, are typically auctioned less frequently, usually monthly or quarterly. A well-defined schedule announced in advance it is believed leads to a lower effective borrowing cost.

Syndication

In markets where there are few bidders, the auction method for distributing new issues may not be the best method. In such cases, central governments appoint a group of financial institutions who for a negotiable fee will subscribe to the purchase the bond issue and then resell the bonds to other investors. This process, called syndication, offers the advantage of reducing placement risk when demand for the securities is very uncertain and when the central government seeks to introduce a new debt instrument. Syndication's main disadvantage is the lack of transparency relative to an auction.

An alternative method for selling government securities is via underwriting. With this method for the distribution of new securities, the central government establishes a minimum price for a debt issue to be sold. For a commission, the underwriter subscribes to the entire issue at the minimum price. The underwriter can then retain the portion of the issue it desires and resells the remainder to other investors.

Tap Sales

A *tap sale* is a method of distributing securities that allows issuers to sell additional bonds from past issues. The bonds are sold at their current market price but retain their original face value, coupon rate and maturity. The British and French governments have issued additional securities using this method. Advantages to the issuer include avoiding some of the fixed costs of auctioning off new securities. This method is used for issuing small amounts of securities when the cost of a new issue is prohibitive.

SECONDARY MARKET

In the secondary market, sovereign bonds can be traded directly from investor to investor, or through a broker or primary dealer to facilitate the transaction. The major participants in secondary government bond markets globally are large institutional investors and central banks. The participation of retail investors in secondary market is small. There are two main ways for secondary markets to be structured: as an organized exchange or as an over-the-counter market.

A hallmark of a liquid, well-developed market is how it handles spot transactions (i.e., a transaction for the immediate purchase or sale of a security). An important gauge of a market's efficiency is the amount of time between trade execution and settlement. The shorter the gap, the more cash-like securities become. Settlement is the process that occurs after the trade is made. The bonds are delivered to the buyer for payment is received from the seller. For most developed secondary markets, cash settlement is standard (i.e., when trading and settlement occur the same day). Trades clear within either or both of the two main clearing systems, Euroclear and Clearstream. Settlement occurs by means of a simultaneous exchange of bonds for cash on the books of the clearing system. An electronic bridge connecting Euroclear and Clearstream allows transfer of bonds from one system to the other.

SOVEREIGN CREDIT RISK

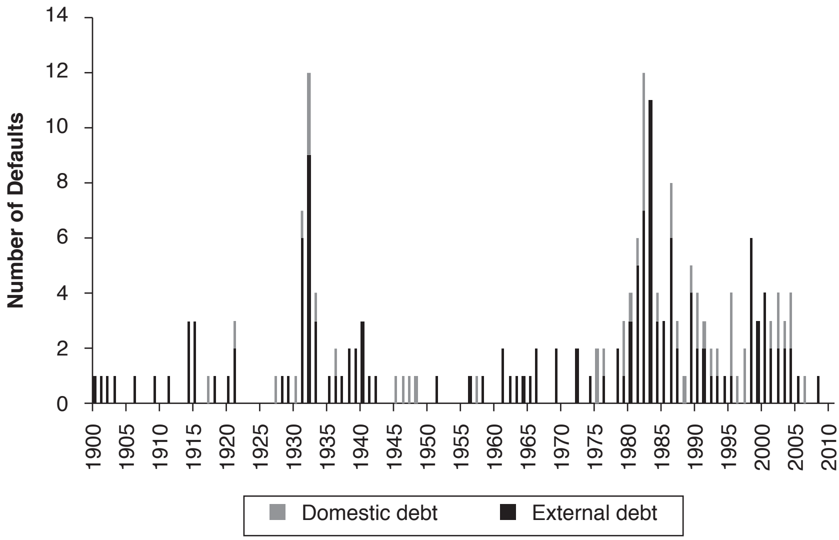
Sovereign debt exposes investors to credit risk. Over history, we could observe several cycles of sovereign debt defaults. These defaults usually came in waves or clusters over time, as Exhibit 16-2 shows based on data collected by Reinhart and Rogoff.[5] It is important to distinguish between domestic and external debt. Domestic debt is issued under national jurisdiction and is typically denominated in the national currency. Domestic debt instruments are usually, but not exclusively, held by residents of the issuing country. External debt, however, is subject to the jurisdiction of foreign creditors or international laws, is typically issued in foreign currency and held by foreign residents. In many cases, it is assumed that domestic debt is not at risk whatsoever, given that the sovereign can always print money to pay its debt back. To service external, foreign currency denominated

5. Carmen M. Reinhart and Kenneth S. Rogoff, *This Time Is Different: Eight Centuries of Financial Folly* (Princeton, NJ: Princeton University Press, 2009).

debt, however, a country needs access to foreign currencies. If the country runs out of foreign reserves and cannot generate sufficient foreign currency inflows by exporting goods or issuing new debt, there is a very obvious technical reason to default.

EXHIBIT 16-2

History of Sovereign Defaults



Authors' construction using data from Carmen M. Reinhart and Kenneth S. Rogoff, *This Time Is Different: Eight Centuries of Financial Folly* (Princeton, NJ: Princeton University Press, 2009).

In reality, domestic debt defaults occurred in the past, although less frequently than external defaults, as shown in the exhibit. Beyond a *de jure* default on domestic debt, we can also consider hyperinflation as a form a default. In such cases, while the government formally pays its obligations back, the purchasing power of the repaid debt is significantly less than when it was borrowed.

Based on historical experience, countries that issue a large portion of their debt with short maturity are usually more prone to face difficulties rolling over their debt during market panics or economic downturns, and thus are more prone to default. From the creditor's perspective, short-maturity debt is a means to force borrowers to follow prudent economic policies, and also is a result of inflation fatigue, as short-maturity debt is much harder to inflate away than long-maturity debt. Nevertheless, even a country with a sustainable debt profile can run into a rollover or debt liquidity crises during recessions and market panics. These types of liquidity crises have been largely reduced by international organizations like the IMF or the World Bank that can provide loans when private lenders would not be able or willing to do so.

Sovereign ratings are credit ratings for countries as assigned by one or more credit rating agency (CRA). The three major CRAs are Moody's Investors Service, Standard & Poor's Ratings Services, and Fitch Ratings. Two CRAs that rate sovereign debt and have the status of a Nationally Recognized Statistical Organization by the U.S. Securities and Exchange Commission are the Japan Credit Rating Agency and DBRS Morningstar. Other CRAs that include Scope Ratings (a German-based CRA) and two Chinese-based CRAs, Dagong Global Credit Rating and China Chengxin Credit Rating Group.

Sovereign ratings are assessments of the relative likelihood that a borrower (i.e., a central government) will default on its obligations. Governments seek these credit ratings to increase their access to international capital markets. Sovereign ratings matter to investors because other things equal investors prefer rated issues to unrated ones. They matter to borrowers as well because the rating agencies are reluctant to assign a credit rating to a lower level of government or corporation that is higher than that of the issuer's home country.

Two sovereign debt ratings are assigned by credit rating agencies, a local currency debt rating and a foreign currency debt rating. The two general categories of risk analyzed in assigning ratings are economic risk and political risk. The former category is an assessment of the ability of a government to satisfy its obligations. Both quantitative and qualitative analyses are used in assessing economic risk. Political risk is an assessment of the willingness of a government to satisfy its obligations. A government may have the ability but may be unwilling to pay. Political risk is assessed based on qualitative analysis of the political factors that influence a government's economic policies.

The reason for distinguishing between local debt ratings and foreign currency debt ratings is that historically, the default frequency differs by the currency denomination of the debt. Specifically, defaults have been greater on foreign currency–denominated debt. The reason for the difference in default rates for local currency debt and foreign currency debt is that if a government is willing to raise taxes and control its domestic financial system, it can generate sufficient local currency to meet its local currency debt obligation. This is not the case with foreign currency-denominated debt. A national government must purchase foreign currency to meet a debt obligation in that foreign currency and therefore has less control with respect to its exchange rate. Thus, a significant depreciation of the local currency relative to a foreign currency in which a debt obligation is denominated will impair a national government's ability to satisfy such obligation. This distinction is not observed with the 17 countries of the European Union's Eurozone, where there is only a single credit rating for a sovereign's issues irrespective of what currency the country is issuing.

A country whose domestic currency is a liquid currency, and which boasts a sizeable domestic institutional savings base, has the capacity to fund its debt in local currency.[6] However where there is a demand for that issuer's name, either

6. By liquid currency, we mean a currency that can be bought or sold quickly and cheaply with a narrow bid-ask spread and without the transaction adversely impacting the exchange rate.

from foreign investors and/or for issues in another currency, a sovereign may also issue in a foreign currency. When this occurs, it will usually swap the proceeds into its local currency. A demand for a particular sovereign name from different investors may cause that issuer to raise debt in a foreign currency; this is common for highly rated borrowers such as Switzerland, Finland, and Sweden, which issue U.S. dollar and euro debt.

The factors analyzed in assessing the creditworthiness of a national government's local currency debt and foreign currency debt will differ to some extent. In assessing the credit quality of local currency debt, for example, Standard & Poor's emphasizes domestic government policies that foster or impede timely debt service.

In assigning a rating for a country's foreign currency debt, credit analysis by S&P focuses on the interaction of domestic and foreign government policies. S&P analyzes a country's balance of payments and the structure of its external balance sheet. The areas of analysis with respect to its external balance sheet are the net public debt, total net external debt, and net external liabilities.

Moody's, another major rating agency, focuses on the following four factors as the foundation of its sovereign bond ratings methodology: (1) economic strength (wealth, size, diversification, and long-term potential), (2) institutional strength (governance, quality of institutions, and policy predictability), (3) government financial strength (ability to deploy resources to face current and expected liabilities), and (4) susceptibility to event risk (risk of sudden risk migration).[7]

SOVEREIGN BOND YIELD SPREADS

There are several studies on the sovereign yield spreads. The focus of most studies is on the importance of a country's fiscal fundamentals on the observed yield spread on sovereign bonds for advanced economies.[8] Several empirical studies for advanced economies find that fiscal fundamentals and default risk are not the key drivers of sovereign yield spreads.

A European Central Bank study by Afonso, Arghyrou, and Kontonikas, however, did find that macroeconomic and expected fiscal fundamentals, international risk, liquidity conditions, and sovereign credit ratings (particularly in the case of a rating downgrade) did have an impact over three time periods: (1) the period preceding the global credit crunch (January 1999–July 2007), (2) the period during which the global credit crunch had not yet transformed into a sovereign debt crisis (August 2007–February 2009), and (3) the period during which the global financial crisis transformed into a sovereign debt crisis (March

7. Moody's, "Sovereign Bond Ratings," September 2008.

8. See Joshua Aizenman, Michael Hutchison, and Yothin Jinjarak, "What Is the Risk of European Sovereign Debt Defaults?" *Journal of International Money and Finance* 34, 2013, pp. 37–59, and Tigran Poghosyan, "Long-Run and Short-Run Determinants of Sovereign Bond Yields in Advanced Economies," IMF Working Paper No. 12/271, 2012.

2009–December 2010).[9] The study looked at 10 euro area countries (Austria, Belgium, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal, and Spain).

Empirical studies do suggest that a key determinant of sovereign yield spread is global market conditions that reflect the risk aversion of global investors rather than conditions specific to a country.[10] This is due to the global financial integration that results in portfolio adjustments by global investors, clearly demonstrated during a financial crisis where there is a flight to countries viewed as a safe haven. Nevertheless, when there is an economic crisis for a specific country, investors become concerned with domestic risk.[11]

There are studies that looked at more than just fiscal variables and default risk in investing observed sovereign yield spreads. These studies look at some proxies for investor expectations about fiscal development for a country. For example, deficit forecasts and potential government liabilities (e.g., the position of the domestic banking sector if it had to be rescued) have been used.[12]

Most of the earlier studied examined observed yield spreads. Since 2013, as a result of data available on forecasts of fiscal variables based on survey forecasts, studies have used forecasts to explain sovereign bond yield spreads. For example, a study by the European Central Bank by Cimadomo, Claeys, and Poplawski-Ribeiro used survey data to investigate how financial institutions forecast sovereign yield spreads.[13] They use monthly survey forecasts for three countries (France, Italy, and the U.K.) between January 1993 and December 2011 to investigate whether survey respondents consider the expected evolution of a country's fiscal balance, as well as other economic fundamentals, are determinants of the expected (as opposed to observed) bond yield spreads over a benchmark German 10-year bond. One-year-ahead forecasts for a country's budget balance, inflation

9. António Afonso, Michael G. Arghyrou, and Alexandros Kontonikas, "The Determinants of Sovereign Bond Yield Spreads in the EMU," European Central Bank, Working Paper Series 1781, April 2015.

10. See, for example, Manmohan Kumar and Tatsuyoshi Okimoto, "Dynamics of International Integration of Government Securities' Markets," *Journal of Banking and Finance* 35(1), 2011, pp. 142–154, and Carlo Favero, Marco Pagano, and Ernst-Ludwig von Thadden "How Does Liquidity Affect Government Bond Yields?" *Journal of Financial and Quantitative Analysis* 45(1), 2010, pp. 107–134; and Simone Manganelli and Guido Wolswijk, "What Drives Spreads in The Euro Area Government Bond Market?" *Economic Policy* 24, 2009, pp. 191–240.

11. See Carlo Favero and Ro Missale, "EU Public Debt Management and Eurobonds." EU Parliament Economic Policy Note, 2012 (Brussels: European Parliament).

12. See, for example, Thomas Laubach, "New Evidence on the Interest Rate Effects of Budget Deficits and Debt," *Journal of the European Economic Association* 7(4), 2009, pp. 858–885, and Robert De Santis, "The Euro Area Sovereign Debt Crisis: Identifying Flight-to-Liquidity and the Spillover Mechanisms," *Journal of Empirical Finance* 26, 2014, pp. 150–170.

13. Jacopo Cimadomo, Peter Claeys, and Marcos Poplawski-Ribeiro, "How Do Financial Institutions Forecast Sovereign Spreads?" European Central Bank, Working Paper Series No. 1750, December 2014. Another survey-based study is Antonello D'Agostino and Michael Ehrmann, "The Pricing of G7 Sovereign Bond Spreads—The Times, They Are A-Changing," *Journal of Banking & Finance* 47, 2014, pp. 155–176.

rate, and GDP are used as a proxy for a country's fiscal development. They find that the expected sovereign yield spread is significantly impacted by the forecasted improvement for a country's fiscal development. Overall, the findings suggest that credible fiscal plans affect expectations of market experts, reducing the pressure on sovereign bond markets.

SOVEREIGN BONDS FROM THE INVESTOR'S PERSPECTIVE

Investors may choose to invest in foreign sovereign bonds for various reasons, and it is also common to bucket foreign sovereign bonds into "developed market" and "emerging market" categories.

From a U.S. investor's perspective, developed market sovereign bonds, as well as bonds issued by supranational organizations like the World Bank, were historically added to investment portfolios to diversify the risk of the U.S. yield curve. Furthermore, return enhancement had been a consideration as well, especially when foreign sovereign yields exceeded U.S. Treasury yields, like 10-year German bund offered higher yield than 10-year U.S. Treasuries in the early 1990s, 2002, or around 2008–2009. As discussed in Chapter 1, many bonds of the highest-rated foreign sovereign issuers currently offer very low or even negative yield, so many investors consider U.S. Treasuries more attractive than those bonds issued by Germany or Switzerland in the present conditions. That said, besides pure diversification, foreign developed market sovereign bonds still play important roles in the market:

- Central banks and other official organizations hold a significant portion of their reserves in the highest-rated sovereign bonds. Based on IMF data,[14] central banks altogether held \$12.2 trillion in assets as of April 2020, and while the U.S. dollar remains the main global reserve currency, about 39% of global central bank reserves[15] is comprised by non-U.S. dollar assets. Foreign reserve currency allocation, and thus allocation to foreign sovereign bonds, is based on various factors, like economic connections with different currency blocks; thus European countries outside the Eurozone would typically have high allocation to euro-denominated bonds.
- Outside of central bank reserve managers, other investors like pension funds may add foreign sovereign bonds to their portfolios on a currency unhedged or hedged basis. If foreign sovereigns are added to on a currency unhedged basis, currency risk (and currency diversification) would be a main contributor to the fixed-income portfolio risk. If, however, foreign sovereign bonds are added on a currency hedged basis, while

14. Total reserves excluding gold: https://data.imf.org/regular.aspx?key=61545869.
15. COFER database: https://data.imf.org/?sk=E6A5F467-C14B-4AA8-9F6D-5A09EC4E62A4.

volatility gets reduced, investors also have to take the cost of hedging into consideration. Based on the covered interest rate parity, a currency with higher interest rates than the same maturity U.S. interest rates would be traded at a discount forward price compared to the spot FX rate, whereas a currency with lower interest rates would have a forward premium versus the U.S. dollar spot rate. For example, while a Japanese government bond offers lower yield than the same maturity U.S. Treasury, if the Japanese short-term interest rate is even more lower than the comparable U.S. interest rate, the carry on the Japanese bonds may be attractive on a currency hedged basis as the investor sells Japanese yen forward at a premium price. When investing in foreign bonds on a currency hedged basis, the difference in the yield curve slopes matter.

Emerging market sovereign bonds are mainly added to the portfolio for return enhancement. J.P. Morgan Global Emerging Market Bond Index, an index comprised of USD-denominated emerging market sovereign and agency bonds, had a spread of 4.63% over U.S. Treasuries at the end of May 2020. Given low yield levels in developed markets, investors may consider the addition of emerging market sovereign bonds as an attractive return enhancer. About 60% of this index is, in fact, comprised of investment-grade bonds, there is no currency risk in this index since all these bonds are USD-denominated, but the duration is high, over seven years, so both yield or spread level increases would adversely impact the index performance. Local currency denominated emerging market bonds have gained importance over the recent decade as well; investors would typically add such bonds on a currency unhedged basis, since hedging high-interest-rate emerging market currencies would have a negative carry based on the logic of the covered interest rate parity.

KEY POINTS

- Sovereign debt refers to the debt issued by the highest level of government in a particular country.
- There are two types of central government securities issued—discount and coupon—and the instruments that can be issued include fixed-rate bonds, floating-rate bonds, and inflation-adjusted bonds
- The three distribution methods used in the primary sovereign debt markets are (1) auctions, (2) syndications/underwriting, and (3) tap sales. For countries with well-developed markets, the primary distribution method is an auction.
- Two sovereign debt ratings are assigned by credit rating agencies (a local currency debt rating and a foreign currency debt rating).
- The two general categories of risk analyzed by credit rating agencies in assigning ratings are economic risk and political risk.

CHAPTER

SEVENTEEN

THE EMERGING MARKETS DEBT

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Emerging markets (EMs) comprise nations whose economies are viewed as developing, or emerging, from underdevelopment. These nations usually include almost all of Africa, Central and Eastern Europe, Latin America, Russia, the Middle East, and Asia (excluding Japan). There is no single definition of EMs. Some define them as countries that do not have G10 currencies, though that might classify some AAA-rated countries as EM. EM status is not defined solely by region, nor low credit rating, as many EMs are now investment grade.

Since the early 2000s emerging economies, which had previously depended on foreign currency external debt funding, started focusing on opening their local debt markets to foreign investors, as well. Many of these countries are heavily dependent on commodity exports, whereas others have extensive service and manufacturing sectors.

EM debt includes sovereign bonds and loans issued by governments, as well as fixed-income securities issued by public and private companies domiciled in EM countries. The assets could be denominated in any currency. Many of these countries had defaulted on commercial bank loans in the 1980s and began the 1990s by converting the defaulted loans to restructured sovereign foreign currency bonds, known as *Brady bonds*. While the early to middle 1990s might be thought of as the era when defaulted foreign currency loans were restructured into global bonds, the late 1990s onward will be thought of as the era when defaulted bonds were restructured into new bonds and local markets opened up to foreign investors.

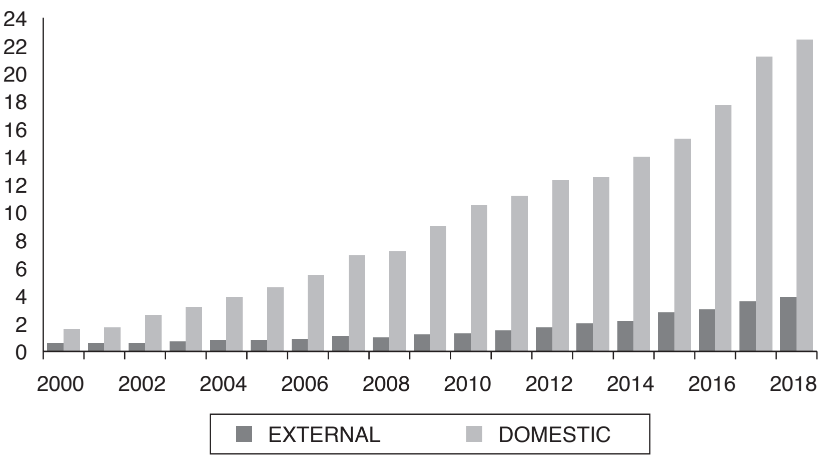
We discuss the market, the evolution of the asset class, the growth of local debt markets, the macro fundamentals that drive sovereign performance, debt sustainability considerations, the compensation provided by spreads, and the issues surrounding defaults, as well as provide a background on selected past defaults and restructurings. The asset class is distinct from the majority of developed market international investing because the largest and most liquid foreign currency bonds are primarily sovereigns bonds, and there is no bankruptcy court for sovereign external debt and countries can institute capital controls that affect all local debt.

THE DEBT UNIVERSE

EMs' tradable debt stock grew almost 1100%, or 15% per year, from 2000 to about US$26 trillion 20 years later. The vast majority of that growth has been in local debt and corporate debt. This is partly due to foreign investment inflows that helped EM countries grow their economies (Exhibit 17-1).

EXHIBIT 17-1

Growth in Domestic versus External Tradable Debt (US$ trillion)



Source: BofA Global Research, Constructed from data obtained from Bank for International Settlement.

Domestic versus External Debt

Domestic debt is issued locally and is governed by the local laws of the issuing country. Domestic debt is usually denominated in local currency and may also be called local debt or local debt markets (LDM).

External debt (EXD) is issued externally and is governed by the laws of a foreign country. It is denominated in foreign currency, primarily U.S. dollars and euros, and may be called foreign currency debt (FC).

Foreign investors initially focused only on *external* debt. The outstanding face value of external EM bonds is close to $3.9 trillion, of which US$2.7 trillion is corporate debt and US$1.2 trillion is sovereign debt. The vast majority of growth in external debt has been through issuance of corporate bonds or sovereign global and Eurobonds, terms that are often used interchangeably.[1] External corporate debt has been growing faster than external sovereign debt.

Domestic debt has become an increasing share of all debt, now over US$22 trillion, or 85% of the total EM tradable debt universe (Exhibit 17-2), up from US$2 trillion in 2000. The lower liquidity, frequent investment restrictions, varied practices, and higher convertibility risk make trading in domestic bonds more difficult for foreign investors than trading in external bonds. However, the potential for significant investment gains due to the decline in local interest rates from highly inflationary and high yielding periods, coupled with currency appreciation, was a driver for significant growth in assets invested in local markets.

Debt Stock by Region

Latin America originally dominated the external tradable debt universe, but with increased issuance in other regions, the breakdown of outstanding external debt has become fairly evenly distributed. Asia now represents 47% of total debt outstanding, with Latin America at 25%, Emerging Europe at 14%, and the Middle East and Africa at 14%. Tradable debt here excludes nontradable debt such as International Monetary Fund (IMF) loans but is not necessarily liquid debt. Tradable debt should not necessarily be considered debt qualifying for benchmark indices, which we describe below, because the latter has an additional requirement of access for foreigners, liquidity for valuation purposes, and other constraining criteria. The growth in debt has been primarily driven by higher issuance of domestic sovereign debt and external corporate bonds, mainly from China.

In local debt, Asia dominates with 78% of the tradable domestic debt, primarily driven by the debt of China and India. China alone has 56% of the domestic debt. Asia is followed by Latin America with 14% of the domestic debt. In the Asian markets, local debt is 90% of all debt in Asia, and in Latin America local debt is 77% of the total debt.

1. A Eurobond is a bond that is issued and sold to international investors and is not subject to registration. A global bond is a bond that is registered in the jurisdictions of the major financial centers.

EXTERNAL DEBT MARKETS

Both the stock of external debt outstanding per country and the number of issuing countries have grown since the early 1990s when countries began to issue foreign currency bonds (Exhibit 17-2).

Size of Market

External debt markets are now dominated by corporate bonds, but sovereign debt still dominates local markets. External debt issuance has been running at around US$600 billion annually, 25% sovereign and 75% corporate, provincial, and quasi-sovereign, compared with US$30 billion during the early 1990s. There is more than US$4 trillion of outstanding tradable external debt in 2020, versus US$1trillion in 2000. Corporate issuance has been increasing in general as corporate borrowers now enjoy wide access to the international capital markets.

Diversification of Issuers

The increase in the number of countries from which sovereign and corporate bonds have been issued has been beneficial to investors seeking diversification and whose investment performance is benchmarked against an index. The larger number of issuers has reduced the concentration of the largest countries in any of the major EM indices.

Major market indices of external debt include outstanding external sovereign debt with sufficient liquidity to provide daily pricing. External bonds have few trading restrictions and historically have been of great interest to the broadest range of foreign investors.

The number of EM countries which issue external debt has increased from 4 in 1991 to close to 80 by 2020. This is a result of large countries with foreign commercial bank loans converting those loans to bonds and smaller countries beginning to tap the external debt markets. The countries with the largest number of bonds in sovereign and corporates are in Exhibits 17-3 and 17-4.

Benchmark EM Sovereign and Corporate Indices

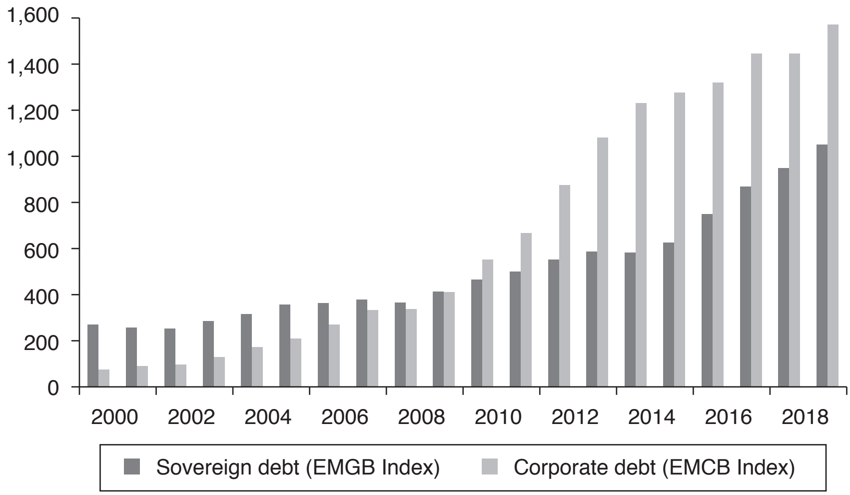
EM sovereign and corporate bonds totaling $2.5–$3 trillion are eligible for inclusion in EM indices. This is larger than the entire US$2.3 trillion market capitalization of the ICE BofA Global High Yield Index.

Sovereigns Are About 40%, Corporates 60% of EM External Debt Indices

The three most frequently used family of benchmark indices are the JPMorgan EMBI Global (EMBIG) index of sovereign and quasi-sovereigns, the Bloomberg Barclays EM Aggregate Index (EMUSTRUU) of USD sovereigns and corporates,

EXHIBIT 17-2

Growth of Sovereign and Corporate USD- and EUR-Denominated Bonds, Many Included in Benchmark Global Indices ($billion)



Source: BofA Global Research, Bloomberg, Constructed from data obtained from ICE Data indices, LLC.

and the ICE BofA EMs External Sovereign Index (EMGB) of EUR and USD bonds. Each of those indices have a sovereign market value near $1 trillion as of 2020. A majority of investors use modified indices that limit the size of the largest countries, so that a credit problem with one issuer does not have an excessively adverse impact on index or portfolio performance.

While there is no unique definition, most investors consider a company to be a "quasi-sovereign" if the government owns more than 50% of its equity. Often, such *quasis* are of such strategic government importance that investors expect them to have an implicit government guarantee, if needed. Quasi sectors are mainly in oil and gas, but also in metals and mining, utilities, and finance.

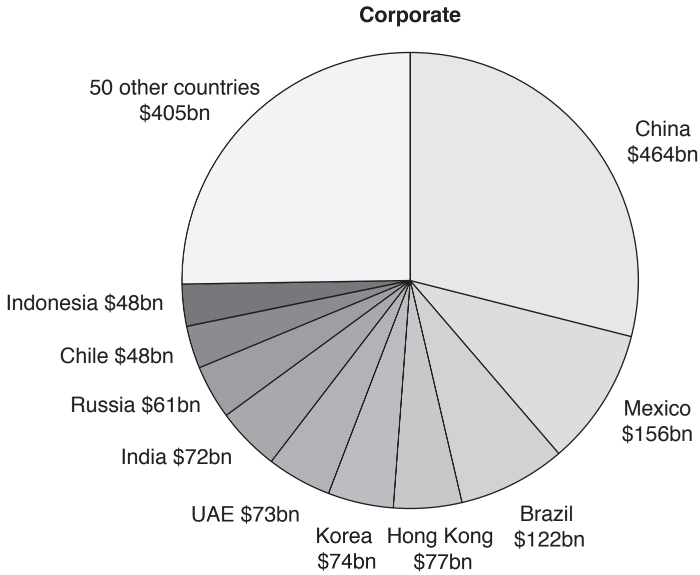
The JPM index includes USD sovereign and quasi sovereigns that are 100% owned by the government, such as Pemex. The ICE BofA index includes only sovereign issuers, not quasi sovereign, from countries that do not issue a G-10 currency. The ICE BofA index includes also EUR-denominated debt. The five largest countries comprise about 30% of the indices today compared to 98% of the index at inception in 1993.

Corporate Debt Growth

The EM corporate bond market is one of the fastest growing asset classes globally, at $1.6 trillion index eligible debt in 2020 from just $74 billion 20 years earlier. In each corporate index family, about two-thirds of the market capitalization is comprised of investment grade bonds.

EXHIBIT 17-3

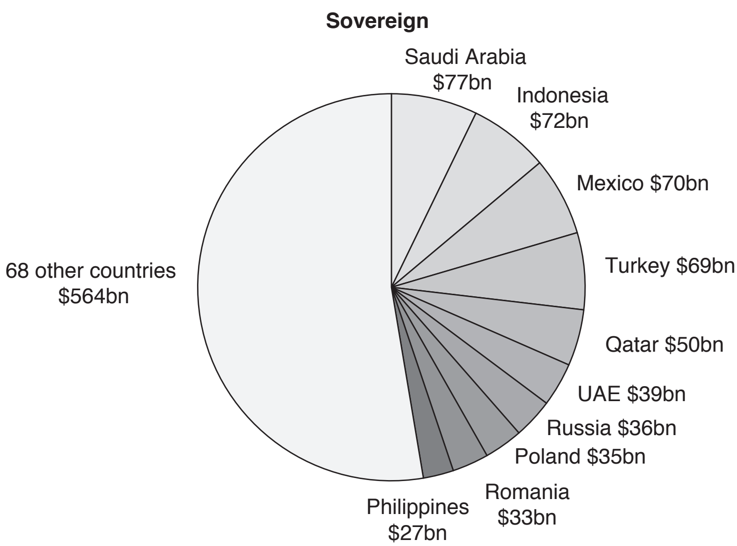
Top 10 Countries: Corporate Debt Index Face Value (EMCB Index)



Source: BofA Global Research, Bloomberg, Constructed from data obtained from ICE Data indices, LLC.

EXHIBIT 17-4

Top 10 Countries: Sovereign Debt Index Face Value (EMGB Index)



Source: BofA Global Research, Bloomberg, Constructed from data obtained from ICE Data indices, LLC.

Over the last three decades, Eastern European, African, Middle Eastern, and Asian markets have gained market share. Asia dominates the market capitalization, mainly from China's large issuance of quasi-sovereign bonds after 2010. This has left Latin America with only 26% of the market capitalization of external debt qualifying for index inclusion, compared to 98% at inception of the indices.

The most frequently used indices that include corporates are the USD JPMorgan CEMBI ($1.1 trillion), the Bloomberg Barclays EM Aggregate Index that includes USD-, EUR-, and GBP-denominated sovereign, quasi-sovereign, and corporate debt from EM issuers ($2.5 trillion LG20TRUU of which $2.2 trillion is in USD) and the ICE BofA Emerging Markets EM corporate index ($1.7 trillion, EMCB).

EM countries are home to Vale, the largest iron ore company; Codelco, the largest copper company; Bimbo, the largest baker; JBS, the largest meat packer; and Gazprom, the largest gas company, to name a few. The Mexican telecommunications company, America Movil, is one of the largest in the world. The Industrial and Commercial Bank of China is the largest bank in the world. Mexico's Pemex has issued some of the most actively traded bonds in the world, including among developed market corporate bonds.

At one time, rating agencies would not rate an EM corporate higher than the rating of its sovereign (this was termed a "sovereign ceiling"), expecting that in a crisis, a government could appropriate the foreign exchange of the corporate or prevent it from converting local currency into foreign currency. But that criterion has been relaxed. Although credit analysts at one time viewed corporate bond valuations primarily based on the sovereign, increasingly, analysts consider a company's global peer group when determining value, in addition to geographic location.

Credit Quality of EM Countries

EMs have improved in credit quality as an asset class. This is now a diverse asset class ranging from investment-grade credits to defaulted debt. The asset class was created from weak economies struggling to improve after the 1980s. Many countries have pursued macroeconomic policies that allow them to better weather external shocks and reduce their sensitivity to changes in capital flows, and their credit quality has improved as a result. During some periods, EM economies have even been the growth drivers of the global economy.

Despite the difficulties surrounding the 1997 Asian debt crisis and 1998 Russian default, there have been many more positive than negative ratings actions since then. Thus the percentage of investment-grade bonds in the major benchmark indices has risen from under 10% in the mid-1990s to close to 60–70% 25 years later. Credit quality also rose by three notches from BB–/Ba3 to BBB–/Baa3, when considering the rating of the index weighted by market capitalization.

LOCAL DEBT MARKETS

In the 1980s, country fundamentals across EMs were weak with twin fiscal and current account deficits, high inflation, large external debt stocks, currency crises, and in some cases institutional uncertainty. At that point, financing needs were normally covered by external debt, denominated in a G10 currency and governed by New York, London, or Tokyo laws. However, fundamentals started to change in the 1990s as countries implemented macroeconomic stabilization programs, adopted a more responsible fiscal stance, and moved away from fixed-exchange rate regimes toward floating ones. In several cases, monetary policy started to be managed using inflation targeting regimes.

This process led to a gradual improvement in economic fundamentals. Inflation declined and currencies became more stable. Under this new backdrop, investors gained confidence in buying debt denominated in local currency issued by countries and corporations in EM world. Most local debt was bought by local investors, but foreign investors have become an increasing share of holders of local debt. In some countries, foreigners now hold close to 50% of local government fixed-rate bonds.

Investing in local EM debt is similar to investing in any international foreign currency denominated bond; returns have two main sources: local yields and local currency returns. Because holders also incur currency risk, convertibility risk and other capital controls risks, local market bond yields are normally higher than those for external debt. In addition, local yields of EM countries have traditionally been more volatile than those of developed markets, consistent with higher volatility in inflation. That said, in the last two decades we saw a significant decline in local yields responding to better fundamentals, higher credibility, and/or to lower global yields.

Capital Controls

Capital control is a policy device that a government uses to regulate the foreign currency flows into and out of the country, usually used to restrict volatile movements of capital due to investor speculation. Controls on inflows typically respond to the macroeconomic implications of the increasing size and volatility of capital inflows, such as currency appreciation, loss of competitiveness, and credit booms. Controls on outflows are used to limit the downward pressure on their currencies and foreign reserves, a significant risk to a local bond investment.

The implementation of capital controls is a key risk for foreign investors holding, or planning to hold, local debt. Most EM countries have some form of capital controls that can be increased as needed. Even countries with free convertibility of their currencies could institute capital controls if deemed necessary. Capital controls normally can take the form of transaction taxes, transfer taxes, withholding taxes, reserve requirements, unremunerated reserve requirements, multiple exchange rate systems, and/or limitations in terms of the amount of assets to be held, caps on volume permitted, controls on the international sale or purchase of various financial assets, and sometimes even limits on the amount of money a private citizen is allowed to take out of the country. As the IMF discussed,[2] the most common experiences in using capital controls are capital controls to limit short-term inflows, capital outflow controls during financial crises, and extensive exchange controls during financial crises.

Convertibility Risk

Convertibility, or transfer, risk is the risk that a government will restrict the conversion of local currency into foreign currency or restrict the transfer of foreign currency out of the country. In other words, it is the risk that an investor will not be able to repatriate the cash flows of the investment, normally due to exchange restrictions imposed by a government. Drastic measures may occur during crises. Several such examples are:

- **Korea, 1997**: Daily currency move was limited to 5% and the FX market would shut down after that level was reached.
- **Russia, 1998**: Banks froze dollar withdrawals and the central bank terminated the fixing of the currency in the Moscow International Currency Exchange auctions.
- **Argentina, 2001 and 2019**: Authorities limited domestic residents' access to dollars and required exporters to sell dollar proceeds promptly after collection.
- **Venezuela, 2003:** Limited ability of locals and foreign companies to convert bolivars into U.S. dollars.
- **Brazil, 2008–2013**: The government adopted an IOF tax on foreign inflows for specific financial transactions, but the tax moved back to zero in 2013.

Investing in Local Debt Markets

As discussed above, investors can gain exposure to local currency returns by buying a local currency instrument in a particular market. To do so, an investor would have to send funds to the country, convert it into local currency, and then buy a local debt instrument. While this process appears simple, there are several nuances that need to be managed.

Countries have different regulations, laws, and limits for foreign investment, typically including the need to set up a local account, hire a local custodian, report activity to the local regulator, and pay taxes if applicable. Also, each country has its own requirements: some countries limit the amount and/or the type of

2. International Monetary Fund, "Capital Controls: Country Experiences with Their Use and Liberalization," Occasional Paper 190 (2000).

bonds that foreign investors can hold; others impose taxes on capital inflows, have minimum holding periods, or intervene heavily in the foreign exchange market, and so on. In some cases, local trading conventions differ from the international ones, adding an additional layer of caution when trading a local debt instrument.

Holders of Domestic Debt

Although foreign investors have significantly increased their percentage ownership of assets in emerging local debt markets, and in a few markets they hold close to 50% of the sovereign fixed-rate bonds, local investors are still the main holders of local debt.

Banks are a key player among local investors, but so are other local institutional investors (pension funds, mutual funds, and insurance companies). When risk aversion picks up globally, local institutional investors with a longer investing horizon have been able to step in to buy bonds, cushioning the price and yield movements.

Types of Local Bonds

Local bond types issued by EM countries are no different in nature than those issued by developed markets. While calculating conventions may differ, foreign investors normally have access to several debt instruments denominated in local currency. The most common instruments are fixed-rate bonds (coupon bonds), fixed-rate notes or bills (zero-coupon bonds sold at discount), inflation-linked bonds, floating bonds (linked to the reference interest rate or to a market rate close to the reference interest rate), and in some cases foreign exchange linked bonds (linked to a hard currency but payable in local currency) or fixed-rate local bonds with debt service payable in U.S. dollars at the then-prevailing foreign exchange rate.

THE FOREIGN INVESTOR BASE

The profile of the EMs' sovereign investor base has become more diverse due to the growth of EM debt and excess historical returns. Ownership was once concentrated in the hands of a few creditor banks and dealers, but now is distributed more widely through actively traded global and local bonds.

In the 1980s, EM debt was mostly in the form of U.S. dollar-denominated loans to EM governments from foreign commercial banks. Intermarket dealers traded participations in those loans. Originally, the principal nonbank investors were high-net-worth individuals from EM countries. They were the first to realize that these countries had begun to "turn the corner," and in the late 1980s began to repatriate their funds by buying distressed assets. This, in turn, triggered a steady recovery in asset values, which was further supported by the subsequent issuance of Brady bonds.

Rise in Credit Quality of the Asset Class Led to Changes in the Investor Base

In 1996, Poland became the first EM sovereign to achieve an investment-grade rating, but not the last, as currently 32% of EM sovereigns are investment grade. This opened the door for demand from high-grade investors for investment-grade EM bonds. Higher returns have played a key role as well, attracting more investors.

To reduce concentration risk, investors usually construct diverse portfolios with a diversified benchmark that caps representation of large countries. This approach lends confidence that an idiosyncratic shock by a single distressed country would not cause excessive deterioration in portfolio performance. Capping corrects for the risk that distressed countries often increase issuance and thus increase uncapped portfolio weight prior to default.

Low Global Yields Boosted Interest in Emerging Markets

As U.S. interest rates have remained low since the 2008 financial crisis, demand for EM assets continues to grow. The high returns on EM bonds increasingly attracted institutional investors. A broader range of insurance companies and pension funds, in search of higher yields and diversification, now invest in EMs. With relatively low financing costs and many newly formed hedge funds offering the potential of levered returns, the demand for assets continues to grow.

The investor base is broad, with a large percentage being dedicated EM managers of mutual funds, pension funds, insurance companies, and sovereign wealth funds. Other participants are hedge funds, including those with macro, credit, or distressed strategies. Finally, there are "crossover" investors from developed high-grade or high-yield bond markets who view EMs as an asset class to include in their portfolios. Notably, EMs are an increasing portion of the global bond funds, partly due to the opening of many local markets to foreigners.

EM DEBT PERFORMANCE

High yields, high returns, and high Sharpe ratios have made EM debt an appealing asset class. Exhibit 17-5 shows the EM sovereign spread widened less than U.S. high-yield spreads during severe market stresses from 2000 to 2020.

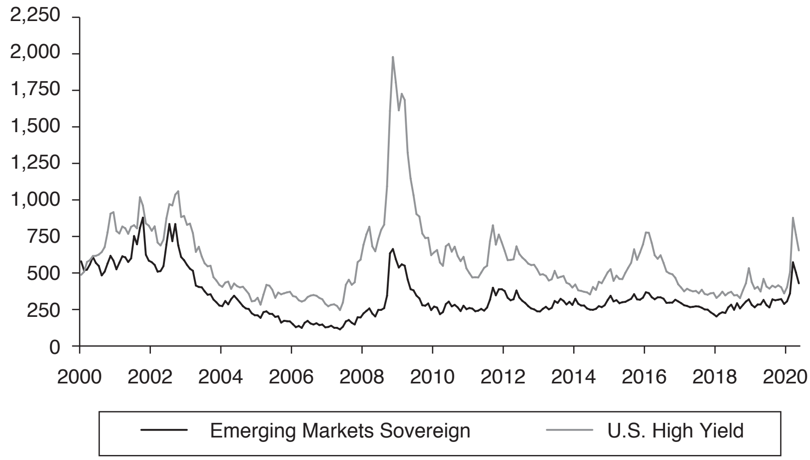
Historical Returns

EM external debt has produced one of the highest returns among major asset classes. Exhibit 17-6 shows the performance of the J.P. Morgan EMBI Global Diversified Composite Index (JPEIDIVR) since inception in December 1993.

For almost three decades, returns for the asset class have exceeded other major fixed-income markets, with a cumulative return of over 800%, far above the average cumulative returns of under 500% for U.S. high-yield bonds or

EXHIBIT 17-5

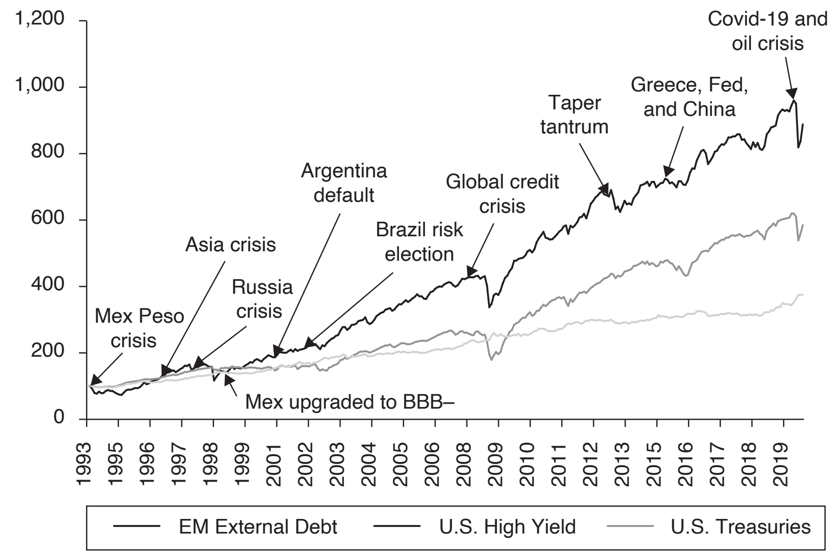
Emerging Markets and U.S. High-Yield Spreads (Basis Points): January 2000 to May 2020



Source: BofA Global Research, Bloomberg, Constructed from data obtained from ICE Data indices, LLC.

EXHIBIT 17-6

Global Market Disruptions and Country-Specific Events—Varying Impacts on the Total Return of EM Debt



Note: Total Return of EM external debt (J.P. Morgan EMBI Global Diversified Composite Index, JPEIDIVR), U.S. High Yield (ICE BofA U.S. Cash Pay HY Index, J0A0) and U.S. Treasuries (ICE BofA U.S. Treasury Index, G0Q0), for a $100 Original Investment since 1993 Source: BofA Global Research, Constructed from data obtained from Bloomberg, J.P. Morgan EMBI Global Diversified Composite Index, ICE Data indices, LLC.

around 300% for U.S. Treasuries over the same period. Over that period, EM debt has provided an 8.7% annualized return compared with 6.9% for the U.S. high-yield market. In comparison, cumulative returns of EM equities posted a 260% return, less than the approximately 1000% of U.S. equities.

EM sovereigns tend to issue long maturity foreign currency bonds, mainly 10 to 30 years, while EM corporates, especially lower quality corporates issue shorter bonds. Sovereign bonds thus have an average life of around 12 years, compared to an average life of 7 years for corporates. As a result, sovereign bonds have higher sensitivity to interest rates. Due to the downward trend in U.S. interest rates, the higher interest rate sensitivity has benefited holders of sovereign bonds, which have outperformed EM corporates and Global High Yield. However, if U.S. interest rates rise, the higher interest rate sensitivity would be a disadvantage.

A small part of the historical return of EM external sovereign debt is due to the lower Treasury yields. From inception of the indices in the early 1990s to 2020, U.S. Treasury rates declined by 500 basis points, or an average of 20 basis points per year. This accounts for about 1% of the historical annual return.[32] The remainder of the return can be attributed to the coupon income, price appreciation due to spread tightening, and the steady aging of low-priced bonds as they accrete to par. The end of this period came with Treasury yields reaching historical lows and EM spreads simultaneously touching historically tight levels, providing annualized returns that would be difficult to replicate over the next 25 years.

Volatility and Sharpe Ratios

Periodic crises in EMs have brought volatility along with high returns.

Over the past 10 years, while EM external debt has provided an annualized 7% return, it has come with a 6% annualized volatility (see Exhibits 17-7 and 17-8). Higher risk should come with a higher return. A risk-adjusted return measure, the Sharpe ratio, is used to compare equity investments. It is measured as the ratio of the return in excess of the risk-free rate divided by the volatility.

From 2010–2020, the Sharpe ratio in EM external debt has been higher than that of U.S. Treasuries, with higher annualized returns offsetting higher volatility (Exhibit 17-8). The S&P equity index had the highest Sharpe ratio in the past 10 years. From a Sharpe ratio perspective, EM external debt would have been a better investment than European or EM equity, as both had higher volatility and lower returns than that of EM external debt.

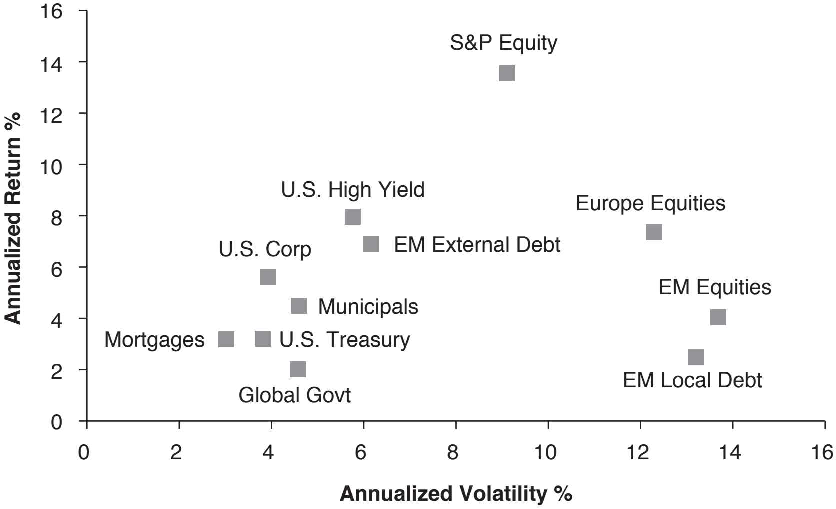
Correlation with Other Asset Classes

EM external debt returns are weakly correlated with the returns of U.S. Treasury bonds (0.27, see Exhibit 17-9). The correlations are higher with U.S. investment

3. A spread tightening of 20 basis points would increase the index value by 1.6%.

EXHIBIT 17-7

10-Year Annualized Total Return versus Volatility



Note: S&P Equity: SPTR Index, U.S. Corp: C0A0 Index, U.S. High Yield: H0A0 Index, EM External Debt: JPEIDIVR Index, Mortgages: M0A0 Index, Municipals: U0A0 Index, U.S. Treasury: G0Q0 Index, Europe Equities: E100 Index, Global Govt: W0G1 Index, EM Equities: GDUEEGF Index, EM Local Debt: GBIEMCOR Index.. Source: BofA Global Research, Constructed from data obtained from Bloomberg, ICE Data indices, LLC.

EXHIBIT 17-8

10-Year Total Return, Volatility, and Sharpe Ratio (Annualized), 2010–2020

	Annualized Return	Volatility	Sharpe Ratio
S&P Equity	13.55	9.10	1.43
U.S. Corp	5.59	3.92	1.28
U.S. High Yield	7.49	5.77	1.20
EM External Debt	**6.90**	**6.17**	**1.02**
Mortgages	3.18	3.02	0.86
Municipals	4.49	4.59	0.85
U.S. Treasury	3.20	3.82	0.69
Europe Equities	7.36	12.29	0.55
Global Govt.	2.02	4.57	0.32
EM Equities	**4.04**	**13.68**	**0.25**
EM Local Debt	**2.50**	**13.19**	**0.15**

Note: S&P Equity: SPTR Index, U.S. Corp: C0A0 Index, U.S. High Yield: H0A0 Index, EM External Debt: JPEIDIVR Index, Mortgages: M0A0 Index, Municipals: U0A0 Index, U.S. Treasury: G0Q0 Index, Europe Equities: E100 Index, Global Govt: W0G1 Index, EM Equities: GDUEEGF Index, EM Local Debt: GBIEMCOR Index. Source: BofA Global Research, Bloomberg, ICE Data indices, LLC.

EXHIBIT 17-9

Intermarket Correlations 2010–2019

	EM Debt	U.S. High Yield	U.S. Corp	U.S. Treasury	Global Govt	Municipals	Mortgages	S&P Equity	Europe Equities	EM Equities	EM Local Debt
EM Debt	1.00	0.69	0.72	0.27	0.58	0.46	0.46	0.42	0.57	0.67	0.81
U.S. High Yield		1.00	0.52	–0.15	0.26	0.08	0.07	0.73	0.76	0.76	0.63
U.S. Corp			1.00	0.69	0.64	0.69	0.71	0.11	0.21	0.33	0.46
U.S. Treasury				1.00	0.59	0.74	0.83	–0.45	–0.38	–0.25	0.02
Global Govt					1.00	0.53	0.59	0.00	0.20	0.30	0.54
Municipals						1.00	0.69	–0.16	–0.05	0.01	0.22
Mortgages							1.00	–0.22	–0.12	–0.02	0.21
S&P Equity								1.00	0.81	0.74	0.47
Europe Equities									1.00	0.80	0.64
EM Equities										1.00	0.82
EM Local Debt											1.00

Note: EM Debt: JPEIDIVR Index, U.S. High Yield: H0A0 Index, U.S. Corp: C0A0 Index, U.S. Treasury: G0Q0 Index, Global Govt: W0G1 Index, Municipals: U0A0 Index, Mortgages: M0A0 Index, S&P Equity: SPTR Index, Europe Equities: E100 Index, EM Equities: GDUEEGF Index, EM Local Debt: GBIEMCOR Index.

Source: BofA Global Research, Constructed from data obtained from Bloomberg, ICE Data indices, LLC.

grade corporates (0.72), U.S. high yield corporates (0.69), EM Equities (0.67), and Global Governments (0.58). Low correlations can give EMs an important diversification role in a global portfolio.

EM local debt is equally highly correlated with EM equity as with EM external debt because both local debt and local equity returns have a currency component and local and external debt is increasing managed together by a similar investor base.

Liquidity

Many investment-grade and high-yield bond portfolios include some EM debt, and thus high-yield managers represent an important source of "crossover" investors. Crossover investors include EM debt because these bonds may be included in their global credit or bond indices. In addition, valuations can be better at times than in developed market debt and liquidity can be better.

Compared to EM Corporates and U.S. high-yield indices, average EM sovereign issues are twice as large, making sovereign pricing more transparent and bid-ask spreads narrower. Thus, EM debt plays a key role in high-yield portfolios by offering greater liquidity when needed.

Some EM corporate bonds are as liquid as most U.S. corporate bonds. Over 419 corporate issues in the ICE Emerging Market Corporate indices have outstanding face value of at least US$1 billion, in addition to 531 sovereign issues in the sovereign index. This is more than the 402 bonds in the ICE BofA Global High Yield Index that are over US$1 billion.

Average trading volume of EM debt recorded by the Emerging Markets Traders Association is usually about US$15 billion per day, of which $10 billion is local debt. These volumes can decline by 20–40% following market crises or periods of low risk appetite. Corporate bonds have smaller issue sizes and trade about 30% less frequently than sovereigns, despite the larger stock of corporate bonds compared to external sovereign bonds.

EM Fundamentals That Contribute to Returns

EM debt investors monitor economic indicators to allocate their investments across countries and such reallocations can affect relative spreads. Many of the indicators are important for analyzing debt sustainability (a concept described in the next section).

Important economic indicators include: real gross domestic product (GDP) growth, consumer price index (CPI) inflation, current account/GDP, fiscal balance/GDP, public debt/GDP, net external position/GDP, foreign exchange (FX) reserves/short-term external debt, current account balance/GDP, net foreign direct investment/GDP, private credit/GDP, bank loans/deposits, nonperforming loans as a percentage of bank portfolios, and external debt/exports of goods and services.

Political and institutional stability is always taken into account as well. Many investors increasingly look at Environmental, Social, and Governance (ESG) indicators to complement their economic analysis.

SOVEREIGN DEBT SUSTAINABILITY

Sovereign spreads are closely linked to investor's perception about a country's probability of default and the sustainability of its debt. There are many dimensions to understanding a country's debt sustainability. We focus on three steps: (1) debt dynamics, (2) debt structure, and (3) gross financing needs.

Step 1: Debt Dynamics

The first step to understanding debt sustainability is calculating how a country's debt-to-GDP ratio will change over time. Investors monitor the debt-to-GDP ratio, instead of the nominal stock of debt, because a country's capacity to service its debt is proportional to the size of its economy (tax revenue is proportional to nominal GDP).

Fiscal policy and automatic debt dynamics: Contributions to changes in the debt-to-GDP ratio can be grouped into two categories: (1) fiscal policy and (2) automatic debt dynamics.

- **Fiscal policy:** Contribution from the current year's fiscal primary balance (revenues minus non-interest expenses)
- **Automatic debt dynamics:** Contributions of macroeconomic variables (growth, interest rates, inflation, currency fluctuation) and pre-existing debt-to-GDP ratio

Fiscal policy is not set in a vacuum from the variables that contribute to automatic debt dynamics. Tax revenues are impacted by growth and many EM governments receive significant revenues from commodity exports, such as oil and metals. In addition, many expenses are mandated by laws or constitutional rights, limiting the government's discretion to reduce spending.

Debt-stabilizing primary balance: The debt-stabilizing primary balance is the fiscal primary balance that the government needs to maintain so that its debt-to-GDP ratio remains unchanged from one year to the next. If a country's fiscal primary balance is lower (higher) than the debt-stabilizing primary balance, then debt-to-GDP will rise (fall) from one year to the next.

Note that the debt-stabilizing primary balance may be a surplus or a deficit, depending on the country's macroeconomic variables. The debt-stabilizing primary balance will typically be a surplus if growth is lower than real interest rates. The debt-stabilizing primary balance will typically be a deficit if growth is higher than real interest rates.

The debt-stabilizing primary balance is an important concept for debt sustainability because political constraints limit the feasibility of fiscal adjustments within a short period of time. If a country is far away from its debt-stabilizing primary balance and fiscal policy is adjusted only gradually, then the country's debt ratio may continue to rise for several years.

How economic variables affect a country's debt-to-GDP ratio: The year-over-year change in a country's debt-to-GDP ratio is affected by the following variables:

- **Fiscal primary balance** (revenues minus noninterest expenses): A fiscal primary *deficit* will *increase* the country's debt-to-GDP ratio and a primary fiscal *surplus* will *reduce* the country's debt-to-GDP ratio.
- **Growth**: Higher real growth will *lower* the country's debt-to-GDP ratio, since it will increase the denominator of the debt-to-GDP ratio.
- **Debt-to-GDP ratio in prior year:** Higher pre-existing debt-to-GDP ratio will *increase* the debt-to-GDP ratio by increasing the interest payments due on the pre-existing stock of debt.
- **Interest rates:** Higher effective interest rates will *increase* the debt-to-GDP ratio by increasing interest payments.
- **Inflation:** Higher inflation will *decrease* the debt-to-GDP ratio by reducing the real cost of interest service and increasing the nominal size of GDP (however, note that higher inflation is not a panacea because inflation can increase the interest rate demanded by investors and can also lead to currency depreciation).
- **Exchange rate:** A depreciation of the domestic currency will *increase* the debt-to-GDP ratio by increasing the local currency value of the foreign currency debt.
- **Proportion of foreign currency debt:** A higher proportion of debt denominated in foreign currency increases the sensitivity of the debt-to-GDP ratio to exchange rate fluctuations.

Calculating the change in debt-to-GDP ratio: The intuition behind the formula for calculating the change in the debt ratio is the following: the debt-to-GDP ratio increases (decreases) by the primary deficit (surplus) plus the contribution of the automatic debt dynamics due to growth, the pre-existing debt stock, inflation, interest rates, and currency depreciation.

The change in a country's debt-to-GDP ratio can be calculated as follows:

$$D_t - D_{t-1} = -pb + \left[\frac{i - \pi(1+g) - g + \alpha e\left(1+i^f\right)}{1+g+\pi+g\pi} * D_{t-1} \right] \tag{17-1}$$

where D_t is the current year's debt-to-GDP ratio, D_{t-1} is the prior year's debt-to-GDP ratio, pb is the fiscal primary balance (revenues minus non-interest expenses), g is the real GDP growth rate, i is the nominal effective interest rate (weighted average of domestic and foreign nominal interest rates), i^f is the nominal interest rate on foreign currency debt, π is the inflation rate (growth rate of GDP deflator), α is the proportion of debt denominated in foreign currency in year $t-1$, and e is the nominal exchange rate depreciation (percentage increase in local currency value of one U.S. dollar). Unless noted otherwise, variables refer to their values in year t.

Calculating the debt-stabilizing primary balance: The debt-stabilizing primary balance (pb^*) can be calculated by setting the change in the debt-to-GDP ratio ($D_t - D_{t-1}$) equal to zero and then re-arranging as in the following equation:

$$pb^* = \left[\frac{i - \pi(1+g) - g + \alpha e(1+i^f)}{1+g+\pi+g\pi} * D_{t-1} \right] \tag{17-2}$$

Note that the debt-stabilizing primary balance is reached when the government's primary fiscal balance exactly offsets the contributions from automatic debt dynamics.

Step 2: Debt Structure

In addition to a country's debt-to-GDP ratio, characteristics of a country's debt structure may also expose the country to higher or lower vulnerability to macroeconomic shocks.

Currency denomination: Countries with large shares of debt denominated in foreign currency are more vulnerable to an increase in the debt-to-GDP ratio due to a depreciation of domestic currency. Sharp currency depreciations usually accompany EM crises and can make the country's foreign currency debt unaffordable.

Fixed vs. floating rates: A country's effective interest rate is more sensitive to fluctuations in interest rates if the country has a high proportion of floating-rate debt. Fixed-rate debt protects the country from spikes in interest rates (historically, EM central banks have hiked interest rates during crises to protect against a currency depreciation). On the other hand, fixed-rate debt reduces the transmission of declining interest rates.

Maturity profile: Debt with a short maturity profile is more vulnerable to a decline in refinancing rates because a short maturity profile means that a larger proportion of debt is coming due each year. To reduce this vulnerability, many countries perform liability management operations where they buy back short-term debt prior to maturity (this is typically financed by simultaneously issuing long-term debt).

Ownership: If debt is primarily owned by a captive group of investors, then it may be less vulnerable to a decline in refinancing rates during a crisis. Generally, domestic institutional investors are more captive than foreign investors, since the former often need to own government securities to meet regulatory requirements and domestic investors often have a home bias.

Governing law: It is generally easier for a country to restructure its debt if the debt is governed by domestic law rather than foreign law, such as New York or English law. Restructurings typically result in significant losses for bondholders.

Step 3: Gross Financing Needs

GFN = Primary Deficit + Debt Service: Gross financing needs (GFNs) refers to the debt that a country needs to issue to cover its fiscal primary deficit and to cover its debt service (interest expense plus principal amortizations), as follows:

$$\text{Gross Financing Needs} = \begin{array}{l}\text{Fiscal Primary Deficit + Debt Service} \\ \text{(Interest and Amortizations)}\end{array} \tag{17-3}$$

Gross financing needs are typically expressed as a percentage of GDP and are often distinguished between domestic currency needs and foreign currency needs. Note that if the country has a fiscal primary surplus, then the gross financing needs are reduced by the surplus.

Gross financing needs are subject to two important risks:

- **Interest rate risk:** Risk that investors demand higher interest rates to purchase new debt. Higher interest rates could make a debt stock that was affordable with lower interest rates no longer affordable.
- **Rollover risk:** Risk that investors fail to purchase new debt to refinance maturing debt. If refinancing rates drop significantly, a country is said to have lost market access.

Refinancing rates decline when investors fear default: Investors often reduce their purchases of sovereign debt when they believe that a sovereign can no longer afford to pay the coupons and principal on its debt. When refinancing rates decline and a country loses access to debt markets, countries must cover debt service by drawing down on assets, such as savings or international reserves, or by printing money that can push up inflation. Loss of market access is often accompanied by capital flight by both residents and nonresidents, leading to currency depreciation and depletion of international reserves. Countries may impose capital controls to preserve their international reserves, but the controls may not be sufficient.

Depletion of assets can trigger default: If investor confidence is not restored, the depletion of assets due to loss of market access can force a country to stop paying its debts, leading to a moratorium and an eventual debt restructuring. For this reason, external debt investors monitor closely the country's stock of international reserves and exchange rate developments.

High GFNs increase vulnerability to investor sentiment: Countries with high gross financing needs are therefore more vulnerable to changes in investor sentiment that could lead to higher interest rates or lower refinancing rates. Lack of appetite for debt issuance can force a country to enact fiscal austerity to reduce its fiscal deficit (reducing financing needs) or may lead to a debt crisis if it cannot find resources, like an International Monetary Fund (IMF) loan, to refinance maturing debt.

Domestic ownership of debt can mitigate risks of high GFNs: It may be easier for countries with a deeper pool of domestic institutional investors to sustain higher gross financing needs. Otherwise, countries must rely on foreign investors to fill their financing gaps. Foreign investors are usually more sensitive to changes in global liquidity conditions and may reduce rollover rates during periods of global uncertainty.

Example: Comparing Debt Sustainability

In Exhibit 17-10, we compare the debt-stabilizing primary balances of three hypothetical countries (Country A, Country B, and Country C), calculated with the formula presented earlier. To simplify the comparison, all countries have the same growth rate, inflation rate, and have no foreign currency debt.

EXHIBIT 17-10

Example of Debt Sustainability Comparison

	Country A	Country B	Country C
Debt/GDP Ratio, t-1	80%	40%	80%
Effective Interest Rate, Nominal	7.0%	9.0%	9.0%
Growth Rate, Real	3.0%	3.0%	3.0%
Inflation Rate	2.0%	2.0%	2.0%
Share of Foreign Currency Debt	0.0%	0.0%	0.0%
Debt-Stabilizing Primary Balance (pb*), % of GDP	**1.5%**	**1.5%**	**3.0%**

Source: BofA Global Research.

Countries A & B: Different debt ratios, same debt-stabilizing primary balances: Note that both Country A and Country B have the same debt-stabilizing primary balance of 1.5% of GDP. Country A has twice the debt ratio (80%) as Country B (40%). However, Country A's interest rate is 2pp lower (7% for Country A and 9% for Country B). As a result, Country A needs to run a 1.5% primary surplus to keep its debt ratio unchanged at 80%. Country B needs to run the same 1.5% primary surplus to keep its debt ratio unchanged at the lower rate of 40%.

Country A probably more vulnerable to shocks than Country B: Although both Country A and Country B need to keep their fiscal balances at the same level to stabilize their debt ratios, Country A is probably more vulnerable to a debt crisis than Country B due to Country A's higher debt ratio. A high debt ratio usually implies high gross financing needs, subjecting Country A to higher interest rate risks and rollover risks. Policymakers cannot control the interest rates demanded by investors to refinance debt nor can they control the demand for new debt issuance. A spike in interest rates could make Country A's debt service less affordable, as illustrated with Country C.

Country C shows how higher interest rates can make debt unaffordable: Country C illustrates the risks that higher interest rates could make debt unaffordable. Country C combines Country A's 80% debt ratio with Country B's 9% interest rate. Country C's debt-stabilizing primary balance is 3% of GDP, twice as large as the 1.5% debt-stabilizing primary balances of Countries A and B. It is therefore much harder for Country C to stabilize its already high debt ratio than it is for Country A or B. The pace at which a country's effective interest rates could increase depends on the country's debt structure (fixed vs. floating rates and maturity profile) and gross financing needs.

WHAT DO EM SPREADS COMPENSATE FOR?

Probability of Default and Risk Premium

Sovereign external debt investors require compensation for both default and nondefault risks. Despite the focus that sovereign investors place on debt sustainability, it is likely that a large proportion of the sovereign spread can be attributed to risk premiums that compensate for uncertainty, price volatility, liquidity, and correlations with risky assets, among others. The risks that sovereign external debt investors face include:

Default: Risk that interest and principal payments are not made on full and on time. After defaults, sovereigns typically restructure and extend maturities, reduce coupon rates, or reduce principal amounts. These modifications often result in significant losses for bondholders. The historical rate of default over five years for foreign-currency, foreign law bonds are low for investment-grade countries (around 2%), but higher for high-yield countries (5% for BB-rated countries and 12% for B-rated countries).

Uncertainty in assessment of creditworthiness: To evaluate creditworthiness, investors must make assumptions about fiscal policy and macroeconomic variables in the long term. All of these assumptions are subject to uncertainty, particularly in countries where polices can change dramatically after elections. In addition, although credit ratings signal potential risk, rating agencies are often slow to adjust their assessments, particularly when fundamentals are deteriorating quickly.

Price volatility risk: Spreads widen during periods of risk aversion as investors re-price bonds lower to protect themselves against larger-than-typical price adjustments. Higher volatility regimes can persist, and it is difficult for investors to predict how long the higher volatility will last.

Liquidity risk: Risk that bid-offer spreads will widen during periods of uncertainty and risk aversion, increasing transaction costs.

Correlations with selloffs in other risky assets: EM assets tend to perform poorly when global risk aversion increases. When global liquidity conditions are loose and risky assets are favored by investors, EM spreads tend to compress slowly while investors search for yield and accept lower risk premiums. But when global conditions deteriorate, EM spreads can widen quickly, especially for lower-rated countries.

Weak Link Between Asset Class Spreads and Defaults

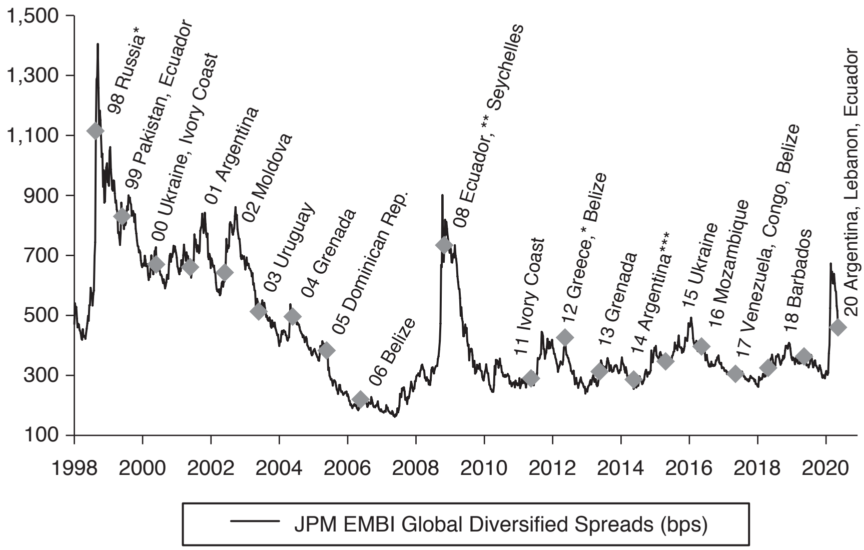
Wider spreads for the asset class have not been strongly linked to higher default rates since 2000 (Exhibit 17-11). Default frequency has not increased during periods of higher overall EM spreads and defaults have still occurred while EM spreads were compressing.

Sovereign defaults by large countries on foreign currency bonds issued under foreign law are historically rare. On the other hand, defaults by small economies, particularly island nations, have been more common. But losses from defaults by small countries are typically immaterial for diversified foreign investors, given the small weights of such countries in typical portfolios.

Over the past 20 years, defaults on foreign currency, foreign law bonds by large issuers were limited to just two countries: Argentina (2001, 2014, and 2020) and Venezuela (2017). And though prominent, defaults by Russia and Greece were actually primarily against domestic law bonds.

EXHIBIT 17-11

Sovereign Defaults on Foreign Currency, Foreign Law Bonds Through Three Financial Crises—Not Concentrated in One Point of a Credit Cycle



Source: BofA Global Research, Constructed from data obtained from Bloomberg, Moody's.

Note: *Denotes default that is primarily on domestic law bonds and included in the exhibit for context. **Default due to unwillingness to pay, rather than inability to pay. ***Technical default related to court decision.

Remarkably, the 2008 financial crisis did not unleash a wave of defaults. That year, Ecuador selectively defaulted on its foreign bonds, but this default resulted from an unwillingness rather than inability to pay. Several sovereign defaults occurred in 2020 in the context of the COVID-19 pandemic, including Lebanon, Ecuador, and Argentina. However, those economies entered the pandemic with pre-existing vulnerabilities.

At the same time, a longer time horizon would show evidence of clustering of defaults, such as during the mid-1980s. However, during that time external debt was primarily contracted via bank loans rather than bonds. Moreover, the 1980s are less comparable to today due to structural shifts in EMs. These shifts include flexible exchange rates and inflation targeting, accumulation of foreign reserves, and reduced reliance on foreign currency financing.

Wider asset class spreads: Higher risk premiums that can accelerate crises: During periods of higher-risk aversion, the spreads of all countries typically widen. The spread widening is typically proportional to the perceived strength of the country's fundamentals (countries with weaker fundamentals widen more).

For countries with stronger fundamentals, it is probable that wider spreads primarily reflect larger risk premiums, rather than a higher probability of default. Investors can usually expect risk premiums to recede once the period of heightened risk aversion ends and volatility subsides.

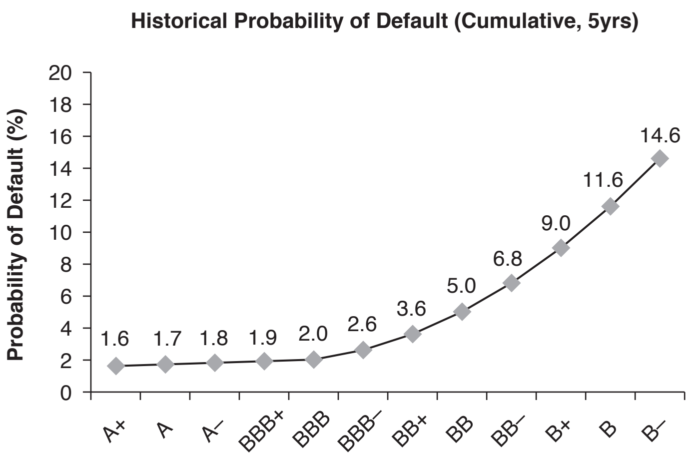
For countries with weaker fundamentals, higher spreads due to global risk aversion could hasten the onset of a crisis. Higher interest rates increase interest expense and can lead to a self-fulfilling bad equilibrium. Persistently higher interest rates increase the risk of default, which increases the interest rate demanded by investors, which in turn increases the risk of default, and so on. Without a circuit breaker, this cycle can lead to a debt crisis.

Historical probabilities of default by rating: Exhibit 17-12 shows the historical rate of default on foreign currency debt by rating published by rating agencies. The historical probability of default over five years is around 2% for BBB-rated countries and similar for countries with higher ratings. In contrast, the probability of default for high-yield countries increases significantly as credit quality declines, reaching 5% for BB-rated countries and 12% for B-rated countries.

Though these historical estimates are useful benchmarks, they should be treated with caution. In contrast to the large sample size of corporate defaults, sovereign default rates are based on a small sample of sovereigns, very few of which have defaulted.

EXHIBIT 17-12

Historical Probability of Default on Foreign Currency Debt—Only 2% for BBB-Rated Countries, but Rises Significantly for High-Yield Countries



Source: BofA Global Research, Constructed from data obtained from Moody's, S&P, Fitch. Note: Probabilities of default are averaged by rating bucket (A/BBB/BB/B), as published by Moody's (1983-2019), Fitch (1995-2019), and S&P (1975-2019). For intermediate rating notches, a linear trend is used to interpolate ratings above BBB and a quadratic trend is used to interpolate ratings below BBB.

Compensation for default risk: Exhibit 17-13 shows the five-year spreads required to compensate for the historical probability of default given a country's rating. For investment-grade countries, five-year spreads of about 25–40 bps would be required to compensate for the historical probability of default. For high-yield sovereigns, downgrades imply large increases in the spread required to compensate for the incremental risk of historical default. For example, a downgrade from BB to B would increase the required spread from about 80 bps to 185 bps.

Exhibit 17-14 compares the sovereign CDS spread (as of June 2020) against the spread required to compensate for the historical probability of default. The difference between the CDS spread and the spread required to compensate for the historical risk of default likely reflects risk premiums for nondefault risks (the gap may also reflect different assessments about the relative creditworthiness of countries or the future probability of default). Note that the gap is smaller for investment-grade countries and wider for lower-rated countries such as Brazil, South Africa, and Turkey.

SOVEREIGN RESTRUCTURINGS

The goal of a debt restructuring is to provide the sovereign with some debt service relief, particularly in short-term, so that the sovereign can eventually regain market access. This can be done by lowering the coupon rates, extending maturities, reducing the face value of existing debt, or some combination of the three measures.

If the debt exchange sufficiently lowers the country's debt burden, then spreads could tighten to reflect a lower probability of default on the new cash flows, supporting post-restructuring bond prices. This should in turn create a positive feedback loop supporting bond prices. An orderly pre-default exchange would be in the interest of investors, the issuing country, and third parties such as the International Monetary Fund (IMF). Outright defaults can result in a deepening of the financial crisis that can reduce the payment capacity of the country.

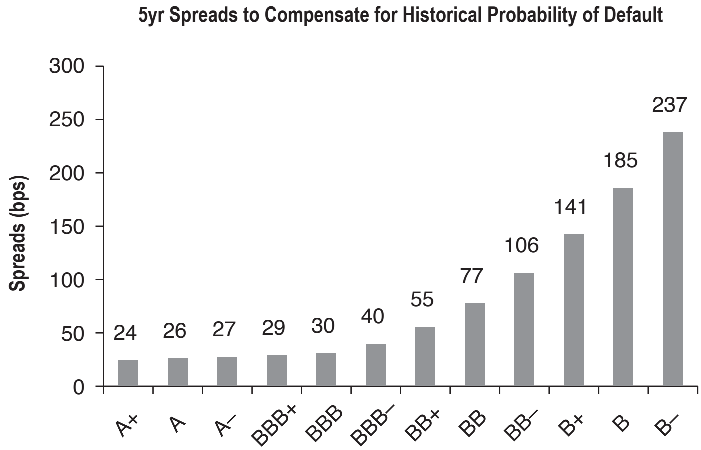
There have been successful pre-default voluntary exchanges in EMs. Addressing "holdout" investors has become an increasingly difficult issue. Holdouts are funds that buy distressed debt at a low price, decline to participate in a debt exchange, and then litigate to collect par for the defaulted assets. In this section, we discuss the role of third-party support, New York law documentation, and collective action clauses (CACs) intended to mitigate the problem of holdouts in sovereign debt restructurings. We follow with details of some exchanges that took place in the past as guides for future exchanges, both inside and outside of EM debt.

Third-Party Support, the Role of the IMF

The Western nations established the International Monetary Fund (IMF) and the World Bank after World War II as "permanent machinery" to anchor the Bretton Woods system. When developing countries began experiencing debt problems in

EXHIBIT 17-13

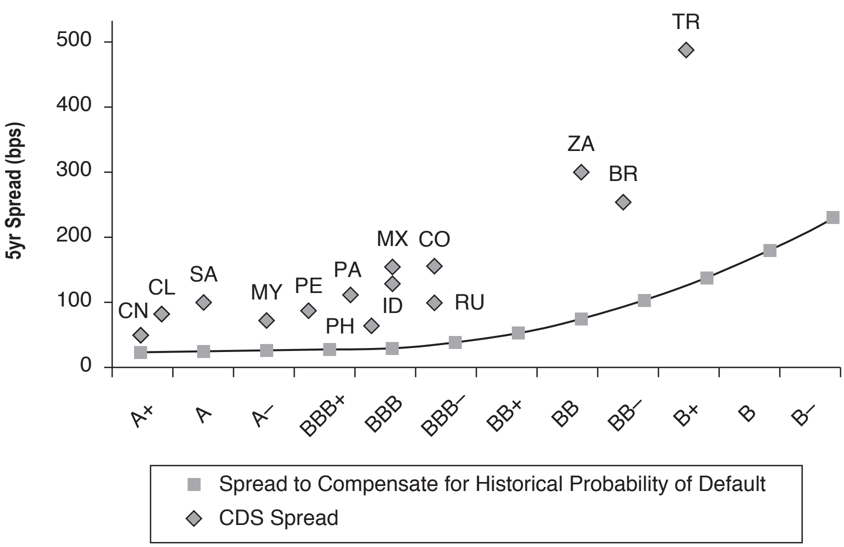
Spread of Only 30 bps Needed to Compensate for Historical Probability of Default of BBB-Rated Countries



Source: BofA Global Research. Note: Required spread calculated with simplified formula: Spread = [-(1-RR)/T]*[ln(1-PD)], where RR=Recovery Rate (in percent) and PD=Probability of Default (in percent). Calculation uses 25% Recovery Rate.

EXHIBIT 17-14

Difference Between CDS Spread and Spread Required to Compensate for Historical Probability of Default Likely Reflects Risk Premium for Nondefault Risks



Source: BofA Global Research, Bloomberg, Moody's, S&P, Fitch. Note: Calculation uses 25% post-default recovery rate. CN=China, CL=Chile, SA=Saudi Arabia, MY=Malaysia, PE=Peru, PA=Panama, PH=Philippines, ID=Indonesia, MX=Mexico, RU=Russia, CO=Colombia, ZA=South Africa, BR=Brazil, TR=Turkey, CDS spreads as of June 2020 the late 1960s, the Paris Club was formed to restructure debt from export credit agencies. A decade later, the London Club was formed to deal with workouts of foreign commercial bank debt. When countries had a significant amount of outstanding bonds rather than loans in the 1990s, restructuring defaulted debt required a new process.

The IMF and the U.S. Treasury have played significant roles in proposing a permanent mechanism to deal with defaulted debt. More recently, however, the IMF also started to play a key role in providing funding for developed economies.

In past programs, the IMF would typically lend enough money for the sovereign to service its debt, so long as it stuck to a plan, including extensive supervision and review by the IMF. Some distressed countries have presented greater challenges when foreign reserves declined rapidly or when a sovereign could not, or would not, print money to cover local debt service (Argentina pegged to USD, Russia chose to default).

Historically, the condition for receiving IMF support is that a sovereign must not only adhere to IMF targets for inflation, fiscal deficits, and exchange rate controls, but also that the sovereign must repay the IMF loan in full. There has never been IMF debt forgiveness, except in the case of some Highly Indebted Poor Countries (HIPC), an initiative launched in 1996 by the IMF and World Bank, with the aim of ensuring that no poor country faces a debt burden that it cannot manage. Thirty-two countries, mostly in Africa, benefited with full debt relief. More recently, the IMF created the flexible credit line (FCL) with less conditionality but for countries with stronger fundamentals. Although IMF debt is not typically forgiven, maturing payments can sometimes be refinanced with new loans.

Distressed Debt International Litigation

There is no bankruptcy court for sovereign defaults, like exists for corporate defaults. Therefore, the outcome of most of sovereign defaults is either the resumption of payments or, in most cases, a distressed debt exchange.

No bankruptcy court: The absence of a formal bankruptcy process clouds sovereign debt restructuring. There is a debate on reforming the international financial system, with a primary focus on the need for a sovereign debt restructuring process that would limit the risk that litigation could disrupt or delay a debt restructuring. Yet in many cases, progress is impeded by interference from "holdout" investors.

Holdout investors do not participate in the restructuring but will demand payment on the original contractual agreement or negotiate a preferred settlement for themselves through litigation. Typically, these investors are distressed debt funds that have large enough positions and the means to engage attorneys to sue the sovereign and then to attach assets. Furthermore, no restructuring would be possible if too many creditors did not participate.

So, there is a need to make the sovereign debt restructuring process swift and orderly, reducing the holdout risk. Without a process in place, there is a fear that concerned investors would be inclined to sell their bonds before the event of default, thus actually speeding the decline and preventing the sovereign from constructing a solution.

Sovereign immunity: Investors have won judgments against sovereign issuers in default. However, in contrast to corporate defaults, it is very difficult to attach the assets of a sovereign. There is a more favorable legal climate for attaching assets in Continental European law than in Britain and the United States. In Continental Europe, successful litigators attached the assets of the central bank of the sovereign whose claims they were holding.[4] In addition, central banks that are incorporated separately for commercial purposes do not have immunity; only the sovereign does.

The Foreign Sovereign Immunities Act of 1976 precludes a waiver of immunity of prejudgment attachment of the accounts of a foreign central bank. Since then, a number of common law countries have adopted similar legislation on sovereign immunity. During one litigation case, Deutsche Bundesbank considered amending the law (via Parliament) on the non-immunity provided to a sovereign whose assets were deposited with a German bank.[5]

These laws have an impact on non-participants in distressed exchanges. Another avenue open to non-participants involves wire transfers. In the United States, an attachment order can only reach a wire transfer either before it is initiated or after payment is made complete. However, Europe does not have an equivalent law. A distressed investor is able to intercept payments from a sovereign on restructured debt to bondholders in Europe.[6]

Changing the provisions of a bond: To deal with the holdout problem and encourage maximum participation in an exchange, all contractual proposals seek to change the restructuring process by changing the provisions found in sovereign debt contracts, allowing a supermajority to vote on restructuring terms.

New York law documentation: A standard New York law contract on pre-2003 bonds requires the unanimous consent of all creditors to change "key financial terms" (such as payment dates and amounts). Typically, all other terms can be amended with the support of one-half or two-thirds of the outstanding bondholders. Some New York law bonds also require that 25% of the bondholders agree before litigation can be initiated.

4. Cardinal vs. Yemen and Leucadia vs. Nicaragua.
5. Cardinal vs. Yemen.
6. Elliot vs. Peru.

English law documentation: A standard English law contract allows a supermajority of bondholders (typically 75%) present at a meeting that meets quorum requirements to amend all of the bond's terms, including the bond's payment dates and amounts. Many English law bonds also have provisions that make it difficult for an individual bondholder to initiate litigation.

Collective action clauses: A collective action clause (CAC) defines how many bondholders are needed to agree on a change in the repayment terms of a bond, in order to effect the change and make it applicable for all bondholders. The CACs were introduced to deal with rogue creditors. CACs have long been present in bonds sold under UK law. Under New York law, these clauses began to be included in many bonds since Mexico introduced it in 2003.

With CACs, the bond terms specify lower percentages required to change both financial and nonfinancial terms of the bonds. The typical structure allows 75–85% of bondholders to amend a bond's financial terms, as long as no more than 10% of the bondholders object. Financial terms could include payment dates and amounts. The remaining nonfinancial terms might be amended only with the support of 66% of the bondholders. Also, certain provisions that relate to the ability of creditors to sue to collect on their bonds previously cannot be amended at all.[7]

Initially, these collective action clauses applied to each bond series individually, reducing the likelihood of holdouts getting better terms on a specific bond. However, these single series CACs were thought to be insufficient to prevent a small number of bondholders from purchasing enough bonds to reach a voting block that could obstruct the whole-debt restructuring process in one or more bond series.

In 2014, most sovereign bonds were also issued with additional aggregated CACs, which allow bondholders to vote on a restructuring or re-profiling proposal applied to multiple series of notes (in aggregate), provided that they all contain the necessary contractual provisions. For example, they may require a 66⅔% threshold for each individual series plus an 85% threshold in aggregate for several series, versus an individual 75% threshold under series-by-series CACs. Nevertheless, creditors may still obtain a blocking position with respect to a particular series.

Because these CACs have evolved over time to offer greater issuer protection from creditors, prices of specific distressed sovereign bonds tend to be higher when the voting thresholds are lower.

7. Issuers use only a few jurisdictions for international bond issuance. New York is the largest jurisdiction by far, followed by England and Germany. German law bonds traditionally have also lacked clauses, but German law is being used less in new issuance following the introduction of the euro.

Successful Debt Exchanges

Since 2000, several exchanges were successful, which we define as one in which the exchange offer is made, at the latest, before the end of the debt service payment grace period, there is high creditor participation, and one in which the issuer does not default during the following five years.

Any exchange in an EM can set a precedent for future exchanges. This includes distressed debt, prior to and averting a default, as well as defaulted debt exchanges. Issuers in distressed global bond restructurings tend to expect that bondholders should get the same or less favorable treatment than the restructurings before it. Bondholders, on the other hand, tend to look back at the exchanges with modest haircuts and where bond prices then rallied, exemplified in the 2003 Uruguay exchange and the 2015 Ukraine exchange, viewing those as ideal restructurings for the next exchange, because it would be most beneficial to them.

Successful distressed debt exchanges: We highlight some aspects of the US$4.9 billion 2003 Uruguay exchange, because it was relatively large at the time and included several important features that could be considered in the future global debt restructuring discussions.

Successful exchanges have several commonalities. The most important is that every communication, from the economic statistics to the political speeches, shows that the sovereign is nearing default. Regardless of any IMF or other support, investors would understand that this issuer is highly likely to default without the exchange. This is clear when the issuer misses a coupon payment and pays during the grace period or offers an exchange during the grace period. It is also clear when officials stop short of declaring a moratorium but announce that they expect to miss the next debt service payment.

With that as a backdrop, the second commonality is that prices need to collapse, as investors realize that the only choices are restructuring or default. If bond prices remain in the US$80–90 range, the issuer has not communicated that there will be no more payments without a reduction in debt service.

There also needs to be some subtle coercion in the exchange offer, so that bondholders that do not participate in the exchange are not paid in full while other bondholders accept a haircut or write-off. This holdout issue has been addressed through collective action clauses, by conditioning the exchange on some minimum participation threshold with the perception that insufficient participation would result in a default, and through exit consents.

Exit consents are created when holders accept new bonds in the exchange, but in the process provide their consent to amend the nonpayment terms of the old bond. Exit consents can destroy value by impairing the liquidity and litigation prospects as they change such features as cross-default, listing, and acceleration clauses. Typically, these changes can be undertaken without a unanimous vote from bondholders.

Recovery values: Recovery values have been diverse, each credit with its own features at default. There are two values that are both referred to as "recovery values." One is the settlement price in a credit default swap (CDS) auction, which indicates the price of the cheapest bond around 30 days after default. The other is the eventual value of the original debt after an exchange has taken place.

Following the eight large EM defaults since 2008, that had outstanding CDS swap contracts, almost all prices were in the \$20–\$40 range (Exhibit 17-15). Moody's also provides a list of foreign currency and local currency defaults and distressed debt exchanges with recovery rates around 30 days after default, including defaults, missed payments and distressed exchanges (Exhibit 17-16).

EXHIBIT 17-15

Credit Default Swap Auction Prices, Typically Taking Place About 30 Days After Default

Date	Country	Bonds Avg Price
Jan-08	Ecuador	31.375
Mar-12	Greece	21.500
Sep-14	Argentina	39.500
Oct-15	Ukraine	80.625
Dec-17	Venezuela	24.500
Apr-20	Lebanon	14.125
May-20	Ecuador	34.875
Jun-20	Argentina	31.500

Source: BofA Global Research

Note: First CDS auction was Ecuador in 2008

Uruguay, 2003—orderly exchange, avoided default: Uruguay was among the first large market-friendly distressed sovereign debt restructurings, seen as beneficial for both issuer and investors. It serves as a model for other countries. Over 95% of the \$4.9 billion eligible bonds were exchanged for new securities that matured later and paid lower interest, stretching out debt payments. However, to call it successful, one must appreciate how distressed the situation was for Uruguay at that time.

Distress: Uruguay had an investment-grade rating before Argentina defaulted on US\$95 billion of debt in 2001. Uruguay was current on its debt service prior to its 2003 voluntary exchange, but there was great concern that the spillover effect from the contraction in neighboring Argentina was making it impossible for Uruguay

EXHIBIT 17-16

Default or Distressed Exchange of Foreign Currency (FC) and Local Currency (LC) Debt

Default Date	Country	Recovery Rates 30d After Default * (% of PAR)	Total Defaulted Debt ($bn)	Sequence of Default Events (DE=Distressed Exchange)	Foreign Currency or Local Currency Bonds
Aug-98	Russia	18	72.7	Missed payments, DE, Missed payments, DE,DE	FC, LC
Sep-98	Ukraine	na	1.3	DE, DE, DE, Missed payments, DE	FC, LC
Jul-99	Pakistan	52	1.6	(Grace period missed payments), Missed payment, DE	FC
Aug-99	Ecuador	44	6.6	Missed payments, DE	FC, LC
Jan-00	Ukraine	69	1.1	Missed payments, DE before maturity	FC
Mar-00	Ivory Coast	18	0.4	Missed payments	FC
Nov-01	Argentina	27	82.3	Debt swap open to locals only, DE, Missed payment, Pesoization, DE, Re-open DE	FC, LC
Jun-02	Moldova	60	0.1	(Grace period missed payments), DE, Missed payment, DE	FC
May-03	Uruguay	66	5.7	DE	FC
Sep-04	Grenada	65	0.1	Missed payments, DE	FC, LC
May-05	Dominican Rep	95	1.6	(Grace period missed payments), DE	FC
Dec-06	Belize	76	0.2	Missed payment, DE	FC
Jul-08	Seychelles	30	0.3	Missed payments, DE	FC, LC
Dec-08	Ecuador	28	3.2	Missed payment, DE	FC
Sep-12	Belize	40	0.5	Missed payments, DE	FC
Feb-13	Jamaica	89	9.1	DE	FC, LC

(Continued)

EXHIBIT 17-16

Default or Distressed Exchange of Foreign Currency (FC) and Local Currency (LC) Debt (*Continued*)

Default Date	Country	Recovery Rates 30d After Default * (% of PAR)	Total Defaulted Debt ($bn)	Sequence of Default Events (DE=Distressed Exchange)	Foreign Currency or Local Currency Bonds
Mar-13	Grenada	36	0.2	Missed payments	FC, LC
Jul-14	Argentina	68	29.4	Missed payments	FC
Oct-15	Ukraine	80	13.3	Missed payments, DE	FC
Apr-16	Mozambique	88	0.7	DE	FC
Feb-17	Mozambique	61	0.7	Missed payments, DE, ongoing	FC, ongoing
Mar-17	Belize	65	0.5	DE	FC
Nov-17	Venezuela	28	31.1	Missed payment, ongoing	FC, ongoing
Jun-18	Barbados	55	3.4	Missed payment, DE	FC, LC
Feb-20	Argentina	47	1.4	Missed payment, DE, ongoing	FC, LC, ongoing
Mar-20	Lebanon	17	6.6	Missed payment, DE, ongoing	FC, ongoing
Apr-20	Ecuador	27	17.3	DE, ongoing	FC, ongoing

Source: Moody's Investors Service; Note: Prices (Moody's calls them recovery rates) are % of the par value of the bond at the time of the initial default event, 30-day post-default for missed payments or around the close of an exchange for distressed debt exchanges. When the trading price is not available, Moody's calculates an equivalent measure estimating the recovery as the ratio of the present value of the cash flows of the new debt instruments received as a result of the distressed exchange versus the outstanding face value of those initially promised, discounted by an approximated market yield at the time of default. For Arg, the trading price-based recovery rate at the time of default in ´14 was 68%. The ultimate recovery as of the time of default resolution in ´16 was about 97% as the missed interest payments were repaid in full., For Barbados, the recovery rate was based on the trading price of its defaulted FC bonds. Arg defaulted on short-term debt in Aug ´19 and on long-term debt in Feb ´20. Only included the recovery rate of the defaulted long-term debt in Feb ´20.

to maintain its fiscal accounts, as its primary trading partner was Argentina and Argentines held a sizable amount of the deposits in Uruguayan banks.

In June 2002, the Uruguayan government lifted the currency bands it had in place and allowed the peso to trade freely. By August 2002, there was a run on the banks, the government froze some deposits, and bonds had plummeted to US$30 from US$100 at the end of 2001.

Uruguay's banking system was heavily dollarized, and neither the banks nor the government held enough liquid dollar assets to back those deposits. Thus, the bank run in Uruguay was due to an increasing recognition by depositors that the central bank's foreign reserves totaled less than the amount of dollar deposits in the system.

Golden gloves: Banks were not able to reopen until the United States pledged $1.5 billion to bolster the financial system (through a bridge loan from the U.S. Treasury's Exchange Stabilization Fund). The IMF pledged $2.8 billion in assistance to Uruguay and asked Uruguay to propose a debt exchange before failing to make a payment on its debt. The objective was to try to avoid the type of crisis that took place in Argentina. The exchange gave Uruguay a fiscal surplus by reducing interest payments and enabled it to draw on IMF loans, regaining investor confidence in its ability to pay debts, and revive the economy. The IMF provided Uruguay an initial $303 million payment on the loan pledge in March 2003, and the exchange was offered a month later.

Uruguayan external support worked because the $1.5 billion loan from the IMF, World Bank, and U.S. Treasury was used to give a 100% guarantee on the dollar checking and savings deposits, while rescheduling the time deposits and the loan brought back depositors' confidence. The resolution demonstrated that a voluntary mechanism and collective action clauses in its bonds were a good way to restructure debt and that there is a need for greater accountability and transparency.

The government had warned that, without a successful exchange, it might not be able to make all its debt payments, even in 2003. The exchange was successful because most investors realized the risks of not participating were high.

Holdouts were a concern of creditors, as well as the government: The government took the following steps to deal with holdouts:

1. It required at least 80% participation to complete the exchange.
2. If resources were insufficient, it would pay on the new bonds first.
3. New bonds would be liquid and be included in benchmark indices; old bonds would not be.
4. Those exchanging international bonds were asked to approve exit consents that reduced the old bonds' liquidity and their holders' ability to enforce debt-service payments.

5. New bonds paid debt service into a trust, which would distribute the payments to bondholders, reducing the attachment risk by holders of the old bonds. Notification was made that the old bonds would be treated less favorably by bank and pension fund regulators because of their future illiquidity.

S&P and credit default swap market considered it a default: Standard & Poor's called the swap a default and rated the nation's long-term foreign currency debt at about five levels below investment grade after investors received the new bonds. The rationale was that the new bonds, with both a longer maturity and lower coupon, were worth less than the old bonds in net present value terms.

A rating agency default rating is not a "credit event" criterion for triggering a credit default swap (CDS). Because this was a voluntary exchange of USD debt, the USD exchange did not trigger CDS. However, the yen Brady bond included a collective action clause, in which 50% of the bondholders could vote to change the material payment terms of the bond; the new terms would apply to 100% of the bondholders.

The holders of the yen bonds at a bondholders' meeting agreed to amend the terms to extend the maturity and this extension would be effective for 100% of the yen bondholders. This was, in effect, a forced restructuring for some percentage of these bondholders, and this yen rescheduling alone actually triggered CDS in every currency.

A month later, S&P raised its Uruguay rating to B– from selective default, stating that the exchange "significantly reduces the sovereign's debt amortization burden through 2007" and alleviates near-term funding pressures.

Unsuccessful Exchange, Argentina 2001

The government of Argentina conducted two large voluntary exchanges of debt in an effort to reduce near-term debt service by extending maturities and lowering cash coupon rates, but these were not ultimately sufficient to avert default.

Argentina June 2001 exchange failed, defaulted in six months: In the year preceding its December 2001 default, Argentina was in the midst of a deep recession. The peso was fixed one-for-one with the U.S. dollar by law and Argentina had limited monetary policy tools to be competitive. As a result, it borrowed too heavily from the global capital markets and was sinking in debt, with roughly 90% of Argentina's sovereign debt denominated in dollars. Banks were in a difficult position with most of their assets in pesos and liabilities denominated in dollars. Government bonds represented more than 20% of their assets.

In June 2001, the government conducted its "mega swap," exchanging close to US$30 billion of local, external global, and external Brady debt, which was about one-third of the outstanding external debt, much of it coming due in the near future. It swapped that debt for four liquid external bonds, most of which paid no cash coupon initially, but instead capitalized at a 12% per annum rate for five years before paying a high 12% cash coupon on a larger capitalized face amount. There was no coercion and it was a fair market level. Some investors, mostly local, hailed the exchange as the solution to Argentina's debt problem. Others were less optimistic and feared that the country's borrowing costs would soar after 2006.

Argentine local banks and pension funds were active participants in that exchange. The attractive feature for Argentina was that it significantly reduced debt service for close to five years. However, investor confidence did not increase sufficiently, and Argentina's funding needs could not be sustained.

The situation had deteriorated further by November, and a second "voluntary" exchange of Brady and Eurobond debt for local loans was offered. This exchange was originally only open to local investors, but participant restriction was eventually relaxed. The exchange was viewed as coercive by S&P, who downgraded all eligible bonds to a default rating of "D."

Simultaneously, there was a run on the banks, forcing the government to set limits on bank withdrawals. Within a month, the sovereign declared a moratorium on the payments of US$95 billion of external debt, which at the time was by far the largest sovereign default in history. The government also broke the currency peg, converted deposits to pesos, and had to bail out the banks, which were heavily dollarized. The government froze and then "pesified" the dollar deposits, effectively wiping out all of the banking system's existing capital. But it then issued new bonds to the banks to offset those losses.

Argentina default—large, complex, equitable: The Argentine restructuring from the 2001 default was much more complex and unique than any that had preceded it:

- The size and disparity were enormous—US$95 billion total face defaulted external debt obligations covered over 80 individual external bond issues in eight legal jurisdictions and in multiple currencies.
- There were many more different parties with their own agendas coming to the negotiating table. Many of the investors were original or early holders that wanted to reduce the losses on their investments.
- There were large blocks of bonds held by distressed debt funds with teams of litigators to bring them top recovery value. An active market for defaulted bonds over the next 10 years allowed such funds to accumulate sizeable holdings.

Exchange proposal came three years after default: In early 2005, Argentina proposed a relatively balanced exchange to all holders after Argentina declared a moratorium on December 24, 2001. Rather than extend maturities or discount all bonds by the same yield, Argentina determined the amount of accrued but unpaid interest through December 31, 2001, and added that to the face; this was the factor applied to a par claim for each bond.

For each Argentine claim, investors received a principal bond, with the Discount option requiring a 66.3% haircut or the Par option requiring no haircut, past-due interest in cash accruing from December 2003, and a GDP warrant giving investors the right to receive additional payments based on GDP growth in the event that the economy recovered. The concept of GDP warrants was promoted by the IMF, which expected this to be a beneficial solution to volatile economies in distress. The principal bonds had no Treasury collateral and over 50% of the coupon on the Discount bond was capitalizing (i.e., it was not paid in cash but added to the bond's face value). Only about $63 billion was exchanged in 2005.

In 2010, Argentina offered another exchange, less favorable to investors than the prior one. This exchange added another $20 billion in participation, for a total participation rate since the default of 92%, which still left close to $6 billion outstanding.

Litigation: Several lawsuits prevented Argentina from being able to issue in the international markets without resolving its disputes with holdouts. For the first time, many disparate foreign bondholders united in an organized committee in the United States and Europe, with strong objections to the framework proposed by Argentina. The most vocal large distressed hedge funds had claims and won judgments against Argentina that totaled more than $2.3 billion from U.S. court suits.

During the litigation, it was up to a U.S. judge to determine if Argentina had shown enough fairness and effort in these multiple exchange offers to keep these funds from exercising those judgments. Although the court ruled in favor of the distressed bondholders in October 2012, Argentina refused to pay.

Applying the *pari passu* clause in the defaulted bonds, a federal judge ruled that if Argentina made any more payments on the exchange bonds issued during the restructuring, then it had to pay what it owed to the holdouts. Appeals to higher courts over several years failed to overturn the decision, and in June 2014 the U.S. Supreme Court refused to hear Argentina's appeal on this case. In addition, the remedy included in the ruling instructed financial intermediaries not to help Argentina pay the exchange bonds if it did not also pay the holdouts.

Argentina chose to default on the June 30 payment of the 2005 and 2010 exchange bonds rather than negotiate a settlement with the holdouts. CDS was triggered in July 2014. Prices had been volatile on both foreign and local law foreign currency bonds from 2013 to 2016, affected by the judicial process and expectations regarding a settlement with the holdouts. It took a total of 15 years for the holdouts to resolve their claims.

Repeat Defaulters

Restructuring, even after a default, does not assure future timely payments, not even for a year or two. Some countries have repeatedly defaulted, including Russia, Ecuador, Ivory Coast, and Argentina.

In 2000, both Russia and Ecuador restructured their US$40 billion defaulted debt into US$27 billion of Eurobonds. When Ivory Coast defaulted, creditors did not vote to accelerate the bonds, likely because the size was small, as was their current ability to pay.

Russia's 1997 restructuring then 1998 default on Soviet era debt: In 1997, Russia restructured US$32 billion of debt obligations from the Soviet era, which Russia had agreed to honor long after the breakup of the Soviet Union. The debt did not cross-default to Russian Federation external bonds. That exchange had no principal collateral, no interest collateral, and no haircut. In addition, the defaulted loans were repackaged into new loans rather than bonds.

That restructuring was not sufficient. In 1998, there was no consensus view on how Russia would be able to solve its debt crisis, as reserves were collapsing. Russia defaulted on local debt and the US$32 billion of Soviet-era restructured loans. Russia did not default on any of its Russian-issued Eurobonds. The defaulted loans traded as low as $6 in 1998–1999. Russia restructured again in 2000, and by 2003 Moody's rated Russia investment grade.

Ecuador—unfair treatment, no willingness: Ecuador was the first country to default on Brady bonds and the first to give differential treatment to its bondholders, both in 1999 and in 2008. Ecuador defaulted in 1999, restructured in 2000, then selectively defaulted in 2008. In 2008, the government in power claimed that the restructured 2012s and 2030s were illegally issued by a prior administration. The government defaulted selectively on those, but not on the 2015 Eurobond that had later been issued under the current government in 2005.

Ivory Coast default—willing, but not able: Ivory Coast had more French Franc Bradys than USD Bradys. It defaulted in 2000 on US$3.5 billion for failure to make a complete payment. This was the only country that has made a partial payment on time. The government had expected to pay the rest after the grace period, but was not able to make the payment. Investors did not vote to accelerate the bonds, likely because the size was small, as was their ability to pay. The bonds were restructured in June 2010 and a political stalemate by December 2010 caused a disruption in government functioning and another default on the bonds.

DERIVATIVES

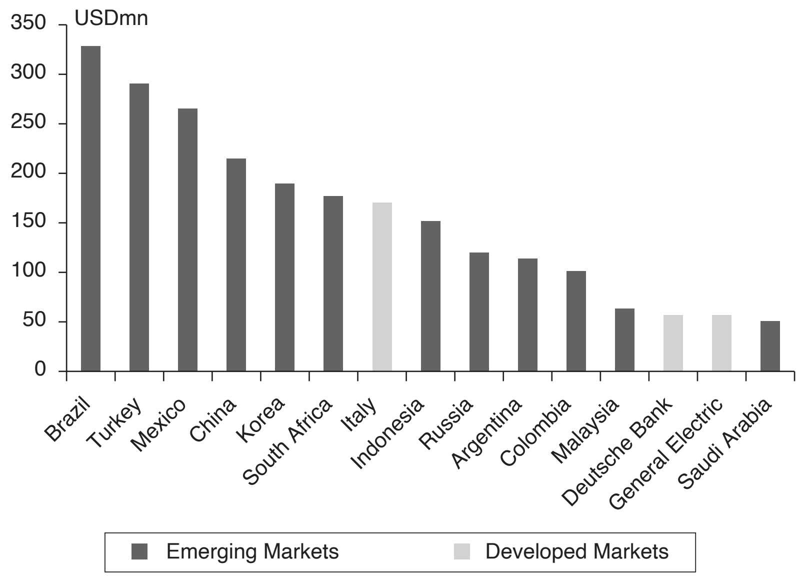
In addition to cash bonds, institutional investors also transact in derivative markets on Eurobonds. Derivatives have given institutional investors leverage and enhanced opportunities to hedge a corporate or sovereign position, express a directional view, or take advantage of relative mispricings in the market.

Credit default swaps (CDS): EM sovereign credit default swaps are among the most liquid and actively traded CDS in the world. Twelve out of 15 of the most actively traded CDS in the world are based on EM sovereigns, according to DTCC data. Therefore, several EM sovereign CDS are more actively traded than most developed market corporate CDS. (Exhibit 17-17). EM credit derivatives evolved alongside the rapid growth of the global corporate credit derivatives markets. CDS have grown to play a major role in emerging-markets investing and hedging.

CDS exposure is similar to the exposure of a floating-rate note investment. Both bond spreads and CDS spreads relate to credit default risk. A CDS offers investors an alternative way of going long or short a particular credit. Brazil, Turkey, Mexico, China, Korea, and South Africa are the most actively traded credits in the world. In addition, there are CDS indices, such as CDX.EM. The index is a basket of 17 global EM sovereign credits, with the largest weights assigned to Brazil, China, Turkey, Mexico, South Africa, and Indonesia.

EXHIBIT 17-17

CDS Credits with Highest Average Daily Notional Trading Volume in 2019 ($mn), Including Emerging Markets, Developed Markets, Sovereign and Corporate Credits



Source: BofA Global Research, Constructed from data obtained from DTCC 2019 CDS average daily traded notional ($mn).

Companies with foreign direct investments or with equities in emerging countries have used the sovereign CDS market extensively to hedge the overall sovereign risk, or to determine what return they should target when lending to various private projects or valuing the purchase of a local asset.

Exchange traded funds (ETFs): A number of ETFs have been created that mirror the overall market and replicate an index similar to those used as common benchmarks. The market capitalization of the largest EMs ETF, EMB, was about 30% as large as the largest high-yield ETF, HYG, in 2015 but five years later it had grown to 80% of the largest high-yield ETF. As with other ETFs, it is also used as a vehicle for taking a long or short market view, as well as for hedging.

KEY POINTS

- The Brady restructurings of the 1990s transformed illiquid commercial bank loans into liquid, globally traded bonds. The issuance of Brady bonds transformed EM debt into an asset class in its own right. As the asset class has evolved, defaults have occurred on external bonds since 1999, and the restructurings of those defaulted bonds have allowed sovereigns to reduce debt service going forward, which provides the sovereign an opportunity to rebuild its economy.
- EM debt has evolved into a sophisticated market with global investors ranging from pension funds and hedge funds to mutual funds and individual investors. It has grown tremendously over the last three decades as it has opened its doors to international investment, not only in international bonds but in local debt markets as well.
- Although EM debt has had well-known market shocks, it has weathered them as investors return to the market for its generous returns compared with other asset classes.
- EM debt has taken its place as a viable asset class, with product choices as extensive as those in some developed debt markets. The ongoing improvement in economic fundamentals may continue to attract investors to this asset class.

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CHAPTER

EIGHTEEN

FIXED INCOME EXCHANGE TRADED FUNDS

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Fixed income exchange traded funds (ETFs) have transformed bond markets since their introduction in the United States in 2002. The significance of their impact is largely due to the combination of features that they offer. Like a traditional mutual fund, a fixed income ETF is advised by an asset management firm that manages and rebalances the portfolio in accordance with stated investment guidelines. And like a listed equity or futures contract, a fixed income ETF provides investors with exposure that can be traded throughout the day on an exchange. As of April 30, 2020, there were $1.2 trillion in fixed income ETF assets under management across 1,475 funds globally and $857 billion in assets under management across 399 funds in the United States.[1]

Fixed income ETFs possess three key attributes:

- *Exchange listing provides transparent, intraday liquidity*. This is in stark contrast to the underlying over-the-counter (OTC) bond market, which is less transparent and less liquid.
- *A mechanism for creating and redeeming new fund shares*. The number of outstanding shares adjusts to market supply and demand. This differs from closed-end ETFs, which have a fixed number of shares. As a result, fixed income ETFs avoid some of the premium and discount volatility experienced by traditional closed-end funds.
- *Targeted market exposure*. ETF managers rebalance the funds and manage cash flows with the objective of providing risk and return characteristics that track (in the case of an index ETF) or seek to outperform (in the case of an active ETF) a published market index.

In this chapter, we discuss the characteristics of fixed income ETFs and how they compare to other fixed income instruments. We will then explore

1. Source: BlackRock, Bloomberg as of 4/30/2020.

various investment applications of fixed income ETFs for individual investors, advisors and institutions. Finally, we examine the structure and management of these funds as well as their trading behavior.

INVESTMENT CHARACTERISTICS

Exchange traded funds provide several key benefits:

- *Low investment management fees*. Fixed income ETFs generally have lower fees than open- and closed-end mutual funds. The average management fee is 30 basis points (bps) for a fixed income ETF versus 89 bps for the average fixed income mutual fund.[2]
- *Transparency*. Holdings of most fixed income ETFs are published on a daily basis. This gives investors regular access to the funds' assets and risk exposures.
- *Intraday liquidity*. The ability to trade fixed income ETFs throughout the trading day provides investors with greater visibility into portfolio valuation, even during periods of volatility and illiquidity. This intraday liquidity is particularly important and valuable during stressed market periods such as the COVID-19 crisis of 2020.
- *Tax efficiency*. The ETF creation/redemption mechanism makes ETFs more tax efficient than traditional mutual funds. When ETF shares are redeemed, the fund delivers securities in-kind (meaning that the underlying securities, rather than cash, are distributed). This in-kind distribution is not considered a taxable event for capital gains purposes. Mutual funds and other vehicles that distribute cash for redemptions must sell securities to raise the cash; in doing so, they potentially realize capital gains (or losses), which are paid to investors in the form of capital gains distributions.
- *Investment breadth*. ETFs provide exposure to a wide array of sectors for which futures and other exchange-traded vehicles do not exist.
- *Risk control*. Because they are exchange traded, and because each fund's underlying securities are held in a separate custodial account, fixed income ETFs have minimal counterparty risk.[3]

Exhibit 18-1 outlines the characteristics of ETFs along with other commonly used fixed income exposure vehicles: individual fixed income securities, futures, and swaps.

2. Source: Morningstar as of 4/30/2020.
3. There are ETFs that rely on uncleared OTC swaps to gain market exposure and, therefore, have a higher degree of counterparty risk relative to ETFs, which solely hold cash bond positions to achieve their exposures.

EXHIBIT 18-1

Key Characteristics of Bonds, ETFs, Futures, and Swaps

	Bonds	ETFs	Futures	Swaps
Advantages	Highly customizable; can target exposure to any asset sector	Priced, traded, and settled like stocks; broad or targeted exposure	Standardization of contracts and electronic trading enable large trading volumes and generally low transaction costs	Standardized exist but also bespoke; can target exposure to multiple sectors
Legal Structure	Security	1940 Act Fund	Derivative	Derivative
Round-Trip Execution Costs	Bid/offer spreads	Bid/offer spreads, commissions	Bid/offer spreads, commissions	Bid/offer spreads, possible early termination and other fees
Holding Costs	Minimal	Expense ratios	Embedded financing and contract roll costs	Embedded financing costs
Transparency of Costs	Low	High	High	Low
Notional Investment	100%	100%	Margin	Collateral (variable amount)
Tracking Error	Potentially high, varies by asset class	Generally low	Lower if a single deliverable exists; higher for basket of deliverables (cheapest to deliver option)	Low
Minimum Investment Size	Single security	Single share	Single contract	Customized (may be based upon minimum volume criteria)
Expiration	Stated maturity	Perpetual and stated end-date liquidation structures exist	Quarterly (usually)	Fixed expiration agreed upon at initiation
Liquidity Sources	OTC; multi-dealer model	Exchange; multi-dealer model	Exchange; multi-dealer model	OTC; multi-dealer model
Counterparty Risk	Minimal	Minimal	Minimal	Significant; can be reduced via collateral arrangements

Fixed income ETFs are used by both retail and institutional investors to obtain fixed income exposure across a broad asset class or a specific sector. Retail investors utilize these funds primarily for both core and custom portfolio exposure. Institutional investors utilize the funds primarily as liquid fixed income access vehicles.

Retail Investors and Financial Intermediaries

Retail investors and financial intermediaries use fixed income ETFs alongside traditional vehicles such as open- and closed-end mutual funds and separately managed accounts, primarily through these strategies:

- *Core exposure*. As with traditional types of funds, fixed income ETFs can be used for core fixed income exposure. A core holding typically provides an investor with broad market exposure. Around this core, exposure to various sectors can be added to satisfy specific risk/return targets. The wide selection of fixed income ETFs enables investors to construct core fixed income exposure either with a single broad market ETF (such as an ETF that is benchmarked to the Bloomberg Barclays U.S. Aggregate Bond Index) or with multiple ETFs that track various government and credit sectors which, when combined, provide broad market exposure.
- *Custom exposure*. Fixed income ETFs can provide targeted exposure to a specific market or sector, allowing investors to tailor portfolios for a variety of investment objectives or constraints. This application is widely used by individuals and is especially popular among investment advisors, because it allows them to customize fixed income exposures for large numbers of individual clients in a scalable way. As an example, an investor who holds a core position in an aggregate bond ETF may wish to periodically overweight exposure to investment-grade credit. The investor may accomplish this by augmenting their core exposure with a tactical allocation to an investment-grade credit ETF. Similarly, an investor may wish to shorten or lengthen the U.S. Treasury duration exposure of their core holding and may do so by blending in shorter or longer duration U.S. Treasury ETFs. The granularity and flexibility of fixed income ETFs have resulted in the creation of fixed income ETF "models," which are portfolios of fixed income ETFs constructed by advisory firms to target specific risk objectives. It is estimated that approximately $60 billion in assets are allocated to fixed income ETF models as of March 31, 2020.[4]
- *Market access.* The ability to target specific fixed income markets with a low-cost, liquid investment vehicle allows investors to gain exposure

4. Source: BlackRock as of 3/31/2020.

to sectors such as high-yield or emerging markets that can be challenging to access through the underlying bond market. As an example, an individual investor may find implementing a broad emerging market bond allocation difficult (if not impossible) through individual bond issues. However, there are a number of large, liquid ETFs in the market today that allow investors to gain access to this challenging fixed income sector instantaneously through an exchange.

- *Leveraged exposure.* There are a growing number of exchange traded products that provide investors with the ability to gain leveraged long and short exposure to fixed income markets. These funds have attracted interest from investors who seek to implement short-term tactical strategies on the direction of the targeted fixed income sector and who are comfortable with the mechanics and implications of leverage. These funds typically achieve their target exposure and leverage synthetically through OTC total return swaps or exchange traded futures.

  Investors considering these investments should be aware that the majority of leveraged and inverse funds reset leverage to a target level on a daily basis. Since the benchmark itself is not levered, the use of fund leverage, coupled with the impact of market path dependency and return compounding, can potentially distort fund returns relative to levered benchmark returns over longer periods of time.

Institutional Investors

Institutional investors rely on ETFs' liquidity, transparency, flexibility, and relatively low-cost structure to implement the following commonly used investment strategies:

- *Liquidity management.* Cash "equitization" (a term borrowed from equity markets) involves short-term investments of excess cash to maintain market exposure. Futures are commonly used for cash equitization due to their liquidity and ease of trading. Cash is invested in a money market account, and the futures position serves as an overlay to obtain the desired market exposure. The challenge with futures is that they generally offer only exposure to money markets or U.S. Treasuries (although credit index futures now exist[5]). Over-the-counter swaps (e.g., index total return swaps) may provide precise, customized exposure to a variety of fixed income sectors, but may exhibit less liquidity and potentially result in higher transaction costs relative to exchange-traded instruments, are subject to counterparty risk, and can be opaque and operationally intensive. Conversely, fixed income ETFs cover a wide range of fixed income sectors through an exchange traded format.

5. CBOE iBoxx iShares Corporate Bond Futures (www.cboe.com/products/futures/corpbondfutures).

As an example, a manager benchmarked to a broad index—such as the Bloomberg Barclays U.S. Aggregate Bond Index—would ideally employ a cash equitization instrument to maintain exposure to the index. While U.S. Treasury futures are liquid, they have a very high tracking error versus the Aggregate index, due to the differences in sector exposure and the presence of the delivery option in the futures contract. A number of fixed income ETFs exist that would allow the manager to invest excess cash efficiently and cost effectively without significantly increasing portfolio tracking error. In cases where a more cash-like exposure is desired, there are now a number of ETFs that offer money market-like exposure but still trade on exchange.

The liquidity management strategy can be implemented with ETFs across asset classes, as with a pension fund that uses fixed income ETFs as part of a core liquidity component within a broader portfolio. The ETF investment represents a portion of the exposure to each asset class. In this way, it complements, rather than replaces, the core holdings. The ETF portfolio provides a "liquidity sleeve" around the overall portfolio that can be accessed as needed to effect rebalancing. This approach allows the pension fund to maintain a strategic asset allocation without the need to continuously trade the less-liquid portions of their portfolio. It is especially valuable in fixed income markets where bid/offer spreads on individual securities can be significant and liquidity can be discontinuous.

- *Portfolio transitions*. When investors restructure their portfolios (e.g., due to changes in their manager profile or strategic asset allocation), they risk significant performance gaps and excessive costs. There is a tradeoff to be managed with respect to moving assets quickly and potentially incurring higher trading costs, and moving assets more slowly, which can result in performance differences relative to the target exposure. As an example, a pension plan that is moving a significant amount of money into the corporate bond market may find that it takes days or weeks to build the desired exposure through individual bonds. While the bond portfolio is being constructed, the plan is underexposed to any market movements that may occur in the corporate bond market. Futures and OTC swaps can be utilized to quickly obtain market exposure, but the tradeoffs discussed previously would still apply. The pension plan could instead purchase a fixed income ETF to rapidly establish and maintain corporate bond market exposure while it assembles the target bond portfolio.
- *Portfolio trades*. In these transactions, investors buy or sell large portfolios of bonds instantaneously at one price from a broker-dealer. Broker-dealers use fixed income ETFs to either hedge or facilitate these transactions by exchanging bonds for shares and vice versa using the creation/redemption mechanism (to be discussed in a later section).

- *Tactical allocations*. To take advantage of a market opportunity, a tactical investor must be able to move in and out of the market quickly. Individual bonds can provide targeted exposure but are generally difficult to trade in a large, diversified basket format. Futures and OTC swaps can be utilized, but the tradeoffs discussed previously apply.

  Fixed income ETFs combine the liquidity of futures and the diversified exposure of index total return swaps. For example, an investor favoring the wide level of credit spreads observed during the 2008–2009 Global Financial Crisis or the 2020 COVID-19-driven market volatility could have purchased a corporate bond ETF far more quickly and efficiently than buying an equivalent portfolio of individual securities. Investment advisors and hedge fund managers often use fixed income ETFs for tactical plays across large numbers of client accounts as they may implement market views more rapidly and cost effectively than could otherwise be accomplished through the underlying bond market.
- *Strategic asset allocation.* For decades, bond portfolio managers have constructed portfolios at the individual security level. Many actively managed portfolios consist of hundreds or thousands of individual bonds. While these bonds may have been selected on their individual merit, in aggregate their idiosyncratic properties may cancel, leaving what is, in effect, beta and factor exposure. As a result, there is significant opportunity to reduce line items, lower the trading costs associated with individual bonds, and increase liquidity through a combination of ETFs that provide similar beta and factor exposure. As an example, many "core plus" managers often have a return profile similar to a combination of a broad, investment-grade bond index (e.g., the Bloomberg Barclays U.S. Aggregate Bond Index) and a high-yield index (e.g., the ICE BofA US High Yield Index). This combination is essentially a core beta exposure plus a credit tilt or credit factor exposure. Such managers could use a combination of low-cost broad market and high-yield ETFs to create these core beta and factor exposures, while using individual securities and derivatives for higher conviction, uncorrelated positioning.

Advanced Applications: Derivative Substitute/Complement

In addition to the more conventional applications discussed in the preceding sections, tactical investors may also employ fixed income ETFs in more advanced strategies involving options, short selling, and vehicles that contain packaged leverage.

- *Options*. As the market for fixed income ETFs has grown and developed, options have been listed on many funds. For listed options on U.S. fixed income ETFs, there is currently over $70 billion in contract notional value outstanding and nearly $6 billion of trading activity per day on average.[6] Because they are listed, options on fixed income ETFs may be attractive relative to OTC fixed income options in terms of cost, transparency, and operational ease. Trading strategies using these options can be structured in a similar manner to those employed in futures options or OTC fixed income options. Options on fixed income ETFs allow investors to access leveraged market exposure and pursue a variety of strategies such as call or put spreads, directional volatility bets through straddles, etc. Credit ETF options have become especially popular and trade hundreds of millions of dollars a day in notional equivalent exposure. They have become a viable alternative to credit index default swap (CDX) swaptions given their high correlation with actual cash bond portfolios.

- *Short selling.* Investors who wish to short a specific fixed income sector may find that such a strategy is easier to implement through a fixed income ETF rather than through the underlying bond markets. Like equities, shares in fixed income ETFs may be borrowed and sold short. The cost varies with supply/demand conditions in the market for the ETF and helps shape an investor's decision on whether to use the ETF or an alternative strategy to short the market. Additionally, dislocations in the cost to borrow a fixed income ETF can create investment opportunities.

  As an example, a relative value hedge fund may find that the borrow cost in a particular high-yield ETF has increased from 1% to 5%, due to a significant level of short interest. The hedge fund may choose to take advantage of this situation by purchasing the high-yield ETF and lending it out at a rate of 5% (less any bid/ask differential). This would allow the hedge fund to achieve the return of the high-yield ETF plus 5%. Furthermore, the hedge fund may find that the high-yield beta exposure can be hedged by shorting a similar basket of correlated securities, CDX, or a credit index total return swap (e.g., a swap based on the iBoxx $ Liquid High Yield Index). If the cost of shorting the correlated exposure is less than 5%, then the hedge fund earns a spread for as long as the dislocation persists. In this example, the hedge fund must also price in the potential basis risk between the ETF and the correlated basket or swap.

FIXED INCOME ETF MANAGEMENT

Because fixed income ETFs are managed funds, an investment advisor is charged with overseeing the portfolio and delivering on its investment objective in accordance with a published prospectus and Statement of Additional Information (SAI). The manager has full investment control of the positions and transactions

6. Source: Bloomberg as of 4/30/2020.

in the portfolio. There are two primary types of funds in the marketplace—index funds and active funds.

Index ETFs

The majority of fixed income ETFs are index funds, which seek to match the performance of a published benchmark. Many fixed income securities have discontinuous liquidity, making it virtually impossible to fully replicate a broad market benchmark. For this reason, most fixed income index ETFs employ a set of techniques to sample from the broad market. These approaches, the most common of which are optimization and stratified sampling, involve creating a portfolio that contains a subset of the securities from an index that match the major risk characteristics of that index. In constructing and maintaining a portfolio, the manager must balance available security liquidity and transaction costs with the objective of creating a diversified portfolio to reduce idiosyncratic risk and better track benchmark performance.

Active ETFs

In 2008, the first active fixed income ETF was launched, and as of March 31, 2020, there are over 100 active fixed income ETFs[7] in the market. Like their index counterparts, active ETFs also have a stated benchmark. But unlike index funds, their objective is to outperform the benchmark. Active ETFs are not typically used by investors as liquid exposure vehicles in the same way that index ETFs have been used, as an active ETF's portfolio exposure will vary through time. What active ETFs do offer is a managed alpha vehicle that can be accessed and traded throughout the day.

Managers of active fixed income ETFs employ an array of investment strategies to achieve outperformance, including security selection, asset allocation, and duration management, similar to traditional open-end or closed-end mutual funds.

As with index ETFs, active fixed income ETF providers publish their holdings on a daily basis, which creates challenges for a portfolio manager holding concentrated positions or investing in illiquid markets. For this reason, most of the active fixed income ETFs that have come to market are those that invest in more liquid asset classes or that hold securities until their maturity. This minimizes the chances of the manager being taken advantage of due to the transparency of their posted holdings.

FIXED INCOME ETF CHARACTERISTICS AND MECHANICS

Fixed income ETFs typically provide daily transparency of holdings and pay income through monthly distributions. The liquidity provided by fixed income

7. Source: BlackRock, Bloomberg as of 3/31/2020.

ETFs is supported by two complementary markets—the primary market, in which fund shares are created and redeemed, and the secondary market, in which existing shares are traded throughout the day on an exchange.

Holdings Transparency

A differentiating factor of fixed income ETFs is that their holdings are disclosed more frequently than mutual funds. The majority of fixed income ETF providers publish holdings on a daily basis, providing investors with continual transparency into the fund's risk profile. The exceptions are ETFs that represent share classes of mutual funds, as well as those ETFs that have received specific regulatory exemptions.

Fund Distributions

As 1940 Act mutual funds, fixed income ETFs are required to distribute earned income to investors. This income reflects accrued interest earned by the fund and includes the amortization and accretion of securities purchased at a price other than par, as well as securities lending income and fund management expenses. Typically, fixed income ETFs distribute income monthly. Earned income may be generally defined as

$$\text{Earned Income} = \text{Accrued interest} + \text{discount accretion} - \text{premium amortization} + \text{securities lending income} - \text{fund expenses}$$

It is important to note that income is earned at the fund level but distributed at the share level. As a result, changes in the number of shares outstanding in a given month can result in a change in the size of the distribution on a per share basis paid to investors. Value is neither created nor destroyed, however. Any perceived surplus/deficit in per share distributions is offset directly in the net asset value (NAV). For established funds with moderate flows, this tends to result in small shifts in distributed income on a monthly basis; for smaller funds and those that experience extreme flows, the impact can be greater. Note that this income distribution mechanism is not unique to ETFs; it also applies to other mutual fund structures.

Fixed income ETF distributions are an important attribute for investors who invest in bonds for income purposes. Distributions create a future stream of cash flows that an ETF holder will receive, in much the same way that an individual bond provides a future stream of coupon payments.

The Primary Market: Creation and Redemption of Fund Shares

Broker-dealers who create or redeem ETF shares are known as authorized participants (APs). Authorized participants generally work with both investors and ETF providers to maintain liquidity in the market.

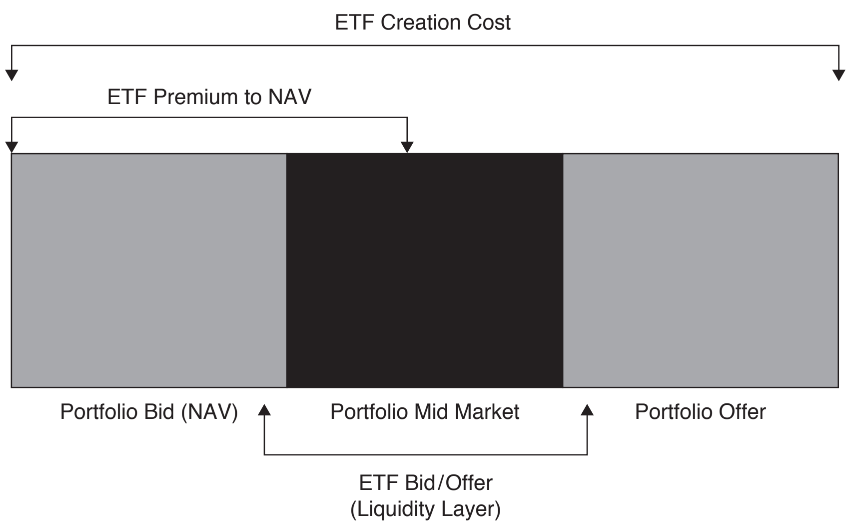
Investors purchase and sell shares of ETFs on an exchange, trading them in exactly the same way as a listed stock. Each share represents partial ownership of the portfolio of securities held by the fund, much like shares in a traditional open-end mutual fund represent partial interest in the underlying fund holdings. What differs is the ETF's creation/redemption mechanism.

On a daily basis, the ETF provider publishes the holdings of the ETF along with the lists of securities that can be delivered for the creation or redemption of shares. During periods of strong demand for an ETF, the price of the shares is bid up in the market as the supply of shares is depleted. If the ETF price is sufficiently higher than the value of the underlying securities held within the ETF, an arbitrage opportunity may exist. Authorized participants could purchase the underlying fixed income securities, deliver them to the ETF provider in exchange for the creation of new ETF shares, and then sell the newly created ETF shares in the market for a profit. This same dynamic occurs in markets with strong selling pressure that results in an excess supply of shares and falling prices. If the ETF trades significantly or persistently below the value of the securities in the fund, APs could purchase the ETF shares in the open market (at a discount), deliver them to the ETF provider in exchange for the underlying bond holdings (i.e., redeem these shares), and then sell these bond holdings at a net profit.

Arbitrage pressure keeps the ETF price in line with the value of the underlying securities. Exhibit 18-2 illustrates the arbitrage boundaries for fixed income ETFs in terms of the bid/ask spread of the underlying securities.

EXHIBIT 18-2

Fixed Income ETF Arbitrage Boundaries



Note that one need not be an AP in order to close an arbitrage opportunity in an ETF. As an example, if an ETF is trading at a discount relative to the value of its underlying securities, then a market participant (such as a hedge fund) may act to close a valuation gap by buying the ETF and selling short against it a group of correlated securities or derivatives. The correlated securities basket could consist of individual bonds, interest rate derivatives, or credit derivatives. The hedge fund would wait for the values of the ETF and the correlated basket of securities to converge. At that time, all positions would be unwound for a net profit.

All ETF creations and redemptions must be done at a value equal to the fund's NAV. This ensures that the value of the securities passing into or out of the fixed income ETF matches the value of the shares issued by or taken back by the fund. In this way, existing shareholders of fixed income ETFs are protected from any potential transfers of wealth during the share creation/redemption process.

Additionally, investors buying or selling the fund transact at the *market price* of the fund, as opposed to the NAV. Market price execution is an important point of differentiation for a fixed income ETF relative to traditional open-end fund structures. In an ETF that utilizes the in-kind creation/redemption process, each investor incurs the transaction costs created by their specific transaction through the market price of the ETF (i.e., the market price should reflect the cost of share creation) and existing investors are unaffected. Conversely, in a mutual fund structure, investors enter and leave the fund at the fund's net asset value, as opposed to market price, and transaction costs are shared by all investors in the fund. Note that it is customary to value fixed income securities on the *bid* side of the underlying bond market for NAV calculation purposes, while investors typically purchase fixed income securities on the offered side of the market. As a result, a new investor may enter a mutual fund at the NAV, but the securities purchased as a result of this investor's entry may ultimately cost more than the bid-side prices that were implied by the NAV. This differential is paid for by existing investors in the fund.

Such a dynamic is generally beneficial for the transacting investor but not the existing investors. An investor's choice of whether to use an ETF or a mutual fund depends, in part, on their desire to incur isolated or mutually shared costs.

The Secondary Market: The Exchange Liquidity Layer

One of the characteristics that differentiate fixed income ETFs from other managed vehicles is that the shares are listed and traded on a stock exchange. Unlike the OTC bond market, the exchange format provides for a high level of visibility into trading volumes, two-sided market levels (both bid and offer), and transaction costs. It also provides investors with the ability to control market execution by using equity trading strategies such as limit orders and stop loss orders, and to employ shorting strategies by borrowing ETF shares and selling them into the market.

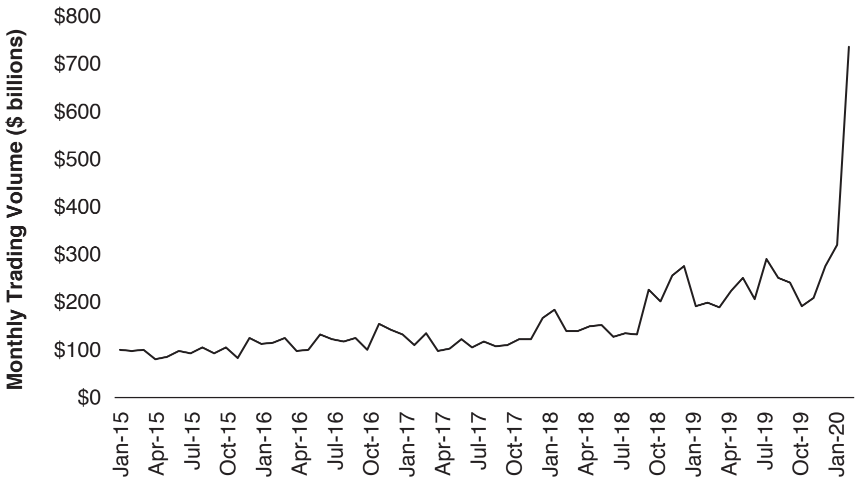
The level of intraday liquidity and market visibility offered by ETFs is in sharp contrast to the underlying OTC bond market, where trades are negotiated directly between parties by phone, e-mail, or other medium. The OTC market creates a number of challenges for an investor. First, it is difficult to determine best execution. An investor can solicit market bids or offers from a selection of dealers, but that investor has no way of knowing whether they executed at the best available price in the market. Second, OTC markets generally provide either the bid or offer price for a transaction, whereas two-sided markets allow the investor to explicitly observe their transaction costs through the spread between the bid-side and offer-side prices.

One of the central benefits of ETFs is that they develop their own independent exchange liquidity layer through the secondary market as trading volume and shares outstanding grow. Secondary market activity accounts for the majority of trading volume, as most ETF transactions occur without the need to create/redeem shares and access the underlying market. Under normal market conditions, secondary trading activity is roughly five times that of primary (creation/redemption) activity. In periods of market stress and volatility, this ratio can move above 20 as primary activity falls due to illiquidity in the underlying bond market and more trading moves to the exchange.[8]

This exchange liquidity can be substantial. As an example, during the first quarter of 2020 when the COVID-19 crisis was gripping markets, fixed income ETFs traded between $25 billion and $35 billion per day, two to three times the average of $11 billion observed in 2019.[9] Exhibit 18-3 illustrates monthly fixed income ETF volumes from January 2015 through March 2020.

EXHIBIT 18-3

Monthly Trading Volumes for U.S. Fixed Income ETFs



8. Source: BlackRock as of 3/31/2020.
9. Source: BlackRock, Bloomberg as of 3/31/2020.

Secondary market liquidity is a key benefit of ETFs in general and fixed income ETFs in particular. The liquidity layer essentially decouples the ETF liquidity from that of the underlying OTC bond market and allows investors to trade in the ETF without having to create or redeem shares. The ability to trade a fixed income ETF within the exchange liquidity layer can result in the ETF trading at a much tighter bid/offer spread than the underlying bond market. When trading demand outstrips available exchange liquidity, the market price action of the fixed income ETF may motivate dealers to access the underlying bond market in order to square orders with inventory.

Accordingly, the level of liquidity available for a fixed income ETF is not driven by the level of observable exchange liquidity alone. A large purchase or sale in a fixed income ETF may potentially absorb the existing level of exchange liquidity, which would then necessitate the creation or redemption of shares by an AP in order to balance the market. The AP would do this by accessing the underlying bond market (i.e., purchasing bonds to facilitate share creation or selling bonds to facilitate share redemption). Therefore, the total available liquidity of a fixed income ETF is a function of not only the observable exchange liquidity but also the liquidity of the underlying bond market (which is substantial in most fixed income sectors).

A fixed income ETF's total available liquidity may be thought of as the sum of the following:

1. Observable exchange liquidity (i.e., the average daily volume)
2. Contingent exchange liquidity that may be unlocked through the use of limit orders, etc. (which is provided by existing fund shareholders who are willing to transact at a price that is more favorable to them than what is currently available in the market)
3. Underlying bond market liquidity that may be accessed through the creation/redemption process

Through careful execution designed to maximize observable and contingent exchange liquidity, market participants are often able to transact in fixed income ETFs in excess of the average daily volume with minimal market impact. Exhibit 18-4 illustrates the layers of liquidity of fixed income ETFs.

Exhibit 18-5 presents observed bid/offer spreads for trades on some of the largest fixed income ETFs relative to spreads in the respective underlying market. Note that, because of the robust exchange liquidity in these ETFs, their bid/offer spreads are a fraction of the underlying bond market bid/offer spreads. This is particularly pronounced in the more esoteric sectors such as high yield and emerging markets.

EXHIBIT 18-4

Fixed Income ETF Liquidity Layers

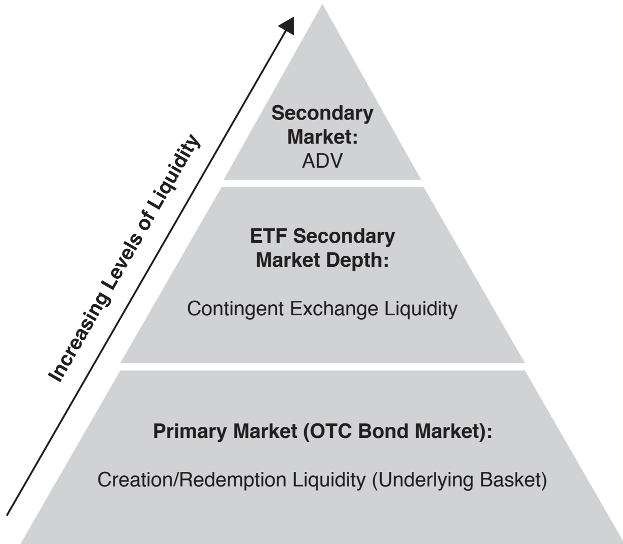
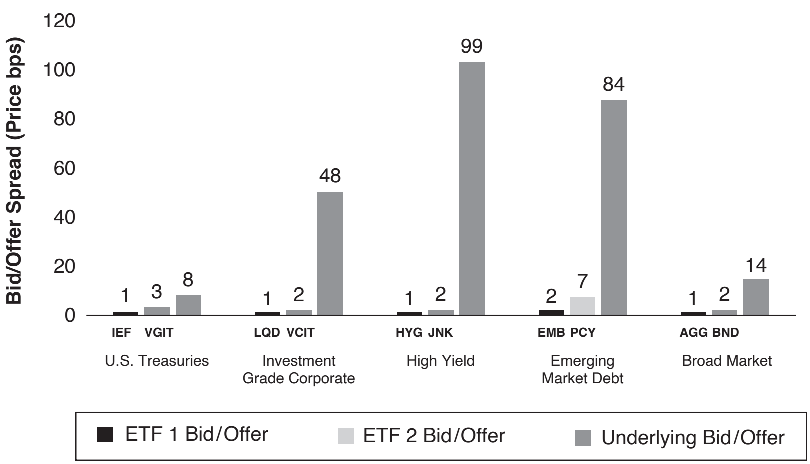


EXHIBIT 18-5

Sample ETF and Market Bid/Offer Spreads 1st Quarter 2020



Source: Blackrock, Bloomberg as of 3/31/2020. Bid/Offer is the average from 1/2/2020–3/31/2020. Funds represented: iShares 7-10 Year Treasury Bond ETF (IEF), Vanguard Intermediate-Term Treasury ETF (VGIT), iShares iBoxx $ Investment Grade Corporate Bond ETF (LQD), Vanguard Intermediate-Term Corporate Bond ETF (VCIT), iShares iBoxx High Yield Corporate Bond ETF (HYG), SPDR Bloomberg Barclays High Yield Bond ETF (JNK), iShares J.P. Morgan USD Emerging Markets Bond ETF (EMB), Invesco Emerging Markets Sovereign Debt ETF (PCY), iShares Core U.S. Aggregate Bond ETF (AGG), and Vanguard Total Bond Market ETF (BND).

TRADING BEHAVIOR: A CLOSER LOOK AT PREMIUMS, DISCOUNTS, AND PRICE DISCOVERY

The price at which an ETF trades is primarily a function of the value of the underlying securities in the portfolio (i.e., the NAV), and is also influenced by market flows, liquidity, and market volatility.[10]

When an ETF trades at a price above the NAV, it is said to be trading at a premium; when the ETF is trading below the NAV, it is said to be trading at a discount. Because the convention in fixed income markets is to value securities using bid-side prices, the NAV of a fixed income ETF is calculated using the bid side of the underlying bond market. Under most market conditions, a fixed income ETF will trade at a premium to this bid-side NAV. Under normal market conditions, the maximum premium should be the full bid/ask spread of the underlying portfolio, otherwise an arbitrage would be possible as discussed previously.

The level of premium or discount for a fixed income ETF is a function of the bid/offer spread of the underlying bond market, the balance of ETF flows, and the level of market volatility and execution risk that a market participant takes on in executing the creation/redemption or arbitrage activity.[11]

In periods of high volatility and market dislocation, the market price of the fixed income ETF can often lead the underlying market, creating the appearance of large discounts or premiums. These larger deviations reflect the fact that many of the underlying bonds held by the ETF may not be trading on a given day. As an example, only about 25% to 35% of bonds trade on a given day in the corporate bond indexes that the larger, more liquid bond ETFs track.[12]

Accordingly, a substantial amount of the NAV may be based on estimates of value calculated by bond pricing services, rather than actual trades. In fast-moving markets, these estimates can lag the price changes that are occurring in the bonds, ETFs, and other securities that are trading. The ETF price is in effect a real-time indicator of the value of the bond portfolio on exchange. The price discovery properties of ETFs are well known,[13] and are particularly pronounced for fixed income ETFs.[14]

To illustrate this point, Exhibit 18-6 shows the market price of the largest corporate bond ETF versus its NAV from February 19, 2020, through March 24, 2020, the peak of COVID-19-induced market volatility. Exhibit 18-7 shows the market price of this ETF versus the prices of its top five holdings over this same period. While this ETF traded at up to a 5% discount to NAV, Exhibit 18-7

10. Matthew Tucker and Stephen Laipply, "Understanding Bond ETF Premiums and Discounts: A Conceptual Framework," *Journal of Indexes* (September/October 2010), pp. 40–48.

11. A timing effect may also arise, given that fixed income markets close at 3:00 p.m. ET while equity markets continue to trade until 4:00 p.m. ET. The timing effect is excluded from this discussion as it distorts the measurement of the premium but is not a driver of its level.

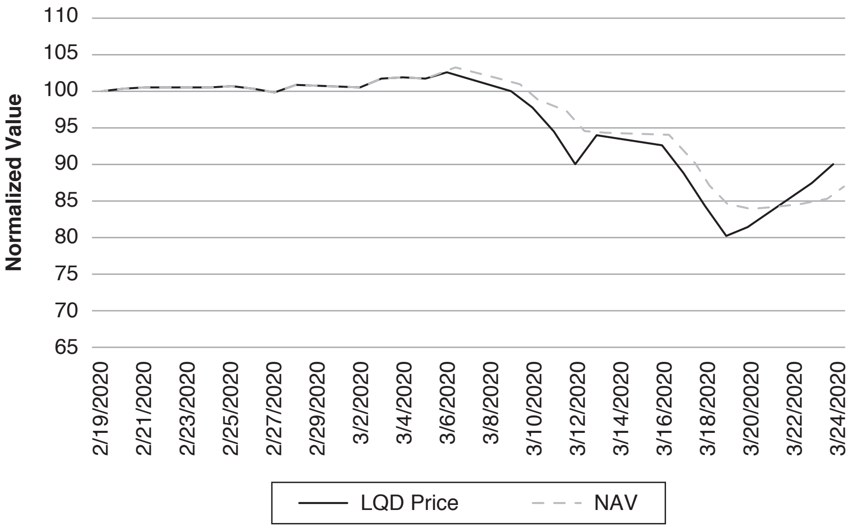
12. Source: BlackRock as of 3/31/2020.

13. Ananth Madhavan and Aleksander Sobczyk, "Price Dynamics and Liquidity of Exchange-Traded Funds." *Journal of Investment Management*, 14(2), 2016, pp. 1–17.

14. Matthew Tucker and Stephen Laipply, "Bond Market Price Discovery: Clarity through the Lens of an Exchange," *Journal of Portfolio Management,* 39(2), 2013, pp. 49–62.

EXHIBIT 18-6

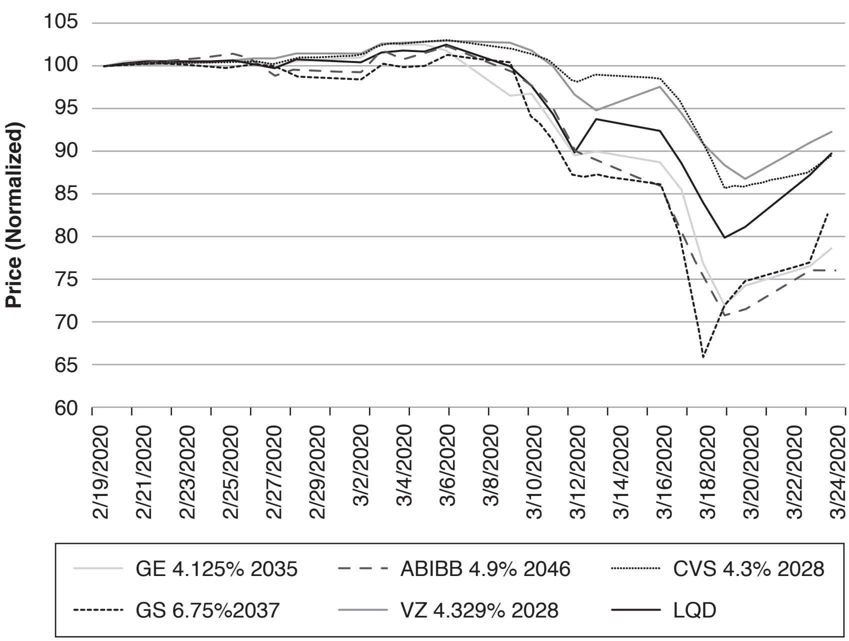
Corporate Bond ETF Price vs. NAV



Source: Bloomberg as of 3/24/2020

EXHIBIT 18-7

Prices of Corporate Bond ETF vs. Top Holdings



Source: Bloomberg as of 3/24/2020

illustrates that its price was very much in context with bonds that were trading. Note that this ETF traded tens of thousands of times on exchange daily, while the top five underlying holdings traded less than three dozen times each day on average over the same period.

Accordingly, fixed income ETFs can provide both valuable information content on real-time market conditions as well as a readily tradeable instrument when underlying bond market liquidity conditions are challenged.

KEY POINTS

- Fixed income ETFs combine many of the attributes of individual bonds and bond portfolios, mutual funds, swaps, and futures to provide transparent, liquid, and efficient exposure for investors.
- Retail and intermediary investors use fixed income ETFs primarily for core or custom exposure, market access, and model portfolios. Institutional investors use fixed income ETFs for cash equitization and liquidity management, portfolio transitions, tactical and strategic allocations, and as a substitute or complement to derivative instruments for investment and risk management purposes.
- In the primary market for fixed income ETFs, Authorized participants help maintain liquidity by increasing shares of the ETF (when demand increases) or decreasing shares of the ETF (when demand decreases) through an exchange of bonds for shares. Arbitrage pressure helps to keep the ETF price in line with the value of the underlying fixed income securities.
- In the secondary market, investors trade ETF shares on equity exchanges. This added liquidity layer can be substantial and may provide significantly tighter bid/offer spreads relative to those observed in the underlying bond market.
- Fixed income ETF pricing behavior is driven primarily by movements in the underlying bond market, ETF fund flows, and the level of market volatility.
- Fixed income ETFs provide price discovery and serve as an actionable vehicle and real-time window into market conditions, particularly when the underlying bond market is stressed.

CHAPTER
NINETEEN

NONCONVERTIBLE PREFERRED STOCK

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Distinguished Professor Emeritus
Moore School of Business
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Preferred stock is a hybrid security that combines features of both common stocks and corporate bonds. While preferred stock possesses some debtlike features, it is considered to be an equity security. Preferred stockholders have a claim on the cash dividends paid by the issuing corporation, and their claim is senior to that of common shareholders. Furthermore, cash dividends paid to preferred stockholders are almost always fixed by contract (e.g., a specified dollar amount or percentage of their face value). Accordingly, "plain vanilla" preferred stock is, in essence, a perpetuity. The specified percentage is called the *dividend rate,* which may be fixed or floating. Almost all preferred stock issued today limits the payments to be received by the security holder to a specified amount with the proviso that the cash flows received will never exceed those specified in the contract and may be less.

Failure to make preferred stock dividend payments cannot force the issuer into bankruptcy. If the issuer fails to make the preferred dividend payments as specified in the contract, then depending on the terms of the issue, one of two things can occur. If the issue is *cumulative,* the dividend payment accrues until it is fully paid. Conversely, if the issue is *noncumulative,* missed dividend payments simply are forgone. Failure to make dividend payments also may trigger certain restrictions on the issuer's management. As an example, if dividend payments are in arrears, preferred shareholders may be granted voting rights to elect some members to the issuer's board of directors. This feature is called *contingent voting* because the voting rights are contingent on a missed dividend payment.[1]

Cumulative preferred stock has some debtlike features, namely (1) the cash flows promised to preferred stockholders are fixed by contract and (2) preferred stockholders have priority over common stockholders with respect to dividend payments and distribution of the assets in case of bankruptcy.[2] However, on a balance

1. By contrast, *blank check* preferred stock contains a provision that gives voting rights to approved preferred shareholders as protection against a hostile takeover attempt.
2. The position of noncumulative preferred stock is considerably weaker.

sheet, preferred stock is classified as equity. When there is more than one class of preferred stockholders, the claims of preferred stockholders to the issuer's assets differ in the event of bankruptcy. For example, *first* preferred stock's claim to dividends and assets has priority over other preferred stock. Correspondingly, *second* preferred stock ranks below at least one other issue of preferred stock.

Almost all preferred stock has a sinking-fund provision, and such provisions usually are structured similarly to those used with corporate bonds. A sinking fund is a provision allowing for a preferred stock's periodic retirement over its life span. Most sinking funds require a specific number of shares or a certain percentage of the original issue to be retired periodically, usually on an annual basis. Sinking-fund payments can be satisfied by either paying cash and calling the required number of shares or delivering shares purchased in the open market. Most sinking funds give the issuer a noncumulative option to retire an additional amount of preferred stock equal to the mandatory requirement. This is called a *double-up option*. Preferred shares acquired to satisfy a sinking-fund requirement usually are called using a random selection process.

Preferred shares offer investors two distinct advantages over debt and other equity investments. Preferred shares offer higher yields on average than bonds or common stock. Moreover, preferred shares provide good diversification benefits owing to their low correlation with stocks and bonds. In order to obtain these benefits, investors in preferred stocks must contend with the risk characteristics of these securities. Preferred shares possess limited potential for price appreciation. The reason is that the lion's share of the total return is due to the stream of dividend payments. Naturally this raises the specter of default risk, meaning a breach in the contract with the preferred stockholder like omission of a dividend. Some preferred shares are callable, which exposes the investor to reinvestment risk. Finally, preferred stocks tend to be less liquid than common stocks.

PREFERRED STOCK ISSUANCE

Corporations use three types of securities—debt, common stock, and preferred stock—to finance their operations. In terms of total dollars issued, preferred stock ranks third by a large margin. There have been two fundamental shifts in the issuance pattern of preferred stock since the early 1980s. Since the mid-1980s, the major issuers of preferred stock are financial institutions and insurance companies, whereas before this time, public utilities issued a majority of preferred stock. Second, most of the preferred stock issued today carries an adjustable-rate dividend. Traditionally, almost all preferred stock paid a fixed dividend.

Types of Preferred Stock

There are three types of preferred stock: (1) fixed-rate preferred stock, (2) adjustable-rate preferred stock, and (3) auction-rate and remarketed preferred stock.

Fixed-Rate Preferred Stock

Prior to 1982, all publicly issued preferred stock paid a fixed dividend rate.

Adjustable-Rate Preferred Stock

For *adjustable-rate preferred stock* (ARPS), the dividend rate is reset quarterly based on a predetermined spread from the highest of three points on the Treasury yield curve. The predetermined spread is called the *dividend reset spread*. The dividend reset spread is added to or subtracted from the *benchmark rate* determined from the yield curve. The three points on the yield curve are the highest of (1) the 3-month Treasury bill rate, (2) the 10-year Treasury rate, or (3) the 30-year Treasury rate. It is often the case that the dividend reset spread is expressed as a certain percentage of the benchmark rate.

Auction-Rate and Remarketed Preferred Stock

Most ARPS is perpetual, with a cap and floor on the dividend rate. Because most ARPS is not putable, however, ARPS can trade below par value after issuance if the spread demanded by the market as compensation for the risk of the security is greater than the dividend reset spread. The popularity of ARPS declined when these instruments began trading below their par value. This occurs because when an issuer's credit risk deteriorates, the dividend-rate formula remains unchanged and the preferred stock's value will decline. In 1984, a new type of preferred stock was issued to overcome this problem—*auction-rate preferred stock*. This innovation was particularly well received by corporate investors who sought tax-advantaged short-term instruments to invest excess funds. The dividend rate on auction-rate preferred stock is reset periodically, but the dividend rate is established through a Dutch auction process. Participants in the auction consist of current preferred shareholders as well as potential buyers. The dividend rate that participants are willing to accept reflects current market conditions. Commercial paper rates typically serve as benchmarks.

In the case of *remarketed* preferred stock, the dividend rate is determined periodically by a remarketing agent, who resets the dividend rate so that any preferred stock can be tendered at par and be resold (remarketed) at the original offering price. An investor has the choice of dividend resets every 7 days or every 49 days.

TRUST PREFERRED

Trust preferred securities are hybrid securities primarily issued by financial institutions with features of both debt and equity. They are treated as debt for tax purposes such that dividend payments are tax deductible and may be deferred up to five years. Conversely, they are treated as Tier I capital for trust preferred securities are senior to both preferred and common stock but subordinate to all debt. These securities possess 30-year maturities allowing for early redemption at the behest of the issuer. Trust preferred shares generally deliver quarterly dividend payments.

In the aftermath of the financial crisis of 2007–08, regulators lamented financial institutions were too highly levered and that more regulation was paramount. These changes in regulation were delivered in two packages—Basel III and the Dodd-Frank Act. Endorsed by the G-20, the Basel III banking standards are to be enacted by member nations through either regulation or statue by January 1, 2013. The Dodd-Frank Act was signed into law and represents the most significant U.S. financial reform since the Depression. Both packages of regulation raise capital standards and phase out trust preferred from Tier 1 capital. Basel III generally gives a much longer phase-out period than the three years stipulated by Dodd-Frank. The other important difference in the treatment of trust preferred stock is that Dodd-Frank exempts small banks from the phaseout. Basel III contains no such exemption.

PREFERRED STOCK RATINGS

Preferred stock is rated just like corporate bonds. A preferred stock rating is an assessment of the issuer's ability to make timely dividend payments and fulfill any other contractually specified obligations (e.g., sinking-fund payments). The three nationally recognized statistical rating organizations (NRSROs) that rate corporate bonds also rate preferred stock. The NRSROs are Fitch Ratings, Moody's Investors Service, Inc., and Standard & Poor's Ratings Group. Symbols used by the NRSROs for rating preferred stock are the same as those used for rating corporate long-term debt. It is important to note that the rating applies to the security issue in question and not to the issuer per se. Two different securities issued by the same firm could have different ratings. Standard & Poor's attaches +*s* and –*s*, which are called *notches,* to denote an issue's relative standing within the major ratings categories.[3]

TAX TREATMENT OF DIVIDENDS

Dividend payments made to preferred stockholders are treated as a distribution of earnings. This means that they are not tax deductible to the corporation under the current tax code.[4] Interest payments are tax deductible, not dividend payments. While this raises the after-tax cost of funds if a corporation issues preferred stock rather than borrowing, there is a factor that reduces the cost differential: a provision in the tax code exempts 70% of qualified dividends from federal income taxation if the recipient is a qualified corporation. For example, if corporation A owns the preferred stock of corporation B, for each $100 of dividends received

3. Moody's attaches 1s, 2s, and 3s to indicate the same information.
4. An exception to this statement is trust-preferred securities.

by A, only $30 will be taxed at A's marginal tax rate. The purpose of this provision is to mitigate the effect of double taxation of corporate earnings.

The tax treatment of preferred stock also differs depending on whether it is classified as *old money, new money,* or *partial money*. Old money refers to preferred stock issued before October 1, 1942. For old money preferred stock, the dividend-received deduction is only 42%. Partial money refers to a very small new set of issues that were classified as both old and new money. Old and partial money comprise only a tiny fraction of the preferred stock outstanding today. In other words, virtually all preferred stock outstanding today is new money.

There are two implications of this tax treatment of preferred stock dividends. First, the major buyers of preferred stock are corporations seeking tax-advantaged investments. Indeed, very few individual investors hold preferred stock in their portfolios. Second, the cost of preferred stock issuance is lower than it would be in the absence of the tax provision because the tax benefits are passed through to the issuer by the willingness of corporate investors to accept a lower dividend rate.

KEY POINTS

- Preferred stock is a hybrid security that combines elements of debt and equity.
- Preferred shares offer higher yields on average than bonds or common stock and provide good diversification benefits owing to their low correlation with stocks and bonds.
- Preferred share possess limited potential for price appreciation and are exposed to default risk.
- There are three types of preferred stock: (1) fixed-rate; (2) adjustable-rate; and (3) auction-rate.
- Trust preferred securities are hybrid securities primarily issued by financial institutions with features of both debt and equity. They are treated as debt for tax purposes such that dividend payments are tax deductible and may be deferred up to five years.

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CHAPTER
TWENTY

PRIVATE INFRASTRUCTURE DEBT

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This chapter discusses the characteristics, pricing, and credit risk of private infrastructure project debt instruments. Long the preserve of banks, private infrastructure debt has become an increasingly common asset class in institutional portfolios of alternative credit. Infrastructure debt is originated with the aim of financing long-term capital projects with limited alternative uses, which makes it different from other forms of corporate debt securities.

INFRASTRUCTURE BORROWERS

The economic literature has identified a number of fundamental economic characteristics of infrastructure companies (and borrowers), which sets them apart from other types of investments.[1] In the TICCS taxonomy of infrastructure companies, these characteristics can be summarized thus:[2]

1. *Single-use investment:* Infrastructure assets can be described as "relationship-specific," that is, the investment required only makes sense in the context of a "relationship"—typically, a contract, license, or concession, which justifies the demand or usefulness of the investment.
2. *Sunk or irreversible capital investment:* This relationship must exist for infrastructure investment to take place because the initial capital expenditure is "sunk," that is, irreversibly invested and unusable for any other purpose than the one originally intended.

1. See, for example, Jose Gomez-Ibanez, *Regulating Infrastructure*: *Monopoly, Contracts and Discretion.* Harvard University Press, 2003.
2. EDHECinfra, *The Infrastructure Company Classification Standard (TICCS®)*, EDHEC Infrastructure Institute, 2020 (url: https://docs.edhecinfra.com/display/TICCS).

3. *Large size requiring a long repayment period:* Infrastructure investments are sizable in absolute terms, making the repayment period necessarily long (multiple decades) and potential losses large as well.
4. *Inflexible total cost structure:* Operating infrastructure at its design capacity implies predictable fixed (operating, maintenance, and capital) costs and low variable costs, resulting in an inflexible cost structure. In turn, investing in infrastructure requires a higher degree of certainty in future revenue streams, which underpins the requirement for long-term contracts, especially since infrastructure assets have little to no alternative uses.
5. *Infrastructure as a service:* Infrastructure companies have value because their assets provide a useful service to its users, the demand for which is the sole justification for the investment. Thus, despite consisting mainly of large tangible, immobile assets, the value of infrastructure assets is determined by their providing a service.
6. *Not a store of value:* It follows that, unlike other "real" assets such as land, building, commodities, or art, infrastructure investment are not a store of value. Instead, infrastructure assets must be useful for them to have (social, economic, and financial) value.

The firms that invest in infrastructure assets can be very similar to other large industrial firms. One speaks then of "infrastructure corporates." In this case, "infrastructure debt" is found to be very similar in form, pricing, and quality to investment-grade corporate bonds, and there may not be much of an infrastructure debt asset class to speak of.[3]

However, the economic characteristics listed above also allow infrastructure investments to be structured in a way that reflects the long-term value and unique purpose of the individual infrastructure assets, thus optimizing leverage and the tenor of debt instruments. This use of "project finance" is very common in the infrastructure sector: about 70% of all infrastructure debt borrowers worldwide are project finance vehicles. The official definition of project finance was put forward by the Bank of International Settlement in a report to the Basel Committee:

> Project finance is a method of funding in which investors look primarily to the revenues generated by a single project, both as the source of repayment and as security for the exposure. In such transactions, investors are usually paid solely or almost exclusively out of the money generated by the contracts for the facility's output. The borrower is usually a Special Purpose Entity (SPE) that is not

3. See Frederic Blanc-Brude and Jing-Lis Yim, "The Pricing of Private Infrastructure Debt: A Dynamic Approach," in *EDHEC Infrastructure Institute Publications* (2019), for a discussion and empirical tests.

> permitted to perform any function other than developing, owning, and operating the installation. The consequence is that repayment depends primarily on the project's cash flow and on the collateral value of the project's assets.[4]

The practice of project financing infrastructure assets is the primary source of new private infrastructure debt instruments. These instruments are 7- to 25-year term loans in their immense majority, as well as the some privately placed and very few publicly traded bonds. Since 2000, global origination of new infrastructure project finance debt typically ranges in the 300 to 400 billion U.S. dollars a year. In what follows, we review the key characteristics of private infrastructure project debt, what factors tend to determine their pricing (credit spread). and how to approach credit risk in an asset class that is designed to avoid hard defaults.

CHARACTERISTICS

Limited Recourse

Project financing amounts to investing in a single-project firm or Special Purpose Entity (SPE) with a predefined lifespan. Before the financing decision can be taken, this SPE has to demonstrate its financial viability with a high degree of probability.

Creditors have no substantial sponsor guarantees (limited recourse) or any tangible assets collateral (relationship-specific capital investment). The only source of value of the SPE is its future free cash flow, that is the cash flow available once the various tasks that the SPE has contractually committed to accomplish in each period (e.g., to build, maintain, and operate an infrastructure project) have been executed.

In project financing, the free cash flow of the firm is thus the sole determinant of asset value. At any time t during the SPE's finite life, the firm's value is simply the sum of expected cash flow available for debt service, or CFADS, discounted at the appropriate rate. This value is the only quantity against which the SPE may initially borrow (and later restructure or refinance) any debt.

In the majority of cases, the project SPE raising the debt in question does not own any tangible assets,[5] or owns assets that are so *relationship-specific* that they have little or no value outside of the contractual framework that determines the future CFADS stream, and justifies the investment in the first place.

4. BIS, *Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework*, technical report, Bank of International Settlements, 2005.

5. In the most frequent case of public infrastructure projects financed through a so-called public–private partnership contract, the ownership of the tangible infrastructure also assets remains in the public domain.

Project financing also means that the owners of the SPE provide very little, if any, collateral to secure its debt. Contracts must suffice to create enforceable and valuable claims and to define expected cash flows with reasonable accuracy.[6]

The only form of collateral available to infrastructure project lenders is the "share-pledge" made by the project owners. In the event of default, lenders can try and maximize recovery by securing a larger share of the project future CFADS, including the debt's "tail," that is, the SPE's cash flow beyond the original maturity of the debt and over which lenders have control rights in states of the world embodied by certain covenant breaches. As is the case during the life of the loan, free cash flow in the tail is determined by the contractual arrangements that led to the SPE's creation—for example, the right to collect a toll. There is no terminal value.

Hence, unlike traditional firms, the value of the total assets of an SPE can be observed. This makes structural credit risk models, which derive a firm's credit risk from its total asset value, a natural and more suitable choice than reduced form models, which approach default as a pure hazard rate. We return to this point in more detail below.

The CFADS thus plays a central role in our approach to value infrastructure debt: it is the risky (stochastic) *underlying process* driving value in project finance debt securities, not dissimilar to the stochastic processes referred to in the design of option pricing formulas.

In this context, an important feature of project finance is the role of *initial* financial leverage (agreed at financial close). The ratio of senior debt to total investment in infrastructure project finance typically averages 75%, irrespective of the business or credit cycle, and can be as high as 90% for certain categories of projects with a the most predictable free cash flow.[7]

It can be argued that the high leverage typically observed in project finance should be interpreted as a sign of *low* asset risk,[8] that is, lenders agree to provide most of the funds necessary to carry out the planned investment without further recourse or security because the probability of timely repayment is considered to be very high.

Beyond the predictability of the SPE's business model and therefore its ability to meet the base case debt service agreed at financial close, lenders agree to extend the majority of the necessary funds because of the covenants and embedded options that are found in project finance debt and that create unique state-dependent control rights for them, of the sort that are not found in traditional corporate debt.

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6. See Frédéric Blanc-Brude, "Towards Efficient Benchmarks for Infrastructure Equity Investments," in *EDHEC–Risk Institute Publications*, Meridiam, Campbell-Lutyens, and EDHEC Research Chair on Infrastructure Equity Investment Management and Benchmarking (2013), for a discussion.

7. Frédéric Blanc-Brude and Omneia R H Ismail, "Who is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt," in *EDHEC–Risk Institute Publications*, EDHEC and NATIXIS Research Chair on Infrastructure Debt Investment Solutions (2013).

8. Benjamin C. Esty, "The Economic Motivations for Using Project Finance," *Harvard Business School, mimeo,* (2003).

Covenants and Embedded Options

Because project finance SPEs typically have a high degree of initial leverage, debt contracts often contain covenants to protect debt holders. These covenants can vary from one loan to another, depending on the bank's relationship with the counterparty and the bank's assessment of the project's risk.

Nevertheless, covenants and embedded options commonly found in project finance debt include:[9]

- *Minimum Debt Service Coverage Ratio (DSCR) requirement:* In order to mitigate credit risk, debt covenants often require the borrower to maintain at least a minimum level of the debt service coverage ratio—the ratio of the free cash flow of the SPE to the current period's scheduled debt payment. If the DSCR falls below a pre-agreed threshold, equity dividends can be "locked-up" to create a supplementary cash buffer for debt holders, as well as to create incentives for equity investors to resolve the problems that have led to lower than expected free cash flow (to the extent that it is in their power).
- *Nonfinancial default triggers:* In addition to covenants that trigger default due to financial weakness (missed debt payment, or a decrease in the DSCR below the minimum stipulated level), default can also be triggered by nonfinancial or operational events. For example, events such as the revocation of the SPE's license to perform a business, the failure to complete construction in time, or the default of a counterparty to the SPE, can lead to an event of default. Once this has occurred, the project cannot be managed without lenders' involvement.[10]
- *Step-in option:* Thus, financial and nonfinancial default triggers give lenders an option to "step in," which, in turn, should impact the debt value. In case of a breach of a debt covenant, debt owners have the right to get involved in the management of the project company. In this context, debt holders can put in a "cash sweep" to accelerate debt payments, or reschedule debt payments to gain more financial flexibility to resolve outstanding issues.
- *Cash sweeps:* Cash sweeps are a form of compulsory prepayment. After an agreed-upon distribution to shareholders, which can be zero, any remaining CFADS balance is used to prepay the debt. This is to minimize the effects of substantial fluctuations in cash flows on credit risk and to use the excess cash generated in good periods to reduce outstanding debt and protect against periods with lower than expected cash flows. Of course, cash sweeps introduce prepayment risk for investors.

9. See E R Yescombe, *Principles of Project Finance*, Academic Press, 2002.
10. See Yescombe, *Principles of Project Finance*, section 13.11.

- *Cash claw-back:* Under a claw-back provision, equity investors agree that if problems occur with future cash flows, they will repay or lend to the project company up to the amount they have received in dividends or other distributions over a set period of time.
- *Reserve accounts:* Reserve accounts are established to reserve cash during periods of higher earnings to service debt payments during periods of lower earnings. These accounts provide security for lenders against short-term cash problems, and can also be set up to fund future expenditures. Reserve accounts may also segregate funds based on their use. For example, debt service reserve account (DSRA) contains funds to service next period's debt payment (principal + interest), and tax reserve accounts contain funds to pay tax liabilities that have been incurred but would be paid in the future.
- *Prepayment option:* Project loans often allow prepayments at little to no cost. If the project does well, the SPE may take advantage of this prepayment option to refinance at lower rates. However, with the development of institutional investors' involvement in lending to infrastructure projects, prepayment may become more penalizing for SPEs since these investors tend to be looking for instruments with a known duration.

Note that traditional capital budgeting methods would fail to take into account the effects of these covenants and embedded options. Structural credit models, on the other hand, can incorporate the effects of these covenants through their effect on the cash flows to debt holders.

Default Triggers

Default mechanisms in project finance have two important dimensions: first, the default point is more straightforwardly known than in standard corporate finance; and second, the presence of debt covenants that impose other obligations on the borrower in addition to the debt repayment means that *technical* defaults are a prevalent form of credit event.

In structural models of standard corporate debt, default is generally modeled as crossing a threshold point below which the total value of the firm's assets is less than its short- and medium-term liabilities. This is because as long as the total value of the firm is higher than its near term liabilities, equity holders can raise more cash by issuing new equity or debt and satisfy their current debt obligations. For infrastructure SPEs, this is not the case because equity holders are constrained in their ability to raise more cash by issuing new debt or equity to preserve the value of existing debt holders' security.[11] The non-recourse nature of the equity investment and the inability of the firm to increase its borrowing make default easier to predict than in standard corporate finance.

11. See Yescombe, *Principles of Project Finance*, sections 13.7 and 13.10.

In project finance, the relationship between the firm's free cash flow or cash flow available for debt service (CFADS) and the expected senior debt service, that is, the ability of a given SPE to service its senior debt obligation, is captured by a debt service cover ratio (DSCR), which is routinely monitored by project finance lenders for each SPE. The DSCR at time t is written as

$$\mathrm{DSCR}_t = \frac{\mathrm{CFADS}_t}{\mathrm{DS}_t^{\mathrm{BC}}} \tag{20-1}$$

in each period $t = 1, 2, \ldots T$ for a project financing of maturity T; $\mathrm{DS}^{\mathrm{BC}}$ is the base case debt service. As a function of the CFADS, that is, the distribution of the DSCR at time t (DSCR_t) in project finance can capture both the firm's asset value and its volatility. Moreover, the DSCR provides an *unambiguous* definition of default.[12]

Thus, a "hard" default of the SPE (a default of payment) can be defined in terms of the *ex post* CFADS at time t as

$$\mathrm{Default}_t \Longleftrightarrow \mathrm{CFADS}_t < \mathrm{DS}_t^{\mathrm{BC}} \tag{20-2}$$

which can be expressed in terms of *ex post* $DSCR_t$ as

$$\mathrm{Default}_t \Longleftrightarrow \mathrm{DSCR}_t = \frac{\mathrm{CFADS}_t}{\mathrm{DS}_t^{\mathrm{BC}}} < 1 \tag{20-3}$$

By definition, if DSCR_t equals unity, the SPE is just able to service its senior debt during the relevant period, and if it falls below unity, the borrower can unambiguously be considered in default.[13]

Credit events may also be defined more loosely. For example, in the Basel II framework, project finance default is defined as "*past-due more than 90 days on any material credit obligation to the banking group.*"[14]

Thus, unlike standard corporate debt where covenants typically only relate to the financial state of the firm, project finance SPEs can also experience *soft* or *technical* defaults; for example, a low *ex post* DSCR may constitute a breach of the loan's covenants and also be considered an event of default.

The formulation of the default point above suggests that credit events can be very finely defined in project finance and that lenders may consider an SPE to be in default and take remedial action long before it has become unable to repay its debt.

Ex ante, that is, at the time of financial close, lenders typically require the DSCR to be significantly higher than unity in order to create a credit-risk

12. Frédéric Blanc-Brude and Majid Hasan, *Infrastructure Valuation*, London: PEI Media, March 2015.

13. Moody's defines project finance default as "a missed or delayed disbursement of interest and/or principal." Moody's, *Default and Recovery Rates for Project Finance Bank Loans 1983–2011*, technical report (London, U.K.: Moody's Investor Service), Feb. 2013, is congruent with this view.

14. BIS, *Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework.*

buffer and also so that equity/junior distributions can be made once senior debt obligations have been met. *Ex post*, if DSCR_t is too low, it can trigger one of the covenants described above.

Hence, the default point in project finance at time t can be defined as

$$\text{DSCR}_t = 1.x \text{ with } x \geq 0$$

And since the DSCR provides an unambiguous default point of infrastructure project finance debt, its probability of default at time t can be written as

$$p_t = \Pr(\text{DSCR}_t < 1.x \mid \min_{j<t} \text{DSCR}j \geq 1.x)$$

which is the probability that the DSCR reaches the default point, conditional on there having been no default until that time.

Hence, knowledge of the distribution of DSCR_t for a category of project financing and of the DSCR-related covenants of a given loan is sufficient to identify and predict default in project finance. We also show that knowledge of the first two moments of the distribution of DSCR_t is sufficient to derive the SPE's distance to default, which is instrumental in our valuation model.

Restructurings

Restructurings are the result of the embedded options discussed above. We use the term restructurings or "workouts" to refer to any change in the SPE's capital structure or debt service schedule (face value, maturity, and seniority) from the base case scenario. Such workouts are very common in project finance.[15]

SPEs are restructured both during financial distress (to avoid bankruptcy), and when the firm's free cash flow is sufficiently high (to take advantage of a lower credit risk to refinance at lower rates). The suitability of refinancing depends on the maturity of existing debt, debt covenants that may penalize refinancing, and external market conditions. If the debt covenants allow refinancing at little to no cost, as is usually the case with bank loans,[16] and demand for infrastructure projects is high, an SPE may be able to refinance at lower costs. However, if the existing debt is expiring soon and the demand for infrastructure debt is low, refinancing can be costly. Long-term investors' greater aversion to refinancing, which can significantly reduce the duration of their fixed income portfolio may lead to the more frequent introduction of prepayment charges and to fewer refinancings.

Such workouts can change the SPE's debt service schedule and hence its default threshold can also deviate from the base-case scenario.

Crucially, in the case of workouts triggered by financial distress, the period between the maturity of the debt and the maturity of the project, the so-called the "tail" of the loan, can allow for debt service restructurings that leave the value of

15. See Yescombe, *Principles of Project Finance*, sections 7.7 and 13.6.
16. See Yescombe, *Principles of Project Finance*, section 13.6.

the initial debt quasi- or completely intact. It allows debt holders to restructure debt schedule and recover any losses suffered during the original maturity of the debt.[17]

Next, we look at the determinants of credit spreads in infrastructure debt.

PRICING DETERMINANTS

Despite project finance being a subset of corporate debt, existing research suggests that the drivers of corporate debt spreads do not necessarily impact project finance credit spreads in the same ways, and vice versa. Here, we summarize some of the key findings of the existing academic literature on the determinants of credit spreads in infrastructure debt.

The literature on corporate finance acknowledges that credit spreads should have multiple determinants.[18] For example, Churm and Panigirtzoglou identify three components of credit spreads: expected default, credit risk (uncertainty about probability of default), and non-credit risk, which is highly correlated to swap spreads[19] for investment-grade debt. The noncredit-risk component, attributed to liquidity, tax, or regulatory effects, increases as the credit-risk component increases, consistent with the empirical evidence that lower-quality credits have higher credit default swap bid-ask spreads and that a small proportion of swap spreads is due to credit risk.

Likewise, existing research about the determinants of infrastructure project finance debt credit spreads suggests a range of potential factors:

- *Maturity:* Unlike in traditional corporate finance, a longer tenor may not equate to greater risk and larger spreads for lenders.[20] Consistent with the inference that high leverage signals low asset risk in project finance, longer maturities can signal greater lender confidence. Previous researchers have found that the credit spread term structure in project finance, unlike other types of debt, is *hump-shaped*—beyond a certain maturity, longer-term projects are cheaper than short-term ones.[21] The authors attribute this to the dependence of project finance debt repayments on project cash flows, which makes longer tenors beneficial. Additionally, time-idiosyncratic risks like construction risk dissipate

17. See Yescombe, *Principles of Project Finance*, sections 12.9.4 and 13.2.

18. Rohan Churm and Nikolaos Panigirtzoglou, *Decomposing Credit Spreads*, technical report, Bank of England, 2005.

19. Swap spreads refer to the difference between interest rate swaps and comparable Treasury yields.

20. Blanc-Brude and Ismail, "Who is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt"; Stefanie Kleimeier and William L Megginson, "Are Project Finance Loans Different from Other Syndicated Credits?" *Journal of Applied Corporate Finance* 13 (spring 2000), pp. 75–87; Marco Sorge and Blaise Gadanecz, "The Term Structure of Credit Spreads in Project Finance," *International Journal of Finance and Economics* 13 (2008), pp. 68–81.

21. Marco Sorge, "The Nature of Credit Risk in Project Finance," *BIS Quarterly Review* (2004); Sorge and Gadanecz, "The Term Structure of Credit Spreads in Project Finance."

with longer maturities.[22] However, Blanc-Brude and Strange suggest that this may be a dynamic effect due to changing market conditions rather than evidence of a nonlinear term structure.[23] In a panel regression of spreads, year and country effects were found to be much stronger drivers of the spreads in project loans. Similarly, Gatti and colleagues do not find a statistically significant relationship between maturity and spread.[24]

- *Leverage:* Spreads are found to have a positive relationship with leverage, signaling a tradeoff between cheaper credit and reduced equity contribution.[25]
- *Size:* Loan size and project finance credit spreads have a negative relationship.[26] However, the effect in project loans is three to four times smaller than in the corporate debt control groups.[27] Kleimeier and Megginson found the relationship to be statistically insignificant.[28]
- *Syndicate size:* The hypothesis that the number of creditors has an impact on spreads is not overwhelmingly supported by empirical evidence. While Etsy and Megginson[29] found that loan pricing is positively related to the number of arranging banks and the shares held by them,[30] they did not find a significant relationship between syndicate size and spreads.
- *Ratings:* Likewise, the impact of credit ratings is not clear-cut. Gattti and colleagues find that rated project debt has higher spreads and argues the very decision to rate project debt signals higher *ex ante* project risk.[31] Most project finance debt is, however, unrated.

22. Blanc-Brude and Ismail, "Who Is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt."
23. Frédéric Blanc-Brude and Roger Strange, "How Banks Price Loans to Public–Private Partnerships: Evidence from the European Markets," in *Journal of Applied Corporate Finance* 19(4), pp. 94–106.
24. Stefano Gatti et al, "Arranger Certification in Project Finance," *Financial Management* 42 (2013), pp. 1–40.
25. Francesco Corielli, Stefano Gatti, and Alessandro Steffanoni, "Risk Shifting through Nonfinancial Contracts: Effects on Loan Spreads and Capital Structure of Project Finance Deals," *Journal of Money, Credit and Banking* 42(7), pp. 1295–1320.
26. Sorge, "The Nature of Credit Risk in Project Finance."
27. Blanc-Brude and Ismail, "Who Is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt."
28. Kleimeier and Megginson, "Are Project Finance Loans Different from Other Syndicated Credits?"; Blanc-Brude and Strange, "How Banks Price Loans to Public–Private Partnerships: Evidence from the European Markets."
29. Benjamin C. Esty and William L. Megginson, "Syndicate Structure as Response to Political Risk in the Project Finance Loan Market."
30. Blanc-Brude and Strange, "How Banks Price Loans to Public–Private Partnerships: Evidence from the European Markets."
31. Gatti et al., "Arranger Certification in Project Finance."

- *Debt seniority:* In general mezzanine or subordinated debt is found to have higher spreads, reflecting a higher degree of risk for creditors who are not senior in the cash-flow waterfall.[32]
- *Guarantees:* Guarantees extended by multilateral banks are generally found to reduce average spreads.[33] Kleimeier and Megginson find also find that among all forms of corporate debt, project finance loans display the greatest sensitivity to third-party guarantees, with a higher reduction in average spreads.[34] The same effect is found by Kleimeier and Megginson.[35]
- *Business risk:* The uncertainty inherent in the business model of the borrower is another proxy for credit risk. Infrastructure projects that have a long-term, contracted revenue stream can raise debt that is systematically cheaper than those whose revenues are exposed to demand risk.[36]
- *Refinancing:* Blanc-Brude and Strange find that refinanced loans tend to have lower spreads by up to 50 bps.[37] In a number of cases, credit spreads are planned to increase post-construction to encourage debt refinancings.[38]

In a recent study, Coelho considers and recomputes the results of most of the studies above and confirms these findings with a more recent. [39] Thus, the research literature suggest that project finance debt is priced quite differently than corporate debt.

However, these studies suffer from a number of limitations. For the purpose of explaining the determinants of credit spreads, existing studies all use linear regression techniques, implying that the determinants of credit spreads do not fundamentally change over time but instead that risk pricing tends to revert to a long-term mean.

Most studies use data sets that generally predate the 2008 credit crisis, which resulted in a step change in the level of credit spreads in private debt as a result of a shock to creditors' cost of funds, followed by the evolution of the

32. Blanc-Brude and Strange, "How Banks Price Loans to Public–Private Partnerships: Evidence from the European Markets."
33. Gatti et al., "Arranger Certification in Project Finance."
34. Kleimeier and Megginson, "Are Project Finance Loans Different from Other Syndicated Credits?"
35. Sorge, "The Nature of Credit Risk in Project Finance."
36. Blanc-Brude and Ismail, "Who Is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt."
37. Blanc-Brude and Strange, "How Banks Price Loans to Public–Private Partnerships: Evidence from the European Markets."
38. Blanc-Brude and Ismail, "Who Is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt."
39. José Pedro Ferreira Coelho. "The Term Structure of Credit Spreads in Syndicated Loans: A Comparative Analysis between Corporate Control, Capital Structure, and Project Finance Loans." Ph.D. thesis, 2016.

average creditor's risk preferences, partly due to new regulation of the banking sector and partly to the entry of new types of creditors in the private debt sector.

Even though more recent papers[40] do take into account the 2008–2009 credit market dislocation event, they fail to capture the evolution of individual risk premia over time. Instead, they fit a static linear model through a time series with nonlinear, non-stationary characteristics.

Moreover, existing studies solely relying on observable spreads over time. Hence, if certain types of private infrastructure debt become less likely to be originated over a period, though such assets are still held on the balance sheet of an investor at that time, they may not be adequately valued using current market spreads.

In a more recent study,[41] Blanc-Brude and Yim develop a dynamic model of the determinants of credit spreads to estimate the evolution over time of the individual risk-factor premia and determine their *unbiased* effects on spreads over time.

They show that infrastructure and corporate credit spreads are determined by a combination of common factors that can be grouped into four categories:

- *Credit market beta:* The largest effect driving credit spreads in infrastructure debt is a time-varying trend factor that captures the state of the credit market over time. This effect is not explained by loan or borrower characteristics. In the case of infrastructure debt, this effect is mostly constant over time but exhibits "regime shifts," especially in 2008 (up) and 2014 (down).
- *Credit risk:* This only explains part of the level of credit spreads.
    - Infrastructure borrowers that are exposed to *merchant risk* (See TICCS® Taxonomy) are required to pay a time-varying premium from 20–40% above the market average at the time.
    - Size has no effect on average corporate spreads but is a driver of lower risk premium in infrastructure debt. In effect, larger loans can be interpreted as a signal of lower credit risk in infrastructure finance.
    - Industrial sectors can be considered a partial proxy for credit risk but are mostly not significant, except for social infrastructure and, among corporate borrowers, infrastructure corporates, which have come to benefit from a substantial discount relative to average market spreads in recent years.

40. Blanc-Brude and Ismail, "Who Is Afraid of Construction Risk? Portfolio Construction with Infrastructure Debt"; Coelho, "The Term Structure of Credit Spreads in Syndicated Loans."
41. Blanc-Brude and Yim, "The Pricing of Private Infrastructure Debt: A Dynamic Approach."

- *Liquidity:* Other drivers of spreads are proxies of the cost of liquidity for creditors.
    - *Maturity:* While it is difficult to capture in static models, maturity is found to be a significant and time-varying driver of spreads.
    - While the effect of size is primarily a matter of credit risk, in periods of limited creditor liquidity (2008), even infrastructure debt becomes more expensive as a function of size. However, this effect is not strong enough to create a persistent "size premium."
    - Refinancings, which are not a significant driver of spreads in normal times, are shown to be more expensive in times of credit-market stress.

- *Cost of funds:* The benchmark against which floating-rate debt is priced is a factor explaining the level of credit spreads.
    - Base rates are inversely related to spread, that is, higher rates imply lower spreads, but this effect is shown to have all but vanished since 2008. Since then, the level of credit spreads and that of base interest rates has become completely uncorrelated.
    - *Market segments:* Taking base rates into account, some markets are cheaper than others as a result of the well-documented segmentation of credit markets. This is the case when comparing LIBOR- versus Euribor-priced loans, but also the different geographic areas in which different lenders operate. Again, since 2008, these differences have tended to disappear.

The dynamic modeling of illiquid debt spreads in Blanc-Brude and Yim allows overcoming structural limitations in the data: observable spreads are biased due to the segmentation and low liquidity of the private credit market, but *unbiased* factor prices (premia) can be estimated from observable spreads and used to determine the factor-implied spreads for any instrument at any time.

The time-varying nature of individual risk premia implies that repricing individual instruments over time can be material and is required if such investments are to be evaluated on a *fair-value* basis.

One of the most important requirements of the IFRS framework is to *calibrate valuations to observable market prices*, thus ensuring that estimated spreads represent current investor preferences at the measurement time. While fair value is not always required for debt instruments, which tend to be booked at cost (outstanding face value) unless they become impaired, the requirement to evaluate assets on a like-for-like basis only grows as the private debt asset class becomes a more significant part of investors' portfolios.

Next, we look at how to approach credit risk in private infrastructure debt.

CREDIT RISK

The extensive control rights of lenders of infrastructure debt are central to understanding its credit risk profile: infrastructure debt is designed to avoid default of payment events, or hard defaults, because these instruments are the object of continuous and extensive monitoring, any material degradation of the credit risk profile of the borrower (e.g., delays, cost overruns, low DSCR, etc.) can trigger a lender-driven restructuring in order to mitigate credit risk and avoid a hard default.

As a result, actual hard defaults can be very rare, sometimes unheard of in certain infrastructure debt portfolios. Of course, the absence or rarity of hard defaults does not mean that credit risk is negligible in infrastructure debt. Rather, with project finance debt credit risk is managed on an ongoing basis. This has two important implications:

1. Infrastructure project debt requires costly monitoring.
2. Because credit risk is dynamic (and endogenous), the usual reduced-form models of default risk are not adequate to measure or model the credit risk of infrastructure debt instruments.

Reduced Form Approach

The limits of reduced form credit risk models is well illustrated by the empirical default studies conducted by rating agencies, which consists of measuring the number of defaults observed within a population of loans at a given point in time and in each loan's life cycle. These studies all imply a reduced form approach because rely on observing discreet events of default, i.e., they derive an implicit "hazard rate" from observed hard defaults, which is the common approach when estimating corporate debt default frequencies.[42]

Several stylized facts are frequently abstracted from these reports:

- On average, the available sample of project finance loans exhibits marginally decreasing cumulative default rates in time, which is the result of a decreasing annual probability of default as project loans mature.
- As a consequence, project finance debt exhibits continuous default risk transitions over a period of approximately 10 years, from a triple-B equivalent to a single-A equivalent. The observed probability of default in available samples trends from around 2% around the time of financial close to near zero after 10 years.

However, observed hard defaults in project finance debt are also clustered in time and space: in sector or countries which experienced a market shock

42. See, for example, Edward I. Altman and Heather J. Suggitt, "Default Rates in the Syndicated Bank Loan Market: A Mortality Analysis," *Journal of Banking and Finance* 24(1–2), pp. 229–253.

(merchant power in the the United States in the early 2000s) or a sector-wide policy reversal (retroactive changes in solar power subsidies in Spain in the early 2010s) or went through a brief moment of over-optimism and "covenant-light" deals (the toll road sector in Spain or Australia in the mid-2000s), defaults of payment can be hard to avoid even with the protection and step-in rights that are available to lenders.

Moreover, if projects are financed that are fundamentally uneconomic or face a shock that makes them durably so, lenders may have little interest in "working-out" the best financial structure going forward and can decide to "wipe out" the project owners instead and sell the project to distressed asset investors to minimize their loss. Evidence suggests that in this rare case, lender haircuts are significant.[43]

In the majority of cases, workouts do take place after a "soft" or technical default, and hard defaults never materialize. Again, this should not be understood to mean that the risk of hard default is low. Rather it is conditionally low, if the adequate monitoring is in place and effective and successful workouts are possible. If these conditions are not met in some projects, then the probability of hard default may be quite high.

As a result, reduced forms approaches to infrastructure debt credit risk are likely to provide very biased results since very few defaults are observable and they are unlikely to be representative of the credit risk that characterizes different types of infrastructure borrowers.

Structural Approach

Unlike reduced form models that specify a default process exogenously, structural models postulate the existence of a default triggering mechanism, that is, a discrete event at the threshold between two states (default vs. no default), the probability of which is determined endogenously. In other words, default events do not occur randomly but are linked to a firm's assets and liabilities. Structural models assume a link between the firm's fundamentals (assets and liabilities) and its credit risk variables and predicts credit events from the change in these fundamentals.

In Merton's classic model of valuation of corporate debt, the value of the company follows a stochastic process (Vt).[44] The company is financed from debt and equity, its debt is a single obligation and resembles a zero-coupon bond with face value B and maturity T. At time t, the value of the firm is the sum of its equity St and debt Bt ($Vt = Bt + St$, for $0 < t < T$). In this model, the firm does not pay any dividends nor issues any new debt. If at maturity the value of the firm

43. See also Majid Hasan and Frédéric Blanc-Brude, "You Can Work It Out! Valuation and Recovery of Private Debt with a Renegotiable Default Threshold," *Journal of Fixed Income* 26 (2017), pp. 113–127, for a game theoretic model of debt restructuring in project finance.

44. Robert C Merton. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29 (1974), pp. 449–470.

is less than its liabilities ($VT < B$), the firm is considered to be in default. The equity holders then choose not to provide any new equity capital as an expression of their "limited liability option" and hand over the firm to the debt holder, which liquidates the remaining assets and receive the proceeds $B_T = V_T$. If there is no default, the debt holder receives the payoff B, and equity holders receive the remainder of the firm's value $V_T - B$.

The original Merton model has been criticized for making a number of strong assumptions, including a simplistic capital structure (the firm borrows once and subsequently deleverages) and the idea that the default point is not only known unambiguously, but the firm must default exactly when this point is reached, neither of which is self-evident empirically for corporate credits.

However, the Merton model is rather well-suited to project financing: SPEs borrow once and subsequently deleverage, default is unambiguously known and actively monitored, and the underlying process driving asset value (CFADS) can be captured by the distribution of the DSCR.

Indeed, given the definition of DSCRt given above, the CFADS for a given period is simply obtained as

$$\text{CFADS} = \text{DSCR}_t \times \text{DS}_t^{\text{BC}} \tag{20-4}$$

with DS_t^{BC}, the debt service. The same relationship holds in expectation. Hence, as long as the base case debt service is known, we can reduce the question of modeling the free cash flow of the firm in project finance to that of the dynamics of DSCRt and its determinants.

Furthermore structural models have been further developed to extend the original Merton model and address most of the issues found in the asset pricing literature. These include models that incorporate complex capital structures[45] and endogenous default thresholds.[46]

Structural models are thus the most suitable choice for infrastructure project debt, as the primary input of these models is the value of the firm's assets and loan covenants, which we know can be observed in the case of SPEs, and because they can incorporate the endogenous credit risk dimension.

45. Philip Jones, Scott Mason, and Eric Rosenfeld, *Contingent Claims Valuation of Corporate Liabilities: Theory and Empirical Tests,* University of Chicago, 1985; Philip E Jones, Scott P Mason, and Eric Rosenfeld, "Contingent Claims Analysis of Corporate Capital Structures: An Empirical Investigation," *Journal of Finance* 39 (1984), pp. 611–625; Fischer Black and John C Cox. "Valuing corporate securities: Some effects of bond indenture provisions," *Journal of Finance* 31 (1976), pp. 351–367; Francis A. Longstaff et al. "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt," *Journal of Finance* 50 (1995), pp. 789–819.
46. Hayne E. Leland, "Corporate Debt Value, Bond Covenants, and Optimal Capital Structure," *Journal of Finance* 49 (1994), pp. 1213–1252; Ronald W. Anderson and Suresh Sundaresan. "Design and Valuation of Debt Contracts," in *Review of Financial Studies* 9 (1996), pp. 37–68.

Blanc-Brude and Hasan demonstrate how the standard distance to default metric can be derived for infrastructure debt using only the first two moments of the DSCR distribution.[47]

In the KMV model, Crosbie and Bohn[48] posit that the "distance to default" is a sufficient statistic to arrive at a rank ordering of default risk. The firm's distance to default can be approximated as

$$\text{Distance to Default} = \frac{[\text{MV}] - [\text{DT}]}{[\text{MV}]\ .\ [\text{Vol}]} \tag{20-5}$$

where MV is the market value of assets, DT is the default threshold, and Vol is the standard deviation of the annual percentage change in the asset value.[49] The numerator expresses the firm's financial leverage, or *financial risk*, while the denominator reflects its *business risk*. In other words, KMV assumes that differences between the credit risk of different companies are reflected in the value and volatility of their assets, as well as their capital structure, which are all present in the distance to default measure.

Following the definition of default in infrastructure project finance given above, distance to default at time t can be defined as

$$\text{DD}t = \frac{\text{CFADS}_t - \text{DS}_t}{\sigma_{\text{CFADS}_t}\,\text{CFADS}_t} \tag{20-6}$$

with CFADSt, the cash flow available for debt service, and DSt, the debt service at time t.

Using the definition of DSCRt above, the above expression can be written as a sole function of the DSCR:[50]

$$\text{DD}t = \frac{1}{\sigma_{\text{DSCR}_t}}\,\frac{\text{DS}^{\text{BC}}_{t-1}}{\text{DS}^{\text{BC}}_t}\left(1 - \frac{1}{\text{DSCR}_t}\right) \tag{20-7}$$

where σ_{DSCR_t} is the standard deviation of the annual percentage change in the DSCR value. Hence, the first two moments of the distribution of DSCR$_t$ together with the debt repayment profile (the growth rate of the debt service defined by DS$_t$ – 1/DS$_t$) are sufficient inputs to estimate the distance to default of project finance debt instruments.

47. Frédéric Blanc-Brude and Majid Hasan, "A Structural Credit Risk Model for Illiquid Debt," *Journal of Fixed Income* 26 (Summer 2016).

48. Peter Crosbie and Jeff Bohn, *Modeling Default Risk*, technical report, Moody's KMV, 2003.

49. Crosbie and Bohn, *Modeling Default Risk*.

50. See Blanc-Brude and Hasan, "A Structural Credit Risk Model for Illiquid Debt," for a complete derivation.

Empirical Validation

Blanc-Brude, Hasan, and Whittaker[51] propose a Bayesian estimation of the DSCR process in different types of infrastructure projects and derive unbiased measures of credit risk in private infrastructure debt using a data set of the financials of hundreds of private infrastructure borrowers.[52]

The left panel of Exhibit 20-1 shows the unconditional probability that DSCR*t* falls below the hard default threshold at each point in the life cycle of projects. Only the first default of payment is counted, which is consistent with Moody's definition of default (missing one payment) and computation of marginal default frequencies.[53]

Consistent with rating agencies results, project finance borrowers tend to de-risk over time. However, at the aggregate level (black line), marginal default frequencies are higher than in the reports produced by Moody's.[54] This is because a structural model measures all potential defaults, as opposed to a biased sample of actual credit events. After 10 years, conditional on no default until that time, default risk in infrastructure debt is typically not equal to zero, in contrast with the conclusion of reduced form approaches but more in line with actual credit ratings.

In calendar time (right panel of Exhibit 20-1), the aggregate default risk follows the business cycle, decreasing from the early 2000s until the 2008 financial crisis and increasing again from 2009 onward. This is consistent with previously reported evidence. Here, the default risk of "merchant" projects that have a business model more exposed to the economic cycle (e.g., toll roads) also tends to increase more markedly at bad times in the economic cycle, as illustrated by the blue line on Exhibit 20-1. Infrastructure projects that have very predictable cash flows (and the resulting higher leverage) like PFI projects[55] have very low default rates at all times and countries where such projects are more commonly found (e.g., the U.K.) and also exhibit lower default risk than the average infrastructure borrower.

51. Frédéric Blanc-Brude, Majid Hasan, and Timothy Whittaker, "Calibrating Credit Risk Dynamics in Private Infrastructure Debt," *Journal of Fixed Income* 27 (2018), pp. 54–71.

52. The dataset includes 267 projects spanning two revenue risk families ("Contracted" and "Merchant"), in seven sectors (Transportation, Telecoms, Oil & Gas, Industrial, Government Services, Environmental Services, and Energy), from the 2000 to 2016, from all major European markets (U.K., Spain, France, Italy, Portugal, Germany, Norway, Sweden, Ireland, the Netherlands, Poland, Slovakia, and Austria).

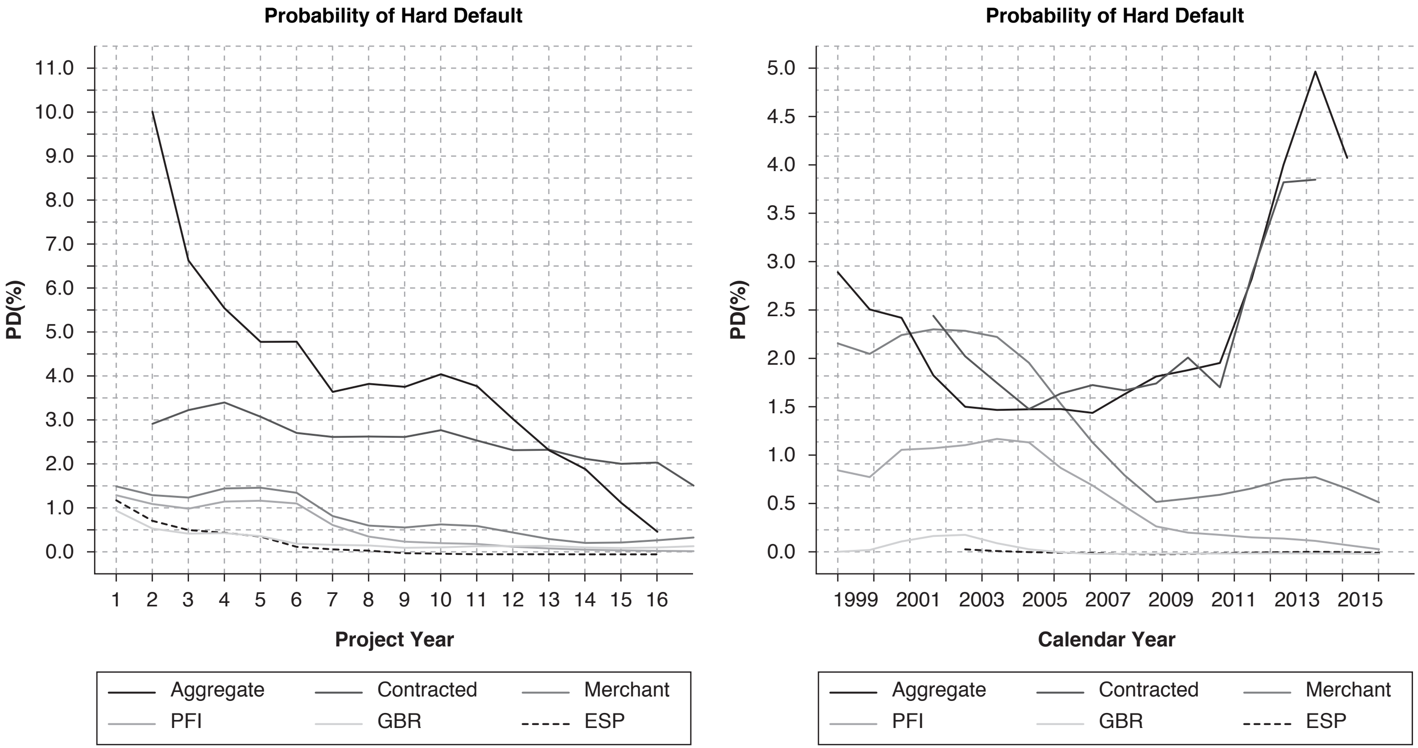
53. Moody's. *Default and Recovery Rates for Project Finance Bank Loans, 1983–2015*, technical report, Moody's Investors Service, 2017.

54. Moody's, *Default and Recovery Rates for Project Finance Bank Loans, 1983–2015*.

55. The Private Finance Initiative (PFI) is a U.K. procurement policy that led to the creation of several hundred infrastructure project companies all of which provided an infrastructure service in exchange for a pre-agreed revenue stream paid by the public sector.

EXHIBIT 20-1

Probabilities of Hard Default over Time, Computed as the Probabilities of DSCR*t* Falling Below 1.0



KEY POINTS

- Both theory and empirical evidence suggest that private infrastructure debt is different from other forms of corporate debt.
- The determinants of its pricing are different and its credit risk profile is in great part determined by the monitoring, control rights, and resulting embedded options that can be exercised by creditors in order to manage credit risk on an ongoing basis, mitigate default risk, and maximize recovery.
- The requirement to monitor infrastructure project borrowers also implies higher servicing costs and the credit quality of these instruments must then be closely related to the quality of the monitoring.
- Credit risk management requires advanced modeling to overcome the paucity of default event data, which may be a challenge for smaller investors and complicates the prudential treatment of this asset class.

PART
FOUR

MORTGAGE-BACKED AND ASSET-BACKED SECURITIES

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CHAPTER

TWENTY-ONE

AN OVERVIEW OF MORTGAGES AND THE MORTGAGE MARKET

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Over the last few decades, the mortgage market in the United States has emerged as one of the largest financial asset classes. As of the third quarter of 2019, the total face value of one- to four-family residential mortgage debt outstanding was approximately $11 trillion, with more than $8 trillion having been securitized into a variety of investment vehicles. As a point of comparison, at the same point in time, the outstanding amount of marketable U.S. Treasury notes and bonds totaled roughly $12 trillion. For a variety of reasons, such as product innovation, technological and regulatory changes, and evolving consumer and lender preferences, the composition of the primary mortgage market continues to evolve on a fairly dynamic basis. The mortgage lending paradigm has undergone a number of profound changes over the past two decades. Between 2002 and mid-2007, there was a proliferation of product offerings designed to both appeal to changing consumer preferences and broaden the range of borrowers that could qualify for mortgage loans. While this had the effect of increasing the home ownership rate in the United States, it eventually led to a disastrous combination of relaxed underwriting standards and inflated values for residential real estate. The subsequent financial crisis led to the collapse of numerous large financial firms and lenders, as well as Freddie Mac and Fannie Mae, which were placed into conservatorship in 2008. While underwriting and lending practices have subsequently evolved to comply with a new regulatory framework, at this writing many aspects of the mortgage market and housing finance, including the form that Freddie Mac and Fannie Mae will ultimately take, remain unclear and the subject of intense debate and speculation.

The purpose of this chapter is to outline fundamental aspects of the mortgage markets in the context of the post-crisis industry and regulatory environment. We will define the terminology and metrics associated with various mortgage products, describe the process by which lenders compute their loan pricing, and discuss the different risks associated with mortgage products.

PRODUCT DEFINITION AND TERMS

In general, a mortgage is a loan that is secured by the underlying real estate that can be repossessed in the event of default. For the purposes of this chapter, a mortgage is defined as a loan made to the owner of a one- to four-family residential dwelling and secured by the underlying property. Standard product offerings are level-pay "fully amortizing" mortgages, indicating that the obligor's monthly payments are calculated in equal increments to pay off the loan over the stated term. There are, however, a number of key characteristics that are considered critical in understanding the instruments, and they are differentiated along the following attributes.

Lien Status

The lien status dictates a loan's seniority in the event of the forced liquidation of the property owing to default by the obligor. The preponderance of mortgage loans originated have first-lien status, implying that a creditor would have first call on the proceeds of liquidation of the property if it were to be repossessed. Borrowers have often used second-lien loans as a means of liquefying the equity a home for the purpose of expenditures (such as medical bills or college tuition) or investments (such as home improvements). A second-lien loan also may be originated simultaneously with the first lien in order to maintain the first-lien loan-to-value (LTV) ratio below a certain level. A fairly common practice prior to mid-2007, this allows the obligor to avoid the need for mortgage insurance, which is required for loans with LTVs greater than 80%.

Original Loan Term

The majority of mortgages are originated with a 30-year term and amortize on a monthly basis. Loans with stated shorter terms of 10, 15, and 20 years also are utilized by borrowers who are motivated by the desire to own their home earlier. Among these mortgages, where the monthly mortgage payment is inversely related to the term of the loan, the 15-year mortgage is the most common instrument. Small numbers of loans are also structured to have so-called balloon payments. The loan amortizes over a 30-year term; however, at a preset point in time (the "balloon date," generally five or seven years after issuance) the borrower must pay the balance of the loan in full.

Interest-Rate Type (Fixed vs. Adjustable Rate)

As is indicated by the nomenclature, fixed-rate mortgages have an interest rate that is set at the closing of the loan (or, more accurately, when the rate is "locked" by the borrower) and is constant for the loan's term. Based on the loan balance, interest rate, and term, a payment schedule effective over the life of the loan is calculated to amortize the principal balance. Note that while the monthly payment is constant over the life of the loan, the allocation of the payment into interest and principal changes over time, as we will demonstrate later in this chapter. During the earlier years of the loan, the level-pay mortgage consists mainly of interest, whereas the constant payment is composed mainly of principal in the later years of the life of the loan.

Adjustable-rate mortgages (ARMs) have note rates that change over the life of the loan. The note rate is based on both the movement of an underlying rate (the index) and the spread over the index (the margin) required for the particular loan program. A number of different indexes, such as the one-year Constant Maturity Treasury (CMT) and the London Interbank Offered Rate (LIBOR) can be used to determine the reference rate. (As LIBOR is scheduled to be discontinued after 2021, other rates, such as the Secured Overnight Financing Rate [SOFR], are being contemplated as replacement indices for ARMs.) ARMs typically adjust or reset annually, although instruments with alternative reset frequencies are originated. Owing to competitive considerations, the initial rate is often somewhat lower than the so-called fully indexed rate. In this case, the initial rate is referred to as a "teaser rate." In any case, the note rate is subject to a series of caps and floors that limit how much the note rate can change at the reset. Structurally, the caps serve to protect the consumer from the payment shock that might occur in a regime of rising rates, whereas the floor acts to protect the interests of the holder of the loan by preventing the note rate from dropping below predefined levels. The vast majority of adjustable-rate loans have 30-year terms.

The most commonly originated type of ARM is the fixed-period or hybrid ARM. These loans have fixed rates that are effective for longer periods of time (3, 5, 7, and 10 years) after funding. At the end of the period, the loans reset in a fashion very similar to that of more traditional ARM loans. Hybrid ARMs appeal to borrowers who desire a loan with lower initial payments (because ARM rates generally are lower than rates for 30-year fixed-rate loans) but without as much payment uncertainty and exposure to changes in interest rates as ARMs without the fixed-rate period.

Amortization Schemes

As noted, mortgages traditionally have been originated as fully amortizing instruments, meaning that some portion of all payments is dedicated toward reducing the loan's balance. Alternative amortization patterns that grew increasingly popular prior to 2007, particularly in the ARM market, were interest-only loans. The product's payments are divided into two stages. During the interest-only phase, the borrower's monthly payments consist only of interest, and are calculated as a simple function of the loan's note rate and balance. When the interest-only period ends, the loan is recast (i.e., its payments are recalculated) to reflect the loan's remaining term. This means that the loan's payments increase at some point after origination; this phenomenon, called payment shock, caused financial problems for borrowers that were unable to make the higher post-recast payments. A simple example at this point will be helpful. A loan with a balance of \$100,000 and a 6% note rate would have a monthly payment of \$600 calculated over the normal 360-month term. The same loan with a 10-year interest-only period would have an initial payment of \$500 per month for the first 120 months.

In month 121, the loan would recast and require a new monthly payment (calculated at 6% over a 240-month remaining term) of \$716. The borrower is therefore allowed to make a lower payment for the first 10 years of the loan, but accepts the facts that the loan is not being amortized during the interest-only period, along with the commitment to a larger future payment once the loan is recast.

Another variation that had a brief burst in popularity was the payment-option or negative-amortization loan. Although the terms of these products were often quite complex, the product basically allowed for payments that were less than the amount required to make the loan's full monthly interest payment. If the payment made was less than the interest amount due in any month, the shortfall was added to the loan's balance, causing its balance to increase and creating the "negative amortization" in the product's name. For a variety of reasons, the product was discredited and, in some states, outlawed entirely.

Credit Guarantees

While our discussion has centered on the basics of mortgage loans, one of the considerations that also distinguishes various mortgages is the form of the eventual credit support required to enhance the liquidity of the loan. While a complete discussion of secondary markets is beyond the scope of this chapter, the ability of mortgage lenders to continually originate mortgages is heavily dependent on their ability to create fungible assets from a disparate group of loans made to a multitude of individual obligors. Therefore, mortgage loans can be further classified based on whether the eventual credit guaranty associated with the loan is provided directly by the federal government, indirectly through quasi-governmental agencies, or by various alternative entities and practices.

One of the dimensions into which loans can be classified is based on the degree of support received from the Federal government. As part of housing policy considerations, the Department of Housing and Urban Development (HUD) oversees two agencies, the Federal Housing Administration (FHA) and the Department of Veterans Affairs (VA), that support housing credit for qualifying borrowers. The FHA provides loan guarantees for borrowers who can afford only a low down payment and generally also have relatively low levels of income. The VA guarantees loans made to veterans, allowing them to receive favorable loan terms. These guarantees are backed by the U.S. Treasury, which provides these loans with the "full faith and credit" of the U.S. government. These loans are referred to under the generic term of *government loans*. Government loans are securitized largely through the aegis of the Government National Mortgage Association (Ginnie Mae, or GNMA), an agency also overseen by HUD.

Loans that are not associated with government guarantees are classified as *conventional loans*. Conventional loans can be securitized either as so-called private label structures or as pools guaranteed by the two government-sponsored enterprises (GSEs), namely, Freddie Mac and Fannie Mae. The GSEs are shareholder-owned corporations that were created by Congress to support housing activity. Both Fannie Mae and Freddie Mac were placed into conservatorship by the U.S. Treasury in August 2008. By the end of 2010, the GSEs had received a combined total of more than $150 billion in support from the government, in exchange for preferred stock owned by the Treasury (and for which the two firms paid a 10% dividend rate). The terms were revised at the end of 2012 to eliminate the dividend but pay virtually all of their earnings to the Treasury, a clause known as the *net worth sweep*. The very existence of the GSEs, as well as their form and function, remains quite uncertain at this writing; in any case, however, it is likely that they will play a smaller role in housing finance in the future. For as long as they continue to exist, however, the actual choice of the vehicle (GSE versus private label) used to securitize a particular loan depends on a number of factors, such as conformance of obligor credit attributes and property features with GSE loan requirements, the cost of credit enhancement, and loan balance.[1]

Loan Balance (Conforming vs. Nonconforming)

As noted earlier, a mortgage's balance often determines the investment vehicle into which it can be securitized. This is due to the fact that the agencies have limits on the loan balance that can be included in agency-guaranteed pools. The maximum loan sizes for one- to four-family homes effective for the following calendar year are recalculated every November. The year-over-year percentage change in the limits is based on the October-to-October change in the average home price (for both new and existing homes) published by the Federal Housing Finance Agency, the GSEs' regulator since 2008. Since their inception, Freddie Mac and Fannie Mae pools have had identical loan limits because the limits are dictated by the same statute. The effective conforming balance for any individual loan was complicated by the financial crisis that erupted in 2007. The statutory limit rose to $417,000 for a single-family loan in 2006. The Housing and Economic Recovery Act of 2008 (HERA) effectively increased the conforming limit in high-cost areas, based on the area's median home price, to a maximum of $625,500 (or 150% of the statutory limit) for loans on single-family homes.

1. A note with respect to terminology: throughout this chapter, we will use the term agencies to refer to Freddie Mac, Fannie Mae, and Ginnie Mae; the term GSEs refers to Freddie Mac and Fannie Mae only.

The Economic Stimulus Act of 2008 (ESA) temporarily increased the ceiling in high-cost areas to $729,750, subject to annual renewal. (As of October 2011, the limit in high-cost areas was reduced to the HERA limit in effect for that year.) The statutory limit remained at $417,000 from 2006 through 2016; for 2020 the conforming limit was $510,400 (and $765,600 in high-cost areas).

Loans larger than the conforming limit (and thus ineligible for inclusion in agency pools) are classified as jumbo loans and are securitized in private-label transactions (along with loans, conforming balance or otherwise, that do not meet the GSEs' required credit or documentation standards). While the size of the private-label sector is significant, it has long been dwarfed by the agency market. Despite the GSEs' difficulties, the market share for loans being securitized as agency MBS has been, through 2020, in excess of 90%, largely due to regulations and expenses associated with the issuance of non-agency MBS transactions.

Loan Credit and Documentation Characteristics

Mortgage lending traditionally has focused on borrowers of strong credit quality who were able (or willing) to provide extensive documentation of their income and assets. These loans are generically referenced as prime loans. As we noted in the introduction, the period between 2002 and mid 2007 was characterized by the rapid expansion of product offerings to consumers who had been outside of the traditional credit paradigm. Loans made to borrowers with demonstrably weaker credit are classified as *subprime* loans. This sector grew rapidly between 2003 and 2006; at its peak, it comprised roughly 20% of all issuance, by loan amount, in the United States before declining precipitously after the beginning of 2007.

A category between prime and subprime loans is was comprised of so-called alternative-A or *alt-A* loans. This category historically consisted of loans with nontraditional attributes, such as relaxed documentation and occupancy requirements. By 2007, however, the sector effectively became the middle ground for loans that could not be easily categorized as prime or subprime. As a result, its credit profile and performance were wildly uneven, and issuance of loans under the alt-A rubric also dropped dramatically as the product fell out of favor.

The primary factor that enabled the growth of subprime and alt-A lending was the degree of investor acceptance of securities collateralized by these loans. In particular, subprime loans were almost never held in lenders' loan portfolios, making their issuance particularly dependent on securitization as the means of monetizing their production. As a result, the collapse in investor demand for investment products backed by such loans was a primary factor in the demise of these products, as well as many lenders that specialized in their production.

Mechanics of Mortgage Loans

As discussed previously, most mortgage loans are structured as immediately and fully amortizing instruments, where the principal balance is paid off over the life of the loan. As noted previously, fixed-rate loans generally have a monthly payment that is fixed for the life of the loan, based on loan balance, term, and interest rate. A fixed-rate loan's monthly payment can be calculated using the following formula:

$$\text{Monthly payment} = \text{Original balance} \times \frac{\text{interest rate} \times (1 + \text{interest rate})^{\text{loan term}}}{(1 + \text{interest rate})^{\text{loan term}} - 1}$$

Note that the interest rate as used in the formula is a monthly rate calculated by dividing the loan's rate by 12.

Using this formulation, the allocation of the level payment into principal and interest over time provides insights regarding the buildup of owner equity in the property. As an example, Exhibit 21-1 shows the total payment and the allocation of principal and interest for a $100,000 loan with a 5.5% interest rate (or *note rate,* as it is often called) for the first 60 months.

EXHIBIT 21-1

Payment Analysis for $100,000 30-Year Loan with a 5.5% Rate

Month	Payment	Interest	Principal	Unpaid Balance
1	$567.79	$458.33	$109.46	$99,890.54
2	$567.79	$457.83	$109.96	$99,780.58
3	$567.79	$457.33	$110.46	$99,670.12
4	$567.79	$456.82	$110.97	$99,559.15
5	$567.79	$456.31	$111.48	$99,447.68
6	$567.79	$455.80	$111.99	$99,335.69
7	$567.79	$455.29	$112.50	$99,223.19
8	$567.79	$454.77	$113.02	$99,110.17
9	$567.79	$454.25	$113.54	$98,996.63
10	$567.79	$453.73	$114.06	$98,882.58
11	$567.79	$453.21	$114.58	$98,768.00
12	$567.79	$452.69	$115.10	$98,652.90
13	$567.79	$452.16	$115.63	$98,537.27
14	$567.79	$451.63	$116.16	$98,421.11
15	$567.79	$451.10	$116.69	$98,304.41
16	$567.79	$450.56	$117.23	$98,187.18
17	$567.79	$450.02	$117.77	$98,069.42
18	$567.79	$449.48	$118.31	$97,951.11
19	$567.79	$448.94	$118.85	$97,832.27
20	$567.79	$448.40	$119.39	$97,712.87
21	$567.79	$447.85	$119.94	$97,592.93
22	$567.79	$447.30	$120.49	$97,472.44
23	$567.79	$446.75	$121.04	$97,351.40

(Continued)

EXHIBIT 21-1

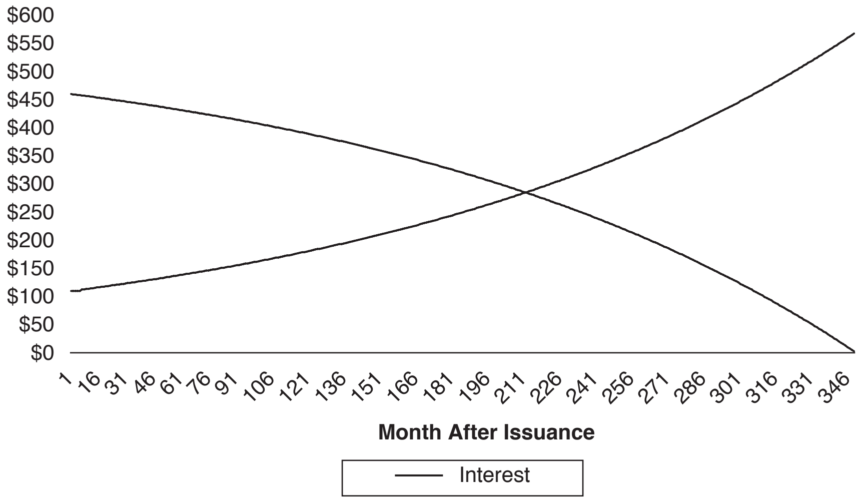
Payment Analysis for $100,000 30-Year Loan with a 5.5% Rate (*Continued*)

Month	Payment	Interest	Principal	Unpaid Balance
24	$567.79	$446.19	$121.60	$97,229.81
25	$567.79	$445.64	$122.15	$97,107.65
26	$567.79	$445.08	$122.71	$96,984.94
27	$567.79	$444.51	$123.28	$96,861.66
28	$567.79	$443.95	$123.84	$96,737.82
29	$567.79	$443.38	$124.41	$96,613.42
30	$567.79	$442.81	$124.98	$96,488.44
31	$567.79	$442.24	$125.55	$96,362.89
32	$567.79	$441.66	$126.13	$96,236.76
33	$567.79	$441.09	$126.70	$96,110.05
34	$567.79	$440.50	$127.29	$95,982.77
35	$567.79	$439.92	$127.87	$95,854.90
36	$567.79	$439.33	$128.46	$95,726.44
37	$567.79	$438.75	$129.04	$95,597.40
38	$567.79	$438.15	$129.64	$95,467.76
39	$567.79	$437.56	$130.23	$95,337.53
40	$567.79	$436.96	$130.83	$95,206.71
41	$567.79	$436.36	$131.43	$95,075.28
42	$567.79	$435.76	$132.03	$94,943.25
43	$567.79	$435.16	$132.63	$94,810.62
44	$567.79	$434.55	$133.24	$94,677.38
45	$567.79	$433.94	$133.85	$94,543.53
46	$567.79	$433.32	$134.47	$94,409.06
47	$567.79	$432.71	$135.08	$94,273.98
48	$567.79	$432.09	$135.70	$94,138.28
49	$567.79	$431.47	$136.32	$94,001.96
50	$567.79	$430.84	$136.95	$93,865.01
51	$567.79	$430.21	$137.58	$93,727.43
52	$567.79	$429.58	$138.21	$93,589.23
53	$567.79	$428.95	$138.84	$93,450.39
54	$567.79	$428.31	$139.48	$93,310.91
55	$567.79	$427.68	$140.12	$93,170.80
56	$567.79	$427.03	$140.76	$93,030.04
57	$567.79	$426.39	$141.40	$92,888.64
58	$567.79	$425.74	$142.05	$92,746.59
59	$567.79	$425.09	$142.70	$92,603.88
60	$567.79	$424.43	$143.36	$92,460.53

The exhibit shows that the payment consists mostly of interest in the early period of the loan. Since interest is calculated from a progressively declining balance and the aggregate payment is fixed, the amount of interest paid steadily declines; conversely, the principal component consequently increases over time. In fact, the exhibit shows that the unpaid principal balance in month 60 is $92,460, which means that of the $34,067 in payments made by the borrower to that point, only $7,539 was composed of principal payments. However, as the loan ages, the payment is increasingly allocated to principal. The crossover point in the example (i.e., where the principal and interest components of the payment are equal) comes in month 210. A graphic representation of principal and interest payments, along with the balance of the loan, is shown in Exhibit 21-2.

EXHIBIT 21-2

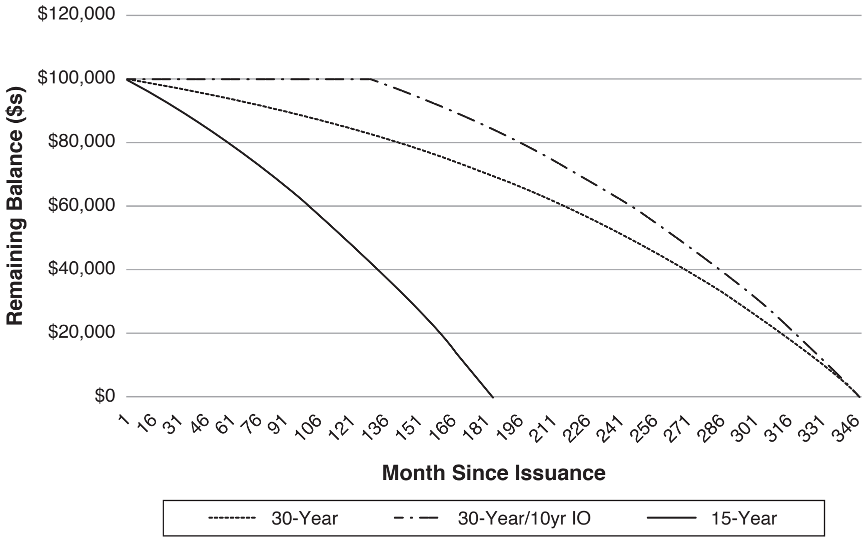
Allocations of Principal and Interest Payments for a $100,000 30-Year Fixed-Rate Loan with 5.5% Note Rate (Total Monthly Payment of $567.79)



Loans with shorter amortization schedules (e.g., 15-year loans) allow the buildup of equity in the home at a much faster rate. Exhibit 21-3 shows the outstanding balance of a $100,000 loan with a 5.5% note rate using 30- and 15-year amortization terms. Note that while 50% of the 30-year loan balance is paid off in month 246, the halfway mark is reached in month 151 with a 20-year term and month 107 with a 15-year loan. The chart also shows the outstanding balance for a 30-year loan with a 10-year interest-only period. In the case of balloon loans, the monthly payments are calculated to amortize the principal balance over a 360-month term. The balloon payment occurs at either month 60 (for a five-year balloon) or month 84 (for a seven-year balloon) and refers to the unpaid principal balance at the balloon date.

EXHIBIT 21-3

Unpaid Principal Balance for a $100,000 Fixed-Rate Loan at 5.5% for Different Loan Terms and Amortization Schemes



For an amortizing ARM loan, the payment is calculated at the initial note rate for the full 360-month term. At the first reset and at every subsequent adjustment, the loan is "recast," and the monthly payment schedule is recalculated using the new note rate and the remaining term of the loan. For example, the payments on a three-year hybrid ARM with a 4.5% note rate initially would be calculated as a 4.5% loan with a 360-month term. If the loan resets to a 5.5% rate after three years, the payment is calculated using a 5.5% note rate and a 324-month term. The following year, the payment would be recalculated again using the prevailing rate (depending on the performance of the index referenced by the loan) and a 312-month term.

In general, mortgage loans can be prepaid at the option of the borrower. When a loan is prepaid, the holder of the loan (either in the form of a loan in portfolio or as part of a mortgage-backed security) receives the prepaid principal at face value. *Prepayments* take place for a variety of reasons. They may occur when a borrower "refinances" the loan, sells the underlying property, or defaults on the loan. Prepayments (especially those due to refinancing) hurt the holder of the mortgage by calling away the asset and forcing the holder to reinvest the proceeds at lower interest rates. The causes and implications of prepayments are discussed in more depth below.

THE MORTGAGE INDUSTRY

Within the mortgage market, there are a number of different types of financial institutions involved, either directly or indirectly, in the business of making mortgage loans. A number of different classification schemes can be used to distinguish businesses and functions.

Direct vs. Third-Party Originations

The Fannie Mae Selling Guide defines *third-party originations* (TPOs) as "any loan that is completely or partially originated, processed, underwritten, packaged, funded, or closed by an entity other than the seller . . . that sells the loan to Fannie Mae." TPOs are often originated through mortgage brokers that represent clients but do not make underwriting decisions or actually fund loans. In addition, loans are often originated by a *correspondent lender* but sold to a larger entity (the *correspondent investor*), which in turn either holds or securitizes the loans. *Direct lenders*, as the nomenclature indicates, deal directly with borrowers, and also underwrite and fund their loans. Many large lenders are involved in multiple business lines, divide their operations into units or "channels" that deal with TPOs (generally called the *wholesale channel*) along with those that work directly with borrowers (the *retail channel*). These distinctions are necessary partly because the different channels have differing cost structures, necessitating alternative pricing.

As indicated by the nomenclature, a direct lender actually underwrites and funds loans. Conversely, a mortgage broker represents clients and typically works through multiple lenders to obtain financing for borrowers. The broker does not, however, either make the underwriting decision or fund the loan in such "third-party" originations or TPOs, but rather serves as an agent linking borrowers and lenders. The Fannie Mae Selling Guide defines third-party originations (TPOs) as "any loan that is completely or partially originated, processed, underwritten, packaged, funded, or closed by an entity other than the seller . . . that sells the loan to Fannie Mae." TPOs are often originated through mortgage brokers that represent clients but do not make underwriting decisions or actually fund loans. In addition, loans are often originated by a correspondent lender but sold to a larger entity (the correspondent investor), which in turn either holds or securitizes the loans. Direct lenders, as the nomenclature indicates, deal directly with borrowers, and also underwrite and fund their loans. Many large lenders involved in multiple business lines divide their operations into units or "channels" that deal with TPOs (generally called the wholesale channel) along with those that work directly with borrowers (the retail channel). These distinctions are necessary partly because the different channels have differing cost structures, necessitating alternative pricing.

Depository vs. Nondepository

Depository institutions (which include banks, savings and loans, and credit unions) collect deposits from both wholesale and retail sources and use the deposits to fund their lending activities. Since depositories have portfolios (for both loans and securities), they have the option of either holding their loan production as a balance sheet asset or selling the securitized loans into the capital markets in the form of *mortgage-backed securities* (MBS). (In addition, there is a market for nonsecuritized mortgage portfolios among depositories because there are accounting advantages to holding loans on their books instead of securities.) *Nondepository lenders* (mainly so-called *mortgage bankers*) do not have loan portfolios; virtually all their loan production is sold to investors through the capital markets. (This is sometimes referenced as the "loans-to-bonds" business model.) Depositories that can hold mortgages or MBS in portfolio sometimes can be more aggressive in how they price different products, especially products they wish to accumulate in their loan or investment portfolios (most frequently short-duration assets such as adjustable rate loans). By contrast, mortgage bankers must price all their production based on capital markets execution. This means that mortgage bankers are at a competitive disadvantage in issuing products for which capital market demand is either weak or nonexistent; they may also find it difficult at times to compete in some product sectors targeted aggressively by banks.

Originators vs. Servicers

Loan originators underwrite and fund loan production. However, once a loan is closed, an infrastructure is required for collecting and accounting for principal and interest payments, remitting property taxes, dealing with delinquent borrowers, and managing the process of foreclosing on nonperforming loans. Entities that provide these functions are called *servicers*. For providing these services, such entities receive a fee, which generally is part of the monthly interest payment. Servicing as a business is both labor- and data-intensive. As a result, large servicing operations reap the benefit of economies of scale under normal industry conditions (i.e., when delinquencies are relatively low), However, such large servicers are often poorly prepared to deal with large numbers of seriously delinquent loans. In the wake of the financial crisis, this led to a serious backlog in the handling of nonperforming loans, as well as controversy surrounding the practices and activities of a number of large servicers.

Servicing as an asset may be classified along several dimensions. Required, or *base*, servicing is compensation for undertaking the activities described earlier, and is either dictated by industry guidelines or (in the case of nonagency securities or loans) conditional on the product. For example, as of this writing, lenders must hold 25 basis points (bps) of base servicing for fixed-rate loans being securitized into GSE-eligible pools, whereas Ginnie Mae requires either 19 or 44 bps (depending on the securitization vehicle) for similar loans. The ownership of base servicing also provides the servicer with ancillary benefits, including interest float on insurance and tax escrow accounts, along with the ability to cross-sell other products using the database of borrower information. *Excess* servicing is any additional servicing over the base amount and is merely a strip of interest payments held by the servicer that allows the loan to be securitized with an "even" coupon, as demonstrated later in the section on execution dynamics. Excess servicing neither requires any activity on the part of the servicer nor does it convey any benefits; it is strictly a by-product of the securitization process.

THE LOAN UNDERWRITING PROCESS

After the application for a loan is filed, it is considered to be part of the "pipeline," which suggests that there is a planned sequence of activities that must be completed before the loan is funded. At application, the borrower can either lock the rate of the loan or let it float until some point before the closing. From the perspective of the lender, there is no interest-rate risk associated with the loan until it is locked. However, after the loan is locked, the lender is exposed to risk in the same fashion as any fixed-rate asset. Lenders typically track locked loans and floating liabilities separately; they are referred to as the "committed" versus the "uncommitted" pipeline.

There are two essential and separate components of the underwriting process:

- Evaluation of the ability and willingness on the part of the borrower to repay the loan in a timely fashion
- Ensuring the integrity of the property and whether it can be sold in the event of a default to pay off the balance of the loan

There are several factors that are considered important in the evaluation of the creditworthiness of a potential borrower.

Credit Scores

Several firms collect data on the payment histories of individuals from lending institutions and use sophisticated models to evaluate and quantify individual creditworthiness. The process results in a credit score, which is essentially a numerical grade of the credit history of the borrower. There are three different credit reporting firms that compile credit data—namely, Experian, Transunion, and Equifax. The data are provided to *FICO* (originally Fair, Isaac and Company), which calculates a set of credit scores used as proxies for borrower creditworthiness. While the various scores have different underlying methodologies, the scores generically are referred to as *FICO scores*. Lenders attempt to obtain more than one score in order to minimize the impact of variations in credit scores across providers. In such cases, if the lender obtains all three scores, generally the middle score is used, whereas the convention is to use the lower value in the case of the availability of only two scores.

Credit scores are useful in quantifying the potential borrower's credit history. The general rule of thumb has traditionally been that a score in excess of 700 represents a "strong" borrower. The problems associated with the financial crisis led to a reassessment of this threshold; a 730 or higher score is typically considered necessary for borrowers to receive the best rates and offerings from lenders.

Loan-to-Value Ratio

The *loan-to-value ratio* (LTV) is an indicator of a borrower's leverage at the point when the loan application is filed. The LTV calculation compares the value of the desired loan to the market value of the property. By definition, in a purchase transaction a loan's LTV is a function of the down payment and the purchase price of the property (subject to an appraisal). In a refinancing, it depends on the requested balance of the new loan and the appraised market value of the property.[2] LTV is important for a number of reasons. First, it is an indicator of the amount that can be recovered from a loan in the event of a default, especially if the value of the property declines. It also has an impact on the expected payment performance of the obligor because high LTVs may indicate a greater likelihood of default on the loan. While loans can be originated with very high LTVs, borrowers seeking a loan with an LTV greater than 80% generally must obtain insurance for the portion of the loan that exceeds 80%. As an example, if the borrower applies for a $90,000 loan in order to buy a property for $100,000, he or she must obtain so-called mortgage insurance (MI) on $10,000 of the balance. Mortgage insurance is a monthly premium that is added to the loan payment and can be eliminated if the borrower's home appreciates (or the loan is paid down) to the point where the loan has an LTV below 80%. (Borrowers seeking loans with very high LTVs often utilize government loans issued by entities such as the FHA, which requires only a 3.5% down payment on a purchase loan.)

Another measure used by underwriters is the combined LTV (CLTV), which accounts for the existence of any second liens. A $100,000 property with an $80,000 first lien and a $10,000 second lien will have an LTV of 80% but a CLTV of 90%. For the purposes of underwriting a loan, CLTVs are more indicative of the borrower's credit standing and indebtedness than LTVs and therefore a better gauge of the creditworthiness of the loan.[3]

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2. If the new loan is larger than the original loan, the transaction is referred to as a "cash-out refinancing." Otherwise, the transaction is described as a "rate-and-term refinancing."

3. This, of course, assumes that the lender is aware of all loans made on the property; a loan made against a property carrying an unknown or "silent" second lien likely would result in an overly leveraged loan and a higher probability of ultimate principal loss.

Income Ratios

In order to ensure that borrowers' obligations are consistent with income, lenders calculate debt-to-income (DTI) ratios that compare the potential monthly payment on the loan to the borrower's monthly income. The most common measures are *Debt-to-Income* ratios (DTIs). Two forms of DTIs are typically used by underwriters. The *front-end ratio* (sometimes also referenced as the *housing ratio*) is calculated by dividing the total monthly payments on the home, including principal, interest, property taxes, homeowners' insurance, and HOA fees, by the borrower's pretax monthly income. The *back-end ratio* is similar but includes other debt payments and obligations (including auto loan and credit card payments) to the total payments. The traditional maximum ratios, which remain in force for many loan programs, are 28% and 36%, respectively. However, the maximum back-end ratio that will allow a loan to be considered a QM loan is 43%, as discussed below.

Documentation

Lenders traditionally have required potential borrowers to provide data on their financial status and to support the data with documentation. Loan officers typically require applicants to report and document income, employment status, and financial resources (including the source of the down payment for the transaction). Part of the application process routinely involves compiling documents such as tax returns and bank statements for use in the underwriting process. In the period between 2000 and 2007, however, documentation standards were progressively relaxed, leading to the proliferation of limited- and no-documentation loan programs. Popular options included "stated income" loans (which required borrowers to supply an income figure but did not require supporting documentation) as well as programs that required no disclosures of incomes, assets, or employment. (These programs were often labeled "no income/no asset"—"NINA"—loans.)

The trend began in the mid-1990s with programs targeted to borrowers whose credit was sound but who had income streams that were either variable or, in the case of self-employed borrowers, difficult to document. This eventually led to the widespread marketing of loans to wage earners who often used the absence of formal documentation to inflate their incomes and evade DTI analysis.

One result of the financial crisis that began in 2007 was the return of rigorous underwriting standards, with full income and asset documentation a key requirement. While this certainly strengthened the credit quality of loans issued under this regime, it unfortunately also served to shut many otherwise strong borrowers out of the mortgage and housing markets due to difficulties in documenting their incomes.

A key reason for the change in how documentation is treated by lenders was the passing of the Dodd-Frank Act of 2010. Commonly referenced as the DFA, the law fundamentally altered the way mortgages are originated and securitized while also creating a new regulatory entity, the Consumer Financial Protection Bureau (CFPB). A key provision of the DFA was the requirement that mortgage lenders must verify an applicant's ability to repay a loan under an expanded set of criteria as part of the underwriting process. Failure to make a good-faith effort to ensure that the borrower can reasonably be expected to repay a loan (the *ATR requirement*) may allow the borrower to recoup fees and finance charges paid to the lender, as well as serve as a defense in a foreclosure action. The law states that a loan is presumed to meet the ATR requirement if (1) it is underwritten to certain standards (including a maximum 43% DTI), (2) the borrower's income or assets are verified and documented, (3) the loan is not considered a "higher-priced" loan, and (4) the loan does not include features such as negative amortization, interest-only payments, or a balloon payment. Such loans are classified as Qualified Mortgages (QMs). Loans that do not meet these criteria are considered Non-Qualified Mortgages (Non-QMs). Non-QM loans cannot be placed into agency-issued pools and must be securitized through private-label transactions. In order to meet the ATR standards without standard forms of income documentation, underwriters often use documents such as bank statements to estimate the applicant's income.

GENERATION OF MORTGAGE LENDING RATES

While it may appear simple on the surface, the determination of mortgage lending rates is a complex interplay between levels in the secondary market for loans (or, more typically, MBS), the value of servicing, the cost of credit enhancement, and the costs associated with generating the loan. In this process, the pricing of different MBS (quoted directly and through the mechanism of inter-coupon spreads) is very important in determining the eventual disposition of loans. The MBS market serves to institutionalize the intermediation function by allowing providers of funds (investors) and users of funds (lenders) to interact at the national level. Using the MBS market, lenders make loans, package them into securities, sell them into the capital markets, and use the proceeds to make new loans. While certain lenders may hold some loans and products in loan portfolios (e.g., banks tend to hold short-duration products such as ARMs), the bulk of production is sold into the capital markets either directly or indirectly, using correspondent investors and/or the GSEs.

While a complete discussion of the MBS market is beyond the scope of this chapter, it is instructive to review the process involved in securitizing loans because of the importance of this process in the determination of lending rates. For the sake of simplicity, the following discussion focuses on fixed-rate conforming loans securitized through the GSE programs. The coupons on such pools (or *pass-throughs*, because they pass principal and interest through to the investor) generally are created in 1/2 percentage point increments (e.g., 3.5%, 4.0%, etc.). Loans, by contrast, generally are issued in 1/8 percentage point increments. The creation of pools to be traded as MBS involves the aggregation of loans with similar characteristics, including note rates that are higher than the coupon rate but within a specified rate, depending on the agency and program. The weighted average of the note rates of the loans in the pool is referred to as the pool's *weighted average coupon* (WAC). The spread between a pool's WAC and its coupon rate (or pass-through rate) is allocated to three sources:

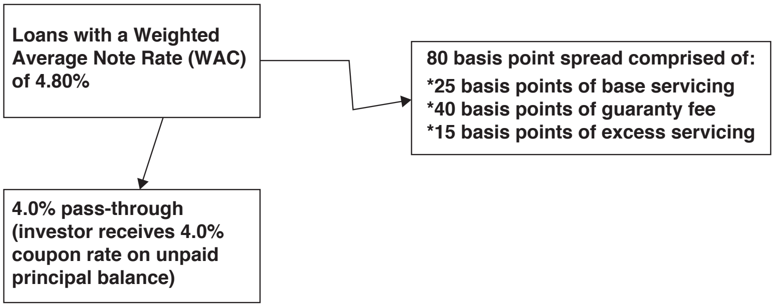
- *Required or base servicing*, which refers to a portion of the loan's note rate that is required to be held by the servicer of the loan. As noted previously, this entity collects payments from mortgagors, makes tax and insurance payments for the borrowers, and remits payments to investors. The amount of base servicing required differs depending on the agency and program.
- *Guaranty fees ("g-fees")* are fees paid to the agencies to insure the loan. Since these fees essentially represent the price of credit risk insurance, there is variation across loan types. In the conventional universe, loans that are perceived to be riskier typically require a higher g-fee for securitization. For Ginnie Mae pools, the guaranty fee is almost always 6 bps. Note that for Fannie Mae and Freddie Mac securities, g-fees can be capitalized and paid as an upfront fee in order to facilitate certain execution options, as discussed below.
- *Excess servicing* is the remaining amount of the note rate that would reduce the interest rate of the loan to the desired coupon. This asset is often capitalized and held by the servicer. Nonetheless, secondary markets exist for trading servicing in the form of either raw mortgage servicing rights or securities created from excess servicing.

Pooling practices for conventional loans changed dramatically in 2019. Prior to June of that year, Freddie Mac and Fannie Mae each issued pool under its own rubric which traded separately in the forward market. The two pooling programs were similar in that they passed through principal and interest paid by the borrowers to investors; aside from the issuer, the primary difference between the programs was the timing of cash-flow payments. (Fannie Mae pools paid principal and interest monthly on the 25th day of the month following each record date, while Freddie Mae made payments on the 15th day of the month.) In June 2019 both Fannie and Freddie embarked on the *Single Security Initiative* (SSI) and began issuing pools through the *Common Securitization Platform* (CSP), an entity that coordinating issuing pools for both Fannie Mae and Freddie Mac. The new pools are known as *Universal Mortgage-Backed Securities* (UMBS), and trade to the same standards and conventions to which Fannie pools traded before the transition. (Pre-existing Freddie Mac pools can be exchanged for UMBS pools.)

A schematic showing how a typical UMBS pool allocates cash flows is shown in Exhibit 21-4.

EXHIBIT 21-4

Cash-Flow Allocation for a UMBS 4.0% Pool with a 4.80% WAC



A common misconception is that lenders quote rate levels to consumers. In actuality, lenders calculate "discount points" (i.e., an up-front fee paid at closing) for a broad range of note rates. Note that these rate levels can be associated with both positive and negative points. (Negative points can be thought of as a rebate to the borrower in exchange for paying a higher rate.) The process for other products is similar in concept, if not identical in process. Exhibit 21-5 shows a hypothetical matrix of rates and points for 30-year conforming fixed-rate loans, with the zero-point (or *par*) rate highlighted.

EXHIBIT 21-5

Hypothetical Rates/Points Matrix for 30-Year Conventional Loans

Rates	Points
3.250%	3.000
3.375%	2.625
3.500%	2.250
3.625%	1.875
3.750%	1.500
3.875%	1.125
4.000%	0.750
4.125%	0.375
4.250%	**0.000**
4.375%	–0.375
4.500%	–0.750
4.625%	–1.125
4.750%	–1.500
4.875%	–1.875

Given existing market conditions, the process of generating points involves two steps:

- Determining the optimal execution for each note rate
- Calculating the appropriate price and amount of points for each note rate

Loans can be securitized in pools with a range of coupons, although pooling rules changed in 2019 to help facilitate the SSI. To maximize their proceeds, the optimal execution is calculated regularly by the originator and is a function of the levels of pass-through prices, servicing valuations, and guaranty fee buydown costs.[4] Exhibit 21-6 shows two possible execution scenarios for a loan with a 4.125% note rate. Note that execution economics and securitization rules generally dictate that loans are pooled with coupons between 25 and 100 bps lower than the note rates, although the maximum spread under new pooling rules is 112.5 bps. In the example, securitizing the loan in the 3.5% pool is the best execution option because it provides the greatest proceeds to the lender.

EXHIBIT 21-6

Pooling Options for a 4.125% Conventional Loan Using Hypothetical Levels
Assumes 40 Bps Guaranty Fee, 25 Bps Base Servicing

	UM30 3.0%	UM30 3.5%	Comments
Pass-through Prices	99.25	101.50	
Base Servicing	1.00	1.00	25 bps (priced at 4x)*
Guaranty Fee	0.40	0.40	
Excess Servicing/G-Fee Shortfall	0.475	–0.025	
Excess/G-Fee Buydown**	1.90	–0.10	Both assumed 4x*
Gross Proceeds	**102.15**	**102.40**	
Costs and Margin	–3.00	–3.00	Same for both execution options
Net Proceeds	**99.15**	**99.40**	

*For simplicity's sake, the multiple used for base and excess servicing, as well as the g-fee buydown, were assumed to be the same.

**Since g-fee buydowns represent a payment made to the GSE, it is shown here as a negative value.

4. Guaranty fee buydowns are the monetized value of the guaranty fee. They are paid by the originator as a fee at the time of funding.

Once the optimal execution is determined for each note rate strata, the associated points are then calculated. As with the execution calculation, the calculation of points is based on market prices for pass-throughs and prevailing valuations for servicing and g-fee buydowns. Exhibit 21-7 shows a hypothetical calculation of points for loans with rates from 4.125% to 4.5%, assuming that the best execution for all rates would be into pools with a 3.5% coupon rate. The calculated points are shown at the bottom as the difference between the net value of the loan after pricing all components and its par value. While the example does not show it, points generally are rounded to the nearest one-eighth. In practice, points are calculated simultaneously for many rate levels and are subsequently posted in a rates/point matrix similar to the one shown in Exhibit 21-7.

Note also that the costs shown in Exhibit 21-7 include an allocation for the lender's targeted profit margin. Margin requirements change in line with market conditions, most notably based on the levels of lending volumes and the industry's price competitiveness at that time.

In the event that the loan is perceived to be riskier as a result of factors that may include a lower credit score, less documentation, and/or a higher LTV, it might be assigned a higher guaranty fee by the GSE. As a result, the loan would be more costly to the borrower. As an example, assume that the 4.125% note rate loan shown in Exhibit 21-7 was assigned a 50 bps guaranty fee. At the 4× multiple, the guaranty fee buydown costs an extra 0.4 points. The incremental cost of credit enhancement means that the loan's net value is 99.4; the 4.125% loan would be priced to have 1 point. Therefore, the lending paradigm called *risk-based pricing* means that the higher costs (in the form of points at a given note rate strata) associated with riskier loans represent greater credit enhancement costs that are being passed on to the borrower.

As mentioned, the examples show the calculation for a loan that is eligible to be securitized in a pool issued as a UMBS by one of the GSEs. If the loan were ineligible for such securitization, the cost of the guarantee fee is replaced by the cost of alternative credit enhancement needed to securitize the loan. The most common form of credit support in nonagency transactions is called *subordination*. Briefly, this means that bonds created within the deal are prioritized with respect to how they will receive principal and interest cash flows, as well as how they will accrue losses suffered by the transaction's collateral pool. (Higher-priority or more senior bonds have the highest priority for receiving cash flows, and are the last to suffer writedowns.) As a result, the cost of credit enhancement to the transaction is a function of two elements:

- The relative size of the subordinate or junior classes of bonds
- The price at which they can be sold to investors

The size of the subordinate classes has traditionally been assigned by the rating agencies. Their primary role is to determine how large the subordinates need to be in order for the senior bonds to receive a triple-A rating. In turn, the size of the subordinate classes is a function of the perceived riskiness of the loans

EXHIBIT 21-7

Sample Calculation of Points for Different Note Rates All Loans Assumed to Best-Execute into UMBS 3.5s

	4.125%	4.250%	4.375%	4.500%	Comments
Pass-through Price	101.5	101.5	101.5	101.5	
Base Servicing	1	1	1	1	25 basis points, Assuming 4x multiple
Excess Servicing/G-Fee Shortfall	–0.025	0.100	0.225	0.350	Assumes 40 bp g-fee
Excess Servicing Value		0.40	0.90	1.40	Assumes 4x multiple
G-fee Buydown Value	–0.10				Assumes 4x multiple
Gross Proceeds	**102.40**	**102.90**	**103.40**	**103.90**	
Costs and Margin	–3.00	–3.00	–3.00	–3.00	Includes allocated costs and profit margin
Net Proceeds	**99.40**	**99.90**	**100.40**	**100.90**	
Points	0.60	0.10	–0.40	–0.90	
Rounded Points	***0.50***	***0.00***	***–0.50***	***–1.00***	Rounded to nearest 1/8th

backing the transaction. The level at which the subordinates trade in the new-issue market is dictated by the price at which investors feel they can garner attractive risk-adjusted returns. Subordinates typically trade at large price discounts to the more senior bonds in order to account for their greater risks and/or reduced protection from losses.

Therefore, the cost of credit support in nonagency or private-label transactions is expressed by the weighted average price at which the subordinate classes can be sold. Riskier collateral thus has higher credit enhancement costs since the amount of subordination is higher and/or the overall price at which the subordinates can be sold is lower.

Risk-based pricing is accomplished in two ways. Lenders might create separate loan programs that reflect a set of attributes, and price the program based on the loans' credit enhancement costs. This was reflected in the proliferation of different lending programs prior to the financial crisis. In cases where creating a separate program is inefficient or undesirable, attributes are priced using "add-ons," or points added to the discount points calculated in the manner described previously. Add-ons (often called loan-level price adjustments, or *LLPAs*) are fees calculated to account for the incremental cost of credit enhancement for a loan. Similar to discount points, such fees are quoted as percentage points of the loan's face value. For example, a 30-year fixed-rate conforming-balance loan with a 4% note rate may be associated with 0.75 points. However, a borrower may seek a loan with an LTV higher than that specified by the program's guidelines. If the add-on in this case is 1.5 points, the loan then becomes a 4% loan with 2.625 points.

However, the disinclination of many borrowers to paying large amounts of money at closing necessitates a recalculation of the rate, given some targeted amount of points and the rate/point structure prevailing at that time. In the preceding example, suppose that the borrower only wishes to pay 1/2 point after the effect of the add-ons. Referring to Exhibit 21-5, note that a loan with 1.125 points is associated with a 3.875% note rate, whereas a loan with negative 0.375 points has a note rate of 4.375%. Therefore, the borrower in the example could obtain a loan with a rate of 4.375% with 0.75 points. This methodology indicates how the expense (calculated in terms of points) of "alternative" loans is translated into incrementally higher note rates.

RISKS ASSOCIATED WITH MORTGAGE PRODUCTS

Holders of fixed income investments ordinarily deal with interest-rate risk, which is the risk that changes in the level of market interest rates will cause fluctuations in the market value of such investments. Mortgages and associated mortgage-backed securities, however, have additional risks associated with them that are unique to the products and require additional analysis. (In the following discussions, mortgages and MBS are collectively referred to as pools for the sake of clarity.)

Prepayment Risk

In a previous section we noted that obligors generally have the ability to prepay their loans before they mature. For the holder of a mortgage asset, the borrower's prepayment option creates a unique form of risk. In cases where the obligor refinances the loan in order to capitalize on a drop in market rates, the investor has a high-yielding asset payoff, and it can be replaced only with an asset carrying a lower yield. Prepayment risk is analogous to "call risk" for corporate and municipal bonds in terms of its impact on returns, and it also creates uncertainty with respect to the timing of investors' cash flows. In addition, changing prepayment "speeds" owing to interest-rate moves cause variations in the cash flows of mortgage pools, strongly influencing their relative performance.

The importance of prepayments to the mortgage sector has created the need for the measurement and analysis of prepayment behavior. Prepayments occur for the following reasons:

- The sale of the property
- The destruction of the property by fire or other disaster
- A default on the part of the borrower (net of losses)
- Curtailments (i.e., partial prepayments)
- Refinancing

A useful nomenclature is to divide prepayments into "rate-sensitive" and "rate-insensitive" categories. Rate-insensitive prepayments traditionally have been comprised of housing turnover, which normally consists of home sales, along with equity extraction through the vehicle of *cash-out refinancings*. The spike in delinquencies and credit problems after 2007, however, meant that credit-related prepayments also needed to be taken into account in assessing prepayment speeds. (Since mid-2010, for example, the GSEs have bought seriously delinquent loans out of pools. Such *buyouts* are treated as prepayments in agency pools. As we will discuss, credit-related prepayments are treated differently in private-label securities.)

Rate-sensitive prepayments primarily consist of refinancings for which borrowers do not monetize their homes' equity, called *rate-and-term* refinancings. This activity is dependent on borrowers' ability to obtain a new loan at a lower rate, making this activity highly sensitive to the level of interest and mortgage rates. In addition, the amount of refinancing activity can change greatly given a seemingly small change in rates. (Cash-out refinancings are impacted by both interest rate changes and rates of home price appreciation.)

The paradigm in mortgages thus is fairly straightforward. Mortgages with low note rates (that are "out-of-the-money," to borrow a term from the option market) normally prepay fairly slowly and predictably, whereas loans carrying higher rates ("in-the-money") can see spikes in prepayments when rates drop, as well as significant volatility in prepayment speeds.

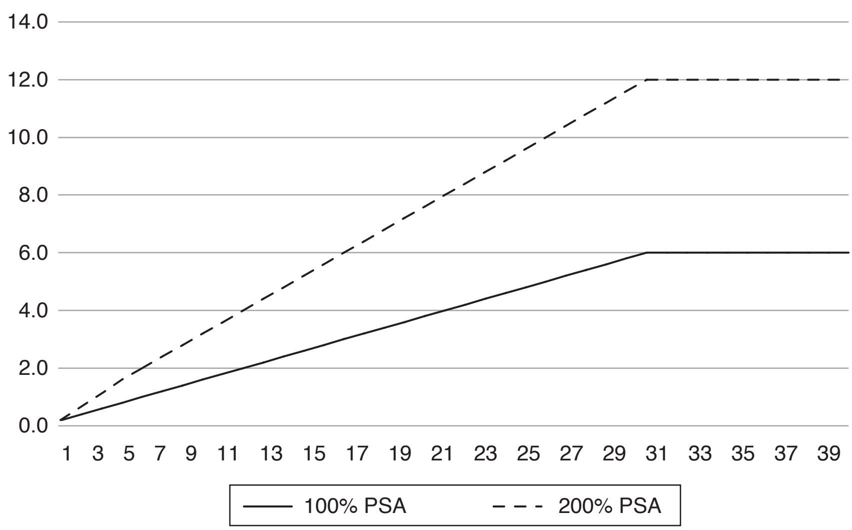
The measurement of prepayment rates is, on its face, fairly straightforward. A metric referred to as *single monthly mortality* (SMM) measures the monthly principal prepayments on a mortgage portfolio as a percentage of the balance at the beginning of the month in question. (Note that SMM does not include regular principal amortization.) The *conditional prepayment rate* (CPR) is simply the SMM annualized using the following formula:

$$\text{CPR} = 1 - (1 - \text{SMM})12$$

While CPR is the most common term used to describe prepayments, other conventions are also used. Logic suggests, for example, that prepayment behavior is not constant over the life of the loan. Immediately after the loan is funded, for example, a borrower is unlikely to prepay his mortgage; however, the propensity to prepay (for any reason) increases over time. This implies that prepayments adhere to some sort of "ramp," where the CPR increases at a predictable rate. The most common ramp is the *PSA model*, created by the Public Securities Association (now called the Securities Industry and Financial Markets Association, or *SIFMA*). The base PSA model (100% of the model or 100% PSA, to use the market convention) assumes that prepayments begin at a rate of 0.2% in the first month and increase at a rate of 0.2% per month until they reach 6.0% CPR in month 30; at that point, prepayments remain at 6% CPR for the remaining term of the loan or security. Based on this convention, 200% PSA implies that speeds double that of the base model (i.e., 0.4% in the first month ramping to a terminal speed of 12% CPR in month 30), Exhibit 21-8 shows a graphic representation of the PSA model.

EXHIBIT 21-8

The PSA Model



The PSA model depends on the age of the loan (or, in a pool, the weighted-average loan age). For example, 4.0% CPR in month 20 equates to 100% PSA, whereas 4.0% CPR in month 6 represents 333% PSA. Conversely, the usefulness of the PSA model (or other ramps that are similar in nature) depends on how quickly prepayments move toward a terminal rate (or, to put it differently, how quickly they "ramp up"). It is generally understood that prepayment ramps have shortened since the model was derived, reflecting the lowering of refinancing barriers and costs. In turn, this arguably has distorted the reported PSA speeds for loans that are 30 months old or less, making the PSA model less useful as a measure of prepayment speeds.

While a full discussion of prepayment behavior and risk is far beyond the scope of this chapter, it is important to understand how changes in prepayment rates affect the performance of mortgages and MBS. Since prepayments increase as bond prices rise and market yields are declining, mortgages shorten in average life and duration when the bond markets rally. As a result, the price performance of the mortgage portfolio or security tends to lag that of bonds without prepayment exposure when interest rates decline. Conversely, prepayments tend to slow when market yields are rising, causing the average life and duration of the mortgages or MBS to increase. This phenomenon, generally described as *extension*, causes the price of the mortgage or MBS to decline more than comparable fixed-maturity instruments (such as Treasury notes) as the prevailing level of yields increases.

Owing to changes in prepayment rates, mortgages and MBS exhibit price performance that is generically referenced as "negative convexity." Since prepayments increase when rates decline, MBS shorten in average life and duration at precisely the time when their performance would benefit from extending. Conversely, when the bond market sells off, mortgage average lives and durations lengthen. This behavior causes the price changes in mortgages and MBS to be decidedly nonlinear in nature and to underperform those of assets that do not exhibit negatively convex behavior. Exhibit 21-9 shows a graphic representation of this behavior. Investors are generally compensated for the lagging price performance of MBS through higher base-case yields. However, the necessity of managing negative convexity and prepayment risk on the part of investors dictates active analysis and management of their MBS portfolios.

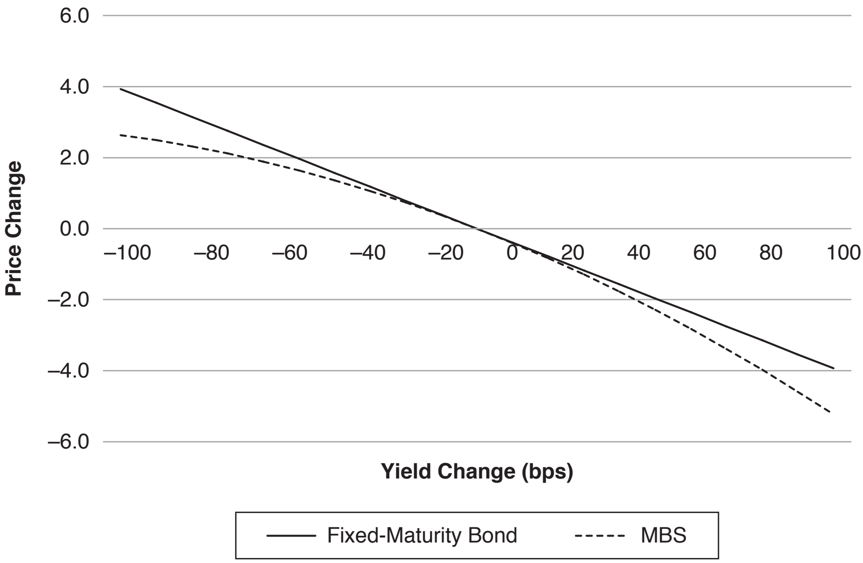
Credit and Default Risk

Analysis of the credit exposure in the mortgage sector is different from the assessment of credit risk in most other fixed income instruments because it requires:

- Quantifying and stratifying the characteristics of the thousands of loans that underlie the mortgage investment
- Estimating how these attributes will translate into performance based on standard metrics and the evaluation of reasonable best-, worst-, and likely-case performance
- Calculating returns based on these scenarios

EXHIBIT 21-9

Changes in Bond Prices Given Yield Changes



In a prior section, some of the factors (credit scores, LTVs, etc.) that are used to gauge the creditworthiness of borrowers and the likelihood of a loan to result in a loss of principal were discussed. Many of the same measures are also used in evaluating the creditworthiness of a mortgage pool. For example, weighted-average credit scores and LTVs are calculated routinely, and stratifications of these characteristics (along with documentation styles and other attributes) are used in the credit evaluation of the pool. In addition to these characteristics of the loans, the following metrics are also relevant for the *a posteriori* evaluation of a mortgage pool.

Delinquencies

Delinquency measures are designed to gauge whether borrowers are current on their loan payments or, if they are late, stratifying them according to the seriousness of the delinquency. The most commonly used convention currently used to classify delinquencies is one promulgated by the Mortgage Bankers Association (MBA); this *MBA method* classifies loans as follows:

- Payment due date to 30 days late: Current
- 30–60 days late: 30 days delinquent
- 60–90 days late: 60 days delinquent
- More than 90 days late: 90+ days delinquent

Defaults

At some point in their existence, some delinquent loans become current (or cure) because the condition leading to the delinquency (e.g., job loss, illness, etc.) resolves itself. However, some portion of the delinquent loan universe ends up in default. By definition, default is the point where the borrower loses title to the property in question. Default generally occurs for loans that are 90+ days delinquent, although loans where the borrower goes into bankruptcy may be classified as defaulted at an earlier point in time.

It is important to note that the treatment of defaults in agency and nonagency securities is different. As noted in the previous section, seriously delinquent loans are bought out of agency pools. Since the agency in question is responsible for the repayment of the full amount of principal to investors, buyouts are prepayments for all practical purposes. No such mechanism exists for private-label securities; principal is only paid to investors once it is recovered through the foreclosure process (or through some alternative mechanism, such as a short sale). Moreover, only the recovered amount of principal is returned to investors, with the transaction absorbing the resulting losses.

Therefore, defaults in private-label transactions must be treated and quoted separately from refinancings, turnover, and other types of voluntary prepayments. Rates for involuntary prepayments are generally measured by the *conditional default rate* (CDR). CDRs are calculated in a fashion similar to CPRs, in which the face value of loans going into default in any given month is divided by that month's initial value. The resulting monthly default rate (MDR) is then annualized in the same fashion as SMMs.

Severity

Since the lender has a lien on the borrower's property, some of the value of the loan can be recovered through the foreclosure process. Loss severity measures the face value of the loss on a loan after foreclosure is completed. Severities are often heavily influenced by the loan's LTV (since a high LTV loan leaves less room for a decline in the value of the property in the event of a loss). However, in the event of a default, even loans with relatively low LTVs can experience significant losses, generally for several reasons:

- The appraised value of the property may be high relative to the property's actual market value.
- The value of a property may have declined since the loan's origination due to changes in the real estate market.
- There are costs and lost income associated with the foreclosure process.

In light of these metrics, the process of evaluating the credit-adjusted performance of a pool involves first understanding the expected delinquencies, defaults, and loss severities of the pool based on its credit characteristics and attributes. Subsequently, loss-adjusted yields and returns can be generated.

KEY POINTS

- Mortgage loans can be categorized using a number of different factors, including lien status, original loan term, interest-rate type, balance classification, amortization type, and borrower credit and documentation standards. Loans can also be categorized by the type of credit support they receive, that is, guarantees directly from the U.S. government, through Freddie Mac or Fannie Mae, or some form of private credit enhancement. Mortgages are also classified as Qualified Mortgages based on their lack of "risky" features and full documentation of income and assets; such mortgages are presumed to comply with the Ability to Repay rule established by the Dodd-Frank Act and policed by the CFPB.
- The payments on a fixed-rate fully amortizing mortgage remain fixed for the term of the loan. Early in a loan's life, the bulk of the payments are classified as interest. However, the portion directed to repay principal grows as the loan ages.
- Mortgage underwriting is a complex process that takes into account borrowers' ability and apparent willingness to service their loans. These are judged using metrics such as credit scores, loan-to-value ratios, and income ratios. The accurate documentation of income, employment, and assets has also proved to be important in assessing borrower creditworthiness.
- Mortgage lenders calculate their pricing in the form of the discount points required or rebated for a series of note rate strata. Consumer mortgage pricing is computed through a complex process that incorporates MBS levels, servicing values, and the cost of credit support.
- Securities backed by residential mortgages have a variety of risks. In addition to interest-rate risk, mortgage-backed securities are exposed to prepayment risk, as well as credit risk if the securities in question do not have explicit or implicit government backing.

CHAPTER
TWENTY-TWO

AGENCY MORTGAGE PASSTHROUGH SECURITIES

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A mortgage note represents a pledge of real estate to secure a loan. The mortgagee (borrower) pledges the property to the mortgagor (lender) as collateral to secure repayment of the loan. Thus, the loan is said to be secured by the pledged property. Ownership of the property rests with the borrower throughout the term of the loan. However, the lender holds a lien against the property and if the borrower is unable to repay the loan according to its terms, then the ownership of the property is transferred to the lender to settle the outstanding debt.

Most residential mortgages are pooled and used as collateral for the issuance of residential mortgage-backed securities (RMBS) as explained in this chapter. The residential mortgage market can be divided into two subsectors based on the credit quality of the borrower: the prime mortgage market and the subprime mortgage market. Certain prime mortgage loans can be included in RMBS issued by either the Government National Mortgage Association (Ginnie Mae), a federally related institution, or one of the two government-sponsored enterprises, Fannie Mae and Freddie Mac. An RMBS issued by any of these three entities is referred to as an *agency passthrough security*, or simply *agency passthrough*. Whether a prime loan can be included in a pool of loans backing an agency passthrough securities depends upon whether it satisfies the underwriting standards specified by these three issuers. Prime mortgages that do not satisfy the underwriting standards of the three entities are typically pooled in private-label RMBS (also called nonagency RMBS), as are subprime mortgages. Agency passthroughs, their cash flow and risk characteristics, and the market in which they are traded are the subject of this chapter. Private-label RMBS are covered in Chapter 25. Agency passthroughs are used to create agency collateralized mortgage securities (REMICs) and agency mortgage stripped securities, the subjects of Chapters 23 and 24, respectively.

ISSUERS OF AGENCY PASSTHROUGHS

The three issuers of agency passthroughs, all created by Congress to increase the supply of capital to the residential mortgage market, are Ginnie Mae (GNMA), Fannie Mae (FNMA), and Freddie Mac (FHLMC).

Ginnie Mae is part of the Department of Housing and Urban Development and the agency passthroughs that it guarantees carry the full faith and credit of the U.S. government with respect to timely payment of both interest and principal. That is, the interest and principal are paid when due even if the underlying mortgagors fail to make their monthly mortgage payment. The security guaranteed by Ginnie Mae is called a "mortgage-backed security." Although Ginnie Mae provides the guarantee, it is not the issuer. The agency passthroughs that carry its guarantee and bear its name are issued by lenders it approves, such as thrifts, commercial banks, and mortgage bankers. These lenders receive approval only if the underlying loans satisfy the underwriting standards established by Ginnie Mae. When it guarantees securities issued by approved lenders, Ginnie Mae permits these lenders to convert illiquid individual loans into liquid securities backed by the U.S. government. In the process, Ginnie Mae accomplishes its goal of supplying funds to the residential mortgage market and providing an active secondary market. For the guarantee, Ginnie Mae receives a fee, called the guaranty fee.

The mission of the two GSEs, Fannie Mae and Freddie Mac, is to support the liquidity and stability of the mortgage market. They accomplish this by (1) buying and selling mortgages, (2) creating passthroughs and guaranteeing them, and (3) buying RMBS. The agency passthroughs they issue are not guaranteed by the full faith and credit of the U.S. government. Rather, the payments are secured first by the cash flow from the underlying pool of loans and then by a corporate guarantee. That corporate guarantee, however, is the same as the corporate guarantee to the other creditors of the two GSEs. The GSEs have a line of credit with the U.S. Department of the Treasury. As with Ginnie Mae, the two GSEs receive a guaranty fee for taking on the credit risk associated with borrowers failing to satisfy their loan obligations.

The passthroughs issued by Fannie Mae are referred to as "mortgage-backed securities": Freddie Mac uses the term participation certificate (PC) to describe its passthrough security.

During the global financial crisis both Fannie Mae and Freddie Mac became insolvent and placed into conservatorship. The Federal Home Finance Agency's (FHFA's) strategic plan for the conservatorship of both Fannie Mae and FHLMC included the goal of developing a new securitization infrastructure, shared by both Fannie Mae and Freddie Mac. The result, the establishment of Common Securitization Solutions, is a joint venture of both Fannie Mae and Freddie Mac. Common Securitization Solutions acts as both Fannie Mae's and Freddie Mac's agency to facilitate issuance of single-family mortgage securities, the release of related at-issuance and ongoing disclosures, and the post-issuance administration of their securities.

Common Securitization Solutions created the Common Securitization Platform to support Fannie Mae's and Freddie Mac's single-family mortgage securitization business. Importantly, the common securitization platform included the issuance by both Fannie Mae and Freddie Mac of a common single mortgage-backed security, the Uniform Mortgage Backed Security (UMBS). The objective of UMBS is to improve the overall liquidity of Fannie Mae's and Freddie Mac's securities to ensure the ongoing liquidity of the U.S. housing financing markets. The characteristics of the UMBS security is discussed in detail later in the chapter.

CASH-FLOW CHARACTERISTICS

To illustrate the cash-flow characteristics, let's begin with the cash flow of a standard loan. Exhibit 22-1 provides a partial amortization table for a standard loan. The monthly payment is $1,013.67. Working across the table, in the first month the scheduled interest is $750 and the scheduled principal is $263.37. By month 12, the scheduled interest has fallen to $738.93 and the scheduled principal has increased to $274.44.

The cash flow of an agency passthrough depends on the cash flow of the underlying loans. The cash flow of a mortgage-backed security includes the monthly mortgage payments representing interest, the scheduled repayment of principal, and any prepayments. A prepayment occurs when the borrower terminates the note due to refinancing or sale of the property or makes a partial payment of principal against the outstanding balance. The termination of the note prior to its final scheduled payment date is termed a "full prepayment," while the partial payment of principle is termed a "curtailment." Notice that only the first and the second components are shown in Exhibit 22-1. What is not known when the investor is considering the acquisition of an agency passthrough is the amount of the cash flow. Moreover, prepayments will alter the schedule shown in Exhibit 22-1 because the balance of the amount outstanding after a prepayment is made changes the interest that will be paid in subsequent months.

Payments are made to security holders each month. However, the amount and the timing of the cash flow from the pool of mortgages and the cash flow passed through to the security holders are not identical. The monthly cash flow for an agency passthrough is less than the monthly cash flow of the underlying mortgages by an amount equal to the servicing and guarantor fee. The latter fee is charged by the issuer or guarantor of the passthrough security for guaranteeing the payment to security holders should any of the underlying borrowers miss a payment or default (discussed later).

The timing of the cash flow also differs. The monthly mortgage payment is due from each mortgagor on the first day of each month, but a delay affects the passing through of the corresponding monthly cash flow to the security holders. The length of the delay varies by the type of agency passthrough.

EXHIBIT 22-1

Mortgage Amortization Table

Original Bal: $200,000
Note Rate: 4.50%
Term: 360 mos.

Period	Begin Bal.	Monthly Pmt.	Sch. Interest	Sch. Principal	Ending Bal.
1	200,000.00	1,013.37	750.00	263.37	199,736.63
2	199,736.63	1,013.37	749.01	264.36	199,472.27
3	199,472.27	1,013.37	748.02	265.35	199,206.92
4	199,206.92	1,013.37	747.03	266.34	198,940.58
5	198,940.58	1,013.37	746.03	267.34	198,673.23
6	198,673.23	1,013.37	745.02	268.35	198,404.89
10	197,593.80	1,013.37	740.98	272.39	197,321.40
11	197,321.40	1,013.37	739.96	273.42	197,047.99
12	197,047.99	1,013.37	738.93	274.44	196,773.55
24	193,685.92	1,013.37	726.32	287.05	193,398.87
25	193,398.87	1,013.37	725.25	288.12	193,110.75
26	193,110.75	1,013.37	724.17	289.21	192,821.54
33	191,063.39	1,013.37	716.49	296.88	190,766.51
34	190,766.51	1,013.37	715.37	298.00	190,468.51
35	190,468.51	1,013.37	714.26	299.11	190,169.40
36	190,169.40	1,013.37	713.14	300.24	189,869.16
180	132,982.60	1,013.37	498.68	514.69	132,467.91
181	132,467.91	1,013.37	496.75	516.62	131,951.29
182	131,951.29	1,013.37	494.82	518.55	131,432.74
357	4,015.76	1,013.37	15.06	998.31	3,017.45
358	3,017.45	1,013.37	11.32	1,002.06	2,015.40
359	2,015.40	1,013.37	7.56	1,005.81	1,009.58
360	1,009.58	1,013.37	3.79	1,009.58	0.00

An investor who is considering investing in an agency passthrough does not know what the cash flow will be because the cash flow depends on prepayments. Prepayments are classified as voluntary repayments and involuntary repayments. Voluntary repayment occurs when the borrower exercises the right to prepay the loan at any time. Voluntary repayments occur due to refinancing and turnover. Refinancing occurs when the borrower obtains a lower rate and/or extracts equity from the property. Turnover involves the sale of property, which is typically related to relocation, family formation, or a life event such as death or divorce. Involuntary repayment is the repayment of a loan as a result of the borrower defaulting and the property repossessed and sold. Defaults may occur as a result of a life event (e.g., a job loss, illness, or family break-up, and the like) or the value of the property falls below the amount owed on the loan (referred to as a strategic default).

The risk associated with prepayments is called *prepayment risk*. This risk can be divided into two risks: contraction risk or extension risk. As interest rates drop and prepayments accelerate (or expectations of prepayments) increase, the expected average life or duration of the passthrough contracts. That is, its price sensitivity to declining rates shrinks as it becomes an effectively shorter security. As such, it will underperform noncallable bonds. This is contraction risk. When rates rise, the passthrough extends in terms of its average life or duration and its price declines faster than comparable noncallable bonds. This is extension risk and this property of passthroughs is referred to as negative convexity.

Prepayment Conventions

Because a borrower may terminate a loan at any time, the lender is said to be "short" the prepayment option to the borrower. Residential real estate loans typically do not carry prepayment penalties, and as a result are subject to considerable prepayment risk attributed to voluntary repayments. In this section we explain the conventions used to describe prepayments and in the next section we review the elements of prepayment modeling.

Single Monthly Mortality Rate and Conditional Prepayment Rate

The monthly prepayment rate, or *single monthly mortality rate* (SMM), measures the percentage of a pool's principal balance that has prepaid in the current month. It is based on the change in the pool's factor (survival factor) from one period to the next, and is given by the following formula

$$\text{SMM} = \frac{\text{Scheduled balance} - \text{Ending balance}}{\text{Scheduled balance}} \times 100 \qquad (22\text{-}1)$$

The equation can be rewritten as

$$\text{SMM} = \frac{\text{Beginning balance} - \text{Scheduled principal} - \text{Ending balance}}{\text{Beginning balance} - \text{Scheduled principal}} \times 100 \qquad (22\text{-}2)$$

The market convention is to state the SMM, as an annualized measure, known as the *conditional prepayment rate* (CPR). The formula for CPR is

$$\text{CPR} = 1 - (1 - \text{SMM})^{12} \times 100 \qquad (22\text{-}3)$$

Public Securities Association Model

The *Public Securities Association (PSA) model* was developed to describe how mortgage prepayments evolve as a function of loan age. The PSA model specifies the mortgage prepayment loan age (seasoning) function as follows:

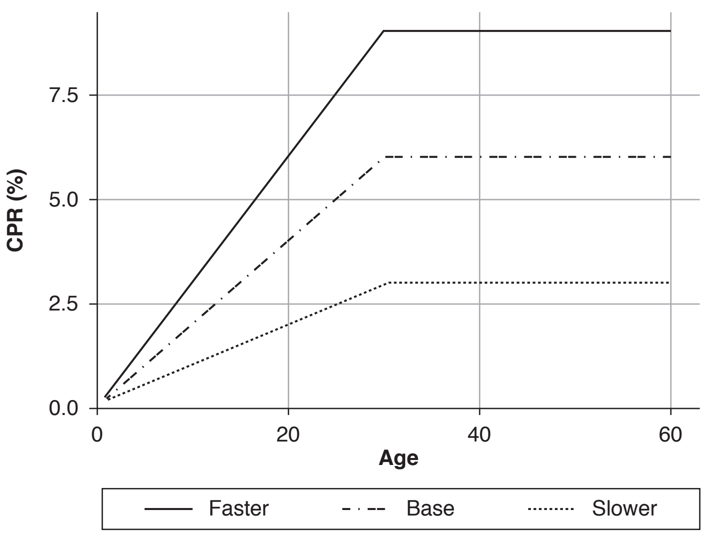
- Begins at 0.2% CPR the first month
- Increases by 0.2% CPR per month
- Reaches a maximum of 6.0% CPR in month 30

Exhibit 22-2 illustrates the application of the PSA model. For example, at 100 PSA the investor is assuming that the pool's prepayment rate will follow the seasoning ramp described above.

- A 150 PSA assumption multiplies the PSA model by 150%. Under this assumption, the pool's prepayment rate will begin at 0.3% in the first month, season 0.3% per month, and reach a peak of 9.0% in month 30.
- A 50 PSA assumption multiplies the PSA model by 50%. Under this assumption, the investor believes that the pool's prepayment rate will begin at 0.1% in the first month, season 0.1% per month, and reach a peak of 3.0% in month 30.

EXHIBIT 22-2

PSA Mortgage Prepayment Assumption



Modeling MBS Cash Flows

Cash-flow modeling drives the valuation of agency passthroughs. It establishes a framework that defines the following: (1) timing of the return of principal, and (2) payment of interest to the investor.

Cash-flow analysis for an agency passthrough is complicated by the presence of any or all of the following: (1) servicing fees, (2) guarantee fees (GFee), and (3) private mortgage insurance (PMI). These three costs are subtracted from the borrower's note rate. The net of the borrower's note rate less servicing, GFee, and PMI is the net note rate, or *net weighted average coupon* (NWac). The servicing fee compensates the servicer on a monthly basis for the mortgage lender's administrative duties.[1] The PMI fee protects the lender from loss in the event that the borrower defaults and there is insufficient equity in the home to cover the outstanding balance of the note. The guarantee fee is a premium paid by the borrower to the guarantor, typically the party that securitized and sold the MBS pool, for its guarantee of timely principal and interest to the investor.

The NWac, scheduled principal, and prepaid principal are "passed through" to the investor, hence, the term *passthrough security*.

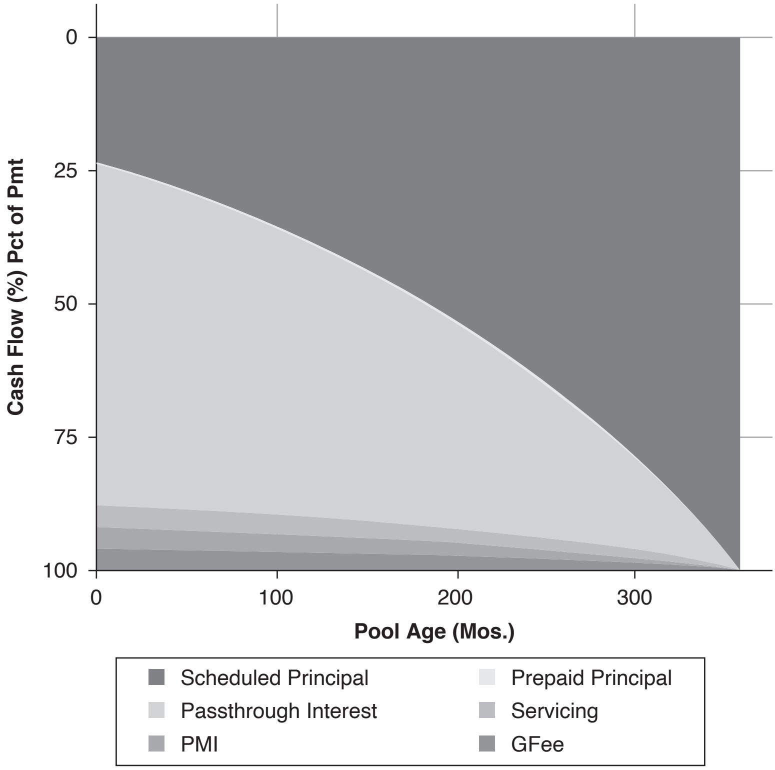
Exhibit 22-3 illustrates the cash-flow profile of a 4.0% MBS pool assuming a 0% PPC—*no prepayments*. In the absence of prepayments, the investor receives a level cash flow over the life of the pool. In this case, the investor receives $609.13 per $100,000 invested. Early in the life of the pool, a greater share of the mortgage payment consists of interest. As the loans underlying the pool amortize, the share of scheduled principal, as a percentage of the borrower's scheduled payment, increases. About halfway through the life of the loan the amount of scheduled principal paid is greater than the amount of interest paid. This accelerates the amortization of the loans underlying the pool as it approaches its final payment *maturity* date.

The borrower's option to prepay the loan at any time alters the timing of the cash flows received by the investor because prepayments are passed through as the *unscheduled* return of principal. The example presented in Exhibit 22-4 uses a 100 PPC assumption and shows that as the borrowers in the pool exercise their option to prepay the principal returned to the investor becomes *front loaded*. This exhibit illustrates how the application of a prepayment assumption changes the share of principal and interest paid to the investor. For example, at month 100 the share of principal paid—both scheduled and prepaid—account for around 75% of the total principal received. In contrast, Exhibit 22-3 shows that in the absence of prepayments, scheduled principal accounts for around 50% of the total principal received by the investor.

1. Loan administration fees are compensation for the following duties: (1) administering escrow accounts for the payment of taxes and insurance, (2) in the absence of escrow, verifying the borrower has paid property taxes and that insurance coverage is maintained on the property, and (3) send the borrower tax information at the end of the year.

EXHIBIT 22-3

Cash-Flow Share Assuming 0% PSA



Applying Prepayment Assumptions

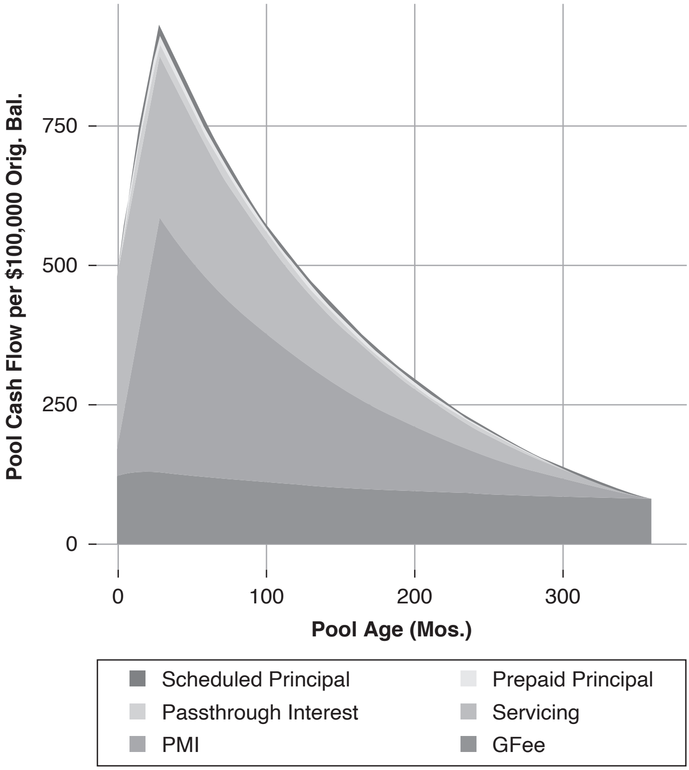
From the cash-flow analysis just presented, it can be seen that the derivation of MBS cash flows is dependent on the investor's underlying prepayment assumption. As a result, it is important to understand both the nomenclature used in the description of structured security cash flows as well their practical application.

The foundation of all prepayment applications is SMM, which is the percentage of the outstanding balance that prepays. However, most investors annualize the measures of prepayment rates. The measure quoted is the CPR, the annualized expression of the SMM. It refers to the amount of prepaid principal an investor would receive over a 12-month period assuming the SMM remains constant.

To calculate a prepaid principal amount, it may be tempting to simply take the CPR or SMM and multiply it by the period's beginning balance. However, that would be an incorrect application of the concept. The amount of prepaid principal is calculated only after giving credit to the scheduled principal paid in the

EXHIBIT 22-4

Pool Cash Flow Assuming 100% PSA



period. Exhibit 22-5 provides the derivation of the cash flows of a passthrough, including the allocation of servicing, the guarantee fee, and PMI.

To calculate an agency passthrough's cash flows assuming 100 PSA, the following steps are taken. First, determine the appropriate CPR. For example, a loan age of 10 along the 100 PSA assumption is equal to 2.2% CPR. Second, de-annualize the CPR to an SMM—this is the monthly principal prepaid and is computed using the following formula:

$$\text{SMM} = 1 - (1 - \text{CPR}^{(1/12)})$$

Assuming a CPR of 2.2%, we get

$$\text{SMM} = (1 - (1 - 0.022)^{(1/12)}) = 0.001852$$

Third, after giving credit to the scheduled principal due, the prepaid principal is calculated as follows:

$$(\text{Beginning balance} - \text{Scheduled principal}) \times \text{SMM}$$

In our illustration,

$$\text{Prepaid principal} = \$96{,}784.04 - \$273.84 = \$162.34$$

Finally, allocate interest in the following priority: investor interest amount, servicing fee, PMI, and G-Fee.

EXHIBIT 22-5

Cash-Flow Table for an Agency Passthrough

Original Balance: $100,000
NWac: 4.00%
Gross WAC: 4.75%
Term: 360 mos.
PSA Assumption: 100

Pmt. Date	Begin Bal.	Sched. Prin	Prepaid Prin	Investor Interest	Servicing	PMI	G-Fee
2013-02	100,000.00	275.80	16.63	333.33	20.83	20.83	20.83
2013-03	99,707.55	275.77	33.20	332.35	20.77	20.77	20.77
2013-04	99,398.57	275.69	49.69	331.32	20.70	20.70	20.70
2013-05	99,073.18	275.56	66.10	330.24	20.64	20.64	20.64
2013-06	98,731.51	275.39	82.42	329.10	20.56	20.56	20.56
2013-07	98,373.69	275.17	98.64	327.91	20.49	20.49	20.49
……							
2013-11	96,784.04	273.83	162.34	322.61	20.16	20.16	20.16
2013-12	96,347.86	273.38	177.93	321.15	20.07	20.07	20.07
2014-01	95,896.54	272.88	193.38	319.65	19.97	19.97	19.97
……							
2015-01	89,377.15	263.45	364.54	297.92	18.62	18.62	18.62
2015-02	88,749.15	262.38	377.42	295.83	18.48	18.48	18.40
2015-03	88,109.34	261.27	390.06	293.69	18.35	18.35	18.35
……							
2028-01	21,621.48	119.03	110.58	72.07	4.50	4.50	4.50
2028-02	21,391.86	118.42	109.40	71.30	4.45	4.45	4.45
2028-03	21,164.03	117.81	108.24	70.54	4.40	4.40	4.40
……							
2042-12	95.26	47.63	0.24	0.31	0.01	0.01	0.01
2043-01	47.38	47.38	0.00	0.15	0.00	0.00	0.00

Determinants of Prepayment Rates

Prepayments are the chief determinant of a passthrough's investment performance. The factors described below have been found to impact agency mortgage prepayments and are incorporated into statistical prepayment models.

Over a holding period, the amount of repayment and actual collections of interest are a function of realized prepayments. So too, the price performance of a passthrough is a function of the market's expectations of future prepayments. Earlier we mentioned the causes of prepayments. Here we take a closer look at the determinants of prepayments, which fall into four categories: refinancing, turnover, seasoning, and default.

Refinancing

Homeowners refinance for three reasons: (1) to lower their monthly payment by lowering the mortgage interest rate (often referred to as a "rate refinance"), (2) to alter the term of the mortgage refinancing from a 30- to 15-year term (generally referred to as "rate and term" refinance), and (3) to extract paid-in equity and/or increases in appraised home value due to home price appreciation (often referred to as a "cash-out refinance").

To varying degrees, all the sources of prepayments in pools are interest-rate-sensitive, but the most variable source of prepayments is refinancing. In theory, a rate refinance occurs when the difference in monthly payment between the current note rate and prevailing mortgage rate is sufficient enough to permit the homeowner to recover the loan fees and points, as well as the legal, appraisal, title-related, and other costs of refinancing over some reasonable period of time. In the 1980s, a commonly invoked rule of thumb estimated that the minimum incentive was an interest rate savings of 200 basis points (bps). Aggressive competition among lenders, innovation, and technological advances have shaved closing costs, simplified paperwork, and cut approval times dramatically. The reductions in the cost and "hassle" of obtaining a mortgage began to be evident in the early 1990s, as mortgage bankers stepped into the breach left by the collapse of the thrift industry and accelerated as the decade progressed. Today, market participants estimate that an interest rate savings as little as 35 bps may be sufficient to trigger a refinance. Indeed, declining transaction costs and originator efficiency have multiplied the refinancing response to a given interest rate decline.

Turnover

MBS investors typically refer to prepayments occasioned by the sale of the house as "turnover."

Intuitively, turnover is interest-rate-sensitive in the sense that houses are easier to sell when interest rates are declining or low.[2] However, the level of

2. Note, however, that turnover is not directly indicated by the pace of existing home sales. Those numbers need to be adjusted for existing housing stock, which generally increases as new homes are built.

interest rates is only one of several factors that determine housing affordability and hence the level of turnover. Household income and housing prices are significant as well and tend to offset somewhat the impact of rising interest rates. That is, improving economic conditions, along with rising employment and incomes, tend to accompany upward pressure on interest rates. Somewhat conversely, rapid home sales tend to be accompanied by rising home prices, diminishing affordability to some degree. By the same token, rising mortgage rates may slow home price appreciation, keeping home prices within reach.

Some degree of turnover takes place even in high-interest-rate environments. Seasonality is an important characteristic of turnover, with peak home sales occurring in the summer and troughs typically occurring in the winter. Weather is a factor, at least in northern states, because house hunting and moving are easier in good weather and houses "show" better in good weather. Also, households with children prefer to move between school years. Understandably, the seasonality of prepayments has a more demonstrable impact on passthrough cash flows in high-interest-rate environments, when refinancings are at a low ebb. Likewise, it dominates perception of value in high-rate, low-refi environments.

Seasoning

Seasoning refers to the number of months since the loan origination or first payment date. For example, a loan outstanding 12 months after the origination or first payment date is said to be 12 months seasoned. Investors broadly classify mortgage pools are "new," "moderate," or "seasoned." A new pool is one whose loan age is 30 months or less, a moderate seasoned pool is one whose loan age is between 31 and 60 months, and a seasoned pool is one whose loan age is greater than 60 months. Seasoning can indicate *burnout*. Burnout refers to the fact that the more times the pool of borrowers is exposed to refinancing incentives, the less likely the remaining borrowers are to respond to subsequent refinancing incentives. That is, as borrowers whose circumstances permit them to respond to attractive borrowing rates do so, the fewer the borrowers remaining in the pool that are likely to respond to a given level of rates—a phenomena known as adverse selection.

Consequently, refinance-driven prepayment rates begin to slow. Likewise, passthroughs that have been heavily refinanced in past rallies tend to respond more sluggishly to subsequent refinancing opportunities. A better indication of the refinancing *path* experienced by a passthrough is origination year and coupon.

Defaults

A default can result in a prepayment when the servicer forecloses on the mortgage and sells the property. A borrower default may be of two kinds. The first is a strategic default wherein the borrower holds—especially in the case of a high loan-to-value—a put option to the lender. A precipitous decline in home prices whereby the borrower is underwater—the value of the home is less than the balance of the loan outstanding—may trigger a default. The second is a life event, typically a job loss or serious illness.

In the case of agency passthroughs, because of the passthrough guarantee, investors are protected from any loss that might occur on foreclosure and sale by the passthrough guarantee. In addition to prepayments in full, borrowers may partially prepay their loans at any time.

Prepayment Modeling

To value an agency mortgage passthrough, as well as any derivative RMBS such as a CMO and stripped RMBS, an investor must generate a prepayment estimate. Typically, a model that estimates both voluntary and involuntary repayment is used for this purpose. Before one can "build" a prepayment model, an understanding the fundamental drivers of mortgage prepayments is essential. For this reason, mortgage prepayment analysis is treated as a separate topic from modeling. Prepayment data and the analysis thereof fall under the rubric of *big data* and *statistical learning*.[3] The topic is beyond the scope of this chapter.

SOME MBS ANALYTICS

In addition to prepayments and models there are other analytics that an investor in the MBS as sector of the market should understand: cash-flow yield, average life, and duration. These measures apply to all MBS, not only agency passthrough securities.

Cash-Flow Yield

Once the prepayment rate for an agency passthrough security is predicted, the cash flow can be projected. Given the market price and projected cash flow, a yield can be determined. The yield is nothing more than an interest rate of return. It is the interest rate that makes the present value of the monthly cash flow equal to the market price. In MBS terminology, this yield when annualized is called the *cash-flow yield.* However, the cash-flow yield resulting from the calculation is a monthly yield.

By market convention, to compare the yield for a passthrough that pays monthly to that of a Treasury or corporate bond, the monthly yield should *not* be annualized by simply multiplying the monthly yield by 12. The reason is that a Treasury bond and a corporate bond pay interest semiannually, whereas a passthrough has a monthly cash flow. By reinvesting monthly cash flows, the investor in a passthrough security has the opportunity to generate greater interest than can be earned by a bondholder who has only semiannual coupon payments to reinvest. Therefore, the yield on a passthrough must be calculated so as to make

3. For a comprehensive discussion of the use of big data and machine learning in estimating prepayments, see Chapters 8 and 9 in Glenn Schultz, *Investing in Mortgage and Asset Backed Securities, Financial Modeling with R and Open Source Analytics*, Hoboken, NJ: Wiley 2016.

it comparable to the yield to maturity for a bond. This is accomplished by computing the *bond-equivalent yield*. The bond-equivalent yield for a semiannual-pay bond is found by doubling the semiannual yield. In the case of a monthly-pay MBS such as an agency passthrough, the annualization of the yield to get the cash-flow yield is done in two steps. The first is to calculate a semiannual cash-flow yield:

$$\text{Semiannual yield} = (1 + \text{Monthly yield})^6 - 1$$

The yield corresponding to a price must be qualified by an assumption concerning prepayments. Although yields are frequently quoted, remember that the yield is based on some underlying prepayment assumption. Consequently, a yield of 4.5% based on 120 PSA means that it is assumed that the underlying mortgages will prepay at a rate equal to 120 PSA. A yield number without qualification as to the prepayment assumption is meaningless. In fact, even with specification of the prepayment assumption, the yield number is meaningless in terms of the relative value of an agency passthrough. For an investor to realize the yield based on some PSA assumption, a number of conditions must be met: (1) the investor must reinvest all the cash flows at the calculated yield, (2) the investor must hold the passthrough until all the mortgages have been paid off, and (3) the assumed prepayment rate must actually occur over the life of the passthrough. Now, if all of this is likely, we can trust the yield numbers. Otherwise, investors must be cautious in using yield numbers to evaluate passthroughs.

Weighted Average Life

The average life of an MBS is the average time to receipt of principal payments (scheduled principal payments and projected prepayments), weighted by the amount of principal expected. That is,

$$\text{Weighted average life} = \sum_{t=1}^{T} \frac{t\,(\text{Principal projected for month } t)}{12\,(\text{Total principal})}$$

where T is the number of months. The weighted average life of any MBS depends on the PSA prepayment assumption. Exhibit 22-6 illustrates the calculation of the weighted average life assuming a 120 PSA. The sum of the time weighted principle is the weighted average life of the passthrough; in this case, 8.8 years.

The PSA assumption determined the prepaid principal in any given period and by extension the scheduled principal in the subsequent period. The acceleration of the return of principal shortens the weighted average life of the passthrough. For example, assuming a 0 PSA, no prepayment, the weighted average life of the passthrough is 15.08 years, given a 100 PSA assumption the weighted average life is 9.5 years, and applying a 200 PSA assumption the weighted average life is 6.7 years. Hence, the need to qualify MBS passthrough yield number with a prepayment assumption.

EXHIBIT 22-6

Example or Weighted Average Life Calculation

Original Balance: $100,000.00
Nwac: 4.00%
Gross Wac: 4.75%
Term: 360 mos.
PSA Assumption: 120

Pmt. Date	Pmt Month	Beging Bal.	Scheduled Prin.	Prepaid Prin.	Total Principal	Time Weighted Principal	Sum of Time Weighted Prin.
2013–02	1	$100,000.00	$275.80	$19.97	$295.77	0.00	0.00
2013–03	2	$99,704.23	$275.76	$39.86	$315.62	0.00	0.00
2013–04	3	$99,388.61	$275.66	$59.66	$335.32	0.00	0.00
2013–05	4	$99,053.29	$275.50	$79.37	$354.87	0.00	0.00
… …							
2013–11	10	$96,636.97	$273.41	$194.88	$468.29	0.00	0.02
2013–12	11	$96,168.68	$272.87	$213.57	$486.44	0.00	0.02
2014–01	12	$95,682.25	$272.27	$232.06	$504.33	0.01	0.03
… …							
2015–01	24	$88,529.56	$260.95	$435.30	$696.25	0.01	0.14
2015–02	25	$87,833.31	$259.67	$450.39	$710.06	0.01	0.16
2015–03	26	$87,123.24	$258.35	$465.16	$723.51	0.02	0.17
… …	13	$95,177.91	$271.62	$250.36	$521.98	0.01	0.03
2028–01	180	$18,136.89	$99.84	$111.97	$211.81	0.03	0.04
2028–02	181	$17,925.08	$99.23	$110.66	$209.89	0.03	0.05
2028–03	182	$17,715.19	$98.61	$109.36	$207.97	0.03	0.05
… …	17	$92,986.88	$268.47	$321.30	$589.77	0.01	0.06
2042–12	359	$66.01	$33.00	$0.20	$33.20	0.01	8.79
2043–01	360	$32.81	$32.80	$0.00	$32.80	0.01	8.80
					Weighted Average Life		**8.80**

Duration of an MBS

Duration is a measure of the sensitivity of a bond to a change in the level of interest rates. The duration of a bond is calculated as follows:

$$\text{Duration} = \frac{V_{-} - V_{+}}{2V_0(\Delta y)} \tag{22-4}$$

where

Δy = change in the bond's yield (in decimal form)
$V0$ = initial price of the bond (per \$100 of par value)
$V+$ = the estimated value of the bond per \$100 of par value if the yield is increased by Δy
$V-$ = the estimated value of the bond per \$100 of par value if the yield is decreased by Δy

The two unknowns in Equation (22-4) are the prices when the yield is increased ($V+$) and decreased ($V-$). The method used to determine the new prices if yields change is what distinguishes the different types of duration measures. And, how good the new prices are in estimating the new price determines how good the specific duration measure is in forecasting the future price change.

In implementing Equation (22-4) it is necessary to change the bond's yield by some number of basis points (Δy). The number of basis points to use to compute the new prices is selected by the investor. There is no rule but only guidelines for how large the change should be, which we describe later.

In general, duration measures fall into two categories: model duration and empirical duration.

Model Duration

Model duration means that the two prices used in the numerator of Equation (22-4) are obtained from some analytical model. For agency passthroughs, model duration measures include modified duration, cash-flow duration, and effective duration. The difference between these duration measures is what the model assumes happens to the cash flow if interest rates change.

***Modified duration*:** This duration measure is the simplest one to compute but is likely to be the least reliable in many circumstances. In the calculation of the two values in the numerator of Equation (22-4), it is assumed that the cash flow used to generate the current price is the cash flow when interest rates are shocked up and down. Thus, the agency passthrough is revalued only by using the interest rate associated with the interest rate shock (i.e., discounting the cash flow by the interest rate associated with the interest rate shock). For example, suppose that given today's price for an agency passthrough (V_0), the implied prepayment rate is 120 PSA. This means that a 120 PSA generates the cash flow that leads to V_0. If interest rates are shocked to obtain the two values in Equation (22-4), V_+ and V_-, the cash flow used is based on 120 PSA but the cash flow is discounted at the new interest rate (i.e., the original yield plus the interest rate shock) to obtain these two values. The assumption being made here is that the change in interest rates will have no impact on future cash flows because it will not change prepayments.

The problem with using modified duration to estimate the interest rate sensitivity is that for an agency passthrough that is highly prepayment sensitive to interest rate changes, failing to recognize how the cash flow will change because prepayments change will produce a misleading estimate of duration.[4]

Cash-flow duration: Rather than assume that the cash flow does not change when interest rates change because prepayments do not change as assumed in the computation of modified duration, it can be assumed that prepayments will change based on a new prepayment speed that reflects the interest rate change. That results in a new cash flow based on the projected prepayment speed, which is then discounted at the new interest rate. When the new prices in Equation (22-4) are computed in this manner, the resulting duration means is referred to as *cash-flow duration*.

For example, assume that the current prepayment rate is 120 PSA for an agency passthrough. To get the two values to use in the duration formula given by Equation (22-4), suppose the cash-flow yield is shocked by 50 bps. If the cash-flow yield is increased, then a prepayment model is used to determine the new cash flow at the higher yield level. Suppose that a prepayment model indicates that at the higher yield level the prepayment speed will decline to 105 PSA. Then the cash flow for this security is generated based on 105 PSA and discounted at the current yield plus the change in interest rates. This gives the value of V_+. Suppose that if interest rates decrease by 50 bps the prepayment model projects that the prepayment rate will increase to 135 PSA. Then the new cash flow for this security will be generated based on 135 PSA and at the original yield level reduced by the change in interest rates. The resulting value for the security is V_-. Using these two values in Equation (22-4) gives the cash-flow duration.

Cash-flow duration is superior to modified duration in that it at least recognizes that the cash flow may change when interest rates change. However, it still suffers from the problem that in computing the V_+ and V_- it only recognizes one possible cash flow in contrast to the valuation methodology described next.

Effective duration**:** In contrast to modified duration, *effective duration* is a duration measure that assumes when interest rates change, the original cash flow will change. Unlike cash-flow duration, which allows for the cash flow to change when interest rates change, effective duration uses a valuation model to determine what the two prices for Equation (22-4) are. This is done as follows. When

4. The same problem with using modified duration applies to its close cousin, *Macaulay duration*. Modified duration is simply Macaulay duration divided by 1 plus a periodic interest rate. That is, there is a simple mathematical relationship between modified and Macaulay duration and since modified duration holds little interest to us, so does the Macaulay duration. In a very low interest rate environment, Macaulay duration and modified duration are almost identical.

interest rates are changed, as explained next when we describe the valuation model, a large number of potential future interest rate paths and associated cash-flow patterns are used to obtain the two new prices. Because the valuation model itself takes into consideration the embedded option associated with an agency passthrough, effective duration is also referred to as *option-adjusted duration***.**

The most common model used to value an agency passthrough is the Monte Carlo simulation model (simply Monte Carlo model, hereafter). All mortgage-backed securities are interest rate path-dependent financial instruments. This means that the cash flow received in one month is determined not only by the current interest rate level, but also by the path that interest rates took to get to the current level. In the case of an agency passthrough, prepayments are interest rate path-dependent because this month's prepayment rate depends on whether there have been prior opportunities to refinance since the underlying mortgages were originated. The bottom line is that valuation by Monte Carlo simulation, the subject of Chapter 37, provides the two values for the numerator in Equation (22-4).

There several key underlying assumptions that are made in the Monte Carlo simulation model for valuation of agency passthroughs. This is the reason why there are differences in the effective durations reported by dealers and vendors of analytical services for all types of mortgage-backed securities.

Market-Based Duration

Market-based duration measures for an MBS use observed market prices rather than projected prices. Several approaches based on observed market prices are used to calculate duration. These market-based approaches are empirical duration, hedging duration, and coupon curve duration.

Empirical duration: This duration measure, sometimes referred to as *implied duration*, is the sensitivity of an MBS as estimated empirically from historical prices and yields. Regression analysis is used to estimate the relationship.[5] On a daily basis the following regression is calculated:[6]

$$\text{Change in mortgage price} = a + b\,(\text{Change in 10-year Treasury yield}) \qquad (22\text{-}5)$$

5. This approach was first suggested by Scott M. Pinkus and Marie A. Chandoha, "The Relative Price Volatility of Mortgage Securities," *Journal of Portfolio Management* (Summer 1986), pp. 9–22. The model was then refined in Paul DeRossa, Laurie Goodman, and Mike Zazzarino, "Duration Estimates on Mortgage-Backed Securities," *Journal of Portfolio Management* (Winter 1993), pp. 32–37.

6. The model described here is the one proposed in Laurie S. Goodman and Jeffrey Ho, "Mortgage Hedge Ratios: Which One Works Best?" *Journal of Fixed Income* (December 1997), pp. 23–33, and Laurie S. Goodman and Jeffrey Ho, "An Integrated Approach to Hedging and Relative Value Analysis," chapter 15 in Frank J. Fabozzi (ed.), *Advances in the Valuation and Management of Mortgage-Backed Securities* (New Hope, PA: Frank J. Fabozzi Associates, 1999).

Given the estimate of b from Equation (22-5), the empirical duration is then calculated as follows:

$$\text{Empirical duration} = \frac{b(\text{Change in mortgage price/ Change in 10-year yield})}{\text{Full price of the MBS}} \tag{22-6}$$

There are advantages of the empirical duration approach:

1. The duration estimate does not rely on any theoretical formulas or analytical assumptions.
2. Estimation of the required parameters is easy to compute using regression analysis.
3. The only inputs that are needed are a reliable price series and Treasury yield series.

The empirical duration approach has the following disadvantages:

1. A reliable price series for the mortgage security may not be available. For example, there may be no price series available for a thinly traded mortgage derivative security or the prices may be matrix priced rather than actual transaction prices.
2. An empirical relationship does not impose a structure for the options embedded in an MBS and this can distort the empirical duration.
3. The price history may lag current market conditions. This may occur after a sharp and sustained shock to interest rates has been realized.
4. The volatility of the spread to Treasury yields can distort how the price of an MBS reacts to yield changes.

From an implementation perspective, there is no standardization as to the frequency of the data that should be used (i.e., daily, weekly, monthly), the length of the time period that should be used, and even the appropriate Treasury maturity yield that should be used. Moreover, it is not possible to calculate the empirical duration for illiquid or non-conforming MBS where little trading is performed.

Hedging duration: A more elaborate empirical model for estimating duration of an MBS that takes into account factors that we have noted impact its price (level of rates, shape of the yield curve, and expected interest rate volatility) has been suggested by Goodman and Ho.[7] The price model that they present, a special type of empirical duration model, allows not only an estimate of the sensitivity

7. Goodman and Ho, "An Integrated Approach to Mortgage Hedging and Relative Value Analysis."

of the price to changes in the level of rates, but also to the other factors. In their price model:

- The 10-year Treasury yield is used as a proxy for the level of rates.
- The spread between the 10-year and 2-year Treasury yields is used as a proxy for the shape of the yield curve.
- The implied 3-month yield volatility on the 10-year Treasury note is used as a proxy for expected interest rate volatility.

The price model involves estimating the following regression:

$$\text{Price} = \begin{aligned} &a + b\,(\text{10-year yield}) + c\,(\ln[\text{10-year yield}]) \\ &+ d\,(\text{10-year/2-year spread}) + e\,(\text{volatility}) \end{aligned} \qquad (22\text{-}7)$$

where ln[10-year yield] means the natural logarithm of the 10-year Treasury yield.

Hedging duration, also referred to as price model duration, is then computed as follows given the estimates for the parameters for Equation (22-7):

$$\text{Price model duration} = -[b + c/(\text{10-year Treasury yield})] \qquad (22\text{-}8)$$

***Coupon curve duration*:** This duration measure uses market prices to estimate the duration of an MBS. It is an easier approach to duration estimation than empirical duration but is limited in its application for the reason explained below.

Coupon curve duration, first suggested by Douglas Breeden,[8] starts with the coupon curve of prices for similar MBSs. By rolling up and down the coupon curve of prices, the duration can be obtained. Because of the way it is estimated, this approach to duration estimation was referred to by Breeden as the "roll-up, roll-down approach." The prices obtained from rolling up and rolling down the coupon curve of prices are substituted into the duration formula given by Equation (22-4).

To illustrate this approach, let's assume the following coupon curve of prices for agency passthroughs as of a particular date are:

Coupon (%)	Price ($ per $100 par)
3.0	101.0000
3.5	103.9688
4.0	106.4063
4.5	108.3750
5.0	110.5625

8. Douglas Breeden, "Risk, Return, and Hedging of Fixed-Rate Mortgages," *Journal of Fixed Income* (September 1991), pp. 85–107.

Suppose that the coupon curve duration for the 4s is sought. If the yield declines by 50 bps, the assumption is that the price of the 4s will increase to the price of the 4.5s. Thus, the price will increase from 106.4063 to 108.3750. Similarly, if the yield increases by 50 bps, the assumption is that the price of the 4s will decline to the price of the 3.5s (103.9688). Using the duration formula given by Equation (22-4), the corresponding values are

$$
\begin{aligned}
V_0 &= 106.4063\\
V_- &= 108.3750\\
V_+ &= 103.9688\\
\Delta y &= 0.005
\end{aligned}
$$

The estimated duration based on the coupon curve is then

$$\text{Current coupon duration} = \frac{108.3750 - 103.9688}{2\,(106.4063)\,(0.005)} = 4.14$$

Note that if a 100 bps rate shock is used, the current coupon duration would be

$$\text{Current coupon duration} = \frac{110.5625 - 101.0000}{2\,(106.4063)\,(0.01)} = 4.49$$

While two advantages of the coupon curve duration are the simplicity of its calculation and the fact that current prices embody market expectations, there are disadvantages. The approach is limited to generic MBS and TBAs and difficult to use for mortgage derivatives.

ANATOMY OF THE AGENCY PASSTHROUGH MARKET

In general, the "anatomy" of the agency passthrough market is driven by two concerns: liquidity and expected prepayment behavior. Liquidity is maximized in the trading of generic agency passthroughs, and prepayment behavior is parsed in the trading of specified pools and small pooling programs.

Generic Securities

One of the unique features of the agency passthrough market is the existence of a liquid forward market for trading these securities, out to a horizon of one to three months. The market for forward trading of agency passthroughs is known as the *to be announced (TBA) market*. The TBA market allows for forward trading of agency passthrough based only on the generic attributes of coupon and term. The actual pools delivered to settle the trade are "announced" 48 hours prior to the settlement of the contract. The agency passthrough TBA market is recognized as one of the world's most liquid markets, second only to the U.S. Treasury market. Indeed, throughout the Global Financial Crisis, the TBA market functioned flawlessly as the GSEs were placed into conservatorship and liquidity in the private label MBS market seized. The performance of the TBA market throughout the financial crisis garnered the TBA market the title of the "The Eighth Wonder of the World." As a result of the TBA market's performance throughout the financial crisis, policy regulators were keen to support and enhance the TBA market's liquidity. Hence the creation of the Uniform Mortgage Backed Security (UMBS).

Beginning June 3, 2019, both Fannie Mae and Freddie Mac began offering TBA-eligible Uniform Mortgage Backed Securities (UMBS). It is important to note that UMBS are TBA-eligible securities and both Fannie Mae and Freddie Mac continue to offer passthroughs that are not TBA-eligible and by extension are not UMBS.

UMBS contracts mirror that of the Fannie Mae's legacy mortgage contract in terms of guarantee and payment day delay, specifically the mortgage contracts pay cash flow through to the investor on a 55-day delay. Thus, all outstanding Fannie Mae TBA eligible passthroughs are considered UMBS. However, Freddie Mac's TBA-eligible Gold fixed-rate passthroughs pay cash flow through to the investor on a 45-day delay. Thus, legacy TBA Gold mortgage contracts are not considered UMBS. However, investors may exchange Freddie Mac Gold passthroughs for Freddie MAC UMBS. As part of the exchange a one-time 10-day float compensation is paid to the investor. UMBS are issued as 30-year fixed rate, 20-year fixed rate, 15-year fixed rate, and 10-year fixed rate pools. Both Fannie Mae and Freddie Mac guarantee the timely payment of interest and scheduled principal.

Fannie Mae and Freddie Mac UMBS are considered fungible. That is, the investor or dealer may deliver each to satisfy TBA delivery. The fungibility of the UMBS created the concept of level 1, level 2, and level 3 securities with respect to mortgage securitization. Level 1 securities are passthroughs and include UMBS, Level 2 securities are pools of pools, Supers are pools of pools of UMBS, and Level 3 securities REMICs and Strips. UMBS are eligible for re-securitization in either Supers (Level 2) or REMICs (Level 3) securities. An investor or dealer that owns a UMBS may re-securitize either by itself or comingled with other Fannie Mae or Freddie Mac securities. The re-securitizing Enterprise will also guarantee the re-securitization.[9]

Generic passthrough classes are divided first by agency. GNMA should trade distinctly from GSE passthroughs; the guarantee is backed by the U.S. government, and the underlying loans are assumable, subject to lower loan limits, and possess demonstrably different credit performance.

The market does perceive a difference in credit quality between GNMA and the GSEs and consequently demands a risk premium for the conventional agency passthroughs. All other factors being equal, this would translate into a higher yield for the GSE-guaranteed issues. However, all else is not equal.

9. SIFMA Single Security Fact Sheet 2019. Available at https://www.sifma.org/wp-content/uploads/2016/05/Single-Security-Fact-Sheet.pdf.

Fundamental and technical issues influence the price behavior of the securities and over time have tended to swamp differences in credit quality. At one time, 30-year GNMA also enjoyed a liquidity advantage over the conventional 30-year programs. In the 1970s and 1980s, 30-year GNMA passthroughs were the de facto market benchmarks (Ginnie Mae was virtually a synonym for mortgage-backed security), giving way to Fannie Mae by the mid-1990s. However, declining market share (of both new and outstanding passthrough supply) has not consistently hurt its price relationship to FNMA (and by extension, FHLMC). Rather, much of the demand for GNMA passthroughs is entrenched, coming from foreign investors who look more to the guarantee than to the underlying credit quality of the loans or quality of the GSE's reserves funded by guarantee fees and from Ginnie Mae and "government" mutual funds that have written these securities into their prospectuses. Entrenched demand in the face of sharply shrinking supply now tends to support GNMA prices, so they can be significantly higher than FNMA prices than the difference in payment delay alone would suggest (the 14 days of delay are worth four to eight ticks depending on the interest rate environment and FNMA should trade behind GNMA).

Finally, changes in pooling criteria boosted production of GNMA IIs relative to GNMA Is. This resulted, at times, in new issuance of GNMA Is trailing that of GNMA IIs. Also, differences in pooling criteria have an effect on the prepayment characteristics and hence on the relative value of GNMA IIs to GNMA Is. An exploration of these differences, however, is beyond the scope of this chapter.

Fannie Mae and Freddie Mac guarantees are comparable, and the eligible loans are fungible, but they trade differently for a variety of reasons. The difference in delay is worth about four to eight ticks, depending on the level of yields, making Freddie Mac's shorter delay more expensive, a factor that influences demand, all else equal.

Coupon Stacks

Within programs, such as 30-year Gold PC or GNMA I SF, pools are aggregated by coupon. While it is feasible to create agency passthroughs with coupons that vary by as little as one-eighth of a percent, concentrating issuance in whole and half coupons simplifies relative-value analysis, and trading strategies and maximizes liquidity. Most standard market reports, such as daily price reports or monthly prepayment reports, ignore the small amounts of quarter and eighth coupons outstanding. Market slang refers to the whole and half coupons as the "coupon stack."

Within a generic coupon, pools are grouped by issue year or vintage. The most useful strategy is to define issue year at the loan level rather than by the issue date of the pool. In other words, if a pool is issued January 1, 2019, but the average age of loans at issue indicates the loans were closed in November 2018, the pool is included in the 2018 vintage.

TBA COUPONS

In current practice, in the fixed-rate market, TBA securities, or coupons, are the whole and half coupons of the mainstay 30- and 15-year programs, as well as the 10- and 20-year GSE pools. As noted earlier, the term TBA means that the actual pools delivered to settle the trade are "to be announced."[10] Actual pool numbers are provided within 48 hours of the delivery date; notification or "allocation" dates are set by the Securities Industry and Financial Markets Association (SIFMA).

Unlike other fixed-income securities and other structured products that settle a defined number of days after the trade, TBA passthroughs settle once a month, roughly mid-month. This practice evolved in the early days of agency securitization to accommodate the fact that originators want to sell forward to hedge their pipelines (lock in the prices at which they are originating loans) but cannot predict to a round number the actual principal amount of closed loans going into a pool. (It also follows that pool numbers would not be known.) The practice of trading new pools TBA enlarged quickly to include existing pools, permitting dealers to sell agency passthroughs in response to investor inquiry without owning or having to quickly buy them from another investor or dealer.

Dollar Roll Financing in the TBA Market

The mortgage *dollar roll* is a financing mechanism used in the agency passthrough market. This discussion provides a brief description of the mechanics of the dollar roll. Break-even and financing analyses and the risks associated with implementing a dollar roll program are not addressed.[11]

For investors, the dollar roll is a specialized type of collateralized borrowing unique to the agency passthroughs market that allows for a 100% advance rate against a pool of agency MBS.[12] It evolved due to the dealers' need to borrow these securities to cover short positions and mortgage originators' need to hedge their origination pipeline (long positions) by *selling forward*. The dollar roll is named such because dealers are said to either *roll in* collateral (borrowing) or *roll out* collateral (returning).

The mortgage dollar roll is similar in nature to a mortgage repurchase (repo) agreement in that it represents a loan collateralized by mortgage-backed

10. Those terms are resolved in the pool notification process, which must take place at least 48 hours before delivery. Cutoff times are set by the SIFMA, along with standard requirements for delivery on settlements of agency passthroughs. The chief of these are numbers of pools and variance between trade amount and the current principal balance of pools delivered. The requirements for TBA trading are spelled out in the *Uniform Practices Manual*.

11. For an explanation and illustration of how an investor should evaluate a dollar roll, see Chapter 10 in Glenn Schultz, *Investing in Mortgage Backed and Asset Backed Securities Financial Modeling with R and Open Source Analytics*, Hoboken, NJ: John Wiley & Sons, 2016.

12. The dollar roll also provides mortgage originators and dealers with a flexible means to hedge and finance their respective residential mortgage positions.

securities and calls for the simultaneous sale and purchase of the MBS at execution. However, it is materially different from a *repurchase agreement* in two ways. First, the dealer is not required to return the identical securities rolled out by the investor. Instead, the dealer need only return substantially similar securities.[13] Second, unlike a traditional repurchase agreement, the investor surrenders the right to the bond cash flows. As a result, the forward settlement price is lower than the initial settlement price. The *drop* in price compensates the investor for the forgone interest and principal, which is another feature that differentiates a dollar roll transaction from a traditional repurchase agreement.

SPECIFIED TRADES[14]

Specified pools are those pools whose characteristics have been found to exhibit superior or inferior convexity relative to generic (TBA) pools. Specified pools are identified either by a prefix that is designated by either FNMA or FHLMC or by the pool's characteristics found in either the geographic disclosure files or the quartile files. In some cases, a pool may meet several specified pool criteria. To avoid confusion as to which specified pool sector a particular pool may belong a hierarchical ordering is employed as follows:

1. Assign sector by prefix.
2. Assign sector by geography.
3. Assign sector by loan balance.
4. Assign sector by investor percentage (100%).
5. Assign sector by refinance (100%) and loan-to-value ratio.
6. Assign sector by FICO (≤ 680).

Any pool not assigned to the above sectors is considered TBA or worst to deliver.

Specified pools trade at a premium or concession to TBA pools; the extent to which each trades to a premium or concession is dependent on the convexity profile of the pool. Those pools with superior relative convexity trade to larger a premium while those with inferior convexity trade to a concession. Each of the sectors described above have different convexity profiles.[15]

The earliest established specified pool sector is the loan balance sector. Originally, the specified pool sector was defined by low loan balance (LLB), moderate loan balance (MLB), and high loan balance (HLB). Over time, the

13. Meeting this condition is important from a financial accounting standpoint as set forth in Financial Accounting Standard (FAS) 40. Failure to meet the FAS 140 standard would result in a dollar roll transaction being accounted for as a sale rather than a financing.

14. For a more detailed discussion, see Glenn Schultz, *The Bond Lab Guide to Investing in Agency MBS Specified Pools*, unpublished manuscript.

15. See Schultz, *The Bond Lab Guide to Investing in Agency MBS Specified Pools*.

sector was further stratified to include moderate high loan balance (MHLB), high-high loan balance (HHLB), and super high loan balance (SHLB).

The prefix sectors can be divided into the jumbo loan balance sector, the loan-to-value (LTV) sector, and the relocation sector. The geographic sectors are for geographic pools with a 100% concentration to a given state. The most common geographic pools are Puerto Rico, New York, Florida, and Texas.

Aside from the sectors previously outlined, pools also trade according to New, Moderate, and Seasoned. The definition of each is as follows: (1) New Seasoned pools are defined as those pools whose loan age (WALA) is less than or equal to 30 months, (2) Moderate Seasoned pools are defined as those pools whose loan age (WALA) is greater than 30 months and less than 60 months, and (3) Seasoned pools are defined as those pools whose loan age (WALA) the greater than or equal to 60 months.

KEY POINTS

- Agency mortgage passthrough securities are issued and guaranteed by Ginnie Mae, Fannie Mae, or Freddie Mac and distribute the cash flow pro rata to investors on a monthly basis after deducting servicing and a guarantor fee.
- The monthly cash flow of an agency passthrough includes interest, scheduled principal payments, and prepayments. To project the cash flow for an agency passthrough, a prepayment assumption must be assumed. Prepayment conventions include single monthly mortality rate/conditional prepayment rate and the Public Securities Association model. Because of the uncertainty about the cash flow due to prepayments, investors in agency passthrough are exposed to prepayment risk.
- The chief determinants of prepayments fall into four categories: refinancing, turnover, seasoning, and default.
- The cash-flow yield is the yield calculated based on some prepayment assumptions and is a poor measure of relative value.
- The weighted average life of an MBS passthrough security measures the weighted average time to receipt of principal and is dependent on the prepayment assumption. A slower prepayment assumption extends the weighted average life of a MBS passthrough security. Conversely, a faster prepayment assumption shortens the weighted average life of a passthrough.
- There are various measures of duration for any mortgage-backed security: model duration (modified duration, cash-flow duration, and effective duration) and market-based duration (empirical duration and hedging duration). Of these. the most commonly used by investors and dealers are effective duration and empirical and hedging duration.

- The to-be-announced (TBA) market allows for forward trading, up to three months, of agency MBS passthrough securities. The market is recognized as one of the most liquid markets in the world, second only to the U.S. Treasury market. Trading in the TBA market is based on the generic characteristics of coupon and term. The securities delivered are "announced" 48 hours prior to settlement of the forward agreement.
- Specified pool trading is based on security specific CUSIP or pool number. Specified pools trade at a premium or concession to TBA pools, the extent to which is dependent on the convexity profile of each.
- The dollar roll is a specialized type of financing found in the agency passthrough market that allows 100% collateralized borrowing against a pool of agency mortgage-backed securities. The dollar roll allows dealers to easily cover short positions and originators to sell forward current loan production.
- Specified pool trading is based on security specific CUSIP or pool number.
- Each specified pool sector exhibits a unique convexity profile relative to those pools considered TBA. Due to their unique convexity profiles, specified pools trade at a premium or concession to TBA pools.

CHAPTER
TWENTY-THREE

AGENCY COLLATERALIZED MORTGAGE OBLIGATIONS

Alexander Crawford

This chapter provides an introduction to the U.S. agency collateralized mortgage obligation (CMO) market. It begins with the background of the CMO market and explains the difference between agency and nonagency CMOs. The chapter introduces the issuers Fannie Mae, Freddie Mac, and Ginnie Mae and then covers all of the major CMO tranche types in terms of structure and analysis, providing practical examples. It also covers information about option-adjusted spread (OAS) and prepayment models, and how to use that information to hedge CMOs or determine relative value. Coverage of nonagency CMOs is provided in Chapter 25.

THE CMO MARKET

The CMO market has existed since the mid 1980s. Its original purpose was to allow investors to more closely control when they receive principal from mortgage-backed securities. With mortgage pass-throughs, principal is received each month throughout the life of a security, often for a full 30 years. In a CMO, the principal is divided up into pieces or "tranches" creating some bonds that receive principal right away (and hence have shorter durations) and bonds that do not, typically resulting in longer durations. The creation of so-called PAC, or planned amortization class bonds took the CMO a step further, attempting to create a corporate bond surrogate.

To create a CMO, a dealer must gather agency pass-through collateral, structure a deal, and then pay a fee to Freddie Mac, Fannie Mae, or Ginnie Mae to issue the CMO. Ginnie Mae has the full faith and credit of the U.S. government, whereas the other agencies have the implicit guarantee of the U.S. government.

Now, the CMO market has exploded into a myriad array of tranches using different types of collateral. The cash-flow priority of tranches can even jump around based on prepayments. The same financial technology used to create

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This chapter was written when the author was an employee of Deutsche Bank.

CMOs has been employed to create other securitized products in the world global market.

When comparing nonagency CMOs to agency CMOs, agency CMO analysis tends to be simpler because of more established prepayment models and minimal credit risk. Collateral information disclosure on nonagency CMOs tends to be slightly better, but in general the information gap is marginal for new deals.

THE REASONS WHY CMOs EXIST

Like any security, CMOs exist because there is a market to buy and sell them. From the demand side, there are investors who still want to more closely control the cash flows they get from an MBS investment. In addition, the CMO market has grown to such an extent that many other things are possible using the CMO market than with the MBS pass-through market, such as bonds with coupons that adjust on a monthly basis (floaters). From the supply side, CMO originators continue to operate as long as they can make a reasonable profit in the business. Often, all the CMO tranches are not sold right away, which forces the dealer to hold inventory, and thus take risk.

Size of the CMO Market

Peak issuance of agency CMOs was over $600 billion in 2003. CMO issuance dropped to only $150 billion during the financial crisis of 2008, but has since rebounded. For example, agency CMO issuance in 2020 reached over $400 billion. Historically, issuance of new CMOs has been similar to or surpassed that in most other markets, including Treasuries and corporate bonds.

Liquidity

The raw size of the CMO market suggests it should have enormous liquidity. However, liquidity is somewhat hampered by lack of homogeneity in the CMO market. Even the most common tranche types, PACs and sequentials, may have subtle differences that need to be examined and valued. (We will discuss this in detail later.) The liquidity of CMOs is typically less than agency pass-throughs, but comparable to corporate bonds.

Practical Details

In this section, we cover practical details such as typical payment and settlement structure for CMOs. Rules are generally different for CMOs than for corporate bonds. In some cases, rules are different for certain types of CMO tranches than for pass-throughs.

Bond Settlement

CMOs usually settle in book entry via DTC (Depository Trust Co.). Primary market CMOs may have delayed settlement, similar to pass-throughs. For example, many new-issue CMOs settle in the month after the trade date. New-issue CMOs usually settle at the end of the month, to allow the dealer time to bring in collateral and finish structuring the deal.

Secondary market CMO transactions are typically for corporate settlement, presently T+2 business days. It is possible to trade CMOs for other settlements, such as cash (T+0), if necessary.

Monthly Interest and Principal Payments

CMOs pay interest monthly, similar to the underlying pass-throughs. Tranches eligible to receive principal payments will receive them at the same time as the interest payments. Most CMOs have the same number of delay days as the underlying collateral, for example, 45 stated delay days for GNMA pass-throughs. However, certain tranches, such as CMO floaters, may have reduced delay days to facilitate comparison to corporate bonds. The number of delay days for each tranche is available in the prospectus or from electronic sources. Of course, the number of delay days impacts yield, as interest and principal are returned later (and hence reinvestment interest on that interest and principal is foregone) the longer the delay is.

Deal Clean-Up Calls

Some deals may contain clean-up calls triggered when only a small portion of the deal remains. The percentage trigger is typically set between 1% and 10%, inclusive. This feature is typically set up to avoid the burden of high fixed costs for the deal's trustee when a small amount of bonds remains outstanding. We discuss analyzing deal clean-up calls later in this chapter.

New Issue vs. Secondary Markets

The new issue CMO market typically settles as much as one or two months in the future, allowing the issuer to gather the requisite collateral for the deal and complete structuring. This structuring period also affords the investor the opportunity to custom design CMO tranches that fit the portfolio. Most secondary tranches trade for corporate settlement. While the investor cannot change existing tranches, more information about the tranche, such as historical prepayment speeds, can be valuable to the investor.

CMO TRANCHE TYPES

The crux of understanding the CMO market is understanding the different tranche types and how they are structured. Today, CMO deals are very complex, with multiple collateral sources, multiple tranche types, etc., in a complex array for each CMO deal. It is important to realize that each of these deals is made primarily from two basic flavors.

- A *planned amortization class* (PAC) deal, in which the non-PAC (support or companion) tranches have highly variable cash flows and average lives, while the PAC enjoys relatively stable, prescheduled cash flows.
- A *sequential deal*, where standard sequential tranches have cash-flow priority (i.e., absorb most or all of the principal from the deal) in turn until they are all retired.

These types of deals can be altered or dressed up slightly (such as in a PACquential deal), but there are still two basic flavors. Once the PACs and sequentials are created, they can be divided even further (e.g., into a PAC floater and PAC inverse floater). It is also possible to add other tranches with special features, such as a tranche where interest accrues back into the principal, called a Z-bond (i.e., zero coupon). Nevertheless, to understand the structure of CMOs, one must always start with that first question on which deal type it is, then walk through how an individual tranche was created in order to correctly analyze it.

For each tranche type in this section, we will provide the following: description, example, yield table, and methods of analysis. Note that while we have tried to be as realistic as possible in showing yield table and OAS analysis for CMO tranches, these numbers do not necessarily correspond to anything available in the market currently. These examples have been constructed mainly for learning purposes, not to illustrate relative value or hedging purposes! We also do not identify deal names or CUSIPs on any of these bonds for those reasons.

Sequential

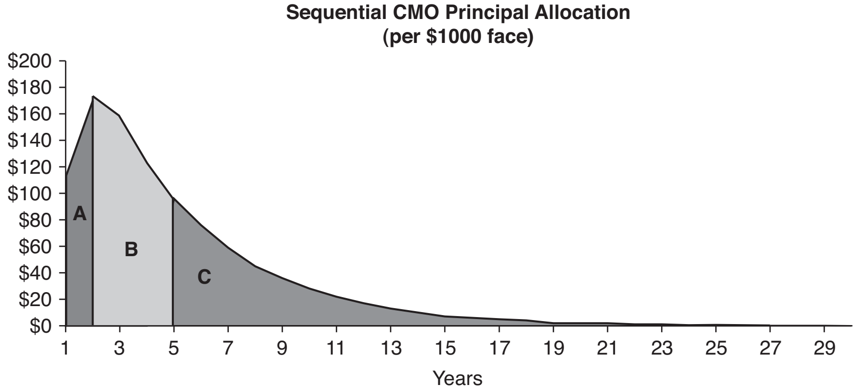
A *sequential CMO*, also historically referred to as a "vanilla bond," deal typically takes the collateral's principal and time tranches it. The first sequential tranche receives all of the prepaid and scheduled principal from the deal until the tranche is retired, then the next sequential in line starts receiving principal. For example, in a simple three-tranche sequential (Exhibit 23-1), the first sequential could be allocated 30% of the deal's principal. All principal cash flows from the underlying collateral would pay down the first sequential tranche to a zero balance. Then, the second sequential would receive its principal, and finally the third. The purpose of this structure is twofold. Investors may want a shorter or longer duration than the underlying collateral. In addition, the period of time before which the second sequential receives any principal is known as *lockout*. This lockout feature may be valuable to some investors who do not want to receive (and possibly need to reinvest) principal for some period of time.

Example

Sequential bonds will have a different duration, average life, and projected cash flow for each prepayment assumption tested. In many respects, they perform like

EXHIBIT 23-1

Cash Flows from a Three-Tranche Sequential Deal



the underlying collateral of the CMO deal. Increase prepayments, and sequentials shorten their average life and duration. A few differences between sequentials and collateral:

- The window of time principal is returned to the investor in a sequential is narrower than that for collateral.
- A sequential can be locked out from prepayments (i.e., the factor remains 1.0) for some period of time. Pass-throughs start to factor down from 1.0 as soon as they are created.
- The coupon on a sequential (or any other CMO bond) can be different from the underlying collateral. Most commonly, the coupon on the sequential is "stripped down" lower than the collateral in order to create bonds that trade at or below par.

When a sequential coupon is stripped down, a portion of the interest from the collateral is diverted elsewhere in the deal.[1] The purpose of this maneuver is to lower the price of the sequential bond, although typically the yield of the bond will also fall. Nomenclature in the CMO world talks of the *tranche coupon* versus the *collateral coupon*. For example, a 5.0/5.5 sequential would be a bond with a 5% coupon in a deal using 5.5% pass-through collateral.

Exhibit 23-2 compares the yield tables of a full coupon, 5.5/5.5 sequential with a stripped down 4.0/5.5 sequential. Note that the principal cash flows are essentially the same—the principal cash flows on these bonds react in the same way to changes in prepayment rates. However, market performance will likely be

1. Note that the coupon income stripped off these tranches could become an IO/IOette tranche, or could be added to a regular tranche with principal to create a premium tranche, for example, a 6% coupon off 5.5% collateral.

EXHIBIT 23-2

Comparing the Yield Tables of Full vs. Stripped Down Coupon Sequentials

Sequential, 4% on 5.5% Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	225	145	120
Price					
96.625	7.20%	6.03%	4.87%	4.67%	4.61%
97.625	6.20%	5.40%	4.61%	4.47%	4.43%
98.625	5.21%	4.78%	4.35%	4.27%	4.25%
Average Life	1.09	1.76	4.50	6.20	7.05
OAS	25				
OAD	5.26				
OAC	–1.36				

Sequential 5.5% on 5.5% Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,596	823	223	146	121
Price					
101.9375	3.51%	4.23%	5.00%	5.13%	5.17%
102.9375	2.58%	3.63%	4.75%	4.93%	4.99%
103.9375	1.67%	3.04%	4.50%	4.73%	4.81%
Average Life	1.09	1.73	4.54	6.18	7.01
OAS	35				
OAD	3.11				
OAC	–2.27				

Source: DB Global Markets Research.

quite different, due to the longer duration of the 4.0/5.5 tranche. The 4.0/5.5 tranche has a 5.26 option-adjusted duration (OAD) versus a 3.11 OAD for the 5.5/5.5 full coupon sequential in our example. When interest (IO) is removed from a tranche, the negative duration associated with the IO is also removed, extending the duration of the remaining bond.

An intuitive way to think about premium and discount CMO durations is callable corporate bonds. As the price of the bond goes over par, it becomes harder for the price to rise given a drop in interest rates because of the call feature (in the case of MBS, faster prepayments). The duration of a high premium callable bond will be close to the call date because it is likely to be called. However, the duration of a deep discount callable bond is longer, close to the maturity date of the bond, because the bond is unlikely to be called.

Analysis

Analysis of sequentials falls into two broad categories:

- Analysis of short duration sequentials that are currently paying, typically as short duration bonds. They may be compared to short agencies, ABS, hybrid ARMs, other CMOs, etc.
- Longer duration sequentials that are often compared with the underlying collateral. Many characteristics of the sequential and collateral are typically similar: prepayment speeds, duration profile, etc.

For short duration bonds, investors are typically looking at yield and comparing it with similar duration bonds. In addition, investors need to evaluate the extension risk of the sequential to make sure it is not beyond their risk tolerance if interest rates rise, prepayment speeds slow, and the sequential extends.

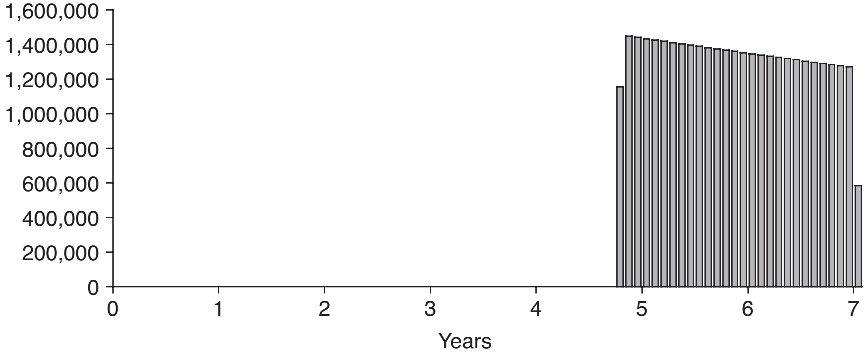
For long duration bonds, comparison to collateral can be made using OAS or yield analysis, plus potentially a total rate of return analysis that compares expected returns of different bonds under different interest rate scenarios.

Planned Amortization Class

The second basic type of CMO deal is a PAC/support structure. PAC stands for *planned amortization class* and is one of the most stable classes of CMO. It is given a pre-set schedule for its principal pay down. If prepayment speeds were to remain at a fixed speed in a specific prepayment band (the *PAC band*) for the life of the security, the PAC would adhere to its original schedule and behave similarly to a corporate bond with a pro rata sinking fund structure. Exhibit 23-3 shows the amortization schedule for a hypothetical PAC.

EXHIBIT 23-3

Amortization Schedule for a Hypothetical PAC



Source: DB Global Markets Research.

PAC Bands, Band Drift, and Broken PACs

As mentioned, each PAC has a band, expressed in PSA terms. If prepayments remained constantly at that level throughout the life of the PAC, it would adhere to its planned amortization schedule and have the expected average life.

Of course, prepayments do not remain constant from month to month, let alone the life of a security. Therefore, over time, especially in a fast prepayment environment, the *PAC bands* on a PAC can drift, generally growing tighter over time (i.e., less advantageous for the investor).

One example of PAC band drift is in a fast prepayment environment. If approximately one-third of a PAC CMO deal is support bonds and prepayments increase over the top end of the PAC band, at some point, all the support bonds will be paid off. When the supports are gone, the PACs behave like sequential bonds, and are termed *broken PACs* in the marketplace. In reality, a broken PAC will behave like a sequential bond. However, due to the stigma of being "broken," the broken PAC may trade more cheaply than a similar sequential.

Exhibit 23-4 shows an example of a new PAC with a band of 100–250 PSA. Note that as interest rates rise, its average life stays around 5.95 years. However, since all MBS are inherently callable in any given month, very fast prepayment speeds engendered by a drop in mortgage interest rates cause the PAC to break out of its PAC band and shorten its duration significantly.

Exhibit 23-5, by contrast, shows a broken PAC originated a few years ago. All the support bonds in this deal have been paid off, so it effectively behaves like a sequential. Note also that its OAS happens to be higher than the sequential bond analyzed earlier in this chapter. This can occur in the market if there is a glut of broken PACs. This bond currently does not have a PAC band left, but originally had a band of 100 to 255 PSA.

EXHIBIT 23-4

Example of a New PAC, Original PAC Band 100–250 PSA

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	220	143	120
Price					
101.1875	3.99%	4.39%	4.75%	4.75%	4.75%
102.1875	3.30%	3.96%	4.56%	4.56%	4.56%
103.1875	2.62%	3.54%	4.37%	4.37%	4.37%
Average Life	1.50	2.47	5.95	5.95	5.95
OAS	41				
OAD	3.65				
OAC	–1.26				
Vol Duration	0.05				

Source: DB Global Markets Research.

EXHIBIT 23-5

Example of a Broken PAC, No PAC Band Left

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	225	145	120
Price					
102.9375	0.74%	2.97%	4.57%	4.84%	4.92%
103.9375	–0.74%	2.17%	4.26%	4.61%	4.72%
104.9375	–2.19%	1.38%	3.96%	4.39%	4.53%
Average Life	0.66	1.26	3.52	5.02	5.79
OAS	37				
OAD	1.98				
OAC	–4.07				
Vol Duration	0.03				

Source: DB Global Markets Research.

Analysis

The decision to buy PACs over sequentials or pass-throughs involves a couple of questions. First, is there a reason to buy cash-flow stability?

- Is cash-flow stability cheap via purchasing PACs?
- Is hedging pass-through or sequential cash flows using options or other derivatives expensive or cumbersome from an accounting perspective?
- Does the investor think the bond market is range-bound or could break out of its range?
- What do implied and actual volatility in the market look like and where are they going?

The answers to these questions can guide an investor toward whether to purchase PAC bonds.

Note that broken PAC analysis will be similar to sequential bond analysis. As mentioned, often broken PACs will trade at wider spreads than similar sequentials, creating relative value opportunities.[2]

Like sequentials, PACs can be compared using OAS analysis, yield, total return analysis, etc., with other MBS or even to corporate bonds because of the PACs' stable nature.

2. Broken PACs tend to trade slightly cheaper than sequentials, whether because of the stigma of the "broken" deal or selling by investors who sell them to buy new PACs with intact bands.

EXHIBIT 23-6

Example of a PAC 2, No PAC Band Remaining

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	220	145	120
Price					
97.875	8.05%	7.06%	6.11%	5.97%	5.84%
98.875	6.63%	6.20%	5.80%	5.74%	5.68%
99.875	5.23%	5.36%	5.49%	5.51%	5.53%
Average Life	0.75	1.27	3.81	5.54	8.78
OAS	36				
OAD	5.37				
OAC	–2.19				

Source: DB Global Markets Research.

PAC 2

In some structures, the effectiveness of PAC classes is enhanced by creating a structure similar to a PAC, but with tighter PAC bands. In the priority of the cash-flow waterfall, the PAC takes priority, followed by the PAC 2 (also referred to as Level II PACs and supports with schedules), and finally the support bonds. If the support bonds are retired and PACs remain, then the PAC 2s effectively become the new support bonds.

In return for the higher cash-flow variability of the PAC 2, it will yield more than similar PACs in the same deal. At the same time, in extreme prepayment environments, the PAC 2 will suffer extension or call risk before the PAC. The PAC 2 bond selected for Exhibit 23-6 has a relatively tight PAC band—so tight we cannot observe cash-flow stability on this bond in the ± 100 bp scenarios.

Analysis

PAC 2 analysis needs to be very careful, as bonds from this class exhibit much more variability of structure, cash flows, and value than the PAC 1 or sequential tranche types. OAS analysis can help an investor make a determination if a bond is attractive. Investors also need to focus on potential duration extension and shortening in radical interest rate scenarios to make sure that duration change is tolerable. In our example bond, duration extension if rates rise is worse than with our example sequential bond.

Support Bonds

The support or companion bonds take whatever principal is left over each month after the PAC bonds have been paid as closely to schedule as possible. If prepayment

EXHIBIT 23-7

Example of a Support Bond

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	225	145	120
Price					
94.375	44.97%	25.96%	9.44%	6.00%	5.98%
95.375	36.95%	21.93%	8.70%	5.92%	5.90%
96.375	29.29%	18.03%	7.97%	5.83%	5.82%
Average Life	0.16	0.30	1.57	23.95	25.66
OAS	90				
OAD	11.00				
OAC	–16.04				

Source: DB Global Markets Research.

speeds are fast, excess principal will pay down support tranches once planned principal payments to the PACs have been made. On the other hand, if prepayment speeds are very slow, all of the principal may go to the PAC bonds, with the support bonds receiving no principal for that month.

Example

The structuring of the support bond, with approximately 30% of a deal being companions and the balance PACs, makes for highly variable cash flows and a wide variety of performance characteristics. Because of this, companion yields tend to be quite high. Exhibit 23-7 shows how the average life of the bond can vary widely.

Analysis

Structures are very deal specific, and OAS models can help determine relative value among support bonds. Note however, that OAS and hence relative value will be very sensitive to model assumptions. Discount companions are more popular because they can be sold to retail investors more easily. Exhibit 23-7 shows our example companion, with high average life variability, but a big OAS. Note also that the structure and price prevents the yield of the bond from falling much below 6%, even in a rising interest rate environment. The yield can exceed 40% in a dramatic interest-rate rally in our example bond.

Targeted Amortization Class

A *targeted amortization class* (TAC) is similar to a one-sided PAC. The bond has some call protection from adverse prepayment speeds. However, it can have a lot of extension risk if prepayments drop too low.

EXHIBIT 23-8

Example of a TAC

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	225	145	120
Price					
92.1875	32.71%	20.16%	8.90%	6.33%	6.22%
93.1875	28.78%	18.09%	8.44%	6.22%	6.13%
94.1875	24.97%	16.08%	7.98%	6.12%	6.04%
Average Life	0.32	0.59	2.74	17.94	21.7
OAS	44				
OAD	10.11				
OAC	–2.46				

Source: DB Global Markets Research.

Example

In Exhibit 23-8, we see that our example TAC has a lot of extension risk. Even at reasonable, although slow, prepayment speeds, the bond extends out to 20-plus year durations.

Analysis

TACs are not all created equal. Some behave more like PAC bonds or PAC 2s. Others look more like companion bonds. The defining characteristic of TACs is they should have some call protection. A first cut of analysis should involve looking at the spread of average lives that can occur. In addition, OAS and perhaps total return analysis may be useful.

While the TAC we have chosen does have a high OAS, it clearly has a large amount of risk if rates rise. The TAC is already at a discount dollar price, and its price could plunge further if prepayments slowed and extended the TAC out to a 20Y average life in a steep yield-curve environment.

PACquential

A PACquential blends characteristics of a PAC and a sequential. While a Type I PAC typically has a lower band of 100 PSA, a PACquential has more extension risk, with a lower band more typically around 150 PSA. Nevertheless, a PACquential does have a PAC band and is supported by its own companion bonds. This feature makes it more stable than a standard sequential tranche.

Example

Our example bond has a PAC band of 150 to 360 PSA, within which it has a 5.1 average life (Exhibit 23-9). In this case, the extension risk of the bond down to

EXHIBIT 23-9

Example of a PACquential

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	220	145	120
Price					
96.75	6.14%	5.26%	4.73%	4.72%	4.65%
97.75	5.42%	4.84%	4.49%	4.48%	4.44%
98.75	4.72%	4.43%	4.26%	4.26%	4.23%
Average Life	1.53	2.7	5.1	5.23	5.85
OAS	37				
OAD	4.48				
OAC	–1.38				

Source: DB Global Markets Research.

120 PSA is minimal. Therefore, the difference between this bond and a regular PAC is not that great.

Analysis

Note that since PACquentials are not that well standardized in the market, each bond must be carefully examined on its own merits. One factor to pay special attention to is extension risk of the PACquential below its PAC band down to as low as 100 PSA. Beyond that, all the standard analysis tools apply: OAS, average life variability, and total return analysis.

Z-Bonds

A bond can have different cash-flow characteristics (PAC, sequential, PACquential). Also, it can have different interest payment features. In the case of a Z-bond, interest accrues and is added to principal initially. This initial phase of a Z-bond's life is similar to a zero-coupon bond. At some point, the Z starts to pay down interest and principal. The characteristic of suspension of interest for some period of time extends the duration of the Z-bond. A Z-bond can be created from any of the fundamental cash flows. Note that the accrued interest taken in from a Z-bond can be used to pay down principal on another CMO tranche. This technique can be used to create bonds with a short legal final maturity, very accurately determined maturity (VADM) bonds.

Example

The companion Z-bond we have chosen for our example (Exhibit 23-10) has a deep discount dollar price, giving it PO-like characteristics, including negative convexity that is pretty close to zero. Note the wide variation in average lives in different scenarios.

EXHIBIT 23-10

Example of a Z-Bond

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	223	145	120
Price					
84	12.58%	8.75%	6.64%	6.45%	6.39%
85	12.09%	8.36%	6.57%	6.39%	6.34%
86	11.61%	8.16%	6.49%	6.33%	6.28%
Average Life	2.57	6.05	17.36	21.03	22.28
OAS	53				
OAD	19.47				
OAC	–0.09				

Source: DB Global Markets Research.

Analysis

There are a few main differences when analyzing a Z-bond versus a regular tranche of the same variety.

- Is the Z-bond currently a payer? If not, the audience of investors may be reduced.
- The OAD of the Z-bond can swing extremely widely in different interest rate scenarios because of its ability to accrete interest payments into principal.
- The OAD can be much longer than that for collateral.

Standard OAS or total rate of return (TRR) analysis should take these factors into account. On our example bond, the OAD is extremely long, almost 19.5. The fundamental question to ask is whether an investor would prefer to own this bond or a zero-coupon Treasury bond. The two can best be compared using TRR analysis.

Note also that these bonds will be extremely sensitive to small changes in model assumptions. Different models will almost certainly give a wide range of OAS valuations.

Very Accurately Determined Maturity

Very accurately determined maturity (VADM) bonds are structured to have short final maturities. They use accrued interest from Z-bonds to pay off principal (see Z-bond discussed previously in the chapter). In general, the average life of a VADM bond is more stable than a comparable duration sequential bond. They are

EXHIBIT 23-11

Example of a VADM

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,595	800	225	145	120
Price					
103.5	3.44%	4.26%	4.81%	4.81%	4.81%
104.5	2.89%	3.92%	4.61%	4.61%	4.61%
105.5	2.34%	3.59%	4.41%	4.41%	4.41%
Average Life	1.85	3.13	5.95	5.96	5.96
OAS	56				
OAD	3.56				
OAC	–1.20				

Source: DB Global Markets Research.

especially resistant to extension risk, as the short final maturity of the bonds is guaranteed even if prepayments drop to zero, a highly unlikely event.

Example

Exhibit 23-11 shows our example VADM bond, 5.95-year average life even as prepayments drop to zero. Note however, that the premium price exposes the bond to big issues if interest rates drop and prepayments speed up.

Analysis

Investors should primarily purchase VADMs if they absolutely need the guaranteed final maturity—such as in certain mutual funds or other investor situations. Check that the VADM maturity does fit the requirements of the investor. In addition, check what the call risk of the bond looks like, which can vary widely among CMOs.

Floater

As well as the principal cash flows having different types, interest may also be paid in different ways. Most tranches have fixed-rate cash flows, as most collateral for CMOs has a fixed interest rate. However, it is possible to construct tranches with a floating rate of interest, generally tied to LIBOR historically and SOFR now, but conceptually to any market interest rate. One possibility is to use an interest rate swap to create a floating-rate bond. However, more likely is the division of a fixed-rate tranche into a "floater" and "inverse floater" whose interest rate moves down as the floater's moves up (see Inverse Floater later in the chapter).

Key components for a floater include:

- The index such as SOFR.
- The margin or spread over the index, paid to the investor.
- The cap, or maximum coupon rate, that the floater can pay, inclusive of the margin paid over the index.
- The floor, or minimum coupon rate, often equal to the margin.

Example

Our example bond shown in Exhibit 23-12 is a companion floater. The average life is highly variable. The major issue for a bond buyer would be difficulty in hedging the risk of the embedded cap. Thus, higher cash-flow variability will in general push the OAS of a floater lower.

Analysis

Floating-rate bond analysis is similar to fixed-rate analysis in terms of examining cash flows and the bond's OAS. However, the floater has the additional complexity of having embedded caps and floors to value (even if the floor is 0%). It is especially important to make sure the term structure model employed correctly values caps and floors at market values in this type of analysis. Additionally, an investor can price out an actual cap or floor for the expected average life of the security and see if the package of floater plus hedge makes sense.

Discount margin refers to the effective spread over the index once the bond's price and a prepayment assumption are factored in. An investor would look at discount margin as well as OAS to determine value in a floater.

EXHIBIT 23-12

Example of a Floater

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	220	145	120
Price					
98	6.84%	5.12%	2.74%	2.53%	2.52%
99	2.47%	2.47%	2.56%	3.64%	4.42%
100	2.04%	2.19%	2.39%	2.41%	2.41%
Average Life	0.42	0.7	7.05	21.34	23.56
OAS	19				
OAD	2.58				
OAC	–2.82				

Source: DB Global Markets Research.

Note that a floater's OAD (if uncapped) is effectively limited to the combination of index and index reset. Most of the duration of the floater duration would be due to the duration from the cap.

Inverse Floater

An inverse floater is typically created by dividing a fixed-rate tranche into a floating-rate portion and the inverse floater. The key understanding is that the sum of the parts (floater and inverse floater) must equal the whole (the underlying tranche) in terms of both interest and principal payments. (Also see the discussion later in the chapter dealing with "creation value.")

Example

Our example is shown in Exhibit 23-13, a discount companion inverse floater. These bonds have a lot of duration and are often used as substitutes for POs. Our example has a highly variable average life, but high yields across interest rate scenarios.

Analysis

Inverse floater duration is increased by higher leverage in the inverse floater's coupon formula. In our example bond, the underlying tranche has an OAD of 9.57 and the inverse floater's leverage is 2.75. If the floater had a duration of 0, then the inverse floater's OAD is roughly equivalent to 1 + leverage times the underlying tranche's OAD. In this case, the floater has significant duration (over 2) because of the extension risk along with the relatively low coupon cap of the floater.

OAS analysis is important for analyzing inverse floaters, and as with floaters, inverse floaters have embedded caps and floors. Therefore, the term structure

EXHIBIT 23-13

Example of an Inverse Floater

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	220	145	120
Price					
84.3125	60.38%	41.89%	19.84%	17.08%	17.04%
85.3125	56.69%	39.75%	19.41%	16.87%	16.83%
86.3125	53.09%	37.66%	18.98%	16.66%	16.63%
Average Life	0.42	0.7	7.05	21.34	23.56
OAS	696				
OAD	28.80				
OAC	–12.45				

Source: DB Global Markets Research.

model is important for evaluation. Also, the prepayment model used to evaluate the inverse floater is critical. As market rates fall, the inverse floater's coupon rises, but faster prepayments (and hence principal paydowns) may eat away the value of this to the bondholder. Effectively, the inverse floater buyer is leveraged to prepayments, and thus must be careful to examine the effect of variations in prepayment assumptions on bond valuation.

Inverse Floater vs. Leveraged Collateral

Does OAS analysis work? One way to check is to compare inverse floaters with leveraged collateral positions. While at first glance it may appear that one should simply buy the bond with the highest OAS, in reality, the duration (or OAD) of the two assets being compared also matters significantly. To correctly compare inverse floaters with collateral, the collateral must be implicitly levered (by borrowing money) to the same duration as the inverse floater for the comparison to be fair. (The comparison is still not completely fair because leveraged collateral probably has more liquidity and easier funding than the inverse floater.)

In Exhibit 23-14, we can see that our prepayment model still prefers the inverse floater over a position of leveraged collateral. Levering the collateral involves investing a similar cash amount as for the inverse floater, then borrowing additional cash to buy more collateral until the investor has a similar duration and convexity exposure between the inverse floater and the leveraged collateral. In this example, we have borrowed money equivalent to the 2.75 times leverage of the inverse floater.

Creation value is another method used to analyze inverse floaters. The value of floaters is relatively easy to determine, as they are relatively liquid and easy to price. Likewise, the underlying tranche for the floater/inverse combination is typically easy to price. Given those two prices, the arbitrage-free creation value of the inverse floater can be determined (Exhibit 23-15). Investors prefer to purchase inverse floaters at or below creation value in the secondary market.

EXHIBIT 23-14

Comparing Leveraged Collateral vs. an Inverse Floater

Tranche Type	Security	Price	OAS	OAD
Inverse floater collateral	FNMA 5.5%	100.578125	5	4.7
Leveraged collateral stats	FNMA 5.5% leveraged	2.75 times lvg.	33	17.5
Inverse floater	*	85.31	696	28.8

*See Exhibit 23-13
Source: Deutsche Bank.

EXHIBIT 23-15

Floater + Inverse Floater = Underlying Companion Bond

	Floater	Inverse Floater	Underlying Companion
Collateral	FNCL 5.5	FNCL 5.5	FNCL 5.5
Amount on issue (curr and orig)	25,626,350	9,318,674	34,945,024
Coupon	1ML + 130 bp	17.05–2.75 × 1ML	5.50
Cap	7.50%	17.05%	
Floor	1.30%	0%	
Yield	2.60%	19.41%	7.08%
Price	99.00	85.31	95.35
OAS	19	696	199
OAD	2.58	28.80	9.57
OAC	–2.82	–12.45	–5.39

Source: DB Global Markets Research.
Note: 354 WAM, 5.90 WAC for all bonds.

Trade Against Forward Rates

Some investors buy inverse floaters as a trade against forward rates rising as fast as the market would suggest. For example, the yield of our inverse floater at unchanged rates and 220 PSA is 19.41%. The yield assuming this prepayment speed but forward rates is 18.4%. If rates rise more slowly than forward rates suggest, the true yield of the bond will be somewhere in between the two numbers.

Analyzing inverse floaters is complex and can be done in many different ways. They are not as liquid as regular tranches. The reward may be discovering some true value in the bonds, or taking advantage of specific views on the market.

Interest-Only and Principal-Only Tranches

Interest-only tranches (IOs) come in several forms. The primary one we will discuss is "trust IOs," in which collateral is contributed to an IO/PO deal by dealers, a small fee is charged by a GSE or Agency, and IO and PO tranches are returned to the dealers involved in proportion to their collateral contribution. This type of structure gets its own IO/PO trust number, hence the name. An IO can also be created by stripping interest off a CMO tranche or in other ways, which typically result in CMO tranches with IO characteristics. Trust IOs tend to have the most liquidity, as they are large size deals that trade on broker screens, while smaller deals have less price transparency.

IOs typically have negative Option Adjusted Duration (OAD). If interest rates rise, prepayment speeds tend to slow. Slower speeds benefit the IO holder, who wants the collateral factor to stay as high for as long as possible. Once loans prepay, they stop paying interest beyond the month in which prepayment occurs. An IO investor wants prepayments to be as slow as possible. In the most extremely negative case for an IO holder, an investor could buy an IO and discover the entire tranche has paid off in that month, reported in the following month.

The principal only (PO) is the complement of the IO. It returns only the principal portion of the pass-through. Thus, a PO holder would prefer prepayments to be extremely fast. Under a dollar price of approximately $85-00 (which is typical), POs have positive convexity. This makes them useful for hedging purposes, for example hedging mortgage servicing rights.

Example

Exhibit 23-16 shows an example of an IO. Since trust IO and PO pricing is relatively liquid, most of the analysis for IOs and POs will concern an investor's view of prepayments or interest rates versus the market's (as represented by IO/PO pricing). Nevertheless, IO/PO prices can also fluctuate due to technicals, including short squeezes on certain tranches. Note how the IO in Exhibit 23-16 has a high negative OAD.

Exhibit 23-17 shows an example PO from the same Trust deal. Some investors buy POs for prepayment protection or positive convexity, but others buy them simply to add duration to their mortgage portfolio. As interest rates drop, observe that the PO yield rises significantly due to increased prepayments. Often, as in our hypothetical example, the PO will have a negative OAS in return for its positive convexity. Effectively, an investor is paying a premium to buy call options when they buy a PO.

Analysis

IO/PO analysis using OAS models or other techniques is notoriously complex, and even seasoned traders have lost money due to technicals in the IO market.

EXHIBIT 23-16

Example of an IO

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	800	325	150	125
Price					
24.53125	–104.60%	–59.38%	2.13%	12.50%	13.94%
25.53125	–106.20%	–60.62%	1.13%	11.52%	12.96%
26.53125	–107.70%	–61.78%	0.21%	10.61%	12.05%
Average Life	1.12	1.55	4.93	8.71	9.69
OAS	328				
OAD	–24.11				
OAC	–17.02				

Source: Deutsche Bank Global Markets Research.

EXHIBIT 23-17

Example of a PO

Scenario	–200	–100	0	100	200
Prepayment (PSA)	1,665	1,200	325	150	125
Price					
74.9375	28.69%	20.71%	6.58%	3.66%	3.27%
75.9375	27.23%	19.66%	6.24%	3.47%	3.10%
76.9375	25.81%	18.63%	5.91%	3.29%	2.94%
Average Life	1.12	1.55	4.93	8.71	9.69
OAS	–132				
OAD	14.71				
OAC	2.78				

Source: Deutsche Bank Global Markets Research.

As IOs and POs are notoriously sensitive to even small changes in prepayment assumptions, one must be very careful to examine the model used to calculate OASs. Variables such as seasoning and burnout are magnified many times in between analyzing the collateral and the IO/PO derivative.

Creation value can also be used to analyze IOs and POs, similar to the analysis of inverse floater/floater combinations. For Trust IOs and POs, at first the combination (combo) typically trades at a small premium above collateral. The combination cannot trade significantly below the price of collateral, because they may be recombined into collateral for a small fee and sold. However, the combination may trade at a price significantly above TBA collateral for a number of reasons:

- The underlying collateral is valuable, for example, it has seasoning worth a pay-up to TBA collateral.
- There is a squeeze or scarcity of the IO or PO, which raises the price of the combination in turn. Sometimes POs get restructured in other deals, potentially leaving them dear.

Historical analysis of IO and PO OAS numbers may be somewhat useful, but ends up being highly prepayment and OAS model dependent.

Premium tranche/IO arbitrage is another way to compare relative value of IOs versus regular classes of CMOs. For example, a PAC IO plus a stripped down PAC should equal the value of the full coupon PAC, or there is an arbitrage. This is similar to the recombination value of an inverse floater. In practice, since many investors are willing to accept tighter spreads for lower dollar price PAC bonds, we can see arbitrage opportunities occur during deal pricings, which make the restructuring of a premium PAC tranche into a stripped-down coupon PAC and a PAC IO attractive.

For POs, some investors may be using them to hedge other assets, such as mortgage servicing rights (MSR). In that case, all the above analysis may be performed, but the investor probably also wants to check how well correlated changes in price of the PO will match changes in price of the hedged asset.

Unusual Features

Note that IOs can be stripped off of any CMO type, for example, PACs, creating PAC IOs. This class of bond will behave like a high-yielding PAC within the band, but if prepayments speed up, will pay off quickly, perhaps leaving a loss for the investor. Other non-Trust IOs must be examined carefully as to the nature of their cash flows.

Exotics

We now describe a number of exotic CMOs for the sake of completeness, but will not spend a lot of time looking at individual bonds.

Inverse IOs

Inverse IOs are created by stripping the premium portion off an inverse floater. In some respects they behave as an interest rate floor. At times, their pricing has been described in relation to floor prices (e.g., 80%). However, they are more like "knockout" floors because if interest rates fall enough, prepayment rates will speed up and pay down the notional principal of the tranche, reducing the remainder of the investment to zero. Because of their illiquidity, these bonds are difficult to hedge and value even more so than trust IOs.

Inverse IOs are highly levered to one's interest rate scenario and prepayment forecast. It is important to analyze how small variations in prepayment or interest rate assumptions change the potential value of the bond.

Jump Zs

A jump Z reacts to fast prepayments by suddenly shifting from accrual to paying interest and principal (becoming a "payer"). This option can be of great value to the investor if the Z-bond is at a discount price. Note also that some Jump Zs are sticky, meaning once the "payer" trigger has been pulled, they continue to pay even if prepayment rates subsequently drop.

Structured POs

POs themselves can be structured into TAC POs, Super POs (companion POs), etc. Analysis is similar to that for PO analysis, except the bonds will probably be even more sensitive to slight changes in prepayment assumptions.

AGENCY VERSUS NONAGENCY CMOs

While most investors who can buy agency pass-throughs are allowed to buy agency CMOs, certain investors cannot participate in the nonagency CMO market. Here, we describe some of the differences between the two markets (see Exhibit 23-18 for a synopsis). Nonagency CMOs are discussed in more detail in Chapter 25.

EXHIBIT 23-18

Agency vs. Nonagency CMO Differences

	Agency CMOs	Nonagency CMOs
Credit support	Agency guarantee of underlying mortgages, primary mortgage insurance	Credit enhancement (e.g., Senior Subordination), underlying mortgages, primary mortgage insurance
Actual delay days	Variable: 0,14, 24	Variable: 0, 24
Collateral types	Agency pass-throughs, conforming Alt-A loans, VA loans	Jumbo or other nonconforming pass-throughs, re-performing loans, Alt-A loans
Prepayment model	Standard agency prepayment model	Specialized model based on collateral
Subject to interest shortfall	No, compensating interest is paid by GSEs	On some deals

Source: DB Global Markets Research.

AGENCY CMO ANALYSIS

The following section looks at how investors analyze and use agency CMOs. We also cover term structure and prepayment models briefly.

Analysis for Regular CMO Tranches

CMO analysis depends upon investor needs. While relative value may seem to be one answer, one rule does not necessarily hold for all investors. The definition of relative value can be different for different investors. Other investors have portfolio constraints. For example, an insurance company may need assets that closely match liabilities even if interest rates exhibit large moves.

Investor Goals and Constraints

Investors can have many goals and constraints when purchasing CMOs. For example:

- Insurance companies and banks sometimes have yield levels (bogies) below which they do not wish to purchase bonds.
- Relative value investors may require a certain OAS, or OAS advantage versus collateral.
- Hedge funds may require a certain amount of liquidity in purchases they make, both for bonds and potential hedges (such as cancelable swaps). If liquidity in the bond or the hedges is insufficient, they may decline to do an otherwise attractive trade.

- Funded investors may need to issue debt or raise equity before adding MBS. If the environment is not amenable to such issuance, then CMO purchases may be delayed.
- Banks may have internal maturity or duration restrictions or preferences on bonds for their portfolio.
- Individual or institutional investors may have a top dollar price limit above which they will not purchase bonds.

Perhaps the variability of investors explains why there are so many different kinds of CMOs, some unique. Different requirements and views are what makes a market.

Cash-Flow Analysis

For most regular tranche types, cash-flow analysis consists of testing various prepayment models and static prepayments to determine what the sensitivity of a bond is to changes in interest rates. This analysis would include a comparison of the negative convexity of different CMO bonds.

For some investors, cash-flow analysis becomes more detailed, as they may be trying to hedge their own stream of liabilities, or perhaps they are hedging the CMO with an amortizing swap.

Finally, for nonstandard tranches, it pays to examine the cash-flow waterfall and test various interest-rate scenarios, examining the results in terms of cash-flow streams. It is important to check for bonds that have unusual cash flows. For example, anything that could cause a bond to have a longer-than-expected maturity, or a gap when principal was not paid would be suspect.

OAS Analysis

For most regular CMO tranches, OAS analysis is relatively useful. For similar tranches off similar collateral, it is easy to use OAS to determine relative value of bonds. In addition, comparing OAS numbers for CMOs versus underlying collateral also is straightforward. The more difficult issue is how to compare OAS numbers of tranches of different durations. For example, often longer dated tranches are at higher OAS numbers than similar shorter dated tranches. This structural issue makes it difficult to evaluate relative value of longer versus shorter dated CMOs.

More issues in OAS analysis are presented later in this chapter and in Chapter 37.

Hedging

For normal CMO tranches, OADs are an acceptable way to calculate how to hedge. However, wide window sequentials may require hedging on multiple points on the yield-curve to avoid yield-curve risk, similar to hedging yield-curve risk in the underlying collateral. Exhibit 23-19 shows how the bulk of duration risk may be in the 10-year area for a specific bond, but hedging in the 2 year, 5 year, and 30 year would help reduce yield-curve risk.

EXHIBIT 23-19

Partial Durations of a Five-Year-Wide Window Sequential

Yield-Curve Point	2	5	10	30
Partial Duration	0.685	1.56	2.795	0.17
OAD	4.7			

Issues in OAS Analysis

There are a number of issues in OAS analysis to discuss in order to determine if the OAS received on a bond is truly what the investor seeks to find out: the spread of the mortgage-backed security, ex-option cost, versus a benchmark such as swaps. While in the 1980s and early 1990s, the primary variable differentiating OAS numbers was the prepayment model, at this point in the technology, the term structure model has become equally as important. We cover a number of other issues in this section, such as deal call risk and variations among prepayment models.

Term Structure Model

As mortgages have linked more tightly over time with the OTC derivatives markets (swaps and swaptions), modeling the relationship between these two markets has become critical. When swaps and swaptions are used to hedge MBS (or vice versa), the two markets need to be evaluated using the same term-structure model and the same assumptions, or else different, and perhaps erroneous, results can be obtained.

While a one-factor interest-rate model was used in the past and may work reasonably for pass-throughs, it is clearly not enough if an investor is looking at ARMs, floaters, or inverse floaters of any kind. More degrees of freedom for modeling the yield-curve are needed. Therefore, in order to keep analysis consistent among different types of MBS tranches and derivatives, it appears critical to use the least common denominator of term structure models that will accommodate all possible tranche types and analysis, and not succumb to using different models for different types of bonds or situations.

Advances in term structure modeling have placed the following features into the hands of mortgage analysts:

- Multiple knots on the yield-curve
- Correct pricing of OTC derivatives using the model
- Pricing in a volatility “skew” (i.e., options not struck at-the-money may be priced at a different volatility than standard at-the-money options)
- Sophisticated simulation of future mortgage interest rates based on the swaps curve and volatility

The point is that a term structure model that does not do these things opens up arbitrage opportunities against an investor using it. In an extreme case, flaws in the term structure model will misstate value and risk numbers associated with a CMO.

Forward Curve Bias

Despite all the care being put into term structure models, and their freedom from arbitrage, it is important also for investors to recognize the forward curve bias in these models, which creates a paradox.

- In order to remain arbitrage free, the term structure model must use the forward yield-curve as its base case.
- In practice, the forward yield-curve is usually wrong.

How can we reconcile these two facts?

The short answer is that we should use the forward yield-curve because if we do not believe something that it is predicting, we can trade against it and make money if we are correct. At times, the second point becomes plainly obvious. For example, when the yield-curve is extremely steep, forward rates predict massive flattening of the yield-curve over a short period of time. If the Fed appears to be on hold during this time, are we likely to get the full amount of the yield-curve flattening? Perhaps not. However, it may be easier to trade on this view directly in the derivatives or futures market rather than trying to implement it in the mortgage market.

Prepayment Model

The prepayment model is a very important component of mortgage analysis and OAS. Over time, prepayments have become more efficient. While most prepayment models address the standard issues of age, relative coupon, etc., there are now various subtleties for which a model needs to account:

- What future home price inflation does the model assume?
- Does the model account for "credit impaired" mortgages issued at above market rates?
- How does prepayment "burnout" work in the model? Can burnout be erased over time?
- Does the model account for "underwater" mortgages correctly (where the loan is for more than the home is worth)?

A prepayment model that is out of date or incorrect, even if only on a small segment of the market (e.g., high-premium mortgages) can have a large impact on an OAS because OAS models tend to generate some paths with very high and low interest rates—testing the boundaries of prepayment models and their ability to generate reasonable prepayment forecasts at out-of-sample interest rates.

Why A + B Can Be Greater Than C…

One of the last topics we will cover in this section is why A + B > C, even if A and B are made up of the component cash flows of C. Here are some factors:

- *A and B are unique and more cannot be created*. For example, once a Trust IO/PO deal is closed, additional collateral cannot be added later to increase the size of the deal. Thereafter, a squeeze in A or B will increase their price in relation to C, which is simply TBA collateral. A + B can never be less than (C – transaction cost) for long, as this would create a recombination arbitrage.[3]
- *A or B is getting squeezed*. One of the risks in the IO/PO market is that bonds can be re-securitized and hence lost to the possibility of recombination. For example, if virtually all of the POs in a Trust deal are re-securitized, the remaining POs will be in very high demand to hedge the remaining IO tranches. In addition, trust IO/PO sizes can be small enough that one dealer or investor can potentially squeeze the market in one of these bonds, making A + B > C.
- *The underlying collateral is valuable*. Sometimes A + B may be compared with the wrong C. For example, comparing a Trust IO and PO to TBA collateral may be appropriate most of the time. However, after the deal is seasoned for a while, the underlying collateral itself may be worth a pay-up to TBAs (seasoned collateral typically commands a premium price to TBAs).

Examining Deal Call Risk

A feature in many CMO deals, but not discussed often and sometimes not modeled, is the embedded ("clean-up") call. Calls were originally conceived as a way to limit ongoing fixed expenses for deal trustees on CMOs that have shrunk to a very small size, but the implications for investors can be significant. For example, the last cash-flow holder will typically be exposed to the call. A call that sounds small for an entire deal (say, 1%), may actually make up a large portion of the last tranche remaining in a CMO deal. For a tranche that was only 5% of the deal's original principal, a 1% cleanup call is exercised when 20% of the last tranche is remaining. The impact for investors of other tranches is *de minimus,* but obviously can be large for the last cash-flow holder.

The good news is this call is exercised most of the time because the fixed costs of the deal tend to be large enough that the trustee wants to exercise the call whenever possible. This assumption makes analysis easy. However, if the price of the collateral is significantly below par, calling the deal costs the trustee money. Analysis of the probability of call of deals in this situation is difficult. Therefore, the bondholder may want to run the bond with and without the call to assess the possible impact.

3. Typically, an IO and a PO from the same trust can be recombined to form the underlying collateral for a 1/32nd fee and resold as collateral. While this typically never happens in practice, it creates an arbitrage floor for the IO and PO prices, which is important from a liquidity and pricing standpoint. This is much harder to do for floaters and inverse floaters, as both sides of the combination in that case may be harder to find and less liquid, not trading on broker screens as Trust IOs and POs do.

Investor Types and Behavior

In this section, we examine different types of investors, such as commercial banks. We cover the following information for each:

- Types of CMOs typically purchased by these institutions
- Methods potentially used by these institutions for bond selection

Historically, banks have been the largest holders of MBS.

Banks

Banks are large consumers of CMOs. For many banks, the longer duration and possible duration extension of pass-throughs does not match their liabilities adequately. Often, it is easier for many banks to achieve a shorter duration security or less extension risk by buying appropriately structured CMO bonds than pass-throughs. Banks are typically buy and hold investors in CMOs, although some bonds may be placed in the trading account.

In general, banks focus on shorter duration CMOs. A 10-year bond typically does not fit the liability structure of a bank. A two-year sequential CMO is a typical purchase for a bank. In general, banks will accept some prepayment and convexity risk in order to get a better spread. Therefore, banks tend to prefer sequentials over PAC bonds. Banks do very little hedging of their negative convexity using the options market, although they may delta hedge their mortgage position as its duration changes.

CMO selection at banks generally comes down to a few things: yield bogey, duration, extension risk, and OAS. In general, a bank will have a target net interest margin over their cost of funds in order to purchase a security. This target may be translated into a yield or spread bogey over a market rate. Also, a bank may not want to take too much duration risk, so the duration of the security must fit the asset-liability framework of the bank, or it must be prepared to hedge the duration of the CMO. Some banks use OAS to determine relative value among tranches, but in general asset-liability and liquidity concerns tend to dominate their CMO purchase decisions.

Note also that banks are the largest consumer of mortgage "whole loans," or mortgages that are not securitized. These whole loans are mostly ineligible for agency securitization, or are ARMs or hybrid ARMs.

Insurance Companies

Insurance companies buy CMOs across the spectrum of "regular" tranches—PACs, sequentials, and PACquentials. Property and casualty companies tend to buy shorter maturity tranches, such as two-year sequentials. Life insurance companies are looking for more structure to match against their liabilities and are more likely to purchase longer duration bonds, such as 10-year PACs. While MBS are a break from the credit risk that insurance companies typically take on the corporate bonds in their investment portfolio, they are well aware of the convexity risk that they are taking in MBS.

In general, insurance companies may have restrictions on selling CMOs because of gain or loss constraints. Property and casualty companies may sell bonds against claims (e.g., after a hurricane).

Money Managers

Money managers vary in sophistication. They generally are not subject to gain/loss constraints because they mark-to-market constantly, unless they are managing a separate account for a financial institution. Some money managers are active in the CMO derivatives market, but many are not. Most money managers are benchmarked against an index that contains pass-throughs. Therefore, any CMO is effectively an "out of index" investment for them. They will typically be comparing that CMO either to collateral or perhaps to Treasuries/agencies for certain types of CMOs. OAS analysis tends to be an important tool for them.

Liquidity tends to be a bigger issuer for money managers than for insurance companies. The money manager may need to be able to shift assets around quickly, and thus is prepared to give up something in order to have better liquidity. Most money managers own many more pass-throughs than CMOs because of this fact. In addition, pass-throughs have the opportunity to finance special (via the dollar roll market). Income from special financing can be a windfall for money managers, as this income is typically not included in mortgage index returns the money managers are benchmarked against.

Money managers frequently take long-term strategic views about the market in mortgages. One type of view is to have a portfolio that has better (or worse) convexity than their benchmark index. A money manager can typically get better convexity by buying PAC bonds, or give up convexity to gain yield by buying companion bonds or certain types of sequentials or broken PACs.

Pension Funds

Pension funds in some ways operate similarly to money managers. However, ERISA (pension fund law) or investor considerations sometimes keep them from investing in mortgage derivatives. Similar to life insurance companies, they can be interested in longer duration tranches at times.

Hedge Funds

Hedge funds can operate in a manner similar to money managers, but at times they enter into more complex trades involving OTC derivatives. For example, they might buy a CMO and try to hedge its cash flows over time using swaps and options, netting a positive spread that they hope to earn over time.

Certain hedge funds specialize in mortgage derivatives: inverse floaters, IOs, inverse IOs, etc. They use sophisticated models to value these tranches, purchase them, and hedge them. One of the main issues for these funds will be pricing of their inventory (as individual bonds may not trade for months) and liquidity. Financing for CMOs can also dry up in a crisis.

Retail Investors/Regional Dealers

Many CMOs, including CMO derivatives such as inverse floaters, end up in the hands of regional dealers. In turn, these regional dealers may sell those bonds to retail clients. In general, yield tends to be the focus of these buyers, and thus companion bonds are often sold via this channel.

Note that any broker who sells CMOs to retail investors must include a series of special disclaimers that is mandated by securities regulation.

Lessons from the Past

Investors in MBS, and especially in derivative MBS, have gone out of business in the past. In a crisis, while the mortgage market may continue to trade via pass-throughs, the CMO market can lose liquidity, and the derivatives market can practically stop trading for some period of time. Investors should be prepared for all risks, including the risk of illiquidity and radical changes in pricing due to such illiquidity. Dealers must make sure they "know their customer" and that the customer is buying bonds appropriate for their goals.

KEY POINTS

- Agency CMOs are structured by broker-dealers into multiple tranches using agency pass-throughs as collateral. The deals are wrapped and issued by Fannie Mae, Freddie Mac, or Ginnie Mae. Ginnie Mae has the full faith and credit backing of the U.S. government, while the other two have an implied guarantee.
- Agency CMOs can be a safe, attractive investment for banks, mutual funds, insurance companies, and other institutional investors. Standard types of CMO tranches include PACs (created to mimic corporate bonds), sequentials (that time tranche principal cash flows), and companions (that return a high yield in return for highly variable principal cash flows).
- Unlike most other bonds, all MBS (including CMOs) have unpredictable return of principal, creating the opportunity of higher yield and the risk of callability. The homeowner in the United States typically has the option to refinance at any time, effectively exercising a call to the investor. Using OAS and prepayment models helps investors understand the nature of the MBS they own or are buying.
- Analysis of CMOs depends to some degree on the type of investor: yield tables, possible bond maturity profile and OAS analysis are all important. Banks typically look at average life profiles and yield tables,

and may consider OAS. Money managers tend to be more focused on OAS and compare CMOs to pass-thoughs and agency bonds.

- CMO derivatives can provide hedging benefits or unusual return profiles. For example, Interest-only strips have a negative OAD—they generally increase in price as interest rates rise. Inverse floaters have bond coupons that rise as interest rates fall, sometimes creating bonds with very long OADs.

CHAPTER

TWENTY-FOUR

STRIPPED MORTGAGE-BACKED SECURITIES

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In 1983 Freddie Mac (FHLMC) launched the collateralized mortgage obligation (CMO) structure that enabled issuers to tailor-make mortgage securities according to investor coupon, maturity, and prepayment risk specifications. In July 1986, Fannie Mae (FNMA) introduced a new addition to the mortgage security product line—*stripped mortgage-backed securities* (SMBS). By redistributing all or portions of the interest and/or principal cash flows from a pool of mortgage loans to two or more SMBS classes, FNMA developed a new class of mortgage securities that enabled investors to take strong market positions on expected movements in prepayment and interest rates. As the mortgage pass-through market has matured, the number of derivative products available has increased to give investors a broad range of choices to help them achieve their investment goals. In addition to straight *interest-only* (IO) securities and *principal-only* (PO) securities, investors may now choose from a wide array of synthetic coupons from each strip issue. Investors are able to fine-tune their derivatives to match their desired sensitivity to interest rate, prepayment, and market risk.

SMBS are highly sensitive to changes in interest rate and prepayment speeds and tend to display asymmetric returns. SMBS certificates that are allocated all or large proportions of underlying principal cash flows tend to display very attractive *bullish* return profiles. As market rates drop and prepayments on the underlying collateral increase, the return of these SMBS will be greatly enhanced since principal cash flows will be returned earlier than expected.

Conversely, SMBS that are entitled to all or a large percentage of the interest cash flows have very appealing *bearish* return characteristics since greater amounts of interest cash flows are generated when prepayments of principal decrease (typically when market rates increase).

OVERVIEW OF THE SMBS MARKET

The SMBS market has grown substantially since the introduction of the first SMBS in July 1986. In total, over $500 billion agency SMBS in over 700 issues have come to market as of December 2019, as shown in Exhibit 24-1. In addition to Trust IOs and POs—the most common form of SMBS—there are billions of structured IOs and POs within collateralized mortgage obligation (CMO) deals (described below). In 2010, Markit introduced the SMBS Indices, i.e., MBX, IOS and PO Index as another source for IO and PO exposure.

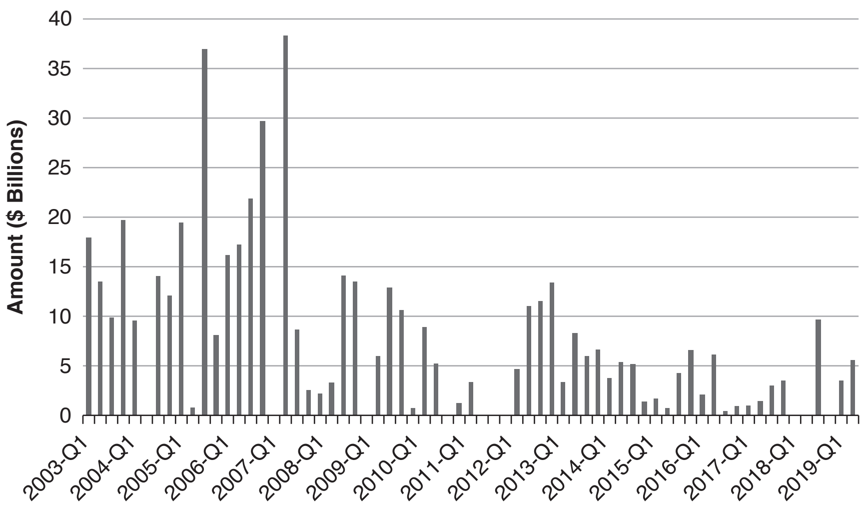
Types of SMBS

Strip securities exist in various forms. The first and earliest type of mortgage strip securities were called *synthetic-coupon pass-through securities*. Synthetic-coupon pass-throughs receive fixed proportions of the principal and interest cash flow from a pool of underlying mortgage loans. Synthetic-coupon pass-throughs were introduced by FNMA in mid-1986 through its "alphabet" strip program.

Trust IOs and Trust POs, the second type of strip securities, were introduced by FNMA in January 1987. IOs and POs receive, respectively, only the

EXHIBIT 24-1

Growth of SMBS Market



interest or only the principal cash flow from the underlying mortgage collateral. FNMA and FHLMC Trust IO/PO SMBS represent the major issuance and trading activities in the SMBS market. A liquid and dynamic secondary market in conjunction with the agency to-be-announced (TBA) market has been established to allow quick and frequent transactions. Benchmark bonds in the sector (large in size and most liquid issues) enhanced liquidity and investor pricing transparency.

A third type of strip security, the *CMO strips* (also called structured IOs and POs) are also popular among issuers and investors. As implied by their name, structured IOs and POs are tranches within a CMO issue that receive only principal or interest cash flows or have synthetically high coupon rates.

Development of the SMBS Market

In this section we provide the historical development of the SMBS market.

The First Mortgage Strip—FNMA SMBS "Alphabet" Strip Securities

FNMA pioneered the first stripped mortgage security in July 1986 through its newly created SMBS Program. For each issue of SMBS Series A through L, FNMA pooled existing FHA/VA and GPM mortgage loans that had been held in its portfolio and issued two SMBS pass-through certificates representing ownership interest in proportions of the interest and principal cash flows from the underlying mortgage loan pools. Alphabet strips were subsequently called synthetic discount- and premium-coupon securities, since the coupon rate of the alphabet strip was quoted as the percentage of the total principal balance of the issue.[1] In total, 12 alphabet strip deals were issued by FNMA in 1986, totaling $2.9 billion.

The FNMA SMBS Trust Program and IOs and POs

The successive and current FNMA strip program, the SMBS Trust Program begun in 1987, provided a vehicle through which deal managers (e.g., investment banks) can swap FNMA pass-throughs for FNMA SMBS Trust certificates. In the swapping process, eligible FNMA pass-through securities submitted by the deal managers are consolidated by FNMA into one FNMA Megapool Trust. In return, FNMA distributes to the deal manager two similarly denominated SMBS certificates evidencing ownership in the requested proportions of that FNMA Megapool Trust's principal and interest cash flows.[2]

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1. For example, a strip that receives 75% interest and 50% principal of the cash flow from a FNMA 10% would be a synthetic 15% coupon security, since the 7.50% coupon is expressed as a 100% principal (i.e., 7.50% coupon/50% principal = 15.00% coupon/100% principal). By the same logic, a strip security from a FNMA 10% that receives 50% interest and 1% principal would be a 5,000% coupon security.
2. FNMA tightly restricts the type of collateral that can be placed in Trust. For example, all mortgage securities must have the same prefix (be of the same loan type) and be within a certain WAC and WAM range to correspond with preliminary pricing. Moreover, the minimum initial principal balance of each SMBS Trust must be $200 million.

To date, the majority of FNMA SMBS Trusts have contained IO and PO securities. IOs and POs represent the most leveraged means of capturing the asymmetric performance characteristics of the two cash-flow components of mortgage securities. Although IOs and POs can be combined in different ratios to create synthetic-coupon securities, some investors have shown a preference for one-certificate synthetic securities due to their bookkeeping ease. In late 1993, FNMA added another feature to their SMBS structure. In addition to IO and PO classes, FNMA SMBS Trusts contained a provision for exchanging IOs and POs for another class with a synthetic coupon. The synthetic-coupon classes that are available are determined in the prospectus supplement for each Trust and generally range from 0.5% to double the coupon on the underlying collateral in increments of 50 basis points (bps). Exchanges are executed for a small fee and may be reversed back into IO and PO components as well as into any other available combination, provided the proportions of IO and PO are correct. To promote liquidity in the SMBS market, all FNMA SMBS certificates (except FNMA SMBS Series L) have a unique conversion feature that enables like denominations of both classes of a FNMA SMBS issue or Trust to be exchanged on the book entry system of the Federal Reserve Banks for like denominations of FNMA MBS certificates or Megapool certificates. Because of the potential for profitable arbitrages, the aggregate price of the two classes of any same FNMA issue or Trust tends to be slightly higher (the "recombo premium") than the price of comparable-coupon and remaining-term FNMA pass-through certificates.

FHLMC Stripped Giant Program

FHLMC is also a participant in the SMBS market. In October 1989, FHLMC announced the Stripped Giant Mortgage Participation Certificate Program.

FHLMC's Stripped Giant Program is similar to FNMA's swap SMBS Trust Program. Deal managers submit FHLMC PCs to FHLMC; FHLMC, in turn, aggregates these PCs into Giant pools and issues Strip Giant PCs representing desired proportions of principal and interest to the deal manager. All FHLMC strip PCs have the same payment structure, payment delays, and payment guarantee as regular FHLMC PCs. Like FNMA SMBS, FHLMC Giant Strip IOs and POs have a conversion feature that allows them to be exchanged for similarly denominated FHLMC PCs. Under the FHLMC Gold MACS (Modifiable and Combinable Securities) program, IO and PO securities may be exchanged for synthetic-coupon classes that have been predetermined in the prospectus supplement for a fee.

GNMA Collateral for SMBS

In 1990 FNMA began to issue SMBS collateralized by GNMA pass-through certificates. Since the beginning of 1990, FNMA has issued 76 trusts that have had underlying GNMA collateral. FHLMC began to issue GNMA-backed SMBS in 1993 and has issued seven GNMA strips to date. The increased availability of GNMA SMBS has further broadened the investor base of SMBS, enhanced the liquidity of the SMBS market, and increased the number of hedging alternatives available to GNMA investors.

In July 2004, GNMA issued its first Trust security GNS 1 of $2.2 billion. Although very few GNMA SMBS have been issued subsequently, structured IO and PO within GNMA-backed CMOs are very popular.

Private Issuance

Investment firms began to issue private-label SMBS in late 1986. Many of these private-labels SMBS were issued through REMIC structures. Since one class of REMIC issue must be designated the residual interest, the super-premium coupon class of many of these private-label SMBS is often the residual interest of the REMIC deal. Unlike investing in FNMA SMBS, investors who purchase these residual securities are responsible for the tax consequences of the entire REMIC issue.

PO-Collaterized CMOs

Profitable arbitrage opportunities led to the introduction of CMO securities collateralized by POs. PO-collateralized CMOs allocate the cash flow from underlying PO securities between several CMO tranches with different maturities and prepayment patterns. The potential for profitable arbitrages with PO securities has enhanced the efficiency of the SMBS market by effectively placing a floor on the price potential of POs and a price ceiling on corresponding IOs in a given market environment.

CMO Strip Securities

Strip securities are included in CMO issues as regular-interest (nonresidual) CMO tranches. CMO strip securities that pay only principal, large proportions of interest cash flows (relative to principal cash flows), or only interest over the underlying mortgage collateral's life are termed PO securities, "higher-interest" securities, and IO securities respectively; they tend to have performance characteristics similar to FNMA SMBS. Other types of CMO strip securities receive initial and ongoing collateral principal or interest in cash flows after other classes in the CMO issue are retired or have been paid. These types of strip CMO securities are structured as PO or PAC IOs, TAC IOs, or Super-POs and can have similar characteristics to FNMA SMBS or can be structured to have higher or lower performance leverage.

IOS, PO Index, and MBX

In February 2010, Markit introduced the IOS, PO Index, and MBX. They are Synthetic Total Return Swaps. The IOS Index was the most actively traded among the three as it served as an additional source for IO exposure. The Markit IOS Indices are composed of the interest component of reference pools of loans. The most common reference pools of loans are 30-year fixed-rate Fannie pools with coupons from an entire issue year. For example, the first pools were issued with coupons of 4.0, 4.5, and 5.0 in 2009. Today there are various reference pools from 3.0 fixed-rate coupon to 6.5 fixed-rate coupon with vintage years from 2003 to 2014.

The economics of the IOS Index is similar to that of owning a cash IO. If an investor buys the IOS index of 2009 4.5 coupon, they will receive the net cash flow based on the reference pool and will pay one-month LIBOR in return.

Buyers of SMBS

The asymmetric returns of SMBS appeal to a broad variety of investors. SMBS can be used effectively to hedge interest rate and prepayment exposure of other types of mortgage securities. Combined with interest rate derivatives, SMBS is a typical instrument for mortgage servicers to hedge the interest rate and prepayment exposure of the mortgage servicing rights. SMBS can also be combined with other fixed-income securities such as U.S. Treasuries and mortgage securities to enhance the total return of the portfolio in varying interest rate scenarios. Insurance companies and pension funds frequently use SMBS as a method of tailoring their investment portfolio to meet the duration of liabilities and thus minimize interest rate risk.

SMBS are used by various types of investors to accomplish their investment objectives. Insurance companies, pension funds, money managers, hedge funds, and other total rate of return accounts use SMBS to improve the return of their fixed-income portfolios.

INVESTMENT CHARACTERISTICS

SMBS enable investors to capture the performance characteristics of the principal or interest components of the cash flows of mortgage pass-through securities. These individual components display contrasting responses to changes in interest rates and prepayment rates. PO SMBS are bullish instruments, outperforming mortgage pass-through in declining interest rate environments. IO SMBS are bearish investments that can be used as a hedge against rising interest rates.

Variation of Interest and Principal Components with Prepayments

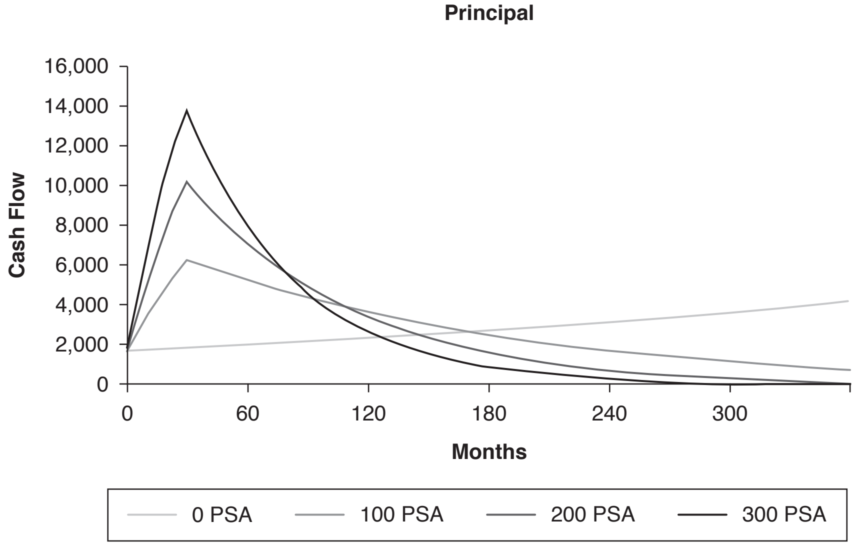
The cash flows that an MBS investor receives each month consist of principal and interest payments from a large group of homeowners. The proportion of principal and interest in the total payment varies depending on the prepayment level of the mortgage pool. Exhibit 24-2 illustrates these cash flows for $1 million 30-year FNMA current-coupon pass-through securities at various PSA prepayment speeds.

Panel a of Exhibit 24-2 shows the principal component of the monthly cash flows. Since the interest is proportional to the outstanding balance, the exhibit can also be viewed as showing the decline in the mortgage balance at the various prepayment speeds.

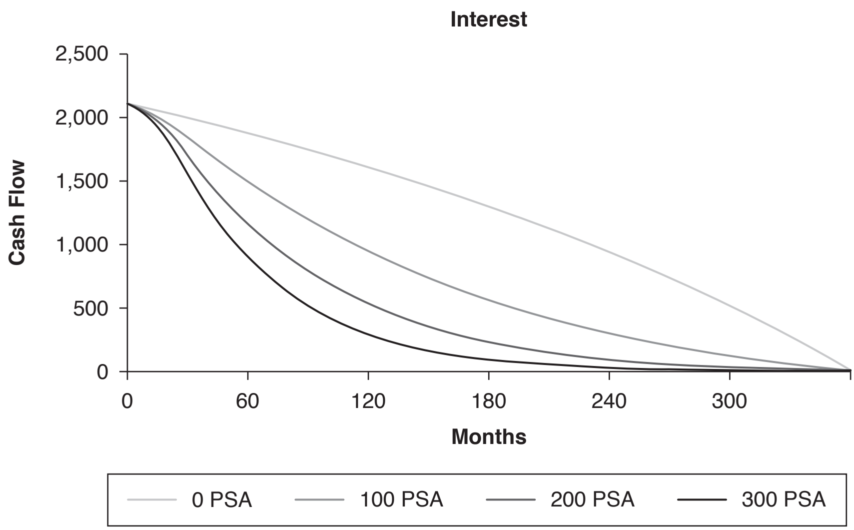
EXHIBIT 24-2

Monthly Cash-Flow Components

Panel a: Principal Component of Monthly Cash Flows



Panel b: Interest Component of Monthly Cash Flows



At a zero prepayment level, the interest and principal cash flows in Exhibit 24-2 compose a normal amortization schedule. In the earlier months of the security's life, the cash flows primarily contain interest payments. This occurs because interest payments are calculated based on the outstanding principal balance remaining on the mortgage loans at the beginning of each month. As the mortgage loans amortize, the cash flows increasingly reflect the payment of principal. Toward the end of the security's life, principal payments make up the bulk of the cash flows.

Prepayments of principal significantly alter the principal and interest cash flows received by the mortgage pass-through investor. Homeowners who prepay all or part of their mortgage loans return more principal to the investor in the earlier years of the mortgage security. All else being equal, an increase in prepayments has two effects:

1. The time remaining until return of principal is reduced as shown in panel a of Exhibit 24-2. At 100% PSA, the average life of the principal cash flows is 10.49 years, whereas at faster speeds of 200 and 300% PSA, principal is returned in average time periods of 7.25 years and 5.50 years, respectively.
2. The total amount of interest cash flows is reduced, which is shown in panel b of Exhibit 24-2. This occurs because interest payments are calculated based on the higher amount of principal outstanding at the beginning of each month and higher prepayment levels reduce the amount of principal outstanding.

Effect of Prepayment Changes on Value

A mortgage pass-through security represents the combined value of the interest and principal cash flows. The effects of prepayments on the present value of each of these components tend to offset each other. Increases in prepayments reduce the time remaining until repayment of principal. The sooner the prepayment of principal is repaid, the higher the present value of the principal. Conversely, since increasing levels of prepayments reduce interest cash flows, the value of the interest decreases.

Thus, the interest and principal cash flows individually are much more sensitive to prepayment changes than the combined mortgage pass-through. This is illustrated in Exhibit 24-3 which shows the present values of the principal and interest components of a FNMA pass-through at various prepayment levels.

The greater sensitivity of IOs and POs to prepayment changes is further illustrated in Exhibit 24-4, which shows the realized yields to maturity (or internal rates of return) for a typical IO and PO and for the underlining collateral for given purchase prices.

The IO and PO reflect sharply contrasting responses to prepayment changes; the IO's yield falls sharply as prepayments increase, whereas the PO's yield falls as prepayments decrease. The yield of the underlining collateral is, on the other hand, relatively stable compared to PO and IO.

EXHIBIT 24-3

Present Values of Principal and Interest Components of FNMA Current-Coupon Pass-Through

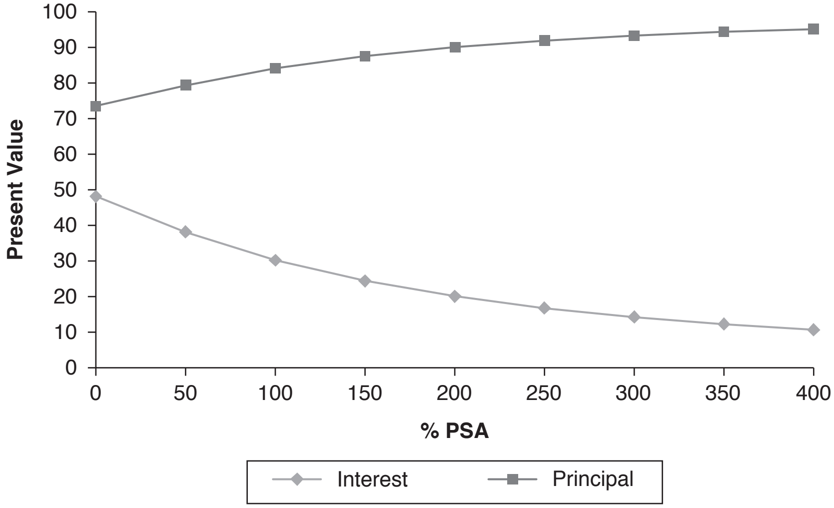
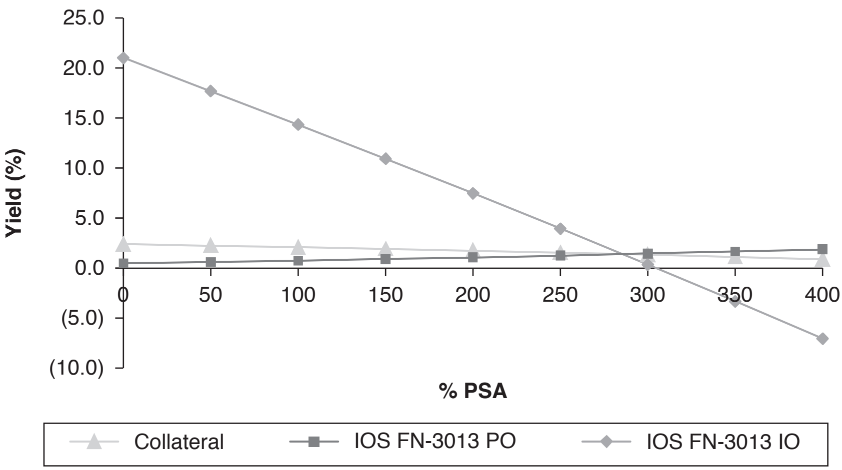


EXHIBIT 24-4

Realized Yields to Maturity for Typical IO and PO



Price Performance of SMBS

The discussion in the previous section indicates that prepayment speeds are by far the most important determinant of the value of an SMBS. Since the price response of an SMBS to interest rate changes is determined, to a large extent, by how the collateral's prepayment speed is affected by interest rate changes, we begin with a discussion of mortgage prepayment behavior.

The Prepayment S Curve

The prepayment speed of an MBS is a function of the security's characteristics (such as coupon and age), interest rates, and other economic and demographic variables. Although detailed prepayment projections generally require an econometric model, the investor can obtain some insight into the likely behavior of an SMBS by examining the spread between the collateral's gross coupon and current mortgage rates

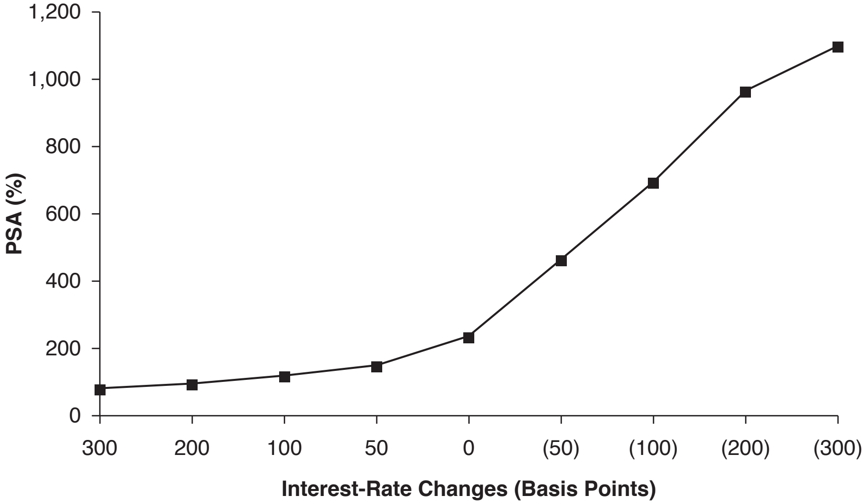
This spread is generally the most important variable in determining prepayment speeds. A decrease of current mortgage rate translates to a higher spread and hence more rate incentive to prepay. A decrease of current mortgage rate has the opposite effect on prepayment. With respect to this spread, prepayment speeds have an S shape; speeds are fairly flat with increasing mortgage rate (when the spread is negative and prepayments are caused mainly by housing turnover), they start increasing when the mortgage rate starts to decrease (when the spread becomes positive), they surge rapidly until the spread is several hundred bps, and then they level off when the security is a high premium. At this point, there is already substantial economic incentive for mortgage holders to refinance, and further increases in the spread lead to only marginal increases in refinancing activity. This S curve is illustrated in Exhibit 24-5, which shows projected long-term prepayments for specified changes in mortgage rates.

In the remainder of this section, we make repeated reference to Exhibit 24-5, since the performance of an SMBS can be explained to a large extent by the position of its collateral on the prepayment S curve.[3]

3. However, the investor should note that not all aspects of prepayment behavior are explained by the spread between the coupon and the mortgage rate. The projected prepayments shown in Exhibit 24-5 are long-term averages. Month-to-month prepayment rates vary (e.g., due to seasonality) even if mortgage rates do not change. If a substantial and sustained decline in mortgage rates occurs, then mortgage holders exposed to mortgage refinancing incentives for the first time initially exhibit a sharp increase in prepayments. This gradually decreases as the homeowners most anxious and able to refinance do so. This non-interest-rate-related decline in the prepayment speeds of premium coupons usually is referred to as "burnout." The projected speeds shown in the declining-rate scenarios are the average of the high early speeds and lower later speeds. For seasoned coupons that have experienced a heavy refinancing period, burnout implies that prepayments may be less responsive to decline in interest rates. This applies to the majority of premium coupons currently outstanding. The age effect on prepayments is well known. Prepayment speeds are low for new mortgages and increase gradually until the mortgages are two to three years old, after which the age is less important. This means that, other things being equal, an IO is worth more if it is collateralized by new FNMA 5.5s, for example, than by seasoned FNMA 5.5s.

EXHIBIT 24-5

Payment S Curve



Projected Price Behavior

Exhibit 24-6 gives projected price paths for a pair of IO and PO for parallel interest rate shifts.[4]

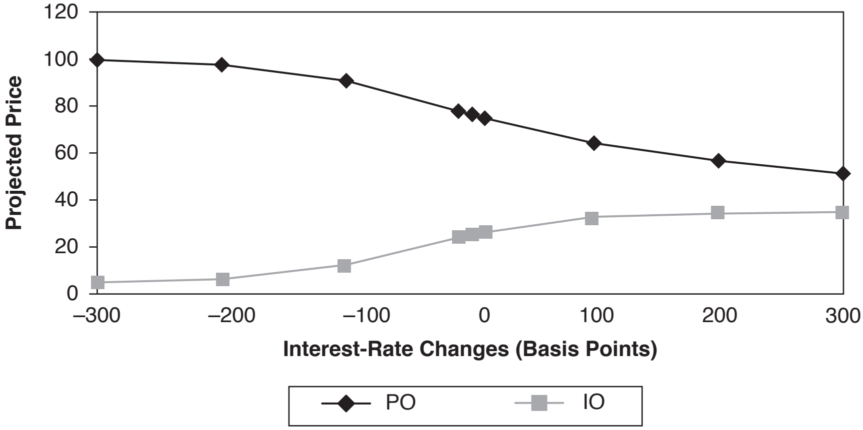
The projected price behavior of the SMBS as interest rates change can be explained largely by the prepayment S curve in Exhibit 24-5.

- As rates drop from current levels, the collateral begins to experience sharp increases in prepayment. Compounded by lower discounted rates, this causes substantial price appreciation for the PO. For the IO, however, the higher prepayments outweigh the lower discount rates and the net result is a price decline.
- If the rates drop by several hundred basis points, the collateral becomes a high-premium coupon and prepayments plateau. The rates of price appreciation of the PO and price deprecation of the IO both decrease. Eventually the IO's price starts to increase, as the effect of lower discount rates starts to outweigh the effect of marginal increases in prepayments.
- If rates rise, the slower prepayments and higher discount rates combine to cause a steep drop in the price of the PO. The IO is aided initially by the slower prepayments, giving the IO negative duration, but eventually prepayments plateau on the slower side of the prepayment S curve and the IO's price begins to decrease.

4. The prices are calculated with constant yield assumption in all cases. The collateral price is the sum of the IO and PO prices.

EXHIBIT 24-6

Projected Price Paths for an IO and a PO for Parallel Interest Rate Shifts



Effective Duration and Convexity

Exhibit 24-7 indicates that POs tend to have large positive effective durations, whereas IOs have large negative effective durations.[5]

The effective durations in Exhibit 24-7 reflect the price paths in Exhibit 24-6:

- For the PO, as rates decline, the effective duration initially increases, reflecting its rapid price appreciation as prepayments surge. Note that this is in complete contrast to traditional measures such as Macaulay or modified duration, which, reflecting the shortening of the PO, would actually decrease. As rates continue to drop, the PO's effective duration levels off and then decreases, reflecting both a leveling off of

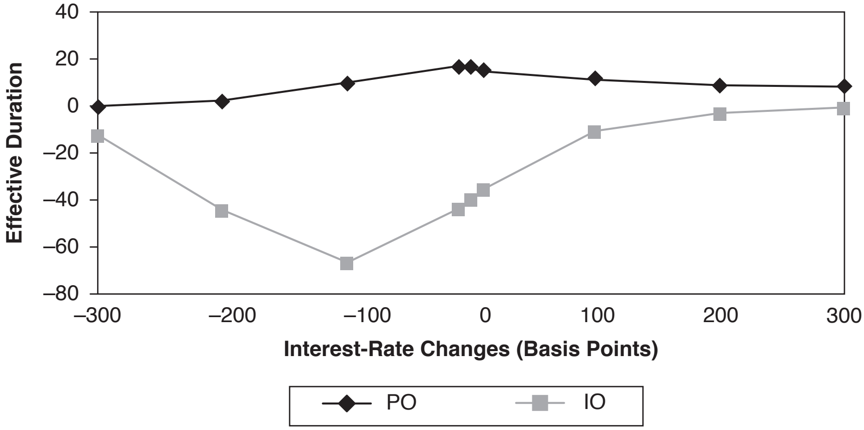
5. Effective duration is a measure of the proportional price change if interest rates change by a small amount. Let Price(0) be the current price of a security. Let Price(Δ) be the price if interest rates increase by a small amount Δy and Price(−Δ) be the price if interest rates decrease by a small amount Δ. Then

$$\text{Effective duration} = \frac{\text{Price}(-\Delta) - \text{Price}(\Delta)}{\text{Price}(0) \times 2\Delta y} \times 100$$

This formula is straightforward: we take the total price change (the difference in the new prices) and divide by the initial price (the 100 is a scaling factor). To obtain the projected price and durations, we have, for simplicity, assumed parallel shifts in interest rates. In practice, of course, rates do not move in parallel (typically, short-term rates tend to be more volatile than long rates). However, using nonparallel yield curve shifts raises questions that, although interesting, are best left for another book. For example, suppose the yield curve shifts such that short rates move twice as much as long rates, and we compute the corresponding price change. The effective duration will be twice as large if we compare the price change against the change in short rates (i.e., Δy change in short rates) as opposed to comparing the price change against the change in long rates (i.e., Δy change in long rates).

EXHIBIT 24-7

IO and PO Effective Durations



prepayments and the fact that, to calculate the effective duration, we are dividing by an increasing price. If rates increase, the PO's duration decreases but remains positive.

- For the IO, the effective duration is initially negative and decreases rapidly as rates drop, before eventually increasing and becoming positive after prepayments plateau. If rates increase, the duration increases and eventually becomes positive.

Convexity measures the rate of change of duration and is useful in indicating whether the trend in price change is likely to accelerate or decelerate. It is calculated by comparing the price change if interest rates decrease with the price change if rates increase.[6] Exhibit 24-8 shows the convexities obtained using the projected prices in Exhibit 24-6.

6. Convexity is calculated by comparing the price change if rates move up or down by small amounts. Let

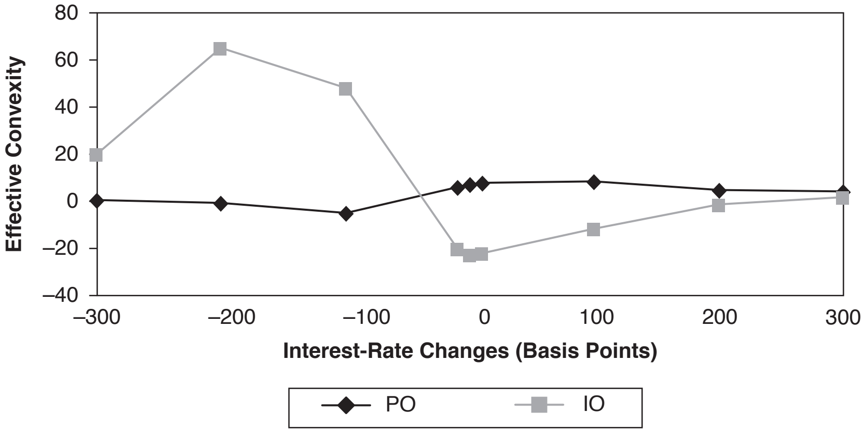
$$\Delta P^{+} = \text{Price}(0) - \text{Price}(\Delta)$$
$$\Delta P^{-} = \text{Price}(-\Delta) - \text{Price}(0)$$

where ΔP^{+} and ΔP^{-} are the price changes if rate increases or decreases by Δy, respectively. Then

$$\text{Convexity} = \frac{\Delta P^{-} - \Delta P^{+}}{\text{Price}(0) \times (\Delta y)^2} \times 100$$

EXHIBIT 24-8

IO and PO Convexities



Comparing Exhibits 24-7 and 24-8 shows that the convexity indicates how the duration is changing. When the duration is increasing (as in the case of the PO when rates begin to decline from the initial value), the convexity is positive, and when the duration is decreasing, the convexity is negative. For example, the IO's convexity is initially negative but begins to increase after rates fall by more than 100 bps; although the duration is still negative at 200 bps, the positive convexity indicates that the duration is increasing. The peak in the convexity of the IO at a change of 200 bps indicates that the rate of increase in its duration is greatest at this point, as shown in Exhibit 24-7.

In summary, the prepayment S curve implies that:

- For SMBS collateralized by current or discount pass-throughs, the PO has substantial upside potential and little downside risk, whereas the converse is true for IOs.
- For SMBS backed by low premiums, there is a somewhat comparable upside potential and downside risk.
- For SMBS backed by high premiums collateral (including the majority of SMBS issued to date), the PO has little upside potential and significant downside risk whereas the reverse is true for IOs.

Pricing of SMBS and Option-Adjusted Spreads

The strong dependence of SMBS cash flows on future prepayment rates, combined with the typically asymmetric response of prepayments to interest rate changes, make traditional measures of return such as yield to maturity of limited usefulness in analyzing or pricing SMBS. The most common method of pricing SMBS is with option-adjusted spreads (OAS). OAS analysis uses probabilistic methods to evaluate the security over the full-term range of interest rate paths that may occur over its term. The impact of prepayment variations on the security's cash flows is factored into the analysis. The OAS is the option-free spread over the benchmark curve (Treasury or swap curve) provided by the security. It gives a long-term average value of the security, assuming a market-neutral viewpoint on interest rates.

Exhibit 24-9 shows the OAS analysis for IOS, PO Index, and MBX of 2013 3% coupon that are illustrations for IO strip, PO strip, and the underlying collateral. Also shown are the yields to maturity, WAL, spread to WAL equivalent treasury rate.

The OAS at a 0% volatility (the ZV-Spread) when mortgage rates stay at current levels, is typically close to the standard benchmark curve spread in a flat yield curve environment. The difference between the ZV-Spread and OAS, which we label the *option cost*, is a measure of the impact of prepayment variations on a security for the given level of interest rate volatility. The option cost, to a large extent, does not depend on the pricing level or the absolute level of prepayment projections (although it does depend on the slope, or response, of prepayment projections to interest rate changes). Hence, the option cost is a measure of the intrinsic effect of likely interest rate changes on a mortgage.

Before discussing the option cost in Exhibit 24-9, note that, in general, interest rate and prepayment variations have two effects on an MBS:

1. For any callable security, being called in a low interest rate environment typically has an adverse effect, since a dollar of principal of the security in general would be worth more than the price at which it is being returned. (An exception is a mortgage prepayment resulting from housing turnover, when the call could be uneconomic from the call-holder's point of view.) To put it another way, the principal that is being returned typically has to be reinvested at yields lower than that provided by the existing security.
2. For MBS priced at a discount or a premium, changes in prepayments result in the discount or premium being received sooner or later than anticipated. This may mitigate or reinforce the call effect discussed in (1).

In general, the first effect is much more important than the second; however, for certain deep-discount securities, such as POs, the second effect may at times outweigh the first. The net result of the two effects depends on the position of the collateral on the prepayment curve shown in Exhibit 24-5.

- For discount or current-coupon collateral, prepayments are unlikely to fall significantly but could increase dramatically if there is a substantial decrease in interest rates. This asymmetry means that the PO is, on average, likely to gain significantly from variations in prepayment speeds. The option cost for the PO is usually negative; that is, the PO *gains* from interest rate volatility, indicating that the benefits of faster

EXHIBIT 24-9

OAS Analysis for IOS, PO Index and MBX of 2013

	Price	YTM	WAL	I-Spread	OAS	ZV-Spread	Option Cost
IOS FN-3013 PO	94-12	1.177	5.07	82	55	100	45
IOS FN-3013 IO	12-08	4.781	5.07	442	16	456	440
IOS FN-3013 PT	106-20	1.595	5.07	124	50	142	92

return of principal outweigh the generic negative effects of being called in low interest rate environments. On the other hand, the underlying collateral tends to have a positive (but usually small in the case of discount collateral) option cost; the negative effects of being called when rates are low outweigh the benefits of faster return of principal. Finally, the IO typically has a large positive option cost; the asymmetric nature of likely prepayment changes, discussed above, means that the IO gains little if interest rates increase (since prepayments will not decrease significantly), whereas a substantial decline in rates is likely to lead to a surge in prepayments and a drop in interest cash flows.

- Given continued rates rally for many years, all outstanding SMBS are backed by premium collateral. FNMA IOS, PO index, and MBX of 2013 3 coupon, shown in Exhibit 24-9, illustrate the characteristics typical of SMBS with premium collateral. For *premium* collateral, there is, generally speaking, potential for both increases and decreases in prepayments, and the net effect of prepayment variations will depend on the particular coupon and prevailing mortgage rates. Seasoned premiums, for example, will not have potential for substantial increases in speeds, and hence IOS FN-3013 PO has a small but positive option cost. The collateral IOS FN-2013 PT has a more positive option cost for the same reasons.

The importance of likely variations in prepayments makes the standard yield to maturity of very little relevance in pricing SMBS, and therefore they tend to be priced (as in Exhibit 24-8) on an OAS basis.

KEY POINTS

- There are many forms of stripped mortgage-backed securities, including pass-throughs, Trust IOs and POs, and CMO strips.
- SMBS are used both as hedges of prepayment and interest rate risk and as yield-enhancement mechanisms.
- POs and IOs exhibit contrasting responses to changes in interest rates: POs outperform mortgage pass-throughs in a declining rate environment, while IOs underperform them.
- Prepayment speeds are by far the most important determinant of the value of an SMBS. As such, the price performance of SMBS is largely determined by the prepayment S curve.
- Current- or low-premium collateral POs tend to have large positive effective durations, while IOs have large negative effective durations.
- Traditional performance measures such as yield to maturity have limited usefulness in the analysis of SMBS; the most common method of pricing them is using option-adjusted spread.

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CHAPTER
TWENTY-FIVE

NONAGENCY RESIDENTIAL MORTGAGE-BACKED SECURITIES: LEGACY, RMBS 2.0, AND NON-QM

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Mario Triantafillou, Ph.D.
Director
BlackRock Financial Management, Inc.

Nonagency residential mortgage-backed securities (nonagency RMBS) are securities that are backed by mortgage loans lacking guarantees from either government-sponsored enterprises (GSEs; e.g,. Fannie Mae and Freddie Mac) or government agencies (e.g., Ginnie Mae). This makes them fundamentally different from agency RMBS in that they are exposed to the *credit risk* of the underlying loans in addition to their prepayment risk. Nonagency loans fail to receive agency guarantees for two primary reasons: they are originated with loan balances exceeding the agency conforming limit and/or they do not meet agency underwriting standards.

Each nonagency RMBS deal contains hundreds to thousands of mortgage loans. The cash flows of a deal are structured into various pools or tranches that each bear different risks to suit different investors. Each tranche is an RMBS bond. Nonagency RMBS deals are primarily categorized by the dominant mortgage type in each deal. Deals issued before or during the subprime mortgage crisis are termed *legacy* RMBS deals, including prime jumbo, alternative-A

The views here are the authors' only and do not represent the views of BlackRock. This chapter was rewritten based on the chapter "Nonagency Residential Mortgage-Backed Securities," coauthored by Dapeng Hu and Robert Goldstein, in the 8th edition of *Handbook of Fixed Income Securities*. The authors thank Robert Goldstein for his contribution to the previous version and his encouragement in this new version. The authors thank Neeraj Kumar for his great assistance in updating many charts and tables. The authors also thank Ying Shen, James Watkin, Caroline Liu, Scott Anderson, Manish Sinha, Kelly Schneiter, Sophia Su, Ibrahim Incoglu, Adam Levi, and other colleagues for their helpful comments and discussions on these materials.

(Alt-A), option adjustable-rate mortgage (OARM), subprime, second (2nd) lien, and manufactured housing (MH) mortgages. After the crisis, new issuances are dominated by three major products: NPL and RPL deals, which repackage legacy nonperforming loans (NPL) and re-performing loans (RPL); RMBS 2.0 deals, which are primarily backed by newly originated high-quality prime jumbo loans with simpler deal structures; and non-QM deals backed by nonqualified mortgages, a new mortgage category following the Consumer Finance Protection Bureau's rule on Qualified Mortgages in 2014.

During the housing boom, nonagency RMBS provided slightly higher yields than agency RMBS with seemingly little additional risk. Perennially yield-hungry investors poured money into this sector. This led to rapid increases in loan origination, to innovations in mortgage products, and to a flood of so-called affordability mortgages. Furthermore, the development of ABS credit default swaps and collateralized debt obligations (CDOs) led to a surge of nonagency RMBS issuance beginning in 2005. Nonagency RMBS issuance reached its peak in 2006 with more than $1 trillion in new issuance and spreads at their tightest levels. The subprime mortgage crisis and its concomitant housing market meltdown substantially slowed new issuance in 2007. Issuance ground to a halt in 2008 and 2009. These legacy securities, still have, as of this writing, a large outstanding balance.

Starting in 2011, nonagency mortgage lenders found that the market was once again willing to finance ultra-prime loans through the issuance of private-label securitizations, termed prime jumbo new origination, or RMBS 2.0. Large banks that have strong mortgage origination operations joined in with their own securitizations in 2013. Collateral characteristics of these deals typically have a large loan size, very high FICO credit score, and low loan-to-value (LTV) ratio. While issuance has currently peaked at $10 billion per year, total outstanding is nearly $50 billion today. These RMBS 2.0 deals typically have simpler capital structures compared to legacy deals.

Another innovation was the introduction of non-Qualified (non-QM) loans starting in 2014. Non-QM refers to loans that do not meet all Qualified Mortgage standards set by the Consumer Finance Protection Bureau (CFPB). Examples of this include loans to borrowers who are self-employed, loans to borrowers who are asset rich but cash constrained, and loans to borrowers who are investing in properties and will use rental proceeds for loan repayment. Precluding these loans from mainstream lending means originators of non-QM loans can charge higher rates and thus reward non-QM deal investors with higher yields. Consequently, the non-QM market has gained increasing interest from investors and the issuance of non-QM products has grown continuously since 2014.

This chapter first provides an overview of the nonagency RMBS market, with a review of the rise, fall, and likely reincarnation of securitization. It then examines three core aspects of nonagency RMBS—collateral, servicing, and capital structure—for legacy RMBS deals, prime jumbo 2.0 deals, as well as non-QM deals. The housing market, the most important macro factor for nonagency RMBS performance, is also discussed. Finally, it concludes with an introduction of relative value and risk analysis.

MARKET OVERVIEW

Industry Structure

The process of nonagency securitization involves several types of institutions including originators, warehouse lenders, issuers, rating agencies, servicers, trustees, and so on. Originators underwrite and originate mortgage loans to borrowers. Major originators include banks, mortgage companies, correspondents, and brokers. Warehouse lenders provide short-term financing to originators allowing a critical mass of loans to be accumulated for a deal. Issuers package the loans and structure them into various tranches, work with rating agencies to obtain credit ratings, and sell the tranches in the capital markets as RMBS. Major issuers include banks, mortgage companies, real estate investment trusts (REITs), and investment banks. Rating agencies analyze the potential collateral loss and deal structure and assign credit ratings to each tranche. They also conduct surveillance of existing bonds to determine if they are eligible for rating upgrades or downgrades. The major rating agencies are Moody's, S&P, and Fitch. Trustees administer the deals including releasing remittance reports that detail the performance of the collateral and the bonds and distributing the cash flows to investors.

Mortgage servicers play a critical role in the nonagency RMBS life cycle. They collect payments from borrowers and pass them on to trustees. Depending on the type of deal and the terms of the prospectus, the servicer is generally responsible for advancing principal and interest payments for delinquent borrowers, provided the servicer believes that the advanced amounts are recoverable. Servicers are also responsible for collection, foreclosure, real-estate owned (REO), and liquidation efforts. Servicers have also become responsible for conducting loan modifications.

During the nonagency securitization boom, several industry participants built vertically integrated securitization businesses named conduits. These businesses acquire loans, either funding them directly through brokers or through a flow program with various correspondents for ultimate securitization exit. They also typically retained the servicing rights to the purchased loans, either performing the servicing themselves or subcontracting to third-party servicers.

Deal type is often identifiable from a deal's prospectus. A prospectus is an offering document that describes collateral characteristics and deal structure and discloses the associated transaction parties (e.g., underwriters, trustees, servicers) and investment risks. Because issuers typically use different entity or "shelf" names for different product types, the shelf is often used to classify the deal type.

Rise and Fall of Legacy Nonagency RMBS Market

Nonagency securitization started in the 1980s. During the early stages of the RMBS market's development, there was an essentially binary division in the secondary mortgage market between agency pools/deals and nonagency deals. Loans that were not agency-eligible were either retained as whole loans or put into a "nonagency deal." The gradations in credit quality and underwriting that later characterized the nonagency sector were, at that point, mostly absent. Consequently, nonagency deals issued in the 1980s and early 1990s frequently contained a wide variety of collateral types.

In the early 1990s, nonagency RMBS began to employ more systematic underwriting standards, standards that were closer to those used by the GSEs. This resulted in more homogenous credit quality among prime jumbo deals. Credit (FICO) scores began to be used in mortgage lending, providing a consistent industry-wide measurement of credit risk levels. This allowed the market to shift from generic "nonagency deals" to "prime jumbo," "Alt-A," and "subprime" deals. Prime jumbo was the dominant sector, while Alt-A was the smallest.

As the housing market started booming in the early 2000s, U.S. mortgage lending began to move away from its traditional roots in the 30-year fixed-rate product. Various alternative affordability products emerged and expanded rapidly. Hybrid adjustable-rate mortgages (ARMs) captured an increasingly large slice of the origination market, as did hybrid nonamortizing (i.e., interest-only) and negatively amortizing (NegAm or Option ARM) products. Before 2003, nonagency RMBS accounted for about 20% of the total U.S. RMBS new issuance market. Beginning in 2004, the nonagency market captured an increasing portion of market share from the agency sector, still dominated by prime jumbo. By 2005, securitized nonagency RMBS origination surpassed that of agency origination reaching $1.2 trillion with subprime as the largest nonagency sector followed by Alt-A.

Nonagency securitization was further fueled by the adoption of the pay-as-you-go (PAUG) structure in ABS credit default swaps (CDS) and the rapid expansion of the ABS collateralized debt obligation (CDO) market. Unlike traditional CDS that requires a hard or clear singular credit event to determine payoff, under PAUG structure if an ABS security encounters a principal loss or an interest shortfall, the protection seller pays the protection buyer the amount of the loss or shortfall. If the security later catches up on the payment, the protection buyer returns the payment to the protection seller. This essentially made ABS CDS work just like a cash bond, which greatly increased the liquidity of ABS CDS.

The PAUG template facilitated two key developments that ultimately became critical ingredients for the subprime mortgage crisis: the launch of ABX, an index for or a basket of subprime ABS CDS, and the creation of synthetic ABS CDOs. The ABX index became the barometer of nonagency RMBS market and the dominant instrument for shorting the market. The creation of synthetic ABS allowed the ABS CDO machine to roar. Synthetic ABS, as opposed to cash bonds, refers to using ABS CDS contracts to create cash flows that are similar to owning the reference bond. Synthetic ABS liberated CDO managers from the relative scarcity of cash bonds by allowing them to create tens of billions of synthetic instruments without actual mortgage origination. This greatly magnified the impact of nonagency mortgage defaults on the overall financial system.

The surge in nonagency mortgage demand directly led to the relaxation of mortgage underwriting criteria. Total combined LTV ratios were increasing as borrowers were not always required to put down the typical 20% of equity in order to buy a house. Debt-to-income ratio, credit score, and documentation requirements were all loosened. Appraisal values were often inflated in order to qualify for a loan, underwriting due diligence was often compromised, and the share of affordability products (interest-only, negative amortization, etc.) increased sharply.

The consequence of loose underwriting soon became apparent as early delinquency (defined as within the first few payment periods) ramped up sharply in newly issued 2006 subprime deals. At the same time, the housing market started to weaken and home sales slowed, which accelerated the 2006 vintage delinquency rates as many borrowers little or no equity buffer. As delinquency levels continued to rise rapidly beyond these early payment defaults (EPDs) in late 2006, it became clear that the 2006 vintage was seriously challenged from a credit perspective and market prices for associated bonds started to fall.

By early 2007, as the housing market showed no signs of a soft landing and both subprime and Alt-A delinquency rates accelerated monthly, the capital markets started to penalize all RMBS prices, and many leveraged investors had to deleverage in order to meet margin calls. This triggered a vicious cycle of decreased valuations and deleveraging in bonds that were originally issued as AAA. As a consequence, the demand for new issuance vanished and many originators either went out of business or ceased production. By the end of 2007, almost all nonagency originations had stopped. Nonagency securitization ground to a halt and RMBS spreads widened dramatically.

Through this vicious cycle and thanks to the large exposures to ABS CDS and CDO, the credit problem in the nonagency RMBS market quickly spread to turmoil in the entire credit market. A downward spiral unfolded as banks started to mark-to-market their balance sheet assets. The mounting nonagency mortgage related credit losses not only led to huge unanticipated write downs to bank balance sheets, but also dramatically increased the capital reserve requirements for these large institutions, which further worsened market liquidity. Because many banks and large financial institutions were the major issuers and holders of RMBS, ABS CDS, and CDO assets, the mortgage credit meltdown eventually led to the downfall of large institutions like Countrywide, Wachovia, Washington Mutual, Bear Stearns, Lehman Brothers, Merrill Lynch, AIG, Fannie Mae, Freddie Mac, and so on.

Since late 2008, the legacy nonagency sector has been in runoff mode with little new issuance. Asset valuations hit a rock bottom in March 2009 and has since been in recovery. Subprime CDO liquidation and bank sales provided a supply of existing bonds to the market. During the crisis, the vast majority of bonds originally rated as AAA experienced rating downgrades, including 99% of

Option ARM, 97% of Alt-A, 94% of subprime, and 85% of prime bonds. Many were downgraded from AAA to below investment grade, including most 2005, 2006, and 2007 vintage bonds.

In early 2010, re-securitization has emerged as a meaningful mechanism to help absorb and repackage the universe of legacy nonagency RMBS. Re-securitizations, also known as re-REMICs, place nonagency RMBS bonds into a trust that then issues a senior and a junior bond to investors. These re-REMICs were primarily created using bonds that were AAA at issuance. They have utilized a simple structure where the senior bonds receive all the principal cash flows until they are paid off while all the losses are first absorbed by the junior bonds. The presence of junior bonds provides the senior bonds a greater credit enhancement; hence the senior bonds can obtain AAA ratings to meet investor needs. These transactions provided capital relief by allowing new AAA bonds to be created and retained while selling a smaller quantity of lower-rated bonds.

Another attempt to revive the nonagency market was the introduction of PrimeX indices in April 2010. PrimeX allowed investors to synthetically gain exposure to a basket of prime jumbo RMBS deals via credit CDS. At inception, they were traded actively and had facilitated the trading of existing prime bonds.[1] However, as the legacy bonds ran off, PrimeX became illiquid.

Today, there are still about $350 billion legacy RMBS loans remaining in running-off mode, including $203 billion subprime, $90 billion Alt-A, $38 billion OARM, and $27 billion prime jumbo. In addition, there are RPL/NPL deals that repackaged legacy loans. Since the remaining bonds are mostly below investment grades, the market liquidity is low with large price volatility. However, given the high coupons and burnout in prepayment and credit, many bonds provide relatively high yields.

RMBS 2.0 and Non-QM

Following the financial crisis, the financial market has been subjected to heightened regulation. Among others, two requirements from The Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (the Dodd-Frank Act) have had significant impact on mortgage securitization market. First, Dodd-Frank requires lenders to consider certain underwriting criteria and make a good-faith determination that borrowers will have the ability to repay their home loans. Second, the law requires securitization sponsors to retain not less than a 5% share of the aggregate credit risk of the assets they securitize.

Based on the Dodd-Frank Act, CFPB released the Ability to Repay (ATR) rules in 2014. The ATR rules require lenders to consider and verify several different underwriting factors, including debt-to-income ratio and credit history. Lenders must make a reasonable determination that a borrower will be able to pay back the loan. At the same time, it compensates for this added regulation by

1. See Dapeng Hu and Kishore Yalamanchili, "PrimeX—A Roadmap for Investors," *American Securitization* 4(3), August 2010, pp. 19–21.

creating a rule that defines a qualified mortgage (QM). If a loan meets the QM standard, it is presumed to meet the Ability-to-Repay rule and thus provides lenders with a "safe harbor" from buy-back and litigation.

In 2015, the Office of the Comptroller of the Currency (OCC), Federal Reserve Board, Federal Deposit Insurance Corporation (FDIC), Securities and Exchange Commission (SEC), Federal Housing Finance Agency (FHFA), and Department of Housing and Urban Development (HUD) finalized risk retention rules. The rules established several exemptions from risk retention requirements, including for RMBS collateralized exclusively by "qualified residential mortgages," as defined in the rule. Later, the interagency decided to define a QRM in full alignment with the definition of a QM.

Ever since the end of the financial crisis, the nonagency mortgage sector has struggled to revive in the securitization market. For several years, the only securitization activity was issuances of RPL and NPL deals, which were repackaging reperforming or nonperforming loans. Nonagency RMBS securitization began to see nascent activity in 2011. The new deals, dubbed RBMS 2.0 by the industry, were (and continue to be) composed of super-jumbo mortgages made with low LTVs to borrowers with the highest credit scores. As all these mortgages are qualified for QRM, the prime jumbo new origination deals are therefore exempted from risk retention. The deal structures are also mostly simple and straight forward. As shown in Exhibit 25-1, new issuance of prime jumbo deals has since increased over time to more than $10 billion a year in recent years, but it remains a much lower level compared to the dominant agency market.

EXHIBIT 25-1

Issuance of Prime Jumbo New Origination and Non-QM

Deal Vintage	New Prime Jumbo		Non-QM	
	Deal Count	Total Loan Bal. ($MM)	Deal Count	Total Loan Bal. ($MM)
2011	2	580		
2012	9	3,495		
2013	32	13,182		
2014	28	8,898	1	10
2015	35	12,279	2	384
2016	14	4,885	7	1,114
2017	21	11,616	14	3,329
2018	38	19,295	27	9,664
2019	34	15,586	55	21,398
2020*	11	6,098	18	6,017
Total	224	95,914	124	41,917

* as of May 2020.

Data sources: Intex and BlackRock Solutions.

Given the heightened regulation environment after the financial crisis, banks have steered clear of the nonagency mortgages aside from jumbo prime. The vacuum has created an opportunity for private lenders that are willing to offer credit to borrowers outside agency or super prime. These borrowers may not meet all the QM requirements, hence the term "non-QM." As securitization of these loans would require risk retention, which was a hurdle for many private lenders, the issuance of non-QM deals has been slow until recently. As of May 2020, there have been 124 non-QM deals issued with $42 billion in total balance.

COLLATERAL

Collateral analysis is a key component of relative value analysis for nonagency RMBS. Here we provide an overall review of the major characteristics of nonagency mortgages, their performance, and major issues in analyzing the collateral for legacy nonagency RMBS deals, and RMBS 2.0 prime jumbo deals, as well as non-QM deals.

Key Collateral Drivers for Loan Performance

Different products, vintages, and deals each have different characteristics. These characteristics, together with the macroeconomic environment, drive different prepayment and credit performance.

Coupon rate and fixed vs. hybrid: Coupon rate and weighted average coupon (WAC) refer to the interest rate of a mortgage or the average rate for a pool of mortgages. Higher coupon usually indicates a higher prepayment incentive. On the other hand, a higher than prevailing interest rate at origination often associates with certain credit impairments. Hybrid borrowers are typically more leveraged than fixed-rate borrowers. In addition, the rate reset can cause substantial payment shocks under an increasing rate environment. Therefore, hybrid loans tend to have worse credit performance. In terms of prepayments, hybrids are also very different from fixed rate mortgages.

In the prime jumbo and Alt-A sectors, deals contain either 100% fixed-rate mortgages or 100% hybrid (fixed for several years then floating) mortgages. In the non-QM or subprime sectors, however, deals typically have a mixture of fixed and hybrid mortgages.

Loan-to-value ratio: LTV is the most important factor for mortgage credit performance. There are several LTV measurements. Original LTV is the loan amount to house value ratio at origination. Original combined LTV includes second liens at origination in the loan amount. Current LTV refers to the current loan amount to current house (home price appreciation adjusted) value ratio, and current combined LTV measures the current total loan amount including second liens to the current house value. Current combined LTV measures how little equity the borrower currently has in the house. When the LTV is higher than 100%, the borrower has "negative equity." Their mortgages are higher than the value of the underlying home.

If the original LTV is greater than 80%, lenders typically require borrowers to buy mortgage insurance. Borrowers often avoided buying insurance by taking out an 80% LTV first lien loan while simultaneously getting a second lien loan. This is referred to as a "piggyback."

High combined LTVs lead to high rates of delinquency and default. When a borrower has negative equity, the default option is in-the-money and the so-called rational default rate increases substantially. High LTVs cause high loss severities when a loan defaults. In addition, high LTV loans prepay more slowly because it is difficult for the borrower to obtain a new loan.

Credit score: The mortgage industry started using credit scores in the 1990s. The most commonly used credit score is the FICO score, which is generated by independent credit bureaus for each borrower using empirical models created by the Fair Isaac Corporation (FICO). Scores range from 350 to 900, with a higher score indicating better credit quality. In mortgage origination, FICO is the most important variable to determine if a borrower is prime, subprime, or Alt-A. The average FICO is around 735 for prime borrowers but only 620 for subprime borrowers.

FICO scores help predict credit and prepayment performance, even though the FICO reported in nonagency RMBS data is the FICO at origination. Borrowers with lower FICO scores tend to have worse credit performance. After the financial crises, with the absence of subprime and Alt-A originations, minimum FICO score thresholds for which a borrower could refinance became nearly universal, making it extremely challenging to obtain a new loan with a FICO score below 660.

Debt-to-income ratio and documentation: The debt-to-income ratio (DTI) is a measure of a borrower's ability to pay the loan. There are commonly two DTI ratios in mortgage underwriting, front-end and back-end. Front-end DTI is the ratio of the housing payment (including mortgage payment and escrow) to gross income, also known as housing ratio. Back-end DTI adds all other financial debt and child support to the numerator. As an ability to pay measurement, a high DTI indicates a high payment risk. The level of DTI is a key criterion in defining non-QM.

Lenders often require various documents as proof of a borrower's income and assets. In general, full documentation involves verification of income (W-2, pay stubs, etc.) and assets (bank statements, brokerage statements, etc.). The definition of limited documentation, also known as "low doc." includes stated income, stated assets, no income, and verified assets. A small number of legacy loans were even originated with no documentation. Low documentation used to be prevalent for special borrowers such as small business owners who may have difficulty obtaining regular income documentation. However, in the run up to the financial crisis, these low-documentation loans were used frequently to qualify borrowers who overstated their income ("liar loans").

In addition to the these risk factors, there are several other factors that impact mortgage performance. They include loan size, loan purpose (purchase, refinancing, or cash-out), occupancy (owner-occupied, second home, or investment property), amortization versus interest-only, property type (single house, planned urban development, condo, co-op, town house, and so on), and prepayment penalty (commonly found in subprime and option ARM products and mainly impacting prepayments).

Measurements of Collateral Performance

Key measurements of collateral performance include delinquency, default, voluntary prepayment, and loss severity. Voluntary prepayment and default speeds are quoted as annualized conditional prepayment rates (CPR) and annualized conditional default rates (CDR), respectively. Additionally, the roll rate metrics provide important indicators for near-term future performance. A roll rate is the rate at which previously current or delinquent loans are "rolling" into another status. A transition matrix is a combination of roll rates for each status.

There were two standards of measuring a borrower's contractual delinquency status; the Mortgage Bankers Association (MBA) standard and the Office of Thrift Supervision (OTS, now part of Office of the Comptroller of the Currency), standard. The difference between the two has to do with whether there is a grace period on the receipt of payment. In the MBA method, which is used in the prime and Alt-A market, there is no grace period. In the OTS method, which was used in the subprime market, there was a one-day grace period on the receipt of the payment that effectively lowers the reported delinquency by one full month, as compared to the MBA method. The OTS standard was thus more relaxed than that of MBA.

There is no standard definition for default, but a commonly used one is liquidation, that is, when a previous delinquent loan is liquidated through short sale, foreclosure sale, or REO sale, the remaining balance of the loan is counted as default balance. In the case of principal forgiveness, the forgiven part of principal is counted as default balance as well. Forbearance is sometimes treated as default as well for the balance forborne with a future recovery assumption at the expiry. A short sale is a sale of the underlying property in which the sale proceeds fall short of the remaining balance of the loan. It occurs when a servicer decides that selling the property short is better than going through a costly foreclosure process. Foreclosure is a process in which a mortgagee (or other lien holder) obtains a legal termination of the mortgagor's (borrower) equitable right to redeem the property. There are two types of foreclosure sales. Judicial foreclosure, which is available in every state and required in many judicial states, involves the sale of the mortgaged property under the supervision of a court. Non-judicial foreclosure is authorized by many states if a power of sale clause is included in the mortgage agreement or if a deed of trust with such a clause was used instead of an actual mortgage. After a mortgage is foreclosed, the property becomes REO. The different types of default can have a large impact on the liquidation timeline and recovery rate and thus greatly impact cash flow and timing for a bond.

When a mortgage is liquidated, the net proceeds from selling the home are remitted to the investors. The proceeds from the home sale are net of maintenance fees, tax and interest, homeowner dues, service fees, and servicing advances, while insurance recoveries (if applicable) are added back. Loss severity refers to the loss after recovery as a percentage of unpaid principal balance. Following the financial crisis, because of the surge in defaulted loans, liquidation timelines extended significantly, very often to five years or longer, which contributed greatly to loss severity.

Legacy RMBS Collateral Characteristics

Exhibit 25-2 provides the average characteristics of legacy prime, Alt-A, option ARM, subprime, and second lien collateral.

As shown in the exhibit, legacy RMBS contained a large amount of hybrid-rate loans. Unlike prime or Alt-A hybrids, subprime hybrids were dominated by short-reset products such as 2/28 and 3/27. While most prime or Alt-A hybrids reset every 12 months where the rate can increase or decrease (subject to caps and floors), most subprime hybrids reset every 6 months where the rate can only increase on reset. There were a large number of piggybacks in Alt-A, option ARM, and subprime loans. Legacy prime originations typically required low DTIs, while subprime originations tolerated higher DTIs.

A key feature of Alt-A and option ARM products is the large percentage of loans with limited or no documentation. Without having to fully document one's income, many Alt-A borrowers grossly overstated their income levels in order to qualify for their loan. From 2005 to 2007, the documentation standards were substantially relaxed, and some full-documentation loans could have considerably inflated incomes. As a consequence of the various documentation standards, the historical relationship between credit performance and DTI became obscured.

Another problem for legacy RMBS was the "silent seconds," or second or third liens that were originated after the first lien. During the housing boom from 2004 to 2007, many borrowers took equity out of their houses by borrowing through a home equity loan (HEL) or home equity line of credit (HELOC) outside of the existing first or second lien. This substantially increases leverage and default risk, but neither the first lien holders nor the servicers would necessarily be aware of these loans (hence the name "silent"). Only recently has data on "silent seconds" been made available through credit bureau reports. Exhibit 25-3 shows how severe the problem was—36% of option ARMs, 30% of prime, 30% of Alt-A loans, and 26% of subprime loans have at least one silent second in addition to the first lien and the simultaneous piggyback.

EXHIBIT 25-2

The Average Characteristics by Mortgage Type of Legacy RMBS at Origination

Loan Program	%HYBRID	%2006 and 2007 vintages	Orig Combined LTV	% PIGGYBACK	FICO	FICO < 680	FULL DOC	DTI	AOLS	%IO	ST of FL, CA, NV, AZ	ST of MI, OH, IN
Prime	39.6	14.3	71	9.9	735	11.7	64	33	411962	27.3	52.5	2.5
Alt A	50.4	35.7	80	31.3	711	27.1	29.2	37	258933	50	52.6	2.6
POA	100	46.1	77	24.6	708	28.1	15.5	35	388488	1.4	74.6	1.4
Subprime	75.6	25.1	84	17.8	622	83.1	61.6	41	169911	15.2	42.3	5.8
2nd Lien	8.5	36.9	96	100	680	51	52.1	40	48575	9.2	46.8	4.1

Data Source: CoreLogic and BlackRock Solutions

EXHIBIT 25-3

Current Combined LTV and Presence of Silent Seconds (as of December 2010)

	Prime	Alta-A	Option ARM	Subprime
Current Combined LTV	87	108	131	115
Current Combined LTV from TU	101	125	155	123
% 1st mortgages with silent 2nds	30%	30%	36%	26%

Note: Silent seconds are defined as current combined LTV from TU higher than current combined LTV reported to investors in LP data.

Data source: TransUnion, CoreLogicCoreLogic, and BlackRock Solutions

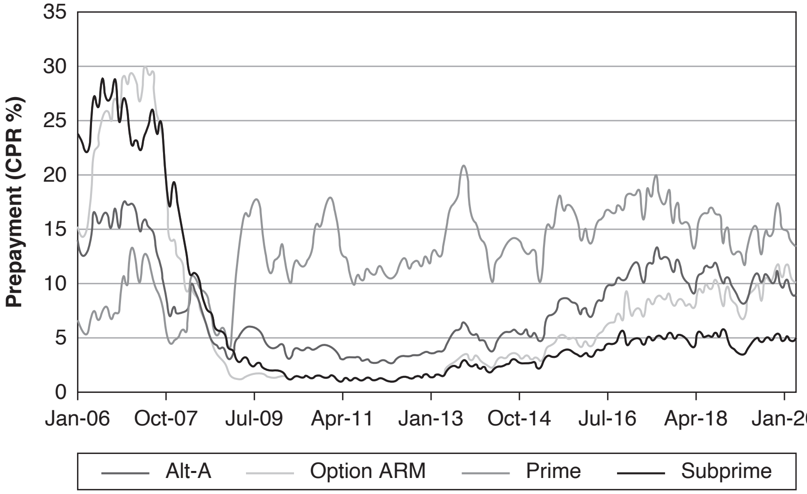
When these problems were layered together, legacy RMBS credit risks increased exponentially. During the 2005–2006 peak of loose underwriting standards, many subprime and Alt-A lenders provided interest-only (IO) mortgages with no down payment. Other common layered risks include high LTV with low documentation and high LTV with high DTI. These loans were extremely sensitive to small declines in home prices because they could easily result in both negative equity and higher future payments.

Legacy RMBS Collateral Performance

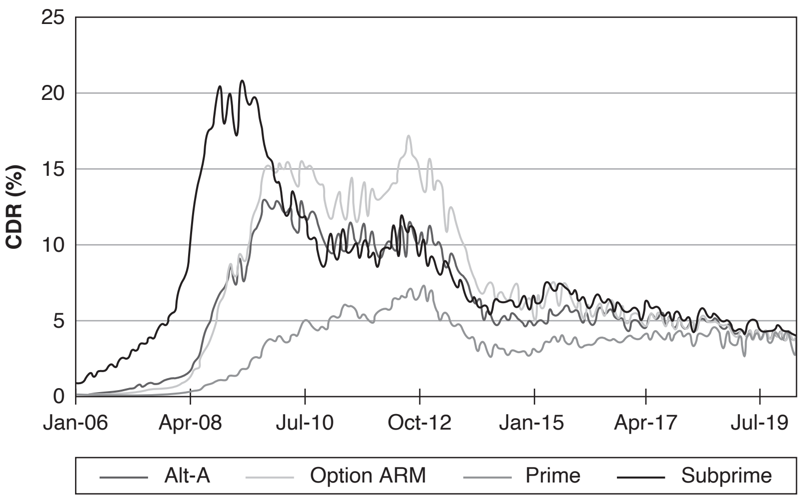
The four panels in Exhibit 25-4 show the historical performance across major products. Voluntary prepayment speeds had declined substantially for all products after the crisis. This was a consequence of increasing delinquency rates, higher current LTVs, tightened underwriting standards, and vanished subprime and Option ARM origination. While prime jumbo speeds have demonstrated some sensitivity to interest rate movements, prepayments for subprime, Alt-A, and Option ARM have been mainly driven by housing prices rather than by interest rates. Delinquency rates rose sharply from 2006 and peaked in 2009. They stayed at an elevated level until 2012 and then started to fall as credit burnout kicked in and the housing market recovered. Subprime default rates peaked in 2008 and have been slowing since 2009 as loan modification requirements and foreclosure documentation issues substantially extended foreclosure timeframes. Default liquidations peaked in 2012 for AltA, Option ARM, and prime jumbo. Loss severity increased greatly from the lows of 2006 and reached a plateau in 2009. Given the massive amount of defaulted loans and loan modification requirements, the mortgage liquidation timeline has become extremely long, hovering around five-plus years on average recently. With the increased liquidation timeline, severities continued to remain at elevated levels despite the housing recovery.

EXHIBIT 25-4

Historical Performance Across Major Products



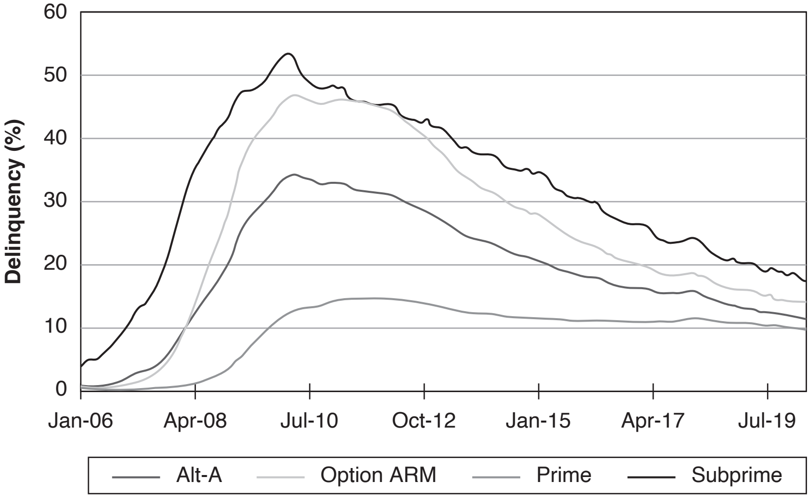
a. Voluntary Prepayments



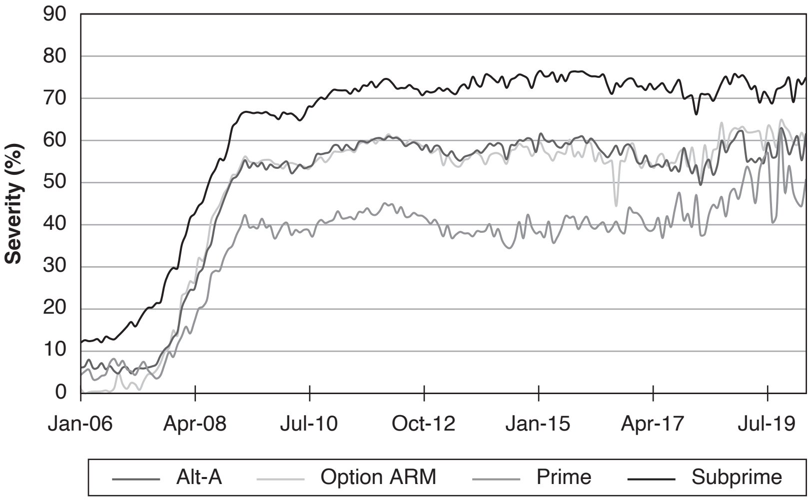
b. Defaults

EXHIBIT 25-4

Historical Performance Across Major Products (*Continued*)



c. Delinquencies



d. Loss Severity

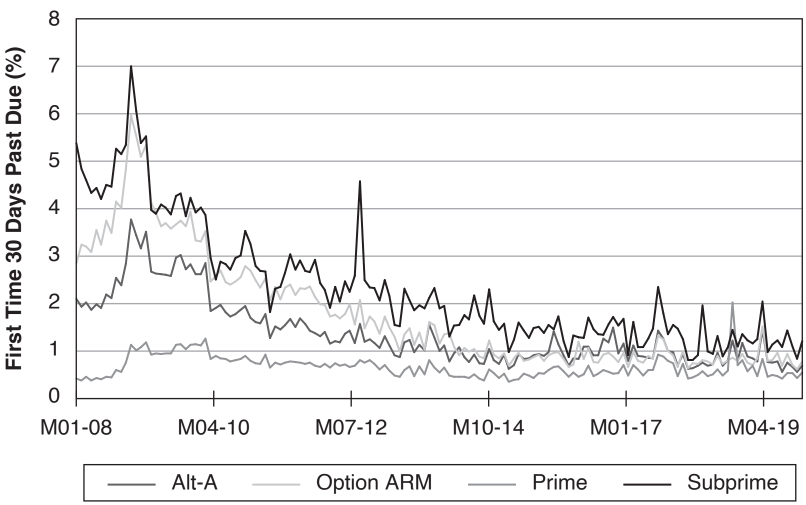
Credit Burnout

After delinquency reached its peak in 2009, subprime mortgage performance started to show signs of improvement. The stabilization can be partially attributed to credit burnout. There are two mechanisms for credit burnout. In a pool of loans, the loans with the worst credit quality will become delinquent and exit the pool, leaving loans with better credit quality remaining in the pool. After flushing out the weakest borrowers from the pool through defaults, the performance of a pool of loans improves because the remaining loans are of better credit quality. Another mechanism is at the loan level. If a high LTV loan is underwater for a long period but the borrower continues to pay, the chance of the borrower becoming delinquent tends to decrease.

Credit burnout can be observed through declines in the first-time delinquency rate. As shown in Exhibit 25-5, the new delinquency rate reached its peak at the end of 2008 and started to decline in 2009. The trend is quite clear for subprime, Alt-A, and option ARM collateral. Credit burnout was less pronounced in prime jumbo collateral. As a consequence, the default and credit performances of various legacy RMBS types tend to converge overtime. See defaults and delinquency trends in Exhibit 25-4.

EXHIBIT 25-5

First-Time Delinquency Rates Since 2008



Servicing Concerns

Collateral performance varies greatly among servicers. While this is partly due to the collateral type and characteristics, differences in servicer behavior have attracted much attention in the industry. Servicer variations are observed in many aspects of deal performance, including liquidation timelines, stop-advance rates, utilization of short sales, and loan modifications.

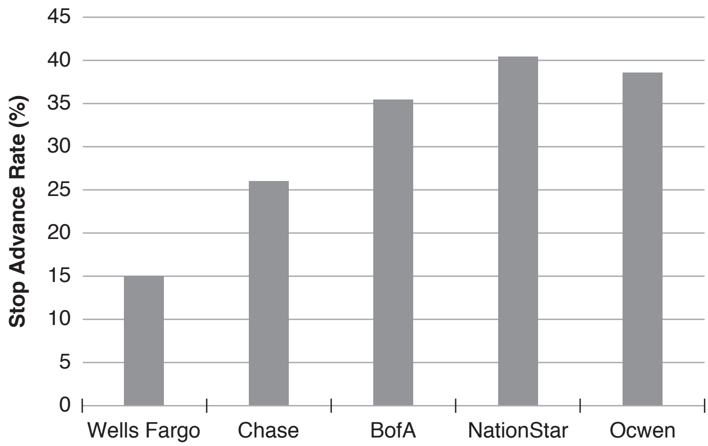
Some servicers are more aggressive and are more efficient in liquidating distressed properties and, as a consequence, the liquidation timeline (time from a loan becoming delinquent to default to liquidation) is much shorter for these servicers. Investors prefer shorter timelines as the recovery can happen earlier, fees are lower, and loss severity tends to be lower.

Service Advance and Stop Advance

In most nonagency deals, the servicer is required to advance delinquent principal and interest (P&I) to the trustee to the extent that it is deemed recoverable. Most RMBS transactions permit the servicer to be reimbursed for advances at the top of the trust payment waterfall.

EXHIBIT 25-6

Stop-Advance Rates by Servicer (as of March 2020)



The high delinquency rates and increased foreclosure and REO timelines after the financial crises had caused liquidity challenges for many servicers that were advancing into RMBS. Additionally, the cost of servicing a delinquent loan had increased and in some cases a servicer may not be able to recover all of its costs from the liquidation proceeds. Consequently, there had been an increasing trend for servicers to stop advances.

There are also large servicer variations, as can be seen in Exhibit 25-6. Servicers with difficult financing are more likely to stop advances. On the other hand, servicers within large banks tend to have a lower stop-advance rate. Servicers that push for more short sales also have lower stop-advance rates.

The impact of stop advance on loss severity comes from savings on advanced principal and interest payments. The more months that the servicer stops advancing, the fewer payments that will be deducted from the liquidation proceeds and therefore the severity will be lower.

Loan Modification

Although loan modifications were always available to servicers as a loss mitigation tool, they had never been widely applied before the crisis. As mortgage delinquencies worsened in 2007, the government started asking mortgage servicers to increase their loan modification efforts to try to keep people in their homes. Several guidelines or programs were created by various government agencies. Many failed due to lack of practical clarity, lack of servicer incentive, and lack of mechanisms to prevent corresponding moral hazards. In 2009, the government introduced the Home Affordable Modification Program (HAMP). HAMP set forth a standard model to determine the net present value of modifications and provided monetary incentives for servicers to participate. HAMP was implemented by most servicers.

There are several types of modifications. The most common approach is recapitalization, in which the accrued interest on a past due loan is rolled into the principal. Sometimes this is accompanied by a term increase, but more often a recapitalization results in an increased monthly payment. A more effective type of modification involves reducing the interest rate of the mortgage, which can reduce the borrower's monthly payment without an immediate principal loss to investors. Principal forgiveness and forbearance are more aggressive approaches, but also the most direct to address the negative-equity issue that borrowers face. Under principal forgiveness, the borrower is forgiven for a certain amount of remaining balance of the loan, which lowers the LTV. Under principal forbearance plan, the remaining balance is due as a balloon payment at maturity.

Subprime mortgages had experienced the highest ratio of modifications or re-modifications, with more than 80% of subprime loans having been modified at least once. There have been fewer modifications in Alt-A loans, but generally the pattern is similar to what is observed in subprime modifications. The number of modifications in Option ARM has been relatively smaller, but the most common type is principal forgiveness or forbearance. Prime jumbo modifications are not as common.

The success rate of modification has varied over time and between servicers. Recidivism, or re-default after a modification, was a challenge to modification policy. In the years just after the crisis, the recidivism rate was very high. When recapitalizations were the most common type of modification, re-delinquency rates within the first year of modification surpassed 60% for subprime. After HAMP was implemented, in the second half of 2009, delinquency rates fell due to the greater use of interest rate and principal modifications. Principal modifications are particularly effective for borrowers with negative equity.

The impact of modification for bond investors depends on the type of bond, where it is in the capital structure, type of modification, and recidivism rate. When recidivism is high, modifications typically do not materially change the cumulative loss to the bonds but delay defaults, thereby extending the WAL of the bonds and lowering their implied yields. Under most pool servicing agreements, servicers can modify a borrower's mortgage if they feel that it will benefit the trust by increasing expected recoveries or making timely payments more likely. If expected default and loss severity levels are high without modification, then modifying loans can actually lead to more cash flowing to the trust. However, for high-risk loans, the re-default risk also tends to be high if modified. So, it is largely up to servicers' discretion on which loans to modify and how many loans to modify.

Prime Jumbo New Origination Collateral Characteristics

New issuance for the nonagency market made a comeback starting in 2011, and since 2013 annual issuance levels have ranged between $15 billion and mid-$20 billion. Exhibit 25-7 shows the history of issuance. While there has been some adjustable-rate loan origination, Pct. FRM shows that fixed-rate loans comprise the vast majority of collateral in this asset class. Average loan sizes have drifted lower over the years, yet as Pct. of Non-conforming shows, almost all the loans continue to be jumbo loans.

The peak in origination in 2013 was due to historically low mortgage rates at that time, and most of these originations were for refinance activities. The peak seen in 2018 occurred where rates were elevated and the high level of purchase loans indicates that the platform had grown to include new business. Credit has been slowly loosening as can be seen in the drift toward lower OALS, higher OLTV, and lower FICO.

Exhibit 25-8 investigates the credit loosening in more detail by plotting the 20%, 50%, and 80% quantiles of OALS, OLTV, and FICO by deal vintage. The shift over the years to lower OALS happened for both the 80% and the 20% quantiles, yet the 80% quantile fell more, and thus produced a compression in the variability of loan sizes. For OLTV and FICO, the greatest move was in the 20% quantile, with FICO falling 20 points from 2011 to 2019.

Prime Jumbo New Origination Collateral Performance

Prime jumbo new origination prepayment performance has been varied over the past few years, as is shown in Exhibit 25-9. Prepayments remained at levels typical for turnover activity prior to 2019. Yet from the beginning of 2019 until mid-2020, as mortgage rates rallied from their highs in November 2018, prepayment speeds have hastened reaching levels nearing 50%.

EXHIBIT 25-7

Prime Jumbo New Origination Issuance and Key Attributes by Deal Vintage

Deal Vintage	Deal Count	Avg. Deal Size	Loan Count	Total Loan Bal. ($MM)	Pct. FRM	Pct. Non-conforming	OALS ($000)	OLTV	FICO	Pct. Purchase
2011	2	290	651	580	89.7%	98.4%	890.7	61.3	773	40.8%
2012	9	388	4,017	3,495	96.4%	99.8%	870.0	67.0	771	39.9%
2013	32	412	16,437	13,182	94.5%	99.3%	802.0	66.4	771	35.5%
2014	28	318	11,674	8,898	83.4%	98.6%	762.2	68.4	768	55.5%
2015	35	351	15,936	12,279	82.3%	99.3%	770.5	67.4	766	47.8%
2016	14	349	6,455	4,885	85.2%	98.7%	756.8	66.9	767	52.7%
2017	21	553	16,826	11,616	94.0%	99.6%	690.4	69.3	766	59.4%
2018	38	508	29,095	19,295	97.9%	97.7%	663.2	70.8	766	64.7%
2019	34	458	22,509	15,586	96.3%	98.9%	692.4	72.4	764	64.2%
2020 (as of May)	11	554	8,275	6,098	100.0%	99.8%	736.9	70.8	767	45.5%

Data Source: CoreLogic and BlackRock Solutions

Note: The data for 2020 is an extrapolation for the whole of 2020, as this data is from May 2020.

EXHIBIT 25-8

Prime Jumbo New Origination OALS, OLTV, and FICO Issuance Quantiles by Deal Vintage

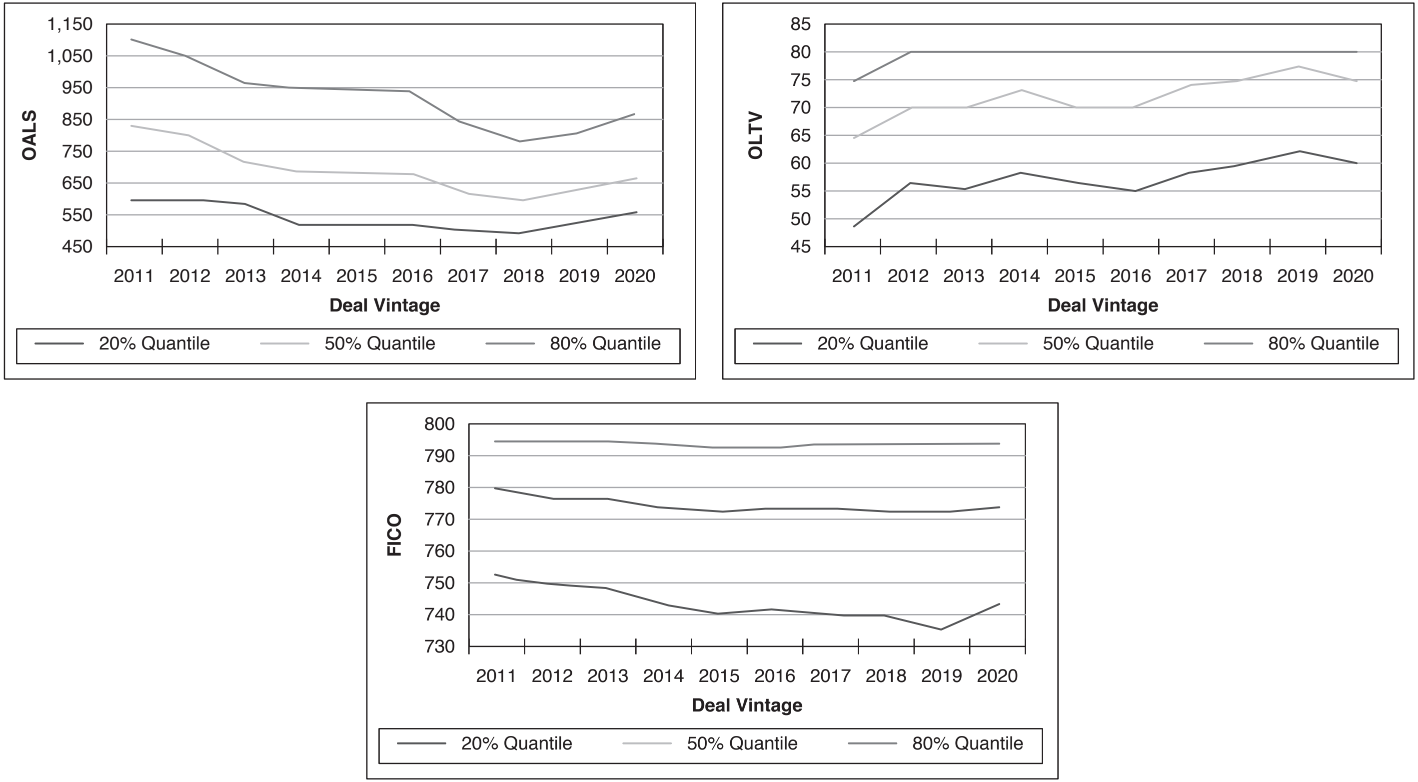
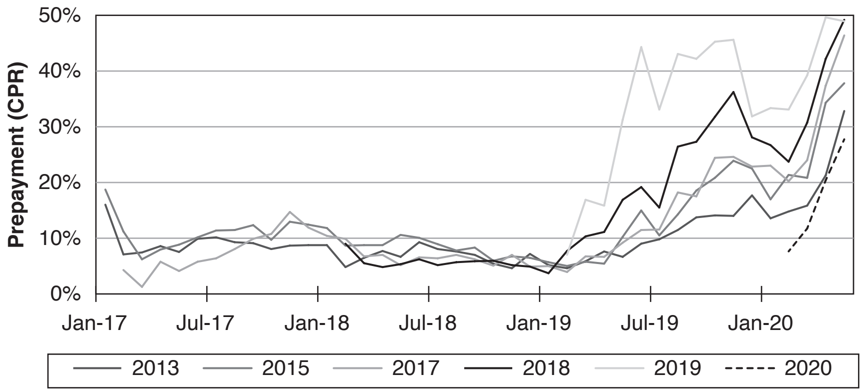


EXHIBIT 25-9

30-Year FRM Prime Jumbo New Origination Prepayment by Date Stratified by Deal Vintage



The prepayment behaviors known as the S-curve and the seasoning ramp are major differentiators of prepayment speeds for this asset class and are highlighted as follows.

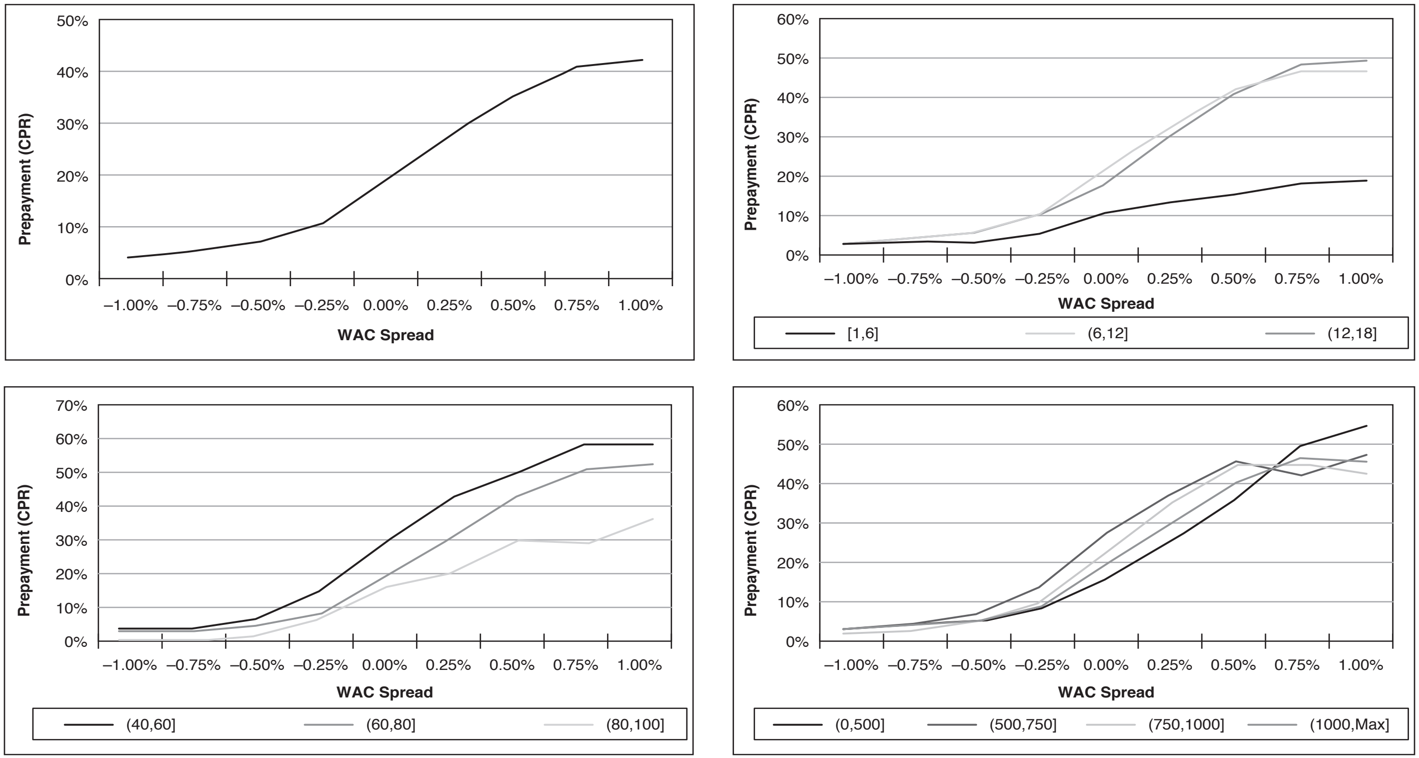
S-curve: Strong sensitivity to interest rates is observed for new origination mortgages (Exhibit 25-9). Exhibit 25-10 plots s-curves, using WAC spread defined as the contemporaneous difference between loan rates and jumbo rates. The strength of prepayment response can clearly be seen in the s-curve chart stratified by WALA; for loans with between 7 and 12 months seasoning, prepayment rises from 20.1% at a WAC spread of 0.0% to 44.2% at a WAC spread of 0.5%.

Seasoning: Prime Jumbo New Origination loans have a steep seasoning ramp (Exhibit 25-11), peaking at eight months of age. It is interesting to observe that seasoning occurs even for loans that have WAC spreads from –0.5% to 0.0%.

Sensitivity to other key attributes is shown in Exhibit 25-12. Actual response to average loan size (ALS) indicates that larger loan size loans tend to prepay less in this asset class. While Current LTV is typically a strong driver, especially when it reaches levels near 100 and higher, prime jumbo new origination collateral were originated with low LTVs and experienced only positive HPA trends during their history. Thus, this collateral has exclusively lower than 80 current LTVs, levels at which this variable plays a limited role in determining prepayment speeds. Strong curtailment behavior is seen from both ALS and Current LTV curves. Higher FICO borrowers are observed to prepay slightly faster than lower FICO borrowers, as expected.

EXHIBIT 25-10

30-Year FRM Prime Jumbo New Origination Prepayment Loans S-Curves Stratified by WALA, Current LTV, and ALS



Note: The Current LTV and ALS plots use loans with WALA between 7 and 12 months.

EXHIBIT 25-11

30-Year FRM Prime Jumbo New Origination Prepayment Loans Seasoning Ramp for All WAC Spread and Stratified by WAC Spread

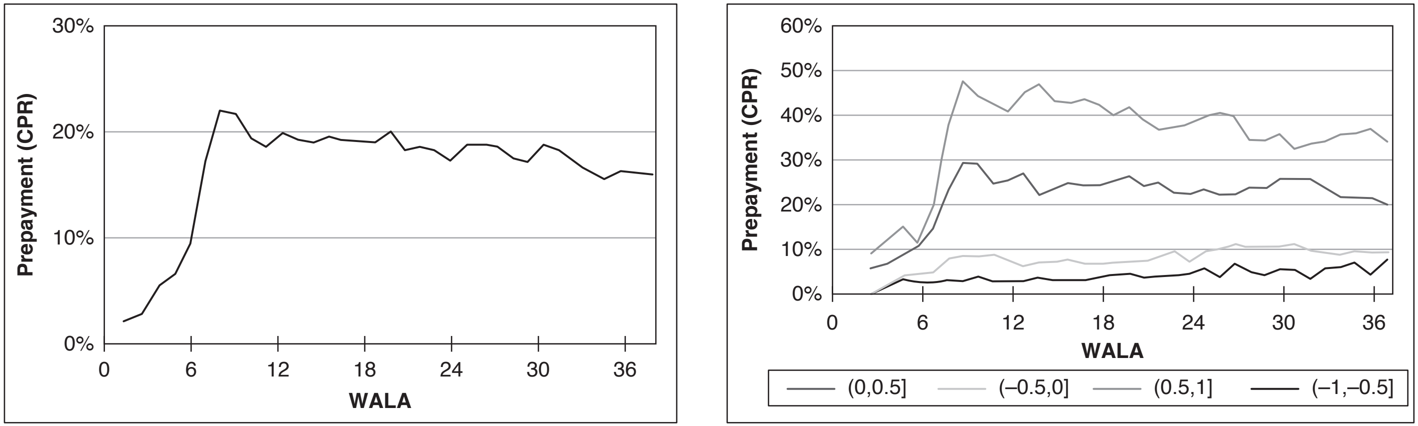
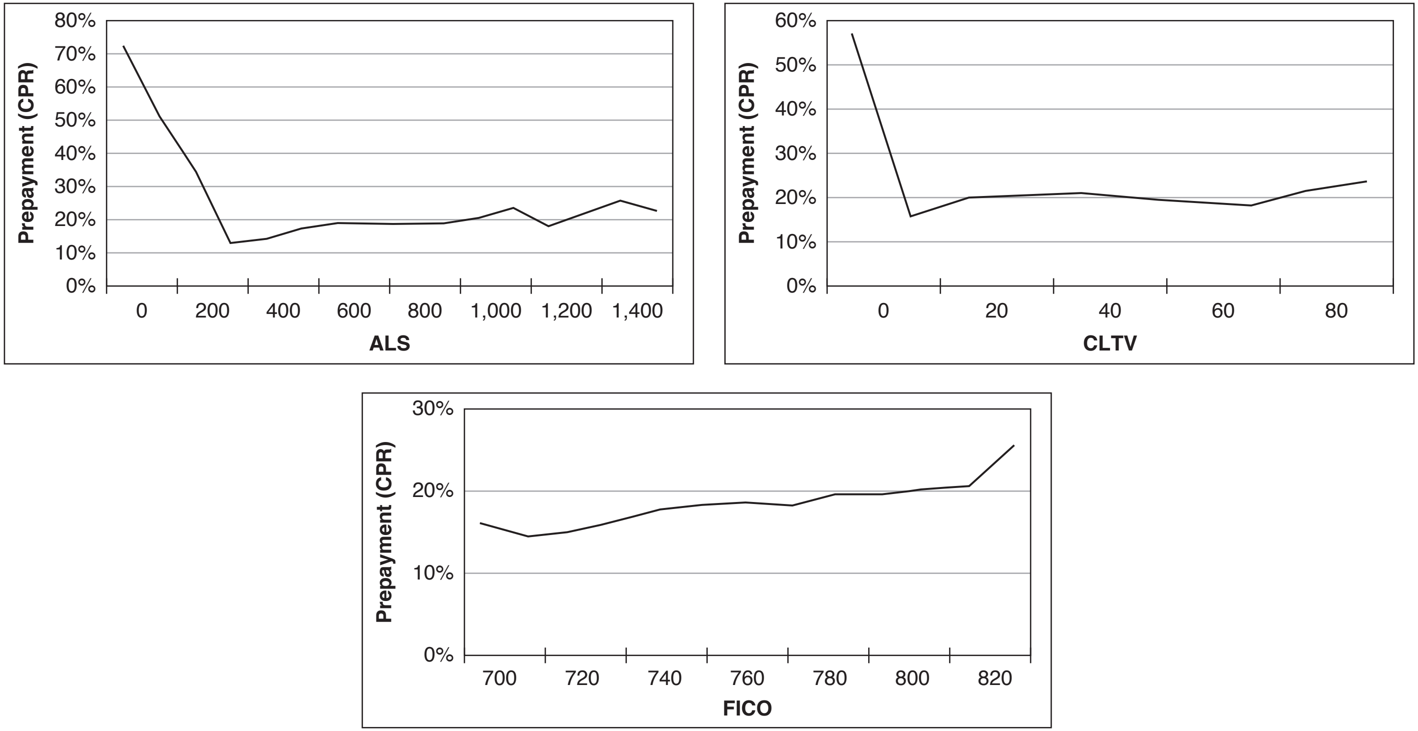


EXHIBIT 25-12

30-Year FRM Prime Jumbo New Origination Prepayment Loans Response to ALS, Current LTV, and FICO



Note: Records are restricted to WAC Spread between –1% and 1% and WALA between 7 and 12 months.

Non-QM Collateral Characteristics

Recall that Exhibit 25-1 details the historical levels of non-QM issuance since 2014. The overall issuance has increased substantially from $384 million in 2015 to over $21 billion in 2019; the origination balance nearly tripled in 2016, 2017, and 2018. Issuance in 2020 has been $6 billion at this writing (May 2020), but is likely to be constrained by the ongoing Coronavirus pandemic.

As of May 2020, the total origination balance for nonagency non-QM deals is $41.9 billion, with over half coming from the top five originators, as listed in Exhibit 25-13. Angel Oak, Verus, COLT, and Deephaven are among the leading pioneers in this newly established market.

EXHIBIT 25-13

Non-QM Issuance by Top 5 Originators

Originator	Total Deal Bal. ($MM)	Deal Count	Avg. Deal Bal. ($MM)
ANGEL OAK MORTGAGE TRUST	5,748.3	16	359.3
VERUS SECURITIZATION TRUST	5,431.5	12	452.6
COLT	5,003.4	16	312.7
DEEPHAVEN RESIDENTIAL MORTGAGE TRUST	3,844.4	12	320.4
ARROYO MORTGAGE TRUST	3,396.3	4	849.1
Total	23,423.8	60	

Data Source: Intex and BlackRock Solutions

Key non-QM deal loan characteristics are detailed in Exhibit 25-14. Note that the data here do not include the entire universe of new issuance loans, yet does include the vast majority which was verified by comparing loan data across vendors. For non-QM deals issued between 2015 and 2020, the average LTV is 72, FICO is 716, DTI is 36, and loan size is $452,000. In terms of loan type, only 38% are FRM and 31% have conforming balance. Finally, OWAC is relatively high at 6.3%.

Important to note is the drift of loan characteristics over time. Most significantly, the percentage of low- or no-documentation loans increased from 11% in 2015 to 63% in 2019 (these were percentages of records where documentation is known), showing a large shift to looser credit standards. Although this statement must be tempered as the percentage of loans (by balance) that have documentation type disclosed has plummeted from 100% to 74% for these two vintages. Average loan size increased from $339,000 in 2015 to $458,000 in 2019. Mitigating these trends are slight drops in LTVs (from 75 in 2015 to 72 in 2019) and increases

EXHIBIT 25-14

Non-QM Origination Loan Characteristics

Vintage	Pct. FRM	Pct. Conform.	OWAC	Orig. LTV	FICO	Pct. FICO < 680	DTI	Pct.DTI > 43	Pct. Doc Known	Pct. Low Doc*	Loan Size ($′000)
2015	32.6%	49.5%	7.3%	74.5	694	34.1%	36.1	27.6%	100.0%	11.2%	339.0
2016	31.9%	34.7%	6.8%	75.9	707	26.3%	36.7	33.0%	70.6%	11.1%	412.3
2017	29.8%	35.0%	6.6%	74.8	706	25.8%	36.8	28.8%	78.4%	26.2%	402.8
2018	32.4%	29.6%	6.2%	71.3	718	21.3%	37.3	31.2%	66.4%	40.2%	463.0
2019	39.8%	30.7%	6.4%	72.4	717	22.0%	34.8	29.5%	73.6%	62.6%	457.7
2020	51.4%	30.1%	6.1%	72.9	715	23.6%	36.6	31.2%	54.7%	54.4%	462.0
All	38.1%	30.9%	6.3%	72.4	716	22.5%	35.9	30.1%	70.2%	51.3%	452.3

Data Source: CoreLogic and BlackRock Solutions

Note: The Pct. Low Doc column is the weighted averaged of low and no documentation loans when documentation is known.

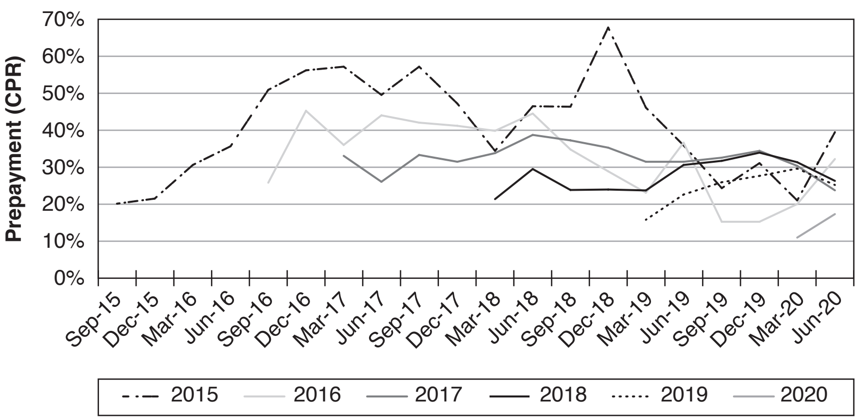
in FICOs (from 694 in 2015 to 717 in 2019). Note that for non-QM loans, the average FICO for full-documentation and for low-documentation borrowers is 705 and 723, respectively, showing that there is a tradeoff between FICO and documentation. Although the non-QM market is expanding to include more low-documentation borrowers, the overall credit profile remains sound given that the credit scores of low-documentation borrowers are scrutinized to ensure the credit quality of the loans.

Non-QM Collateral Performance

One important feature of non-QM collateral performance is elevated prepayment speeds, which can be seen in Exhibit 25-15. Prepayment speeds overall have been 30% CPR or higher and in some cases have been near 60% CPR. Compared this to legacy Alt-A, which in aggregate did not reach 20% CPR, and to prime jumbo new origination, which in aggregate ranged from 5% to 50% CPR. Speeds for seasoned non-QM collateral have abated somewhat since the start of 2019, yet remain generally above 20% CPR.

EXHIBIT 25-15

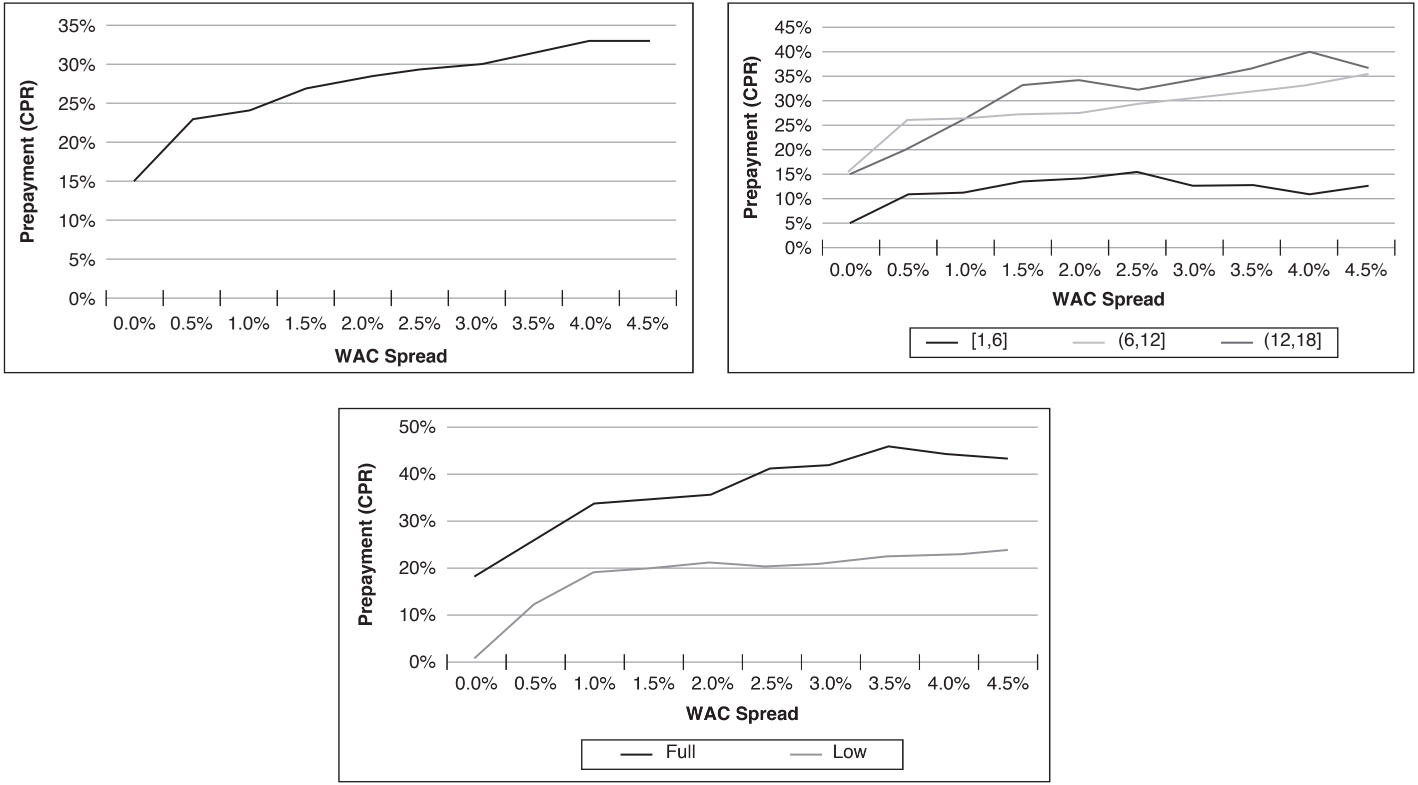
Non-QM CPR by Date, Aggregated Quarterly, Stratified by Deal Vintage



Non-QM loans are typically issued with relatively high interest rates (on average 6.3%). These loans are thus susceptible to having strong prepayment incentives if their credit circumstances change (credit curing, lowering of DTI, etc.). To measure the strength of prepayment incentive, Exhibit 25-16 shows a strong response between monthly prepayment speed and WAC spread. The WAC spread is defined against the corresponding product market reference rate, for example, Jumbo FRM 30Y for nonconforming balance 30-year amortizing

EXHIBIT 25-16

Non-QM Prepayment Loans S-Curves Stratified by WALA and Documentation Type



Note: The Documentation Type plot uses loans with WALA between 7 and 12 months.

loans and Conforming 5/1 ARM for conforming balance 5/1 ARM loans. CPRs increase from 25% to 30% as WAC spread goes from 1.0% to 2.0%. Note that this is significantly less steep than for prime jumbo new origination. As the majority of non-QM borrowers are deep in-the-money, moderate amounts of credit curing have the potential to elevate prepayment speeds.

Non-QM deals also have a strong seasoning ramp, as can be seen in Exhibit 25-17. Prepayment activity ramps up quickly, reaching near 35% CPR in the loan's first year. The seasoning ramp is stratified by WAC spread in the right-hand chart and shows that all but the lowest WAC spread show a quick ramp. When stratifying by documentation type, bottom chart, loans with low documentation have significantly lower speeds than those with full documentation.

Non-QM deals show better credit behavior compared to legacy Alt-A. Deterioration rates are slower and curing rates are much faster for non-QM deals than legacy Alt-A deals. Exhibit 25-18 shows that the current clean-to-30-day delinquent roll rate by loan age for non-QM deals is generally below 1% while for Alt-A deals it reaches almost 2%. The right-hand chart indicates that the 90-day delinquent-to-current roll rates for non-QM deals are generally around 10%, much higher than for Alt-A deals, where this rate drops to around 3% after seasoning. This suggests that the non-QM deals are backed by better credit loans and that once loans go delinquent active actions may be taken to help the loans cure.

CAPITAL STRUCTURE

Nonagency RMBS deals are structured to manage the two principal risks inherent in residential mortgages: prepayment and credit. The structure separates aggregated cash flows from the underlying loans into principal and interest and redistributes the cash flows and associated losses to individual tranches (bonds) according to rules specified in the deal prospectus (this is known as the waterfall).

From a prepayment point of view, many nonagency RMBS work similarly to agency CMOs. They manage prepayment exposure and average life variability through time-tranching the cash flows, that is, each senior tranche has a different expected maturity and expected time window for principal repayment. Actualized maturities will vary based upon realized prepayments, but the bonds are marketed based upon assumed prepayment speeds. One complication is that in nonagency RMBS the recovery from a credit default is treated as prepayment.

Many senior classes of RMBS deals also include specialty tranches which provide additional exposure or protection to mitigate prepayment risk. Some of these include planned amortization classes (PAC) and companion (support) bonds, nonaccelerating senior bonds (NAS), interest only (IO), inverse IO (IIO), and principal only (PO). These are often created to cater to specific investors' preferences. In general, they make up a small percentage of total RMBS issuance, but it is important to carefully examine each tranche for cash-flow timing. Because these classes are analogous to those in an agency CMO, we are not going to cover them in this chapter.

EXHIBIT 25-17

Non-QM Prepayment Seasoning Ramps Stratified by WAC Spread and Documentation Type

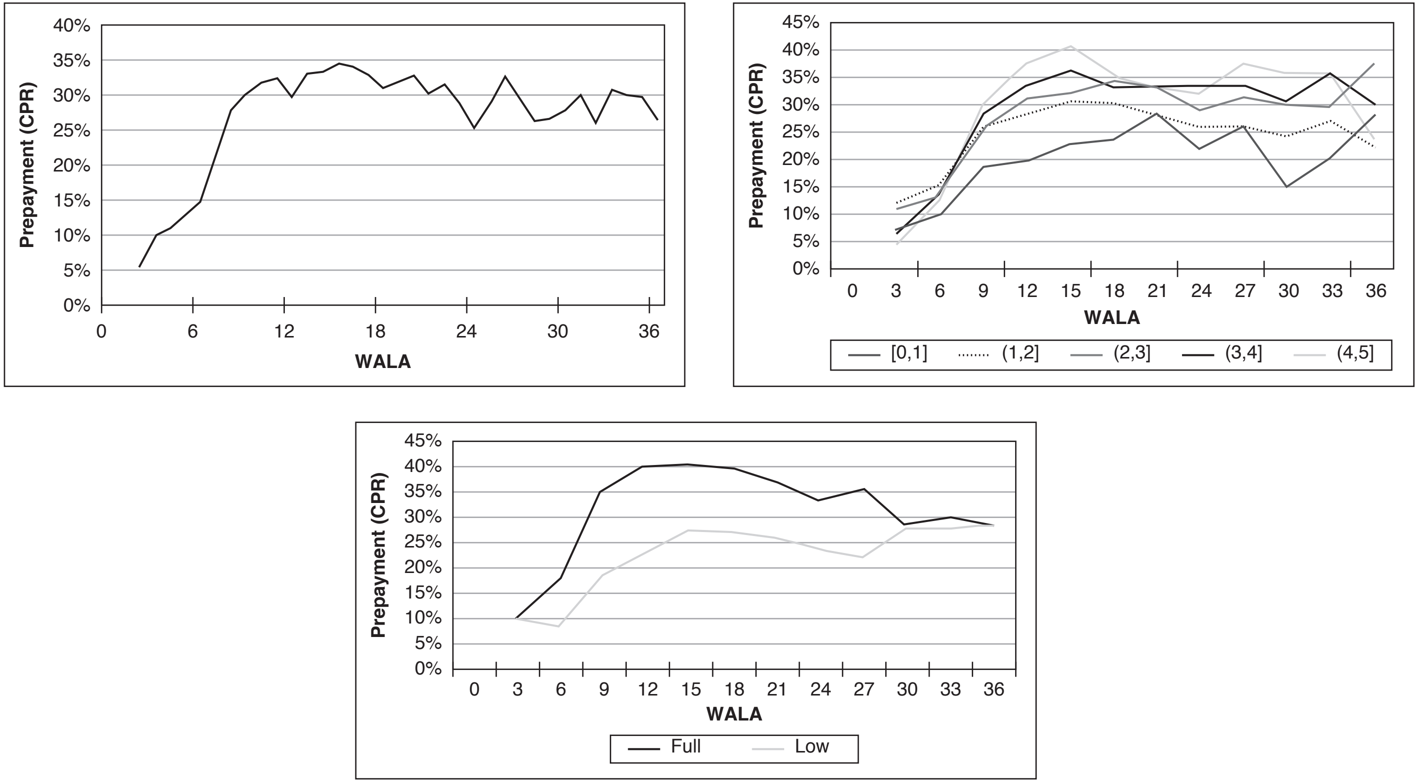
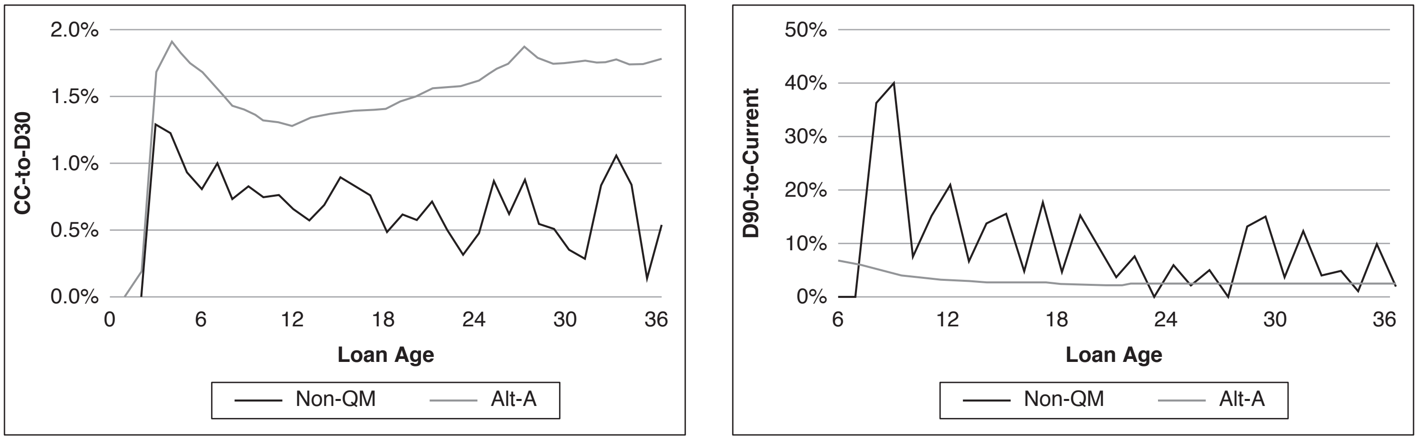


EXHIBIT 25-18

Non-QM and Alt-A CC-to-D3 and D9-to-CD Transitions by Loan Age



Credit risks in nonagency RMBS deals were addressed through credit enhancements: external, internal through deal structure, or both. Credit enhancement levels are established to reasonably insulate senior bond investors from the risk of losses. In practice, issuers structure deals to maximize the issuance of AAA bonds since this maximizes the total deal proceeds. Deals that are backed by loans of high credit quality require less subordination than deals that are backed by loans of low credit quality.

External credit enhancements, primarily bond insurance, were commonly used in the early stages of the nonagency securitization business. Since the early 2000s, internal credit enhancements through deal structuring became the dominant method.

There are two major internal credit enhancement structures, senior/subordination (senior sub) and overcollateralization/excess spread (OC/XS). For deals with moderate credit concerns, such as most prime jumbo deals, credit support relies entirely on redirecting losses to lower tranches. A deal typically has AAA-rated senior classes (groups of bonds that are pari pasu with respect to collateral losses) and subordinate tranches rated from AA to B. The prepaid principal is allocated to the senior tranches first and is then allocated down the deal structure while the losses are absorbed from the bottom up. This is known as the senior/subordination shifting interest structure. For collateral with greater credit loss concerns, as is the case with subprime loans, additional layers of support were often added to the senior/sub structure through extra collateral principal and/or interest. This is the OC/XS structure. Alt-A deals and early vintage deals are more likely to have the senior/sub structure, while deals originated after 2004 increasingly utilized the OC/XS structure.

Fixed versus floating coupon: While deals backed by ARM collateral (hybrid and option ARM) mostly issue floating coupon bonds, deals backed by fixed-rate mortgages can issue both fixed and floating coupon bonds. While the underlying collateral is fixed, floating-rate bonds can be created by simultaneously creating an inverse IO tranche where the coupon is inversely correlated to the underlying index. Almost all residential ABS (subprime, HEL, and MH) and option ARM bonds have floating coupons. Prime, Non-QM and Alt-A deals can issue both fixed rate and floating rate bonds.

Sequential versus pro rata payment: Sequential and pro rata refer to the method of distributing payments across the classes in the deal. For sequential structures, the senior class tranches are paid principal sequentially with all principal going to one tranche until it is paid-in-full, before the next senior tranche starts to receive all principal payments, and so on. Pro rata refers to making payments proportional to each tranche's unpaid principal balance. For senior tranches with the same seniority, principal payments can be sequential or pro rata, but losses are mostly pro rata. Sometimes there are further hierarchies in AAA classes, with senior support bonds receiving losses before super senior bonds.

Lockout period: Subordinate bonds are locked out of receiving prepayments for a period of time after deal settlement. The lockout periods for prime and Alt-A deals are typically 5 to 10 years, while lockout periods for subprime deals are almost always 36 months. At the end of the lockout period, if the collateral performance meets or exceeds minimum credit conditions, determined by what are known as trigger tests, prepayments can flow into junior classes.

Triggers: To ensure that the credit support is still intact during the period when deals are most likely to experience losses, many deals contain a series of trigger tests to place limits on the amount and timing of any release of credit support (i.e., repayment of principal to the owners of the OC and/or subordinate bonds). The most common trigger is a delinquency test, which allows credit support to be reduced only if the 60+-day delinquency ratio is low in relation to the current senior credit enhancement level, expressed as a percentage of the current outstanding balances. Other trigger tests include the factor test, requiring that the pool be paid down by at least half (i.e., the pool factor must be at or below 50%), the credit support level test, which requires that the senior credit support level (in percentage terms) has at least doubled, and the cumulative loss trigger test, which limits principal payments to the OC and/or subordinate bonds if cumulative losses exceed some target level.

Linear or Y-structure vs. H-structure: A deal can have one or several collateral groups. The linear structure is the most straightforward as it only has one collateral group and the cash flows from the single collateral group are distributed to all bonds. The Y-structure is a slight variation of the linear structure. In this structure, all of the subs and mezzanines receive cash flows and are assigned losses from all collateral groups. Yet at the AAA level, the collateral is divided into two groups by loan size (conforming vs. jumbo balance) or by coupon type (fixed rate vs. adjustable rate). Each AAA bond receives payments (including principal prepayments) from only one of these two groups. The separation was intended to provide convenience for the GSEs to buy bonds backed by conforming-size loans or large insurers to buy bonds backed by fixed rate loans. In the H-structure, there are two (or more) sets of mezzanine tranches and collateral groups and each mezzanine tranche is supported by each collateral group, respectively. Each set of mezzanine tranches supports its own senior tranches. There is often cross-collateralization between groups in H-structure deals: after interest payments are made to bonds in one group, available funds from that group can be used to pay interest to bonds from another group. Among other things, this feature can also affect the value of residuals.

Clean-up call provision: Before turning to the details of each type of structure, there is a final provision that is very common to nonagency RMBS deals, similar to agency CMOs—the clean-up call. The clean-up call gives the owner of that call, who is generally the residual holder, the option to purchase the remaining bonds at a pre-specified price, usually at par plus accrued interest, when the factor is at or below certain threshold, typically 10%. The main purpose of the clean-up call provision is to minimize administration costs but it also adds additional risk to senior bond or IO holders. A deal is more likely to get called if the collateral is clean with premium coupons and less likely to get called if it is distressed. When exercised, the call shortens the payment window and the average life of the back-end tranches. If the clean-up call is not exercised when the factor is below the threshold, there is typically a *step-up in coupon* provision, which requires a moderate increase in coupon for the bonds that are still outstanding.

Senior Subordination Shifting Interest Structure

Senior/sub is the most direct approach to generate credit enhancement for senior tranches. In this structure, the senior classes (AAA-rated) typically have six supporting classes (AA, A, BBB, BB, B, and unrated), hence these structures are referred to as "six-packs." The AA, A, and BBB classes are called the mezzanines as they are still investment grade, and the BB, B, and unrated residual classes are often referred to as subs. There is a lockout period at the early age of the deal when all of the unscheduled principal payments are allocated to the senior tranches and the subordinate bonds are locked out from receiving prepayments. The losses are absorbed from the bottom up, starting from the unrated piece, which is often called the "first loss" piece. At the end of the lockout period, if triggers are passed, the subordination will start to receive prepayments pro rata.

Exhibit 25-19A illustrates the capital structure of a prime jumbo fixed-rate RMBS deal. In this deal, 96.1% of the total collateral was designed as senior AAA tranches (excluding the IO, which is nominal based). Those tranches were supported by 3.1% of mezzanine tranches and 0.8% of subs.

There is one IO tranche that receives interest based on all the deal collateral balance. IO tranches are present in most six-pack structure deals. Although it is not the case in this deal, sometimes IO tranches are used to manage the differences between collateral interest payments and bond interest liabilities (essentially the excess spread).

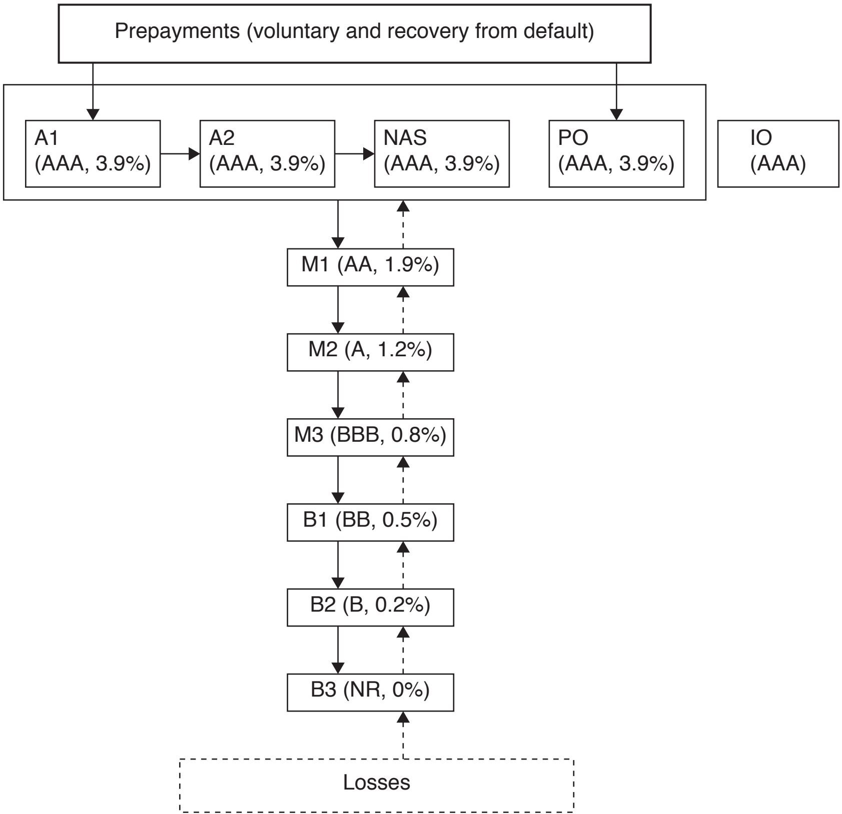
When prepayments are received before the lockout period (in this case, five years), they first go to senior tranches. Prepaid principal only flows down to mezzanines and subs after the lockout expires and trigger tests are passed. Within the senior tranches, A1 and A2 are sequential so that A2 will not get any principal until A1 is paid off. A3 is a nonaccelerating fixed pay bond that receives only a fixed interest strip in the first five years and then amortizes down on a fixed schedule (hence the name). PO and A1 are pro rata for all principal payments.

After the lockout period, if the shift-interest trigger test, measured by delinquency rate, is passed, prepayments will start also flowing to the mezzanines and then to the subs. If at any point the trigger test fails, all of the unscheduled principal will be re-directed back to the senior bonds.

It is important to note that in shifting interest structures, mezzanines and subs are receiving scheduled principal payments (and scheduled interest) during the lockout period. This is different from typical OC/XS structures. In the case of very slow prepayment speeds, as seen in many fixed-rate Alt-A deals, this

EXHIBIT 25-19A

Illustration of the Shift Interest Structure for a Legacy Prime Jumbo Deal RFMSI—2005 S8



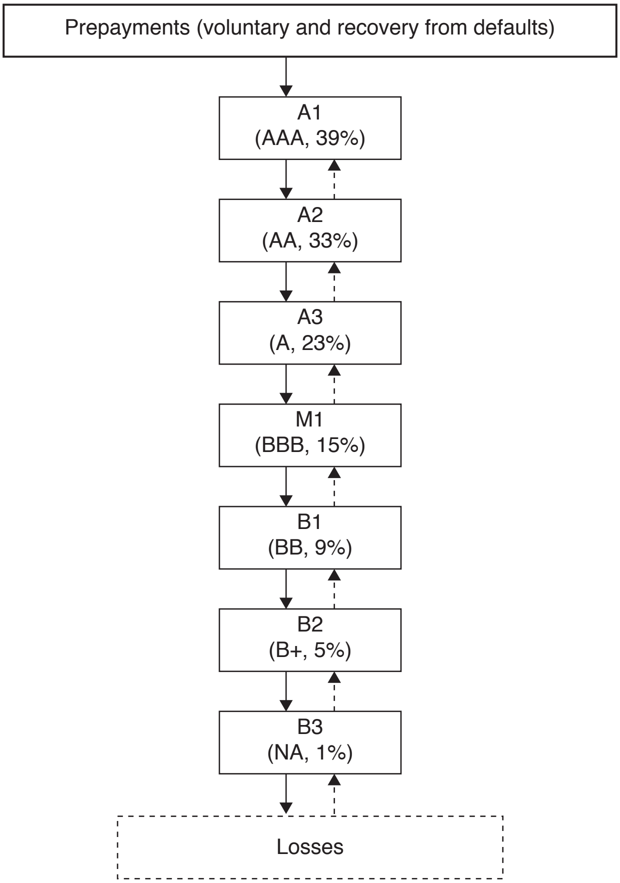
amortization can help shorten the WAL of mezzanine tranches substantially in senior/sub deals compared to that in OC/XS deals.

Losses will be absorbed first by the B3 class and then from the bottom up to other subs and the mezzanines subsequently. If losses penetrate all the way through M1, they will be distributed to all the senior tranches (A1, A2, A3, and PO) pro rata. Note how thin (i.e., small size) these credit cushion classes are. It is not surprising to see the entire sub or mezzanine classes get wiped out (in fact, in this particular deal all sub and mezz tranches were wiped out).

The shift-interest structure was designed mainly to deal with prepayment risk for senior bondholders. Obviously if losses come in much higher than the support level, senior bonds will suffer significant principal write down because of the thin enhancement. In recent non-QM deals, credit support levels for AAA

EXHIBIT 25-19B

Illustration of the Shift Interest Structure of a Non-QM Deal HOFI Trust—2018 2



bonds have been much higher. See Exhibit 25-19B. In addition, the overall structure of non-QM deals are also much simpler than Alt-A deals.

Overcollateralization and Excess Spread

When collateral credit loss becomes a large concern, issuers typically use the OC/XS structure to add extra layers of protection. Most subprime deals and a large number of option ARM and Alt-A deals use this structure. Given credit pressures, some 2007 prime jumbo deals also adopted this structure.

OC/XS also uses the senior, mezzanine, and subordinate framework, but it adds extra collateral so that the collateral balance backing the deal is larger than the total balance of its bonds. In addition, the note rates of subprime or Alt-A mortgages are typically high, allowing collateral WAC (weighted average coupon) to be higher than the WAC of the underlying bonds. As a consequence, there can be extra interest payments (excess spread) each month. In terms of the order of absorbing losses, XS spread is the first line of defense, OC is the second, and the traditional subordinate tranches provide the final protection before losses reach senior tranches.

OC target: There is a predetermined OC target, for example, 2% of deal collateral, before the step-down date. At the inception of a deal, OC can be anywhere from 0 to the target (OC fully funded). If OC is not fully funded at inception, excess spread (after covering losses) will be used to build up OC. When OC is at its target, excess spread will go to the residual holder. For deals with fully funded OC at inception, there is typically a NIM (net interest margin) class to receive excess spread. NIM tranches are often owned by residual holders. After the lock-out period ends (step-down date) and trigger tests are passed, OC is allowed to be released or step-down gradually into either the NIM or residual holder, on the condition that senior bonds have pre-determined levels of support. If triggers fail, the OC step-down can be stopped, or it can step-up.

Step-down: The step-down date refers to the time when junior bonds can start to receive principal and the OC can start to be released. It is typically the later of 36 months and the date at which the senior credit enhancement doubles the original CE or reaches a pre-determined level.

In addition to the credit enhancement requirement for step-down, there are also many collateral performance trigger tests to control the direction of cash flows starting at the step-down date. Delinquency and cumulative loss triggers are quite common. These triggers are designed mainly according to accommodate rating agencies' requirements.

Different from a six-pack deal, junior bonds in OC deals do not receive any principal until the step-down date and performance triggers are passed. The junior and mezzanine bonds can only start to receive principal after the deal step-down and once senior classes have been paid off. Because of the large losses, the vast majority of the junior and mezzanine tranches in such deals had never received any principal since inception. In fact, most of them had been wiped out by losses.

Compared to six-pack deals, the OC/XS structure is much more complicated. There are also more trigger events, which can make a bond's cash flows extremely volatile because small changes in performance can trigger large swings in the cash-flow waterfall and have a major impact on a bond's valuation. Even though most triggers were set according to the rating agencies' requirements at the time to protect senior tranches, all senior bonds in such structure were downgraded and many by several notches. Further, because most OC/XS deals pay floating rates to their bonds, there are additional complications in the structure to manage the mismatch of collateral cash flow versus bond payment and to hedge interest risk. This substantially increased the uncertainty of future cash flows and made it very difficult to properly analyze these deals. This structure has not been used in new issuances post-crisis.

External Credit Enhancements

External credit enhancements are third-party guarantees that provide for loss protection against losses up to a specified amount. Typically, external credit enhancements include pool insurance, letters of credit, bond insurance, and reserve funds.

Pool insurance is lender-paid mortgage insurance at the pool level covering bankruptcy cramdown–related losses, losses due to fraud in origination, or losses due to special hazards not covered by homeowner insurance. A letter of credit (LOC) is a financial guarantee by the issuing bank. LOC is one of the oldest forms of credit enhancement yet has rarely been used in recent years. Reserve funds are straight deposits of cash generated from issuance proceeds. The fund typically invests in money market instruments. While reserve funds are common in auto and other consumer ABS deals, they are less frequently used in nonagency RMBS deals.

Bond insurance is a financial guarantee for the timely payments of principal and interest if these payments cannot be obtained from the cash flows of the underlying collateral. Bond insurance (aka monoline wrappers) was provided mainly by monoline insurance companies. The major primary insurers included Municipal Bond Insurance Corporation (MBIA), Ambac Assurance Corporation, Financial Guaranty Insurance Corporation (FGIC), and Financial Security Assurances (FSA). The main reinsurers are ACE Guaranty Re, AXA Re Finance, Enhance Re, and RAM Re.

Bond insurance covers implied write downs as well. An implied write down occurs when a trustee is prohibited from writing down a bond by the deal documentation and there is a discrepancy between the remaining collateral balance and the bond principal balance. In order to correct this discrepancy and realize the losses more quickly, wrappers typically recognize an implied write down as a credit event, which will decrease the reference obligation notional amount even though the bond principal balance remains unaffected. This works the same way as CDS.

Unlike internal credit enhancements, external enhancements are simple and reduce overall credit risk. However, they introduce counterparty risk. During the subprime mortgage crisis, the monoline insurers suffered a large amount of losses. Some of them are currently in bankruptcy or under serious financial stress and as a result, many bond protections were rescinded. The values of monoline wrappers have dropped substantially and some are even valued at or near zero.

HOUSING MARKET

The housing market is the single most important macro economic driver in the nonagency market. Price appreciation and home sales volume are two critical measures of the housing condition. Exhibit 25-20 shows home price appreciation (HPA) and existing home sales (EHS) in the United States since the late 1980s.

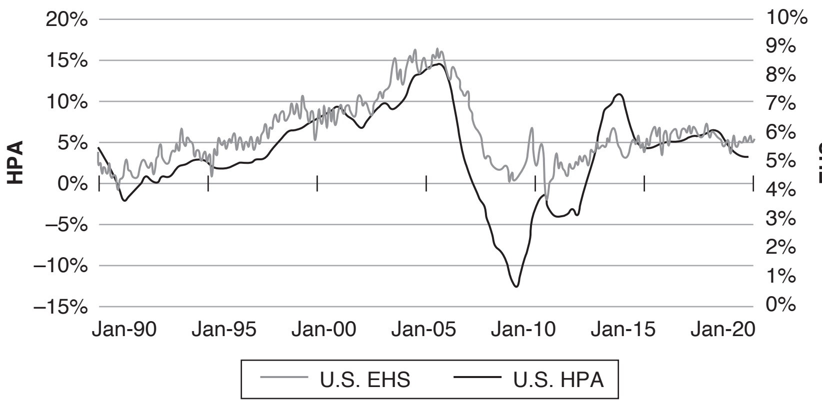
The housing market had experienced rapid growth in the early 2000s, with 10%+ annualized HPA, accompanied by sharp increases in home sales. As a result of the housing market boom, many lenders and investors neglected mortgage credit risks, which in turn greatly stimulated the nonagency RMBS market.

However, this growth was followed by the greatest housing bust in American post-war history as home sales slowed down in mid-2006 and prices started to decline. The decline in 2006 was relatively mild and many people were expecting a soft landing. By early 2007, it was clear that this was wishful thinking and a downward spiral began. Demographic factors played a key role here as baby boomers were entering retirement age and had started to reduce their housing demand. However, the housing market bust also consisted of several vicious cycles. Due to declining home prices, many potential buyers, particularly speculative buyers, held off on purchases, and this substantially slowed down home sales. Additionally, declining prices triggered increases in delinquency, which further increased the distressed housing supply and dragged down overall prices even further. The liquidity crunch then put huge pressure on the housing market as many borrowers could not get a new mortgage. Therefore, the weakened housing market further deepened the subprime mortgage crisis.

The housing market reached its worst point in early 2009 with a –18% year-over-year HPA nationwide. Case-Shiller HPI declined by 32% from the peak of Q2 2006 to Q1 2009, while existing home sales declined from its peak value of 9% in Q1 2005 to 5.2% in Q2 2009 (see Exhibit 25-20).

EXHIBIT 25-20

Annualized House Price Appreciation and % Exiting Home Sales in the U.S. Since Jan. 1990



In mid-2009, driven largely by pent-up demand, the Federal housing tax credit, a low interest rate environment, and credit becoming re-accessible, the housing market started to rebound. Home sales activities increased substantially, and prices started to stabilize with the rate of depreciation slowing. However, after the tax credit expired, excess demand was quickly exhausted. Momentum disappeared and the rate of home sales slowed substantially yet again. At the same time, a significant problem became obvious: the existence of millions of distressed properties, including those in REO, in foreclosure, and with loans in serious delinquency. With this large shadow inventory, it took a few years for home prices to recover. Loan modifications and foreclosure moratoriums slowed the pace of distressed properties flooding the market, which mitigated near-term housing supply pressure. However, these mechanisms also prolonged the liquidation timeline and resulted in a longer housing overhang and a slower recovery.

Five years after the housing crisis, the market started to see a steady increase in home prices and regular home sales activities, which were driven by pent-up demand, low interest rates, a low level of new home construction, a strong job market, and rising consumer confidence. HPA once again reached double-digit growth in 2014 and has since stabilized around 5%. Meanwhile, home sales activities also stabilized around a healthy 6% level.

Geographic Segmentation

The home price and existing home sales indices reveal a clear geographic segmentation within the overall housing market. Exhibit 25-21 shows Case-Shiller HPI for U.S. Census Geographic Divisions along with U.S. aggregate HPI. Geographic segmentation is observed on each level—for states within each census division, metropolitan statistical areas (MSAs) within each state, and zip codes within each MSA.

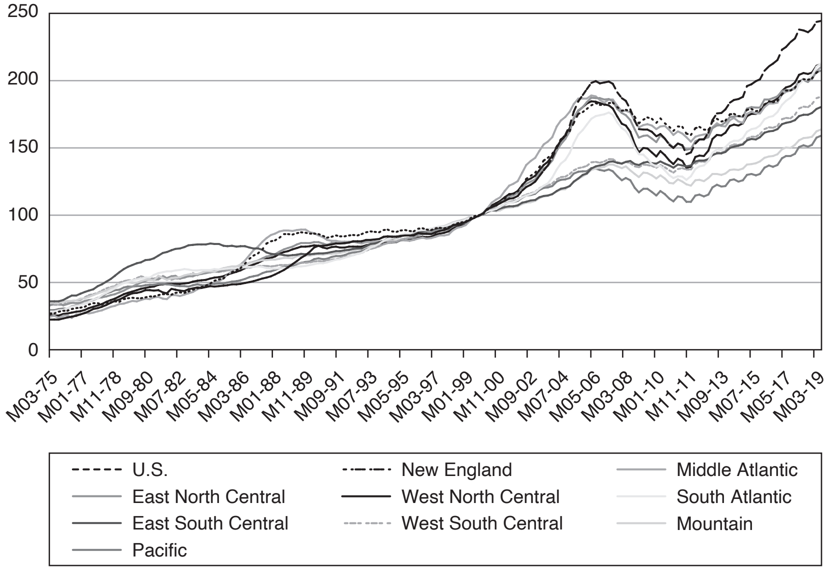
Geographic segmentation within the housing market makes it extremely important to understand the geographic distribution of nonagency collateral. Loans with the same original LTV but collateralized by homes in different geographic regions will have very different mark-to-market LTVs. Future home price appreciation will also be different. It is worth noting that historically the correlation among geographic regions is relatively small, which gives MBS the benefit of diversification. However, the correlation during the crisis was much higher, leading to substantial fat-tail risk.

Variation Among Property Tiers

There is also observed segmentation of the housing market based on home values, that is, price tiers. Fiserv/Case-Shiller provides HPI on different price tiers. All sales are divided into three groups based on property value, high-price, medium-price, and low-price tiers, so that proportions of each tier in total sales are equal. A home price index is then constructed for homes in each pricing tier. Depending on the state, different tiers experienced very different home price appreciation and consequent depreciation paths. For example, in California, low-price homes

EXHIBIT 25-21

Housing Price Index in Different Regions



appreciated the fastest, growing by 230% from Q1 2000 to the peak of Q2 2006, while high-price homes during the same period appreciated only by 115%. Consequently, on the way down, the drop from peak values was –58% for low price homes and only –31% for high price homes.

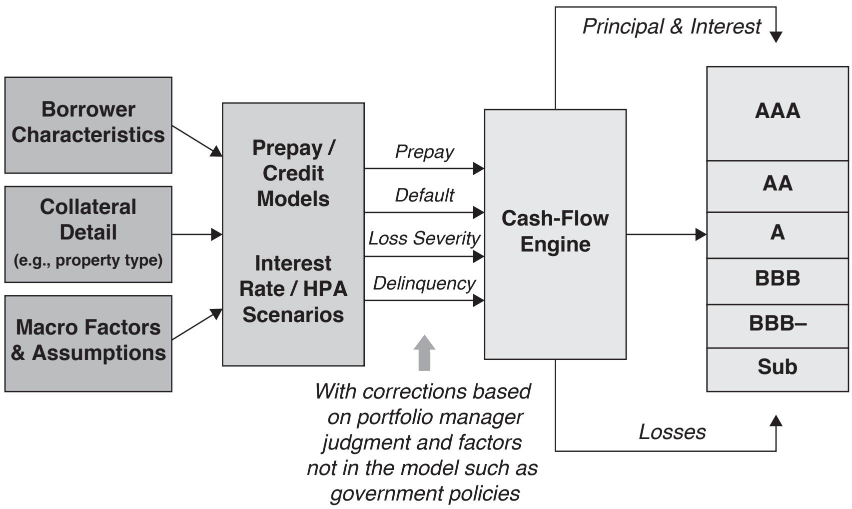
The difference between the high-end and the low-end of the market has a large implication on nonagency RMBS relative values. The prime jumbo sector, for example, is mainly backed by high-end properties. Home price depreciation is less pronounced for high-end properties, which partially contributed to the relatively low delinquency rate in this sector—the prime jumbo delinquency rate is even lower than that of agency mortgages. However, after the crisis, lack of financing in the jumbo mortgage market has been much more serious than in the conforming market.

RELATIVE VALUE AND RISK ANALYSIS

Here we introduce the analytical framework for relative value and risk analysis. Prepayment and credit models and roll-rate analysis are commonly used in this framework**.** As describe above, collateral, servicer behavior, capital structure, and the housing market are all important aspects to analyzing nonagency RMBS bonds. To combine all these factors, investors need an analytical framework similar to the one described in Exhibit 25-22. The primary components of this framework include collateral data, macro assumptions, performance projection models, and cash-flow engines.

EXHIBIT 25-22

Nonagency Analytical Framework



Key Risk Metrics

In addition to the standard mortgage valuation and risk measurements such as yield, spread, weighted average life (WAL), discount margin, option-adjusted spread (OAS), option-adjusted duration (OAD), option-adjusted convexity (OAC), and so on, the following metrics are widely used in the nonagency industry:

1. *Cumulative loss*: realized principal loss plus future expected loss divided by original balance of the deal
2. *Remaining loss*: future expected loss divided by current balance of the deal
3. *Principal write down*: principal loss for the bond
4. *Interest shortfall*: interest distributed is less than the amount of interest accrued
5. *Coverage ratio*: measured by the ratio of remaining loss of a deal collateral to credit enhancement of a bond within the deal
6. *Breakeven multiplier*: an intensity multiplier that when it is applied to a model, the projected remaining loss will be equal to the credit enhancement to a bond

Prepayment and Credit Models

Prepayment and credit models help project collateral future performance, including CPR, CDR, delinquency, and loss severity for each collateral group within a deal. The models typically use historical data to establish relationships of prepayment and credit performance to loan characteristics, current loan status, and macroeconomic environments. For example, a delinquency model can be a function of seasoning, FICO, LTV, DTI, documentation, state, and so on. The delinquency to foreclosure roll rate can be a function of current LTV, state judicial law, the housing market condition, and so on.

The purpose of prepayment and credit models is to project future cash flows under various rate, home price, or other scenarios. Given the empirical natural of these models and the ever-changing market dynamics, it is critical to keep the model updated. As we learned from the mortgage crisis, history does not simply repeat itself. Therefore, a model should never be about purely fitting history. A good model uses historical data to learn about borrower behavior under various environments and puts less emphasis on historical fit and more on forward-looking capabilities; it is really a mix of science and art.

All models require some assumptions. Some are explicit (e.g., the future HPA assumption), while others are more implicit (e.g., the prepayment model may assume that a prepayment channel is always available). It is very important for investors to understand each assumption within the model.

Roll Rate Analysis

Roll rate analysis is a simple but intuitive way to analyze a bond's performance and can be quite accurate in forecasting near term performance. This approach only requires the deal's transition matrix, which can be obtained using recent historical data. Exhibit 25-23 is a sample transition matrix. Given the transition matrix, one can compute the prepayment and default rates for each delinquency status bucket.

The disadvantage of roll rate analysis is that it ignores the underlying economic drivers. For example, it must assume the roll rates stay the same going forward, which is inconsistent with the natural selection phenomena many loan pools exhibit over time. If the macro economic environment changes the roll rates are unlikely to stay constant.

KEY POINTS

- Nonagency RMBS are not guaranteed by GSEs or government agencies and include securities backed by new prime jumbo, non-QM, RPL/NPL loans, and legacy deals of prime, Alt-A, option ARMs, subprime, second lien, and manufactured housing mortgages.

EXHIBIT 25-23

Sample Transition Matrix of Alt-A FRM as of March 2020

	Weight	CC	CD	DQ30	DQ60	DQ90	Fcl	REO	Prepay	Default
CC	76.6%	97.7%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%
CD	9.5%	5.5%	83.0%	10.7%	0.1%	0.0%	0.0%	0.0%	0.7%	0.0%
DQ30	4.4%	0.0%	27.9%	54.6%	16.6%	0.2%	0.0%	0.0%	0.7%	0.0%
DQ60	1.8%	0.0%	8.1%	16.7%	51.5%	23.2%	0.1%	0.0%	0.5%	0.0%
DQ90	3.2%	0.0%	3.7%	1.8%	3.7%	79.4%	9.9%	0.2%	0.2%	1.0%
Fcl	3.5%	0.0%	2.2%	0.3%	0.1%	4.7%	89.0%	2.0%	0.0%	1.8%
REO	0.9%	0.0%	0.0%	0.0%	0.0%	0.5%	0.5%	87.0%	0.0%	12.1%

Note: CC is currently clean with no delinquency history in the past 12 months; CD refers to a loan that is current but with some delinquency history in the past 12 months.

Data Source: CoreLogic and BlackRock Solutions

- Ten years after the financial crisis, which was trigged by nonagency RMBS issue, the market is gradually recovering with cleaner collateral and simpler capital structure. Non-prime loan securitization is on the rise, although still at nascent stage and small scale.
- The two principal risks inherent in a pool of mortgages that nonagency RMBS deals are structured to manage are prepayment risk and credit risk. The structure separates aggregated cash flows from the underlying loans into principal and interest and redistributes the cash flows and associated losses to individual tranches according to rules specified in the deal waterfall.
- Collateral characteristics, capital structure, and servicing concern are the key aspects of nonagency RMBS relative value and risk analysis.
- Key measurements of collateral performance include delinquency, default, voluntary prepayment, and loss severity. Major characteristics of collateral include product type, fixed versus hybrids, coupon, LTV, FICO, and loan size. Servicers can play a large role in servicing advances, loan modification, liquidation timeline, and so on, which can significantly alter bond cash flow and timing.
- Credit risks in nonagency RMBS deals were addressed through credit enhancements: external, internal through deal structure, or a combination of the two.
- The housing market is the key fundamental determinant of nonagency mortgage performance.
- Roll rate analysis, prepayment, and credit models help project collateral future cash flow and timing.

CHAPTER
TWENTY-SIX

COVERED BONDS

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As financial intermediaries create and hold financial assets, they search for variety of ways to refinance them. Corporate bonds are the most traditional form of capital market-based refinancing. However, corporate bonds are a direct exposure on the issuer and are directly affected by the financial strength of the issuer. The issuer's rating determines the rating of corporate bonds. Obviously, over the period of time till maturity, these bonds are affected by the changes in the rating of the issuer, as also its probability of default.

A country's financial system may, for variety of reasons, want financial instruments that are either unaffected, or less severely affected by the credit and rating of the issuer. Assume an issuer creating or holding standard financial assets, such as prime mortgage loans. If a system of refinancing these mortgages allows investors legal access to the portfolio of assets, investors will prefer a claim over a pool of healthy assets over a claim over the issuer. From a policy perspective, if an issuer is allowed to issue bonds that are either solely based on the strength of the asset pool or at least derive from the same, the issuer may hopefully issue better-rated bonds and therefore raise relatively cheaper financing to be able to create and hold the pool of assets in question. If an issuer had to depend on corporate bonds, a low-rated issuer would not be able to raise cheaper financing and therefore hold healthy assets. This leads to a self-sustaining cyclicality whereby a weaker bank must hold inferior quality assets and therefore remain weak or become weaker.

In the world of fixed income securities, markets have been searching for instruments that are asset backed, rather than entity backed. Mortgage-backed and asset-backed securities are instruments that seek to detach completely from the rating of the issuer and depend entirely on the quality of the pool of assets and the structural credit enhancements, mostly to reach highest ratings. Covered bonds, the subject of this chapter, are alternative instruments that may be perceived as midway between corporate bonds and mortgage-backed securities, in the sense that they depend both on the quality of the issuer and the quality of the assets underlying the funding.

COVERED BONDS: FROM EUROPE TO THE REST OF THE WORLD

In an environment of institutional investing that is so heavily reliant on ratings of investment options, both mortgage-backed securities and covered bonds are devices to uplift the rating of the instrument above the rating of the issuer. In case of mortgage-backed securities, under an assumption of complete independence of the funding from the risks of the issuer, the securities often get highest ratings. These ratings, and the strength of the security that they evidenced, came under acute challenge during the subprime crisis of 2007–2008, making mortgage-backed securities at least periodically unpopular. The search for an alternative ended at covered bonds, which have been used in Europe for 250 years. Depending on the jurisdiction, covered bonds may not have the fascination of mortgage-backed securities; however, whereas mortgage-backed securities have suffered the loss of investors' confidence, even if temporarily, during and after the subprime crisis, covered bonds have maintained healthy investor appetite.

Covered bonds, as an instrument of mortgage funding, have a long history. They are first said to have been issued in Germany, then Prussia, in 1769. The first issuance in Denmark occured in 1797, after the fire of Copenhagen in 1795. They are known by variety of names over Europe—*pfandbriefe* in Germany, *realkreditobligationer* in Denmark, *obligations fonciers* in France, and *pantbrev* in Spain, for example. Covered bonds have been essentially a European instrument, mostly backed by specific laws, until recently when countries outside Europe either started enacting legislations to promote covered bonds, or structurers used a combination of securitization-type structuring devices using common law to create covered bonds.

In the United States, Washington Mutual became among the first to come up with U.S. covered bonds in September 2006, followed by Bank of America the next year. Post the subprime crisis, then-U.S. Treasury Secretary Paulson came out with the Treasury's plan to promote covered bonds, including a statement of best practices. However, Washington Mutual went into receivership by the Federal Deposit Insurance Corporation, and its debt was acquired by JP Morgan. Both of the U.S. issuances of covered bonds have been paid off, and there were no issues thereafter.

Other countries too have taken legislative measures to promote covered bonds including, for example, Australia, New Zealand, and Canada. As explained later in this chapter, in some countries covered bonds have been tried without the strength of legislation, on the basis of flexibility of their legal structures.

UNDERSTANDING COVERED BONDS

There is no uniformity in the structure of covered bonds—there are reasons why these differences exist. Before we come to the nuances of their structure, let us understand the philosophy behind covered bonds. Corporate bonds, whether secured or unsecured, have the probability of default dictated by that of the issuer. If the issuer defaults, even secured bonds will default, though one may expect a significantly higher recovery rate based on the value of the collateral. Mortgage-backed securities, on the other hand, are presumably structured to insulate the pool of assets from the risk of bankruptcy of the issuer. Mortgage-backed securities typically attain highest ratings on the basis of credit enhancements sized up to absorb the losses of such insulated pool, to an extent that justifies the highest rating.

Covered bonds borrow from securitization framework, as also from the age-old secured bonds. Secured corporate bonds are the obligation of the issuer and are backed by security interest in the collateral. To what extent this collateral is available in the event of bankruptcy of the issuer, and what are the prioritized or parallel claims on this collateral, is a function of bankruptcy law, which differs from country to country. In the case of securitization, the presumption is that the collateral pool will remain completely aloof from the issuer and would be unaffected by the bankruptcy of the issuer, thus allowing investors undeterred access to its full value. Covered bonds strike an "approximate" midway, by creating a structure that combines at least the following:

- A recourse both against the issuer and the collateral pool, in that order, such that, like corporate bonds, the bond is still the obligation of the issuer yet backed by a claim over a collateral pool that is expected to withstand competing or overriding claims in the event of bankruptcy of the issuer; therefore, there is no complete isolation of the collateral from the issuer as in the case of securitization, yet a structure is in place that will protect the collateral and preserve it for payment to covered bonds investors on a first-priority basis.
- Presence of credit enhancements that are expected to absorb losses, at a stress level to attain the best ratings, is common in covered bonds too. However, the credit enhancement structures used in covered bonds have traditionally been simpler than they are in securitization.
- Thus, covered bonds lean both on the credit of the issuer as also on the strength of the asset pool.

STRUCTURE OF COVERED BONDS

Covered bonds are on-balance sheet securitizations. If by "securitization" is meant the transfer of a pool and its transformation into securities, then covered bonds are not securitization: they are closer to a secured bonds issuance. In a mainstream covered bonds transaction, there is no transfer of the assets to a *special purpose entity* (SPE). On the other hand, the assets are identified, and collateral rights are created on the assets as per local secured lending law and are placed as a security for the bonds. In the event of bankruptcy of the mortgage originator, a general secured lending law or a special law relating to the assets grants the bondholders recourse against the pool of mortgages over which security interest had been created. More often than not, there are overriding and parallel claims, arising out of bankruptcy laws or other laws, that erode a part of the value of the assets attributable to payment to the secured bondholders. In other words, the secured assets are prone to the bankruptcy risk of the issuer.

Securitization structures intend to eliminate this risk by relying on "true sale"—the asset pool itself is sold using a legally defensible sale, generally to an SPE. The SPE itself is, in legal presumption, bankruptcy remote; that is, it is so structured as to be free from the risk of being called into bankruptcy. Thus, securitization transactions may be taken to have insulated the asset pool from the bankruptcy risk of the issuer. That having been done, the only risk to be concerned about is the risk of credit losses in the asset pool. If there are credit enhancements present to absorb that risk to a sufficient degree, the resulting securities may attain the highest rating.

The need for securitization structures to depend on isolation or true sale resulted into some consequential features. One of the most significant consequences is the correlation between the cash inflows from the asset pool and the cash outflows to repay investors. This is commonly known as the *pass-through* nature of the transaction, implying that what is received, and whenever it is received, is the paid out to investors. The pass-through feature leads to several implications:

- The maturity of the mortgage- (or asset-) backed securities is the same as that of the asset pool. For example, if the mortgage pool pays off in 20 years, the last dollar to flow to the securities will also take 20 years. There are, of course, several modifiers that come into play; for example, there may be tranches of securities, with some tranches paying before others. There may also be a *clean-up call option* that allows the seller to complete the redemption once outstanding pool value becomes insignificant. However, on a holistic basis, there are no asset/liability mismatches in the transaction—the repayment of the liability, namely, the bonds, is driven by the repayments on the assets.
- As the mortgage loans prepay, the investors get prepaid too. Therefore, the much-discussed prepayment risk gets completely shifted to investors. Once again, reallocation devices that differentially reallocate the prepayment risk to different classes of investors may be used.
- The repayment of the liabilities flows from a static pool. *Static pool* refers to the mortgages that were there in the pool when it was sold to the SPE. Hence, the mortgage-backed securities will be affected by the expected behavior of a static pool—behavior of key variables, such as prepayment rate, default rate, and average rates of return, as a function of time to maturity.

- Since securitization is based on a true sale of the asset, questions arise as to whether what is a sale in law is also a sale in accounting parlance—leading to questions of off-balance-sheet treatment of the assets and whether the sale treatment is attainable—there is obviously a related question of acceleration of the profit/loss and upfront recognition thereof.

Let us now take the case of covered bonds. Given the fact that covered bonds are the obligations of the issuer, they do not have to exactly derive the cash flows from those of the asset pool. In other words, covered bonds are not based on a pass-through of cash flows of the asset pool. There may be mismatches (however, within limits as discussed further below) in the cash-flow structure. Therefore, all the consequential features of securitization depending on the pass-through nature of the transaction can be avoided, or at least, mitigated, in the case of covered bonds.

But here comes the key question: If covered bonds are nothing but obligations of the issuer, then what is the difference between secured corporate bonds and covered bonds? As discussed before, the genesis of covered bonds lies in giving to the bondholders bankruptcy-proof access to the assets. Hence, covered bonds have to create a legal structure that may allow investors to use the collateral assets, even if the issuer goes into bankruptcy. The basis of this bankruptcy-protected right lies in either a legislation granting them a special privilege, or in the design/structure of the transaction. Accordingly, covered bond structures, based on nature of jurisdictions, may be classified into legislative covered bonds and structured covered bonds.

Legislative Covered Bonds

A legislative covered bonds structure is one where a special legislation gives bankruptcy protection to the investors. This goes with the very genesis of covered bonds—they were created to allow investors in the bonds to have the strength of the assets, not just the strength of the issuer. In most European jurisdictions, covered bonds legislation grants a special immunity to the assets backing the covered bonds—that the bankruptcy trustee shall not take over these assets.

Take, for instance, the German pfandbriefe. Under German law, pfandbriefe could traditionally have been issued only by specialized banks, but the requirement was relaxed in 2005. These pfandbrief issues are expected on a regular and consistent basis, rather than on an opportunistic or sporadic one. There are several different types of pfandbriefe permitted by the German Pfandbrief Act: mortgage pfandbriefe, public pfandbriefe, ship pfandbriefe, and, more recently, aircraft pfandbriefe, each backed by the type of assets that the name implies. Public pfandbriefe are those backed by claims against public sector authorities.

The key feature of pfandbriefs is "covered assets," the collateral backing up the pfandbriefe. Depending on the type of pfandbriefe, the covered assets should be qualifying mortgages, public sector financial claims, or mortgages on ships. In addition, within specific limits, claims against central banks, credit institutions, and derivatives transactions are also recognized as covered assets.

The key to the bankruptcy remoteness of pfandbriefe lies in Section 30 of the Pfandbrief Act. This section provides that if insolvency proceedings are opened in respect of the Pfandbrief bank's assets, the assets recorded in the cover registers shall not be included in the insolvent estate. The claims of the Pfandbrief creditors must be fully satisfied from the assets recorded in the relevant cover register; they shall not be affected by the opening of insolvency proceedings in respect of the Pfandbrief bank's assets. Pfandbrief creditors shall only participate in the insolvency proceedings to the extent their claims remain unsatisfied from the covered assets.

There are independent administration provisions for the covered assets. Section 30.2 provides that the court of jurisdiction shall appoint one or two natural persons to act as administrators, whereupon the right to manage and dispose of the covered assets shall be transferred to the administrator. Thus, the administrator either continues to collect cash flows from the assets or dispose of it and pay down investors at once.

Similar provisions exist in other laws dedicated to covered bonds. In fact, a lot of harmonization has been attained by a pan-EU common regulatory framework. The definition of covered bonds is set forth in article 52(4) of the UCITS Directive. Exemption from any bail-in in the case of a bank restructuring is provided by article 44(2) of the BRR Directive, and preferential capital treatment is provided by article 129 of the CRR Directive.

Structured Covered Bonds

There are several covered bonds jurisdictions that do not have any specific laws to supply the bankruptcy protection. In these countries, issuers have been using a combination of SPEs and a transfer of the assets, presumably to attain bankruptcy-proofing. These may be called structured covered bonds jurisdictions.

There are several parties involved in a structured covered bond:

- Originator—the bank/entity that wanted to raise funding.
- SPE—the special-purpose entity that is interposed in the picture to hold legal title over the pool of assets and to provide bankruptcy protection. The SPE should be so structured as to be free from the risk of consolidation with the originator.
- Cover pool monitor—an entity to ensure that the cover pool satisfies the minimum credit enhancement required by the transaction.
- Administrator—an entity that will take over the assets in the event of bankruptcy of the originator.
- Bond investors.

The typical structure of a structured covered bond is shown in Exhibit 26-1. Although structured covered bonds rely on the common law of the country, and therefore may differ from case to case, the mechanics of a typical structured bond can be described in the following steps:

Step 1: A structured covered bond will typically have an independent SPE that will hold title to the assets or the cover pool. Note the significant difference: In normal securitization structures, the bonds are issued by the SPE. But in the case of structured covered bonds, while the collateral or cover pool is legally sold to the SPE, the issue of bonds is done by the originator or the bank that wanted to raise funding. Hence, the bonds are the direct and unconditional obligation of the originator. The role of the SPE is to provide a secondary recourse. Hence, in structured covered bonds, the SPE is typically a guarantor.

Step 2: The proceeds raised through the issue of covered bonds will be on-lent to the SPE. In turn, the SPE uses these proceeds to purchase from the originator the cover pool on a true sale basis.[1] Thus, the SPE becomes the legal owner of the pool. In other words, from a legal perspective, the sale from the originator to the SPE must satisfy the legal features of a true sale. The sale, however, is not a sale from accounting viewpoint—see discussion below. Also, note that the loan given by the originator to the SPE is subordinated to the obligations of the SPE to the bondholders.

Step 3: Backed by the cover pool, the SPE provides a guarantee to covered bondholders for the payment of interest and principal on the covered bonds, which becomes enforceable if the issuer defaults. The guarantee represents an irrevocable, direct, and unconditional obligation of the SPE and is secured by the cover pool.

Step 4: The originator continues to collect and service the cash flows from the mortgage loans. As there is a mismatch between the payments from the mortgage pool and the payments on the bonds, the originator is allowed to (a) retain the collections from the pool and (b) make payments toward the bonds in excess of collections from the pool. As the originator repays the mortgage bonds, the inter-company loan and the purchase of assets by the SPE are squared off; that is, the SPE's obligation to repay the inter-company loan is taken to have been satisfied.

Step 5: Though the originator holds the collateral pool and may use the collateral pool's cash flows—and may replace assets in the collateral pool or add new assets in place of those amortized or prepaid—the originator needs to ensure that the credit enhancement levels are maintained at all times. Usually, an independent cover pool monitors the compliance with this requirement.

1. As an alternative, the SPE buys the assets but the price for the same is kept unpaid—by way of a deferred purchase price.

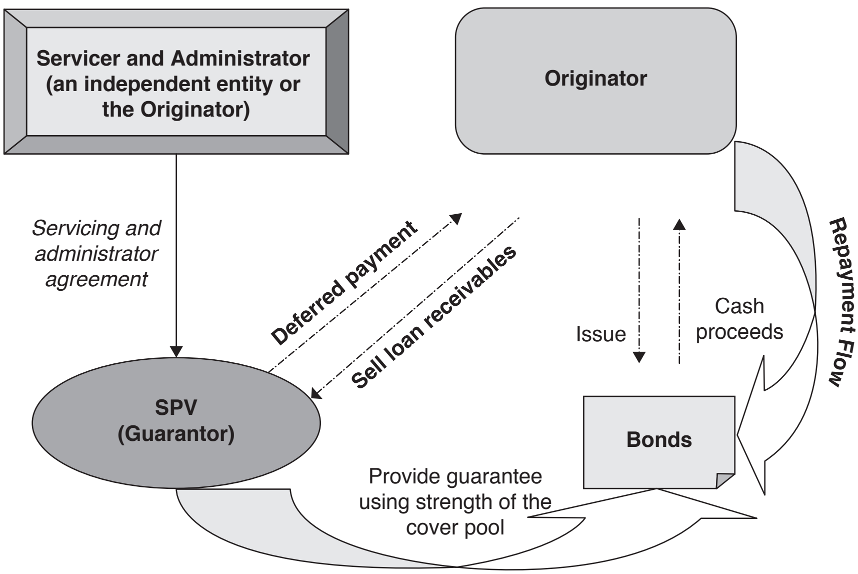
Step 6: While the originator may add further loans to the collateral pool, or withdraw loans from the pool, the aggregate amount of collateral "sold" to the SPE must have a minimum amount of credit enhancement.

Step 7: If an originator bankruptcy event takes place, the SPE's guarantee to the bondholders kicks in. At this stage, the SPE attaches the collateral lying with the originator and passes it to the administrator.

Step 8: The claims of the bondholders are paid from the cover assets. In case of a deficiency, the bondholders will have an unsecured receivable from the issuer.

EXHIBIT 26-1

Structure of Structured Covered Bonds



MATURITY STRUCTURE OF COVERED BONDS

We mentioned above that covered bonds' repayment may not be entirely matched with the repayment profile of the cover pool. In fact, the cover pool itself is dynamic. Thus, there are many covered bond issuances that have a "hard bullet" repayment structure, and many others that have a "soft bullet" structure. A hard bullet has a pre-fixed maturity; a soft bullet allows that maturity to be extended on the occurrence of trigger events, such as issuer default.

There is also an increasingly common structure, called conditional pass-through (CPT). In a CPT structure, on the occurrence of certain trigger events with respect to the issuer, mainly insolvency, the repayment structure of the bond shifts from its original one to a "pass-through." A pass-through, as in the case of mortgage-backed securities, implies that the collateral pool then becomes static and the cash flows from that underlying pool start paying the bondholders on an as-received basis. This enables the cover pool trustee from having to force-liquidate the cover assets and suffer value destruction.

COVER ASSETS AND CREDIT ENHANCEMENTS

Since covered bonds rely both on the asset pool and on originator credit, it is important to ensure that the credit risk of the asset pool is absorbed by credit enhancements. While securitisation transactions have used a variety of forms of credit enhancements, covered bonds have traditionally used *overcollateralization*. That is to say, the originator needs to ensure that the "cover" assets overcollateralize the outstanding bonds by the required minimum degree of overcollateralization. For example, if the required overcollateralization is 10%, for outstanding bonds of \$100, there need to be covered assets of at least \$110. As the bonds are amortized over time, this overcollateralization ratio must be maintained at all times.

In addition to this, the cover assets, that is, assets forming part of the cover pool, must also satisfy certain features laid down by either legislation or regulation, for example, the loan-to-value ratio in case of each loan. In other words, the quality of the underlying loans in the cover pool is carefully guarded by regulators.

ASSET/LIABILITY MISMATCHES AND LIQUIDITY RISK

Covered bonds are repaid independent of the cash flows of the cover pool. So, they are paid from the regular cash flows of the originator. Likewise, the cash flows received from the asset pool go and become part of the regular cash flows of the cover pool. This clearly implies an asset/liability mismatch underlying a covered bond.

If this asset/liability mismatch was completely uncontrolled, then the obligation to repay covered bonds would have been no different from an obligation to repay any secured or unsecured bond issued by the originator. Hence, the strength of a covered bond depends on how wide the asset/liability mismatch is. The asset/liability mismatch reflects the liquidity risk of the transaction. If the asset/liability mismatch is too wide, a covered bond leans too heavily on the liquidity strengths of the issuer and therefore is no different from corporate bonds. If the asset/liability mismatch is negligible, a covered bond leans toward being a mortgage-backed security. Hence, usually, covered bonds issuers keep the asset/liability mismatch under control. The extent of asset/liability mismatch also affects the likely rating upliftment that a covered bond may receive as discussed below.

Exhibit 26-2 shows a computation of the asset/liability mismatch done by rating agency Standard and Poor's. In this exhibit, column A shows the likely balances in the asset pool, and column B shows the likely balances outstanding of the covered bonds. As one may notice, at the inception the cover pool value is \$120, while the bonds outstanding add to \$100, implying an overcollateralization of 20%. There is a mismatch between column A and column B—as is apparent. The outstanding balances of the assets are based on the amortization of the mortgage loans, incorporating assumptions of prepayment and default. The outstanding balances of the bonds in column B are based on the contracted repayment of the bonds—this may be seen in column D. It may also be noted that while the asset pool will take several years to fully pay down, the bonds are scheduled to be fully paid down at the end of 10 years.

The gap between the cash inflows and cash outflows is given in column E. Column F applies a scaling factor, giving more weight to a mismatch in earlier years, and lesser to those in later years. The scaling factor is array of scales used by the rating agency in question.

Finally, in column G the asset/liability mismatches are accumulated and find the highest level of mismatch. This is defined as the asset/liability mismatch of the transaction. The greater the mismatch, the greater the transaction's dependence on the issuer's rating.

We discussed soft bullet maturity above. In the example, column D shows payments to the bonds in five different years. This would most likely not be five payment dates on a single bond, but five different tranches of bonds with single bullet maturity dates each.

RATINGS OF COVERED BONDS

As we have discussed, the desire of a covered bond issuer is to raise funding by an instrument that pierces the rating of the issuer. That is, rating upliftment is a significant objective of every issuer.

All the major rating agencies have come up with criteria to give ratings, in fact, rating enhancements to covered bonds transactions. These criteria have been evolving over time, and as volatility spikes occur within the financial system, rating agencies become more conservative.

We do not intend to discuss the rating criteria of each of the agencies here, but we need to observe that, unlike in case of securitization, ratings of covered bonds are not completely detached from the rating of the issuer. In fact, the issuer's rating significantly controls the ratings of covered bonds. Hence, rating agencies typically lay down a matrix of factors, on consideration of which they will notch-up the rating of the covered bonds by specified level of notches.

COVERED BONDS AND SECURITIZATION

As we have stated before, though covered bonds are historically grounded into secured bonds, in the recent past, transactions have been enriched by

EXHIBIT 26-2

Computation of Asset/Liability Mismatch in Covered Bonds (S&P)

Year	Performing asset balance (€ Mil.)	Liability balance (€ Mil.)	Stressed periodic asset cash inflows (€ Mil.)	Stressed periodic liability cash outflows (€ Mil.)	Net stressed periodic cash flows (€ Mil.)	Scaling factor (%)	Scaled net stressed periodic cash flow (€ Mil.)	Cumulative scaled net stressed cash position (€ Mil.)
	A	B	C	D	E = C - D	F	G = E * F	H = Cumulative of G
Outstanding balance	120.00	100.00	–	–	–	–	–	–
1	114.00	90.00	6.00	10.00	–4	100	–4	–4.00
2	108.30	70.00	5.70	20.00	–14.3	95	–13.585	–17.59
3	102.89	40.00	5.41	30.00	–24.59	90	–22.131	–39.72
4	97.74	20.00	5.15	20.00	–14.85	85	–12.6225	–52.34
5	92.85	20.00	4.89	0.00	4.89	80	3.912	–48.43
6	88.21	20.00	4.64	0.00	4.64	75	3.48	–44.95
7	83.80	20.00	4.41	0.00	4.41	70	3.087	–41.86
8	79.61	20.00	4.19	0.00	4.19	65	2.7235	–39.14
9	75.63	20.00	3.98	0.00	3.98	60	2.388	–36.75
10	71.85	0.00	3.78	20.00	–16.22	55	–8.921	–45.67
Maximum ALMM (€ Mil.)								–52.34
ALMM percentage = maximum ALMM / outstanding liability balance (%)								–52.34%

securitization methodology, particularly in countries that do not have specific covered bonds legislation. Hence, they are a hybrid between securitization and secured bonds. The few points of similarity between the two are (a) both result in the creation of securities, (b) both are methods of funding from the capital markets, (c) both involve creation of a pool of assets, and (d) both have trustees overseeing the implementation of the transaction covenants. The structure of covered bonds would look very similar to the master trust structure of securitization, particularly if the structure is used in case of residential mortgages. However, there are significant points of dissimilarity, as shown in Exhibit 26-3.

EXHIBIT 26-3

Covered Bonds and Securitization Compared

	Covered Bonds	Securitization
Purpose	Essentially, to raise liquidity	Liquidity, off balance sheet, risk management, monetization of excess profits, etc.
Risk transfer	The issuer continues to absorb default risk as well as prepayment risk of the pool. To achieve a partial transfer of prepayment risk, there may be a call option embedded in the bonds.	The originator does not absorb default risk above the credit support agreed; prepayment risk is usually transferred entirely to investors
Legal structure	A direct and unconditional obligation of the issuer, backed by creation of security interest. Assets may or may not be parked with a distinct entity; bankruptcy remoteness is achieved either due to specific law or by using ring-fencing structures of common law.	True sale of assets to a distinct entity; bankruptcy remoteness is achieved by isolation of assets
Type of pool of assets	Mostly dynamic. Borrower is allowed to manage the pool as long as the required “covers” are ensured. From a common pool of cover assets, there may be multiple issuances.	Mostly static. Except in case of master trusts, the investors make investment in an identifiable pool of assets. Generally, from a single pool of assets, there is only issuance.

(Continued)

EXHIBIT 26-3

Covered Bonds and Securitization Compared (*Continued*)

	Covered Bonds	Securitization
Maturity matching	From out of a dynamic pool, securities may be issued over a period of time. Usually, covered bonds are “programs”, that is, series of issuance from out of a dynamic and replenishing mortgage loan pool.	Typically, securities are matched with the cash flows from the pool. When the static pool is paid off, the securities are redeemed.
Payment of interest and principal to investors	Interest and principal are paid from the general cash flows of the issuer	Interest and principal are paid from the asset pool
Prepayment risk	In view of the managed nature of the pool, prepayment of loans does not affect investors, except to the extent of call option embedded in the bonds.	Prepayment of underlying loans is passed on to investors; hence investors take prepayment risk
Nature of credit enhancement	The overcollateralization in the cover pool, that is, excess of the cover assets over the outstanding funding.	Different forms of credit enhancement are used, such as excess spread, subordination, over-collateralization, etc.
Classes of securities	Usually a single class of bonds are issued. There may be multiple time tranches, each having hard or soft bullet maturity.	Most transactions come up with different classes of securities, with different risk and returns
Independence of the ratings from the rating of the issuer	Theoretically, the securities are those of the issuer, but in view of bankruptcy-proofing and the value of “cover assets”, usually ratings may achieve notching up by several notches.	AAA ratings are given usually to senior-most classes, based on adequacy of credit enhancement from the lower classes.
Off-balance-sheet treatment	Not off the balance sheet	May or may not be off the balance sheet, as per applicable accounting standards
Capital relief	Cover pool assets will be treated as on-balance sheet retail portfolio, appropriately risk weighted. No specific capital relief to the issuer. Regulations provide investors with lower risk weights.	If significant risk transfer is achieved, permits capital relief and calls for regulatory capital only up to the retained risks of the seller

ACCOUNTING FOR COVERED BONDS

Looking at the structure of covered bonds, particularly in the case of structured covered bonds, one may notice the presence of a legal transfer of the cover assets from the issuer to the SPE. Would this have the impact of removing the cover assets from the books of the seller-issuer? Under IFRS 9, true sale is not a precondition for off-balance-sheet treatment. Transactions that qualify as pass-through arrangements, even if not backed by true sale, may lead to assets being off the balance sheet. Neither does true sale guarantee an off-balance-sheet treatment. On the other hand, off-balance-sheet treatment is based on the substance of the transaction, that is, risks and rewards from the asset pool. For instance, if the reporting entity creates a pass-through obligation in favor of the investor, that is, retains the right to receive the cash flows, but assumes a contractual obligation to pay the cash flows on pass-through basis to one or more recipients, it can still be treated as transfer of significant risks and rewards and qualify for de-recognition. If the seller retains significant risks and rewards, the asset continues to be on the books of the seller, and the funding raised is treated akin to a borrowing.

As we have discussed above, covered bonds transactions, particularly those not backed by legislation, rely on true sale to achieve bankruptcy protection. Hence, a question may arise: As the originator sells the pool to an SPE that guarantees the repayment of the bonds, should the assets go off the balance sheet of the issuer? The answer would be clearly no, since the bonds are unconditional obligation of the issuer. Hence, the making of the true sale does not put the assets off the balance sheet of the issuer.

KEY POINTS

- As a capital market device for refinancing mortgages, covered bonds have existed in continental Europe for more than 250 years. However, their recent popularity seems to be emanating from their proven robustness in the midst of the several crises, both economic and common life.
- Covered bonds may be viewed as a hybrid between corporate bonds and mortgage-backed securities, in the sense that they are an obligation of the issuer, they are close to secured bonds, but since investors also rely on the assets as a backup, they have features of asset-backed securities.
- The asset-backing in the form of cover assets provides dual recourse to investors. How clear is the ability of investors to rely on the assets, immune from the post-bankruptcy claims of other creditors, depends either on the legislation or on the legal structure of the transaction.
- Where the bankruptcy protection comes from legislation, it is called legislative covered bonds; where it comes from the legal structure, it is called structured covered bonds.

- Structured covered bonds use a special purpose entity that agrees to buy the cover assets, albeit with funding provided by the issuer. The SPE then guarantees the repayment of the bonds.
- The key idea of covered bonds is to provide a rating upliftment, so that the bonds are able to achieve a better rating than that of the issuer. The notches by which rating of covered bonds may go up above the rating of the issuer are based on the quality of the cover asset, extent of credit enhancement, inherent asset/liability mismatch, strength of the legislative support, liquidity risk, and related factors.
- Credit enhancements in case of cover bonds are mostly in form of overcollateralization.
- While structured covered bond transactions make use of the device of sale of the cover pool by the issuer to an SPE, the sale is done such that it qualifies as a legal sale but not a sale in terms of accounting standards. Hence, from accounting viewpoint, covered bonds are not different from secured bonds.

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CHAPTER

TWENTY-SEVEN

COMMERCIAL MORTGAGE-BACKED SECURITIES

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Commercial mortgage-backed securities (CMBS) are structured products that provide debt financing to the commercial mortgage market. CMBS are a component of commercial real estate finance (commercial banks, insurance companies, and pension funds also make direct loans to owners of commercial real estate).

As with residential mortgage-backed securities (RMBS) products, CMBS represent economic interests in pools of mortgage loans. The structure used to create CMBS transfers the credit risk of the underlying commercial real estate loans to the owners of CMBS. Certificate subordination increasingly mitigates the commercial mortgage loan credit risk for certificate holders. CMBS certificate structures apply losses to the most junior outstanding certificates and, depending on the levels of subordination, offer substantial credit risk protection to the holders of the most senior certificates.

CMBS investors should understand the fundamentals of commercial real estate valuations and commercial real estate lending standards to properly analyze the credit risk embedded in CMBS investments. The loans underlying CMBS transactions are typically much larger than loans found in other securitized products. The largest 10 loans in a CMBS transaction can comprise 35% to 70% of a collateral pool. This loan concentration makes asset-level reviews much more important than other securitized products in which the law of large numbers allows effective statistical sampling. Key differences between CMBS and nonagency RMBS are enumerated in Exhibit 27-1.

The authors would like to acknowledge the contributions of Nishith Ajitsaria and Kunal Khara, CFA in writing this chapter.

EXHIBIT 27-1

Comparison of Key Attributes of CMBS Transactions and Nonagency RMBS Transactions

Attributes	CMBS	Nonagency RMBS
Collateral Composition	Larger-sized loans with fewer loans in the trust—underlying collateral is more heterogeneous. Higher concentration risk with top 10 loans comprising 35%–70% of the transaction.	Large number of loans in a transaction. Loans are small in size and individual loans represent a small portion of the transaction. Given large number of loans, collateral is fairly well-diversified.
Loan Types	Shorter-term loans, with 5-, 7-, or 10-year balloon maturities. Most loans are fixed-rate.	15- to 30-year fixed-rate and floating-rate loans.
Prepayment	Mortgage loans typically prohibit prepayment until a few months prior to the maturity date.	Many mortgage loans are freely prepayable.
Transaction Structure	Transactions typically pay principal sequentially, credit enhancement is in the form of subordination, and losses are allocated in reverse-sequential order.	Wide range of principal, interest, and loss cash-flow distribution rules, in addition to triggers and multiple forms of credit enhancements such as over-collateralization, subordination, excess spread, reserve accounts, and external credit guarantees.
Modeling	Modeling typically involves detailed loan- and asset-level review given loan concentrations.	Probabilistic modeling of prepayments, defaults, and severities is fairly common with models built on large historical loan-level performance data sets.
Government Guarantee	Agency CMBS securitizations offer senior certificates that typically include a guarantee from the issuing GSE. Private-label CMBS structures do not benefit from a government guarantee.	No government guarantee.

CMBS issuers have developed several types of transactions. CMBS transactions are broadly classified as private-label CMBS and agency CMBS. Private-label CMBS constituted the vast majority of CMBS transactions until 2008. As markets restarted after the 2008 financial crisis, *agency CMBS* that combine many features of private-label CMBS with a payment guarantee for senior certificates from a government-sponsored enterprise (GSE) became much more prevalent as a source of funding for multifamily properties. Fannie Mae and Ginnie Mae are active in the agency CMBS market with various offerings that finance multifamily and healthcare properties and provide investors government-guaranteed investment options. Freddie Mac has created several programs that incorporate many features of private CMBS securitizations and offer government-guaranteed senior certificates. Agency CMBS junior certificates typically do not benefit from a guarantee. Within private-label CMBS, *conduit transactions* are securitizations of fixed-rate commercial mortgage loans in which no loan comprises more than 20% of a transaction. Issuers created *single asset single sponsor* (SASB) *transactions* for sizeable debt offerings for large owners and sponsors of commercial real estate that justify a separate CMBS transaction. CMBS issuers have created *floating-rate transactions* typically comprised of large loans on transitional properties (i.e., under construction/renovation, undergoing a repositioning) and properties with more volatile cash flows (i.e., hospitality). These loans were usually for one or two years with several one-year extensions. Finally, since 2017 commercial real estate *collateralized loan obligation transactions* (CRE CLOs) reemerged to provide a source of financing for mortgage loans that do not meet the requirements of a conduit transaction. These transactions generally consist of two- or three-year loans that accrue interest on a floating-rate basis. CRE CLOs can have a static pool of collateral or a managed pool in which the CRE CLO issuer can replace loans that prepay or payoff with new collateral.

The majority of CMBS transactions were conduit transactions prior to 2008. After 2009, agency CMBS substantially increased in volume to eventually comprise more than half of the CMBS market. CMBS investors (regardless of credit support) typically perform due diligence on the largest loans to understand whether the mortgage loan originator used a prudent valuation and sized the loan appropriately.

THE COLLATERAL POOL

Because most CMBS transactions have large loans that comprise significant portions of the overall trust, investors typically perform a review of the underlying mortgage loans and mortgaged properties to understand the idiosyncratic credit risks of the investment.

Summary of Valuation Techniques for Underlying Mortgage Properties

Typically, office, retail, industrial, hospitality, and multifamily properties serve as collateral for the underlying mortgage loans. Office, retail, industrial, and hospitality properties constitute "commercial" properties, whereas multifamily properties typically have more than four residential units available for lease. Commercial real estate values are typically computed by using the direct capitalization method, a discounted cash-flow analysis, the comparables method, or the replacement cost method. The direct capitalization method utilizes a *capitalization rate* (cap rate), which is the unleveraged yield associated with the current income from a commercial property. The direct capitalization method determines property value by dividing the net operating income (NOI) by the cap rate. That is,

$$\text{Property Value} = \text{Net Operating Income/Cap Rate}$$

Cap rates are based on many factors and include an interest rate component. Multifamily properties have typically garnered the lowest average cap rates due to availability of debt financing from GSEs, diversified income stream from a range of tenants, and historically strong demand for housing throughout market cycles (people need a place to live). Hospitality properties generally average the highest cap rates due to the volatility of NOI associated with the hospitality and travel/leisure industries. Investors value office, retail, and industrial properties with average cap rates between the multifamily and hospitality benchmarks. The direct capitalization method is useful to CMBS investors because the data inputs are typically available from dealers, such that the analysis is based on a standardized data set.

The *discounted cash-flow analysis* (DCF analysis) is a more precise method of commercial real estate valuation that discounts the property's NOI through time using the weighted average cost of capital as a discount rate. Commercial real estate equity investors utilize a DCF analysis when purchasing commercial real estate properties; however, CMBS investors typically do not have the required inputs (i.e., cash-flow forecast) to use this valuation technique.

The comparables method attempts to determine commercial real estate values by determining a property's value based on the actual sales of similar properties in the same area. This approach is effective at finding a market value if similar properties traded in the recent past. When marketing CMBS investments, dealers often verbally disclose comparables for the properties securing the largest mortgage loans within a transaction. Property values are distilled to a value/square foot (SF) or unit. As an example, Midtown Manhattan Class A (high-quality) office buildings can trade in an average range of \$1,000–\$1,400/SF, whereas suburban office buildings in secondary markets can trade at \$150 to \$250/SF. Although dealers make comparable information available during the offering of a CMBS transaction, updated information is not made available through transaction reporting.

The replacement cost approach values real estate by computing the value of the underlying land and the cost associated with constructing the property's improvements less depreciation. This method is not used extensively in commercial real estate valuation as it does not take into account the property's income stream. The appraiser is also required to determine the value of land using the comparables method—given that land sales in highly developed areas are rare, valuations based on this approach would require significant assumptions.

The classic guideline for commercial real estate valuation has not changed in the modern era: Location is essential to determining real estate values. A CMBS investor should appreciate and consider the bespoke nature of commercial real estate properties and their values to properly model the commercial real estate debt exposures in a CMBS transaction.

Commercial Mortgage Lending Standards

As with most hard assets of reasonable credit quality, owners of commercial real estate can improve their overall yields by utilizing leverage. Mortgage loans are sized based on the ratio of the debt to the value of the property (the loan-to-value ratio, or LTV). Prior to the 2008 financial crisis, most owners of commercial real estate borrowed 50% to 80% of the value (or acquisition cost) of the property, and most CMBS originators made loans up to 75% to 80% LTV. In 2006 and 2007, CMBS originators aggressively offered loan products that provided borrowers up to >95% LTV as underwriting standards deteriorated. During the 2008 financial crisis, most commercial real estate debt offerings (including CMBS) disappeared along with market liquidity. If debt was available, the terms were generally economically punitive (i.e., high coupons and maximum loan sizes up to 50% LTV based on depressed property values). As the CMBS market restarted, most CMBS originators reverted to more conservative underwriting standards with loans generally in the 55% to 75% LTV range.

Mortgage loans are also sized based on the ratio of the NOI of the underlying collateral to the debt service of the mortgage loan. This ratio is the *debt service coverage ratio* (DSCR). CMBS originators usually require a minimum DSCR of 1.2×; however, certain property-level characteristics could enable a CMBS originator to make a loan at lower DSCR thresholds (e.g., collateral is a long-term ground lease or tenants with lease terms greater than 15 years).

Finally, CMBS originators also focus on the *debt yield* to gauge the size of the proposed mortgage loan. Debt yield is calculated by dividing the annual NOI of a mortgaged property by the first mortgage balance. This percentage is the yield a lender would receive if the lender foreclosed on the asset (assuming the NOI remains constant) and provides an additional metric to size mortgage loans in environments where low cap rates, low interest rates, and long amortization periods can skew DSCR and LTV ratios. CMBS originators typically originate loans that provide a debt yield of 9% to 10% or higher.

Loan Structures and Features

CMBS dealers will disclose many loan features in the offering documents of a CMBS transaction. Commercial mortgage loans are generally originated with structural features to isolate the underlying collateral for the benefit of the trust. Most borrowers are single-purpose entities (corporations or limited liability companies) that are created for the sole purpose of owning the commercial real estate that is collateral for the mortgage loan. For larger loans, the single purpose entity includes organizational features that make it difficult for the borrower to declare bankruptcy. These legal protections are necessary for loans underlying CMBS transactions since most loans are nonrecourse, meaning the lender's only recourse in the event of a loan default is seizing the underlying collateral.

CMBS originators require additional loan features to protect the trust in the event the borrower fails to prudently operate the mortgaged property. CMBS originators typically require borrowers to establish reserve accounts with the loan servicer for various property expenses. For example, CMBS originators may require the borrower to remit the prorated portion of the annual property tax and property insurance payments as part of its monthly payment. CMBS originators could also require borrowers to make monthly payments for replacement reserves, tenant improvement, and leasing commissions. Depending on the mortgaged property and its condition, CMBS originators could also require debt service reserves, ground lease reserves, and other reserves to mitigate specific property conditions.

Some lenders may structure "holdbacks," which are additional loan proceeds that are held in reserve by the servicer. Holdbacks can be released to the borrower upon the achievement of certain property benchmarks (leasing goals, NOI goals, occupancy goals, and the like). In the event the holdback release criteria are not met, many holdbacks serve as additional loan collateral. In some cases, unreleased holdbacks could be used to pay down the loan principal balance and would cause a prepayment to the certificate holders.

CMBS originators typically require lockbox structures. Lockboxes are deposit accounts held by the servicer. If the CMBS originator required a hard lockbox, immediately following the closing of the loan, the borrower would be required to notify all tenants to forward their rental payments and reimbursements to the servicer for deposit in the lockbox and the borrower would have access to the funds pursuant to the terms of the loan documents. Originators impose various conditions on the release of funds from lockboxes. In many instances, the servicer will fund escrows and debt service on a monthly basis and release the remaining funds to the borrower. As the CMBS market matured, originators would permit soft lockboxes that allowed the servicer to sweep all amounts in the lockbox to a borrower-controlled account on a daily basis. Upon an event of default, the stringent cash management provisions would be imposed and the borrower would no longer have access to funds from the lockbox.

CMBS loans typically restrict prepayment during the loan term. CMBS originators would typically "lock out" all loans from prepayment during the first two to four years of the loan term. After this initial lockout period, borrowers could defease the underlying mortgaged property by substituting U.S. government securities as collateral for the loan. The substituted securities would generate cash flows to make the interest and principal payments of the underlying loan on schedule. The defeasance feature is acceptable to CMBS investors because it preserves the contracted loan cash flows while significantly reducing default risk. In some cases, in lieu of defeasance, CMBS originators would allow borrowers to prepay their mortgage loans with the payment of a prepayment penalty or yield maintenance charge. These prepayment penalties would partially compensate certificate holders for an early prepayment of a mortgage loan since their overall yield could be negatively affected by the prepayment.

CMBS originators will sometimes cross-collateralize several mortgage loans. This feature is utilized when a borrower finances several properties using separate mortgage loans (rather than collateralizing a single mortgage loan with multiple properties). Cross default occurs when the originator requires the borrower to agree that any default under the identified set of mortgage loans will cause a default under all the mortgage loans. Cross-collateralization is the corollary feature that allows the CMBS originator to use the collateral securing all mortgage loans to offset the loss on any single mortgage loan.

Diversification of CMBS Loan Pools

In order to understand credit risk, CMBS investors focus on large mortgage loan exposures and collateral concentration. The Benchmark 2019-B15 Mortgage Trust offering (Benchmark 2019-B15) illustrates many of the loan features, pool concentrations, and certificate features described in this chapter. Exhibit 27-2 describes the top 10 loans in the Benchmark 2019-B15 transaction.

CMBS transactions usually contain mortgage loans from all U.S. regions. Exhibit 27-3 illustrates the geographic concentration of Benchmark 2019-B15.

CMBS transactions should also contain adequate property type diversification. Concentration in a particular property type may make a CMBS transaction susceptible to specific downturns in a particular industry or segment of the economy. Exhibit 27-4 illustrates the property type concentrations in Benchmark 2019-B15.

The mortgage loans sold into a CMBS transaction can also provide default protection by including amortization. CMBS originators required amortization in the early or post-crisis vintages of CMBS but shifted to a preference of interest-only or partial interest only loans as credit markets mature and spreads tighten. Exhibit 27-5 illustrates the amortization terms and interest-only concentrations in Benchmark 2019-B15.

CMBS transactions may also include multiple loans to the same ownership group (Loan Sponsor) that are not cross collateralized. CMBS dealers typically make this information available during the offering process. CMBS investors should monitor the borrower concentrations in conduit transactions to ensure adequate diversity of borrower risk.

To mitigate concentration risk from the largest loans and keep the exposure below certain size thresholds that would require additional disclosures, CMBS issuers may split mortgage loans into multiple pieces. Structures include A/B notes, in which the B note provides subordination to the senior A note. Originators also split loans into "pari passu" structures in which the individual notes receive a pro rata portion of principal and interest (and losses in the event of a note loss).

If an originator creates a pari passu loan structure, the servicing of the loan would be assigned to the master servicer of the first securitization that owns the first securitized note from the pari passu loan. This servicer is responsible for collecting the loan payments and administering the loan for all the various notes created by the originator. Exhibit 27-6 describes the pari passu loans in Benchmark 2019-B15.

EXHIBIT 27-2

Top 10 Loans in the Benchmark 2019-B15 Transaction

	Loan Name	Cut-Off Date Loan Balance	% of Trust Balance	Property Type	Property Size SF/Units	Cut-Off Date Balance Per SF/Unit	Underwritten NCF DSCR	Underwritten NOI Debt Yield	Cut-Off Date LTV
1	899 West Evelyn	75,000,000	8.9%	Office	75,475	994	2.62x	9.1%	54.9%
2	Innovation Park	67,250,000	7.9	Office	1,854,729	98	2.96x	11.6%	68.8%
3	Century Plaza Towers	62,500,000	7.4	Office	2,401,641	375	4.09x	13.5%	39.1%
4	Harvey Building Products	50,000,000	5.9	Various	2,046,119	78	1.51x	9.1%	69.4%
5	Austin Landing Mixed-Use	50,000,000	5.9	Mixed Use	834,510	106	2.62x	13.0%	61.9%
6	Kildeer Village Square	47,900,000	5.7	Retail	199,245	240	1.89x	7.9%	62.1%
7	City Hyde Park	47,000,000	5.6	Mixed Use	180	622,222	1.06x	6.7%	73.8%
8	Downtown Winter Haven Portfolio	39,000,000	4.6	Various	385,612	101	1.69x	11.3%	70.2%
9	Tysons Tower	35,000,000	4.1	Office	528,730	359	3.07x	11.0%	52.1%
10	Legends at Village West	34,948,301	4.1	Retail	702,750	171	1.67x	9.5%	53.3%
	Top 10 Total / Wtd. Avg.	**$508,598,301**	**60.1%**				**2.42x**	**10.3%**	**60.2%**
	Remaining Total / Wtd. Avg.	338,013,191	39.9				2.15x	9.7%	60.7%
	Total / Wtd. Avg.	**$846,611,492**	**100.0%**				**2.31x**	**10.1%**	**60.4%**

EXHIBIT 27-3

Top 10 Geographic Locations of Benchmark 2019-B15 Transaction

State	Property Count	Aggregate Cut-Off Date Balance[1]	% of Trust Balance	Cut-Off Date LTV	Cut-Off Date DSCR	Maturity/ARD Date LTV	Wtd. Avg. Coupon
California	4	$173,450,000	20.5%	51.0%	3.08x	51.0%	3.249%
Illinois	3	124,838,639	14.7	67.6%	1.47x	60.7%	4.162%
New York	9	88,300,000	10.4	54.6%	2.38x	54.6%	3.512%
North Carolina	2	73,950,000	8.7	68.7%	2.84x	68.1%	3.518%
Ohio	2	69,977,484	8.3	63.8%	2.33x	59.0%	4.371%
Florida	22	56,500,000	6.7	65.8%	1.85x	61.6%	4.201%
Texas	3	42,763,249	5.1	68.6%	1.87x	53.6%	3.923%
Massachusetts	14	41,243,750	4.9	53.7%	2.29x	50.3%	3.809%
Virginia	1	35,000,000	4.1	52.1%	3.07x	52.1%	3.330%
Kansas	1	34,948,301	4.1	53.3%	1.67x	48.3%	3.860%
Other	26	105,640,069	12.4	65.6%	1.98	60.4%	3.725%
Total	**87**	**$846,611,492**	**100.00%**	**60.4%**	**2.31x**	**56.9%**	**3.740%**

(1) Calculated based on the mortgaged property's allocated loan amount for mortgage loans secured by more than one mortgaged property.

(2) LTV and DSCR calculations reflect the aggregate values without any reduction for the pari passu companion loan(s).

EXHIBIT 27-4

Property Type Concentrations in the Benchmark 2019-B15 Transaction

Property Type/Detail	Property Count	Aggregate Cut-Off Date Balance	% of Trust Balance	Cut-Off Date LTV	Cut-Off Date DSCR	Maturity/ARD Date LTV	Wtd. Avg. Coupon
Office	**17**	**345,447,917**	**40.8%**	**58.5%**	**2.79x**	**57.1%**	**3.435%**
Suburban	16	282,947,917	33.4%	62.7%	2.51x	61.0%	3.531%
CBD	1	62,500,000	7.4%	39.1%	4.09x	39.1%	3.005%
Mixed Use	**15**	**172,014,991**	**20.3%**	**58.9%**	**2.27x**	**55.2%**	**3.981%**
Multifamily/Retail	2	72,000,000	8.5%	62.0%	1.96x	58.0%	4.026%
Office/Retail	3	64,905,997	7.7%	59.4%	2.52x	55.6%	3.927%
Office/Laboratory	3	20,000,000	2.4%	37.1%	3.12x	37.1%	3.797%
Multifamily/Office	1	7,250,000	0.9%	70.4%	1.32x	62.5%	4.070%
Retail/Office	4	5,780,118	0.7%	70.2%	1.69x	64.2%	4.390%
Office/Multifamily	1	1,566,180	0.2%	70.2%	1.69x	64.2%	4.390%
Retail/Multifamily	1	512,696	0.1%	70.2%	1.69x	64.2%	4.390%
Retail	**12**	**147,344,537**	**17.4%**	**62.6%**	**1.71x**	**53.8%**	**3.851%**
Anchored	6	144,085,758	17.0%	62.4%	1.71x	53.6%	3.839%
Unanchored	3	2,366,829	0.3%	70.2%	1.69x	64.2%	4.390%
Single Tenant Retail	3	891,950	0.1%	70.2%	1.69x	64.2%	4.390%

(Continued)

EXHIBIT 27-4

Property Type Concentrations in the Benchmark 2019-B15 Transaction (*Continued*)

Property Type/Detail	Property Count	Aggregate Cut-Off Date Balance	% of Trust Balance	Cut-Off Date LTV	Cut-Off Date DSCR	Maturity/ARD Date LTV	Wtd. Avg. Coupon
Multifamily	**9**	**90,135,000**	**10.6%**	**60.9%**	**2.03x**	**60.9%**	**3.806%**
Mid Rise	8	66,800,000	7.9%	61.5%	1.90x	61.5%	3.823%
Garden	1	23,335,000	2.8%	59.4%	2.40x	59.4%	3.760%
Industrial	**29**	**45,101,563**	**5.3%**	**69.4%**	**1.51x**	**62.8%**	**3.820%**
Warehouse/Distribution	22	25,368,750	3.0%	69.4%	1.51x	62.8%	3.820%
Manufacturing	2	15,281,250	1.8%	69.4%	1.51x	62.8%	3.820%
Warehouse	5	4,451,563	0.5%	69.4%	1.51x	62.8%	3.820%
Hospitality	**3**	**38,667,484**	**4.6%**	**63.4%**	**2.22x**	**57.4%**	**4.606%**
Full Service	2	26,977,484	3.2%	60.5%	2.19x	56.9%	4.934%
Extended Stay	1	11,690,000	1.4%	70.0%	2.28x	58.7%	3.850%
Self Storage	**1**	**4,500,000**	**0.5%**	**71.4%**	**1.45x**	**61.8%**	**4.010%**
Other – Leased Fee	**1**	**3,400,000**	**0.4%**	**58.6%**	**1.78x**	**58.6%**	**4.700%**
Total/Avg./Wtd. Avg.[(3)]	**87**	**846,611,492**	**100.0%**	**60.4%**	**2.31x**	**56.9%**	**3.740%**

EXHIBIT 27-5

Stratification of the Amortization Features of the Mortgage Loans in the Benchmark 2019-B15 Transaction

Amortization Type	Loan Count	Aggregate Cut-Off Date Balance	% of Trust Balance	Cut-Off Date LTV	Cut-Off Date DSCR	Maturity/ARD Date LTV	Wtd. Avg. Coupon
Amortizing (25 Years)	2	$42,838,639	5.1%	69.1%	1.46x	49.3%	3.767%
Amortizing (30 Years)	5	91,497,853	10.8	60.9%	1.74x	52.6%	4.151%
Amortizing (50 Years)	1	50,000,000	5.9	61.9%	2.62x	57.1%	3.980%
Interest Only, Then Amortizing(2)	7	166,140,000	19.6	70.9%	1.48x	64.1%	4.214%
24 Initial IO Period	1	11,690,000	1.4%	70.0%	2.28x	58.7%	3.850%
36 Initial IO Period	1	4,500,000	0.5	71.4%	1.45x	61.8%	4.010%
48 Initial IO Period	1	7,250,000	0.9	70.4%	1.32x	62.5%	4.070%
60 Initial IO Period	4	142,700,000	16.9	71.0%	1.42x	64.7%	4.258%
Interest Only	17	496,135,000	58.6	55.9%	2.74x	55.9%	3.479%
Total/Wtd. Avg.	**32**	**$846,611,492**	**100.00%**	**60.4%**	**2.31x**	**56.90%**	**3.74%**

EXHIBIT 27-6

Loan Combinations in the Benchmark 2019-B15 Transaction

Property Name	Cut-Off Date Loan Balance	% of Trust Balance	Aggregate Pari Passu Companion Loan Cut-Off Date Balance	Aggregate Subordinate Companion Loan Cut-Off Date Balance	Loan Combination Cut-Off Date Balance	Servicing of Loan Combination[1]	Type of Loan Combination[2]	Controlling Note Included in Transaction (Y/N)
Innovation Park	$67,250,000	7.9%	$115,000,000	–	$182,250,000	Serviced	Pari Passu	Y
Century Plaza Towers	$62,500,000	7.4%	$837,500,000	$300,000,000	$1,200,000,000	Outside Serviced	Pari Passu-AB	N
Harvey Building Products	$50,000,000	5.9%	$110,000,000	–	$160,000,000	Outside Serviced	Pari Passu	N
Austin Landing Mixed-Use	$50,000,000	5.9%	$38,750,000	$26,000,000	$114,750,000	Serviced	Pari Passu-AB	Y[3]
City Hyde Park	$47,000,000	5.6%	$65,000,000	–	$112,000,000	Outside Serviced	Pari Passu	N
Tysons Tower	$35,000,000	4.1%	$155,000,000	–	$190,000,000	Outside Serviced	Pari Passu	N
Legends at Village West	$34,948,301	4.1%	$84,874,444	–	$119,822,745	Outside Serviced	Pari Passu	N
Elston Retail Collection	$29,938,639	3.5%	$39,918,185	–	$69,856,824	Outside Serviced	Pari Passu	N
600 & 620 National Avenue	$28,950,000	3.4%	$108,950,000	–	$137,900,000	Outside Serviced	Pari Passu	N
The Essex	$25,000,000	3.0%	$92,000,000	$58,000,000	$175,000,000	Outside Serviced	Pari Passu-AB	N
Osborn Triangle	$20,000,000	2.4%	$410,000,000	$145,000,000	$575,000,000	Outside Serviced	Pari Passu-AB	N

(Continued)

EXHIBIT 27-6

Loan Combinations in the Benchmark 2019-B15 Transaction (*Continued*)

Property Name	Cut-Off Date Loan Balance	% of Trust Balance	Aggregate Pari Passu Companion Loan Cut-Off Date Balance	Aggregate Subordinate Companion Loan Cut-Off Date Balance	Loan Combination Cut-Off Date Balance	Servicing of Loan Combination(1)	Type of Loan Combination(2)	Controlling Note Included in Transaction (Y/N)
Sunset North	$20,000,000	2.4%	$130,000,000	–	$150,000,000	Outside Serviced	Pari Passu	N
Hilton Cincinnati Netherland Plaza	$19,977,484	2.4%	$52,440,895	–	$72,418,379	Outside Serviced	Pari Passu	N
8 West Centre	$18,173,249	2.1%	$25,961,785	–	$44,135,034	Outside Serviced	Pari Passu	N

(1) Loans marked as “Serviced” are serviced pursuant to the terms of the Benchmark 2019-B15 transaction. Loans marked as “Outside Serviced” are serviced pursuant to the terms of another CMBS transaction which is usually the transaction where the first note of a loan combination is securitized.

(2) Pari passu means the other notes are in equal priority to the loan in this transaction. Pari Passu-AB means there is junior debt in the loan combination as well.

(3) Should control rights transfer from the B note to the A note, this transaction will control the loan servicing.

The Century Towers Mortgage Loan is a complex loan that the loan originator securitized among several CMBS transactions. A substantial portion of the $1.2 billion loan was securitized in CPTS 2019-CPT (a SASB deal). This $825 million transaction included a $525 million senior note and the $300 million B note. The other six senior notes are pari passu with the senior loan securitized in CPTS 2019-CPT and the B note provides credit support to all the senior loans as show in Exhibit 27-7. Exhibit 27-7 illustrates the loan structure.

By performing due diligence on the largest 10 loans in a CMBS transaction, CMBS investors can understand the credit risk profiles of approximately 35% to 70% of the collateral.

CMBS TRUST STRUCTURE

CMBS transactions begin with the origination of commercial mortgage loans by loan originators. Various insurance companies, specialty finance companies, conduits, GSEs, and banks have served as mortgage loan originators for CMBS transactions. Mortgage loans are sold by the originators to a depositor entity to facilitate the legal isolation of the mortgage loans. The depositor typically forms a common law trust via a Pooling and Servicing Agreement and transfers the mortgage loans to the trust. The trust issues certificates to investors in an aggregate amount that equals the cut-off balance of the mortgage loans. There is typically no over- or under-collateralization of CMBS trusts.

The rating agencies are engaged early in the transaction structuring process to review the proposed loan pool and provide preliminary certificate subordination levels for a CMBS transaction. Mortgage loan originators provide each rating agency with data and loan files to assist the rating agencies with performing their loan due diligence and site visits for properties securing mortgage loans. Rating agencies perform due diligence on the underlying loans and properties, including site visits, to determine the subordination levels required to achieve specific ratings. The issuer and transaction underwriters prepare various documentation for the transaction including the prospectus, pooling and servicing agreement (PSA), and Annex A, which contains detailed information about the underlying loans in the collateral pool. The transaction underwriters market the CMBS certificates to potential investors. The transaction underwriters acquire the certificates from the trust on the transaction settlement date and transfer the certificates to the investors. Exhibit 27-8 illustrates the relationships between the standard transaction participants.

Prior to the 2008 financial crisis, CMBS transactions consisted of tranches at every rating notch resulting in thin classes susceptible to being completely written down in the event a large loan experienced significant loss. Subsequent to the 2008 financial crisis, CMBS issuers have simplified capital structures by creating thicker classes that are better able to withstand the default of a single

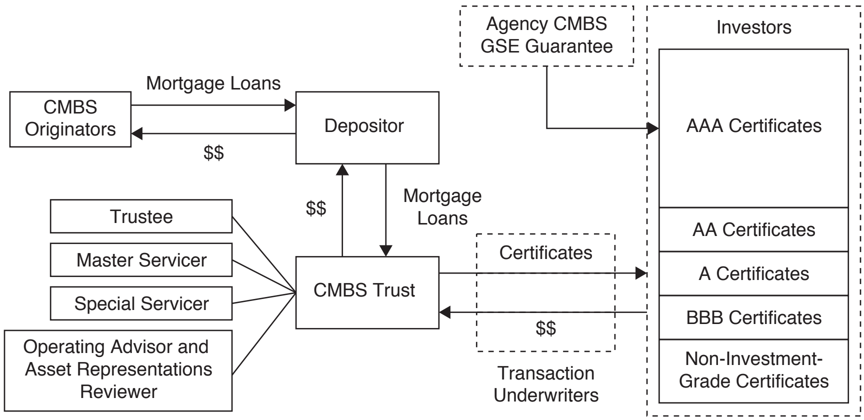
EXHIBIT 27-7

Loan Structure of the Century Towers Mortgage Loan

Note 1	Note 2	Note 3	Note 4	Note 5	Note 6	Note 7
$525.0MM	$62.5MM	$105.0MM	$50.0MM	$105.0MM	$105.0MM	$105.0MM
CPTS 2019-CPT Controlling note and servicer for this transaction services entire loan	Sold into Benchmark 2019-B15	Sold in BANK 2019-BN23	Sold in CF 2019-CF3	Sold in JPMDB 2019-COR6	Sold in UBSCM 2019-C18	Sold in COMM 2019-GC44
B Note $300.0MM Sold in CPTS 2019-CPT						

EXHIBIT 27-8

Diagram of Mortgage Loan Transfer, Certificate Issuance, and Transaction Participants



loan. Exhibit 27-9 illustrates typical CMBS certificate structures before and after the 2008 financial crisis.

TRANSACTION PARTICIPANTS

Post-securitization, several parties are involved in the administration and management of a CMBS trust. The trustee is the administrator of the assets and liabilities of the CMBS trust and fulfills a variety of responsibilities. The trustee calculates and distributes principal and interest payments to CMBS certificate holders, prepares and discloses periodic remittance data, and maintains the trust's books and records. In certain cases, the trustee also provides support to the master servicer if the latter is unable to fulfill its responsibilities. The trustee receives a fee from the monthly interest income generated by the collateral for performing its duties. The trustee fee is senior to certificate holder interest payments. The trustee can also earn additional income by reinvesting cash flows received from the servicer that will be transferred to certificate holders at a later date (i.e., float).

The master servicer collects loan payments for distribution to the trustee in addition to performing basic servicing duties such as management of escrows, reserves, and lockboxes. The master servicer collects and provides periodic loan performance data and property financials to the trustee and rating agencies. When a loan becomes delinquent or distressed, the master servicer transfers its servicing duties to a special servicer that focuses on workout and loss mitigation activities. The master servicer continues to advance principal and interest on the delinquent loan to the trust as long as the advances are deemed to be recoverable upon loan workout. The master servicer also receives a fee that is generally a few basis

EXHIBIT 27-9

Illustration of CMBS Certificate Subordination Levels and Ratings Before and After the 2008 Financial Crisis

Before 2008 Financial Crisis: WBCMT 2007-C32

Class Type	Tranche	Rating	Balance (mm)	% of Transaction	Sub Rate
Senior AAA	A-1	AAA	$26	0.7%	30.00%
	A-2	AAA	946	24.7	30.00%
	A-PB	AAA	63	1.6	30.00%
	A-3	AAA	949	24.8	30.00%
	A-4FL	AAA	250	6.5	30.00%
	A-1A	AAA	443	11.6	30.00%
Junior AAA	A-MFL	AAA	382	10.0	20.00%
	AJ	AAA	253	6.6	13.38%
	B	AA+	43	1.1	12.25%
	C	AA	48	1.2	11.00%
	D	AA–	29	0.8	10.25%
	E	A+	29	0.8	9.50%
Mezzanine	F	A	38	1.0	8.50%
	G	A–	43	1.1	7.38%
	H	BBB+	48	1.3	6.13%
	J	BBB	53	1.4	4.75%
	K	BBB–	33	0.9	3.88%
Credit	L	BB+	19	0.5	3.38%
	M	BB	10	0.2	3.13%
	N	BB–	14	0.4	2.75%
	O	B+	10	0.2	2.50%
	P	B	10	0.3	2.25%
	Q	B–	10	0.3	2.00%
	S	NR	76	2.0	0.00%
Interest-Only	IO	AAA	3,824	NAP	NAP
Total			**$3,824**	**100.0%**	

(Continued)

points of the outstanding mortgage balance. The master servicer's fee, similar to the trustee's fee, is also senior to certificate holder interest payments. The master servicer can also earn additional income by reinvesting underlying mortgage cash flows for a period of time prior to transferring to the trustee (i.e., float).

The special servicer manages distressed loans, which may be in delinquency, bankruptcy, foreclosure, etc. The determination of a distressed loan is typcially made by the master servicer, who then transfers the loan to the special servicer

EXHIBIT 27-9

Illustration of CMBS Certificate Subordination Levels and Ratings Before and After the 2008 Financial Crisis (*Continued*)

Modern CMBS Transaction: Benchmark 2019-B15

Class Type	Tranche	Rating	Balance ($mm)	% of Deal*	Sub Rate*
AAA	A-1	AAA	$15,769	1.9%	30.000%
	A-2	AAA	48,560	5.7%	30.000%
	A-AB	AAA	24,285	2.9%	30.000%
	A-3	AAA	24,167	2.9%	30.000%
	A-4	AAA	75,000	8.9%	30.000%
	A-5	AAA	385,107	45.5%	30.000%
	A-S	AAA	61,380	7.3%	22.500%
Mezzanine	B	AA–	40,921	4.8%	17.500%
	C	A–	36,829	4.4%	13.000%
Credit	D	BBB	23,529	2.8%	10.125%
	E	BBB–	17,394	2.1%	8.000%
	F	BB–	21,483	2.5%	5.375%
Risk Retention	G-RR	B–	8,184	1.0%	4.375%
	J-RR	NR	35,806	4.2%	0.00%
	VRRI*	NR	28,200	3.3%	0.00%
Interest-Only	X-A*	AAA	634,268	NAP	NAP
	X-B*	AA	40,921	NAP	NAP
	X-D	BBB–	40,920	NAP	NAP
	X-F	BB–	21,483	NAP	NAP
Total			**$846,611**	**100.0%**	

*Although the approximate initial credit support percentages shown in the table above with respect to the non-vertically retained principal balance certificates do not take into account the VRR Interest, losses incurred on the mortgage loans will be allocated between the VRR Interest, on the one hand, and the non-vertically retained principal balance certificates, on the other hand, pro rata in accordance with their respective outstanding certificate balances.

for timely resolution and implementation of workout procedures. The special servicer's responsibility to the CMBS trust is to maximize recovery value of the distressed loan. The special servicer receives a monthly fee during the loan workout period based on the outstanding loan balance. The special servicer also receives compensation for a loan resolution, depending on whether a loan is liquidated or modified. Similar to the trustee and master servicer fees, the payments due to the special servicer are paid prior to allocating cash flows to the certificate holders.

The operating advisor was added after the 2008 financial crisis to help provide oversight of the special servicer and to represent the interests of all shareholders. After transaction losses reach a certain threshold, the special servicer is generally required to consult with the operating advisor regarding loan workout strategies. The operating advisor may recommend the replacement of the special servicer to certificate holders. The asset representation reviewer is a transaction participant added pursuant to SEC Regulation AB. Upon breaching a specified delinquency threshold and/or upon a certificate holder vote, the asset representation reviewer reviews delinquent or defaulted mortgage loans to confirm whether any loan seller representations were breached. If a loan seller breaches a representation and cannot cure the breach, the trust can request the loan seller repurchase the loan at par plus accrued interest and expenses.

CMBS transactions typically designate the most subordinate tranche as the controlling certificate holder, also referred to as the B-Piece Buyer. Since the controlling certificate holder is in the first loss position if the CMBS transaction sustains losses from a defaulted loan, the controlling certificate holder (via the controlling class representative) is empowered to make certain decisions. The controlling class representative is typically granted the power to (1) replace the special servicer and (2) approve the disposition plan for loans in special servicing. These control rights migrate to the class immediately senior to the current controlling certificate holder if the controlling certificate holder sustains losses in excess of 75% of its original certificate balance. Prior to 2000 and after 2008, CMBS transactions typically require the control rights to pass to the next most senior certificate holder when principal losses and ARAs (defined below) exceed 75% of the controlling certificate holder's original certificate balance. In contrast, CMBS transactions issued from 2000 through 2008 allowed the controlling certificate holder to remain in place even when principal write downs in excess of 75% of the controlling certificate holders original certificate balance were imminent.

TRANSACTION FEATURES

CMBS issuers generally incorporate a standard set of transaction features regardless of vintage. CMBS transaction features have evolved since the 1990s with issuers incorporating changes to meet investor demands and new risk retention requirements.

Subordination and Risk Retention

CMBS certificates are modeled along time and credit dimensions to create a "capital structure" with varying cash-flow and risk profiles that cater to different investors. For example, senior certificates typically have priority to principal payments, and therefore, are the shortest certificates in a transaction. Junior certificates are subordinate to senior tranches with respect to principal cash flows and are also first in line to absorb collateral losses. The subordination rate, which is a measure of credit support for a certificate, is defined as the percentage of the collateral balance that must experience a complete principal write-down before the certificate in question is exposed to principal loss. Subordination rates are highest for the senior most certificates in the transaction and decrease down the capital structure.

Conduit transactions have three distinct categories of principal-pay certificates—AAA classes, mezzanine classes, and junior credit classes—with one or more interest-only (IO) certificates. Prior to 2008, the AAA classes were generally further divided into three different subordination levels starting with super-dupers (senior-most tranches in the transaction—classes A1 through A4 in Exhibit 27-9) at the top of the capital structure having attained the highest subordination rates (usually 30%), followed by mezzanine AAA (the AM class), and junior AAA (the AJ class) certificates. After 2009, dealers simplified AAA certificate structures. The AAA classes are divided into two subordination levels starting with Senior AAA at the top followed by mezzanine or junior AAA (the AS class).

The senior AAA certificates constitute approximately 70% of the transaction principal balance and are the senior most certificates in the transaction. A typical conduit transaction has six senior classes—A1, A2, A3, A4, A5, and A-AB—each with a different cash-flow profile. The A1 certificate, which is the first-pay AAA, is the shortest certificate in the transaction with a WAL of approximately two years. The A1 also amortizes gradually over time, unlike the A2 and A3 certificates, which have bullet-like principal cash-flow profiles because these certificates are usually tied to five- or seven-year balloon loans. In order to maintain the bullet cash-flow profile of the medium-term AAAs, the A-AB tranche absorbs amortizing principal cash flow between the maturities of the A2 and A3 classes. Similar to the A2 and A3 classes, the A4 and A5 certificates also have a bullet-like principal cash-flow profile tied to 10-year balloon mortgages. The A4 certificates are paid down first in the event of unscheduled principal prepayments from the 10-year loans. The A5 certificate is typically the largest of the AAA classes and also has the longest WAL. The A5 class is often referred to as the benchmark certificate, or "last cash flow" of the transaction.

The mezzanine AAA class (the AS certificates) are usually structured with 18.0% to 22.5% subordination and are also modelled to receive principal from balloon loans with a bullet-like principal cash-flow profile. Most certificates subordinate to the AAA-rated classes are typically rated between AA and BBB– and constitute a smaller portion of the original transaction balance. These certificates are also generally modelled to 10-year balloon payments. CMBS transactions can also include tranches rated below BBB– or unrated first-loss classes known as B-pieces. These tranches are modelled to receive principal from the longest maturity loans in the collateral pool. The B-piece is generally the controlling class and retains certain voting rights that allow them to replace the special servicer.

Government regulation under the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank) significantly impacted CMBS subordination structures. Starting December 24, 2016, CMBS transactions had to comply with the Dodd-Frank Risk Retention rule, which requires securitization sponsors retain 5% of the market value of a transaction to better align the interests of sponsors with those of investors. The risk retention requirements can be satisfied using three methods. First, the issuer can retain a vertical option that equates to a piece of every security in the capital structure such that the total retained amount is equal to 5% of market value. Second, the issuer can retain a horizontal option equating to the most junior 5% first loss tranche. Finally, in the L-shape hybrid option, the issuer can retain a combination of vertical and horizontal interests such that the total interest achieves the 5% level. Transactions sponsors have utilized each of these options with horizontal and hybrid structures being most prevalent.

Dodd-Frank granted an exception to the risk retention rule that allows a B-piece buyer to fulfill the risk retention requirement if certain conditions are met. Regulators recognized that B-piece buyers are sophisticated institutional investors who perform extensive loan-level due diligence and have an alignment of interest with senior investors. B-piece buyers must hold the risk retention certificates for at least five years and they cannot finance the certificates to reduce their credit exposure (interest rate and currency hedges are allowed).

Pass-Through Rates

Traditional conduit transactions are structured such that the net weighted average coupon of the collateral (the assets) exceeds the weighted average coupon of the certificates (the liabilities). The net weighted average coupon of the collateral equals the weighted average coupon of the collateral less the fees payable to the trustee and master servicer. This structure results in excess interest cash flow which is directed to the IO tranches. IOs by definition do not receive any principal.

Conduit CMBS certificates can have three types of coupon structures: fixed-rate, WAC (weighted average coupon), and WAC-capped. Most CMBS tranches pay a fixed-rate coupon. WAC certificates pay the weighted average net coupon of the collateral, which can vary over time as the composition of the collateral pool changes. WAC-capped certificates pay the minimum of a fixed-rate and the WAC rate and are generally lower in the capital structure.

Priority of Payments

In general, given the relative simplicity of CMBS capital structures, the allocation of cash flows and losses across the capital stack—known as the "waterfall structure"—is fairly straightforward. The A-AB tranche adds a layer of complexity, which is described in detail below.

Principal payments are allocated sequentially from the top of the capital structure to the bottom. Principal cash flows are generated from loan maturities, scheduled amortizations, prepayments, and default recoveries. The sequential payment structure implies that in general a certificate will receive principal payments only if the tranches senior to it in the capital structure have completely paid off.

The A-AB tranche first receives principal in accordance with its amortization schedule and any excess is diverted to the A1, A2, A3, A4, and A5 classes in sequential order. The A1 tranche (which is the first-pay certificate) receives principal payments only if the A-AB tranche has received its allocated principal to date. Following the sequential structure, the A2 class does not receive any principal until the A1 class has been fully paid off, the A3 class does not receive any principal until the A2 class has been paid off, the A4 class does not receive any principal until the A3 class has been paid off, and the A5 class does not receive any principal until the A4 class has been paid off.

While principal is allocated in "top-down" fashion, losses are allocated "bottom-up" in reverse-sequential order. Given that the credit enhancement in a CMBS transaction is in the form of subordination, a particular tranche will not experience losses until the certificates underneath it in the capital structure are completely written down. It is important to note that all the senior AAA certificates in a transaction share the same level of subordination. As a result, although principal cash flows are allocated sequentially to the senior AAA certificates, losses are allocated pro-rata across the senior AAA certificates after the more junior tranches experience complete principal write downs. Interest payments are allocated pro rata to the senior AAA certificates and to the IO tranche and then sequentially to the rest of the certificates. Interest cash flows are a function of current debt service payments plus any late interest payments from prior periods, received in the current period.

Exhibit 27-10 illustrates the certificate subordination and priority of payments for the Benchmark 2019-B15 transaction.

Interest-Only Certificates

Most CMBS transactions also have an IO tranche. As mentioned, the weighted average coupon that is paid to all the non-IO tranches is generally less than the total interest from the collateral pool. This excess interest is allocated to the IO tranche, once all the non-IO tranches in the trust have received their allocation of the interest payments. The notional balance of the IO tranche may be based on the aggregate balance of the AAA tranches alone or on the entire transaction, depending on the level of the coupon being stripped off of various tranches.

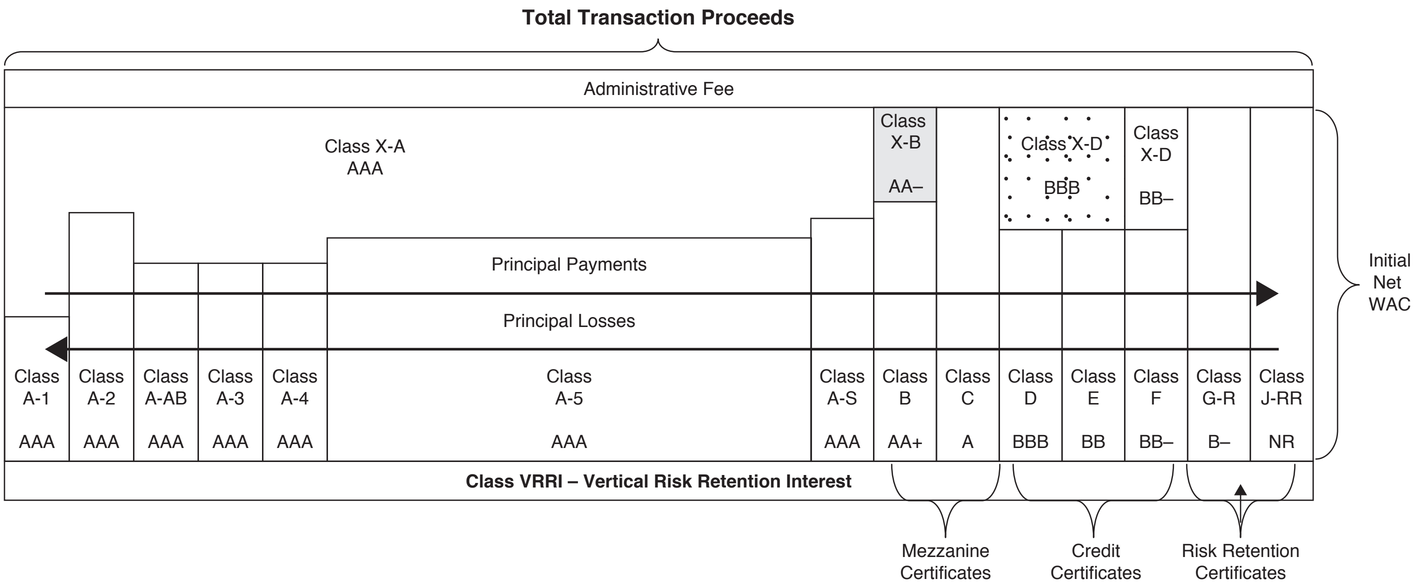
If the difference between the collateral and certificate coupons is substantial, transactions may contain a planned amortization class (PAC) IO structure, where multiple classes of IOs exist, with one class of IO certificates treated as support bonds to absorb the impact of prepayments so that the PAC IO investor receives stable cash flow and low yield variability.

Payment Advancing and Appraisal Reductions

When a loan becomes delinquent, the master servicer is generally obligated to advance principal and interest to the trust to minimize the variability in monthly cash flows to the certificate holders. However, the amount the servicer advances is based on whether it deems the advanced amounts to be

EXHIBIT 27-10

Benchmark 2019-B15 Certificate Structure



recoverable upon liquidation. In order to determine the advanced amount, the servicer hires an appraiser who appraises the property. A haircut (typically 10%) is applied to the appraisal amount and compared to the outstanding loan balance at the time of delinquency. The servicer then advances payments based on the lower of the outstanding loan balance and the adjusted appraised value. This difference is called an *Appraisal Reduction Amount* (ARA). If the delinquency level in a trust is fairly high or if appraised values are substantially lower than the outstanding loan balances, there could be a situation in which interest shortfalls could result to the trust since the servicer's advances are not enough to cover interest payable to all certificate holders. Once the loan is liquidated, proceeds from the liquidation will go first to the servicer to reimburse servicing advances.

Clean-Up Call Provisions

Each CMBS transaction includes a clean-up call provision that enables the outstanding certificate holders to purchase the remaining mortgage loans in a trust. The clean-up call is usually limited to when the remaining balance of mortgage loans represents approximately 1% and 3% of the original balance of the trust. The purchase price is typically the outstanding balance of the mortgage loans plus accrued interest. The clean-up call is utilized to wind down CMBS transactions when the balance remaining in the transaction is too small to justify the ongoing administration costs.

MARKET DEVELOPMENT

The CMBS market developed in the early 1990s with the need to dispose of commercial real estate loans owned by the Resolution Trust Corporation (RTC) as a consequence of the savings and loan crisis. The RTC packaged loans from failed institutions into CMBS transactions using a Real Estate Mortgage Investment Conduit (REMIC) structure under the tax code. This provision was passed as part of the Tax Reform Act of 1986 and allows tranches of securities that would otherwise be treated as equity interests to be treated as debt instruments. The CMBS market grew quickly in the 1990s, culminating in issuance of $74 billion in 1998. The Russian debt crisis and related contagions created substantial turmoil in the debt markets in August 1998, causing a temporary slowdown in CMBS issuance. Transaction volume surpassed 1998 levels in 2003 and CMBS issuance underwent explosive growth through 2007 with $228 billion of issuance as demand for spread products remained elevated.

Beginning in late 2007 with spreads widening and contagion from the subprime crisis spreading, issuers curtailed loan originations, in part due to their inability to hedge credit-spread risk in a spread-widening environment. Issuers delivered nine transactions in 1H-2008 with the CMBS market seizing up in July 2008. No private-label transactions were brought to market until Q4-2009, when the only TARP-eligible securitization was sold to the market. In 2010, the market slowly experienced increased transaction volume with total annual private issuance of approximately $13 billion. Since the 2008 financial crisis, the agency CMBS market has significantly increased in volume compared to pre-crisis offerings. The private-label CMBS market returned to volumes ranging from $70 to $100 billion but never regained the momentum of CMBS 1.0 originations. The CMBS 1.0 deal performance worsened in later vintages, with dozens of junior AAA certificates and at least two mezzanine AAA certificates experiencing losses from the 2005–2008 vintages. This experience validates the modern conduit CMBS structure with mezzanine AAA certificates generally being the lowest offered AAA security with subordination of 18.0–22.5%.

Exhibit 27-11 sets forth historical CMBS origination volumes.

EXHIBIT 27-11

Historical Annual CMBS Origination Volume

Era	Year	Private Label U.S. CMBS[1] ($ Billions)	Agency CMBS[2] ($ Billions)
CMBS 1.0	2001	66	5
	2002	51	7
	2003	76	8
	2004	93	6
	2005	166	5
	2006	196	7
	2007	228	3
	2008	10	4
	2009	0	7
CMBS 2.0	2010	13	23
	2011	30	35
	2012	44	54
	2013	81	63
	2014	88	53
	2015	94	66
	2016	69	80
Risk Retention	2017	87	94
	2018	76	94
	2019	97	102

Source: BlackRock Solutions

1. Private label U.S. CMBS data in this document does not include CRE-CLOs. It is limited to Conduit, Large Loans, and Single Asset/Single Borrower.

2. Agency CMBS data does not include Fannie Mae DUS. It is limited to Freddie Mac, Fannie Mae Remics, and Ginnie Mae Project loans.

From 2001 through 2007, CMBS credit-spreads experienced a general tightening trend.[1] At the height of the market in early 2007, CMBS spreads relative to Treasuries (T) had tightened to approximately T+0.60% for 10-year senior AAA certificates and T+1.20% for BBB-rated certificates. The 2007 subprime mortgage crisis impacted CMBS pricing and in August 2007, spreads on 10-year senior AAA certificates had widened considerably (T+1.50%). Spreads on BBB-rated certificates in early 2007 were T+1.25% and subsequently widened to T+4.75% by the fall of 2007. During the 2008 financial crisis, dealers and investors began trading all certificates on dollar prices (vs. spread-based pricing) with senior AAA certificates trading at steep discounts to par value. Since the restart of the CMBS market in 2010–2011, spreads on senior AAA certificates have generally traded in a range of T+0.60% to T+1.50% and BBB-rated certificates in a range of T+2.00% to T+6.00% (other than spikes related to the 2020 COVID-19 pandemic). Spreads on lower-rated certificates have not returned to the low levels observed prior to the 2008 financial crisis. See Exhibit 27-12 for a history of CMBS spreads for AAA and BBB–certificates.

MODELING

Market participants consider two primary types of risks when analyzing CMBS—interest rate risk and credit risk. Interest rate risk is important given most certificates are fixed-rate and relatively long duration because the underlying loan maturities are in the 5- to 10-year range. Credit risk is relevant since any losses resulting from loan defaults are borne by the certificate holders.

The 0/0 Scenario

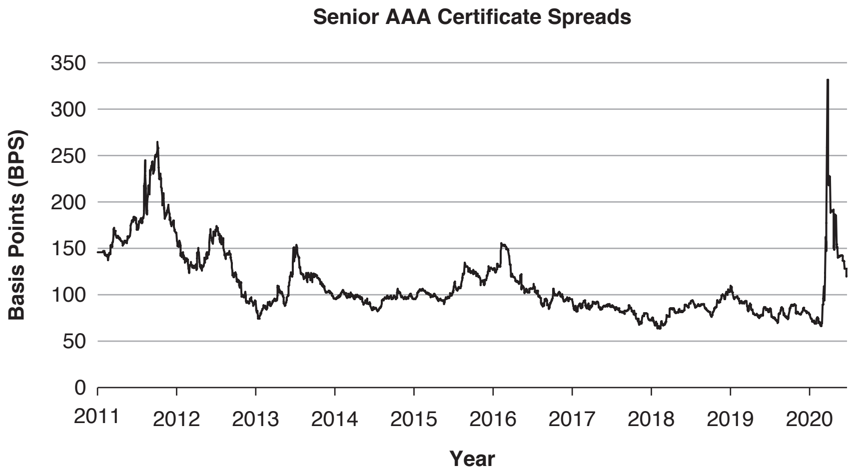
Prior to the 2008 financial crisis and subsequent downturn, commercial mortgage defaults had been low and had not impacted senior certificates. As a result, investors traditionally relied on what is referred to as a *0/0 framework,* which means zero prepayments (as measured by the conditional prepayment rate, CPR) and zero default rates (as measured by the conditional default rate, CDR), to quote CMBS prices and yields. This implies that there are no prepayments, defaults, or losses on the collateral pool. This simplistic modeling framework is often augmented with additional loan default and extension scenarios as liquidations and extensions have become more common. Prepayment risk is generally not significant for commercial mortgages due to typical prepayment restrictions at the loan level.

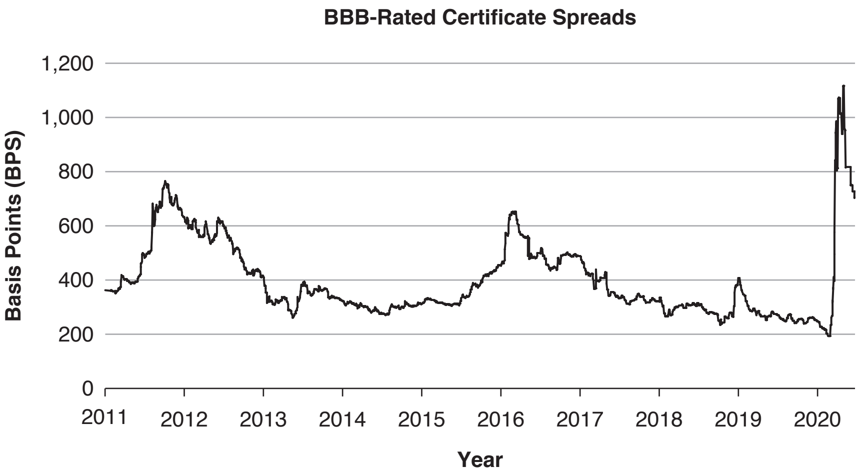
The 0/0 Scenario is important to determine when a certificate holder receives principal payments. CMBS certificates have a *Rated Final Distribution Date* that is usually three years after the amortization term of the mortgage loan with the longest amortization period. For example, the securities in the Benchmark

1. Spread information provided by Trepp LLC.

EXHIBIT 27-12

History of CMBS AAA and BBB Spreads (in Basis Points) to 10-Year U.S. Treasuries





Source: Trepp LLC.

2019-B15 transaction have a Rated Final Distribution Date of December 2072, which would indicate the investments have a 52-year term. This date was set due to one loan with a long amortization period (see Exhibit 27-5) and it would be inaccurate to model cash flows for all certificates assuming this date. CMBS transactions also disclose an *Assumed Final Distribution Date* for each tranche of offered certificates. The Assumed Final Distribute date is the date a certificate's balance would be reduced to zero assuming the 0/0 Scenario. Exhibit 27-13 sets forth the Assumed Final Distribution Dates for the publicly offered certificates in the Benchmark 2019-B15 transaction.

EXHIBIT 27-13

Assumed Final Distribution Dates for the publicly offered certificates in the Benchmark 2019-B15 transaction

Class of Certificates	Assumed Final Distribution Date
Class A-1	November 2024
Class A-2	November 2024
Class A-3	November 2026
Class A-4	October 2029
Class A-5	November 2029
Class A-AB	May 2029
Class B	November 2029
Class C	December 2029

Probabilistic Modeling

Probabilistic models attempt to draw statistical relationships between commercial loan performance and identified drivers of performance. For example, loan default and severity are generally built as a function of DSCR and LTV. All else equal, perceived credit risk is higher with higher LTV and lower DSCR. Investors attempt to project future loan performance by studying the empirical relationship between historical defaults/severities and the pool's DSCR/LTV.

Deterministic Modeling

Market participants also rely on a deterministic modeling approach. Deterministic models employ a rules-based framework in which loan outcomes are determined by projected property performance and valuation after subjecting the underlying collateral to a series of tests and triggers. Loan performance and valuation are estimated using projected DSCR and LTV (similar to probabilistic models), which in turn are calculated from NOI and cap rate. The NOI and cap rate inputs into deterministic models can vary by property type and/or geography and are typically generated using macroeconomic models that incorporate real estate fundamentals. Each mortgage loan's projected DSCR and LTV is compared through time to a set of trigger levels to discretely determine one of three possible loan outcomes: term default, timely pay-off, or maturity default/loan extension. The three loan outcomes are described in more detail below:

- *Term Default*: During the term of the mortgage loan, periodic tests are run to determine if the loan's DSCR drops below a pre-defined *DSCR default trigger and LTV default trigger.* The loan is immediately defaulted and enters a workout period if both triggers fail. At the end of the workout period, the property's terminal value is determined using NOI and cap rate, less a workout or disposition fee. If the final property value is less than the outstanding loan amount, the deficit is recorded as a loss. If the property's NOI never drops below the DSCR trigger, no default is assumed during the loan's term.
- *Timely Pay-Off*: At the loan's maturity date, property value is once again determined by applying a cap rate to projected NOI. The loan is assumed to pay off on time if the property value is sufficiently above the outstanding loan amount (e.g., LTV < 80%).
- *Maturity Defaults/Loan Extensions*: If the loan does not pay off as scheduled at maturity, it either enters into a one-time term extension or defaults. Deterministic models generally assume that the loan is extended as long as it is not underwater (LTV < 100%), whereas under-collateralized loans (LTV >100%) are assumed to default at maturity. In the case of maturity default, the property value is calculated at the end of the workout period to determine the loss amount. If the loan is extended, the pay-off versus default calculation is repeated at the end of the extension period.

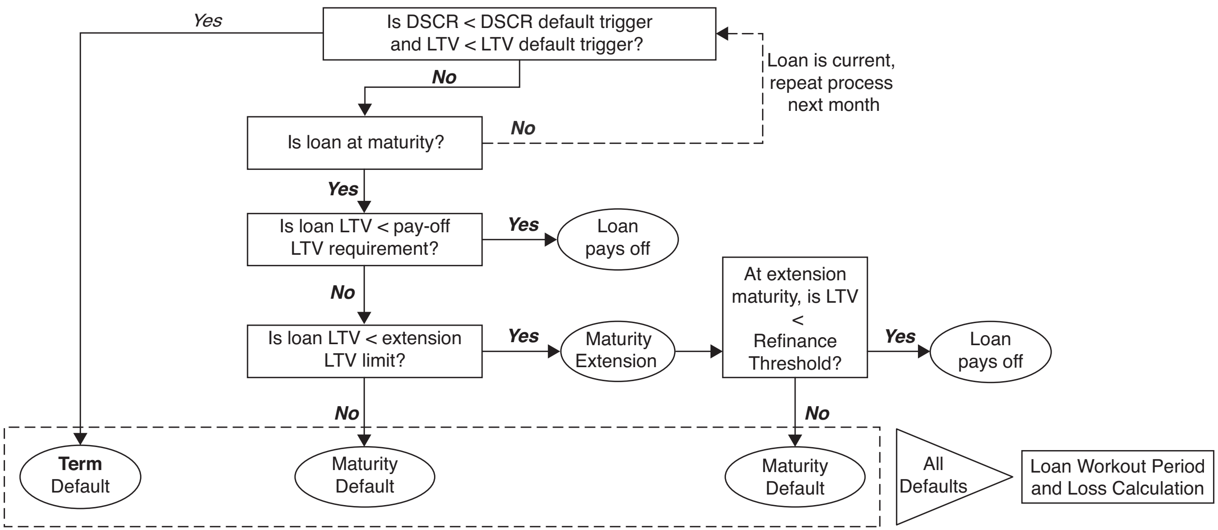
The DSCR and LTV thresholds are typically set based on a combination of observed historical performance, real estate market trends, and the participant's experience and judgment. Exhibit 27-14 is a graphical representation of a sample deterministic framework.

KEY POINTS

- There are major structural and modeling differences between CMBS and other mortgage products.
- Agency CMBS transactions have increased market share in recent years alongside private-label transactions. Agency CMBS transactions are generally backed by multifamily and healthcare facilities, while private-label transactions have office, retail, industrial, hotel, and multifamily as the primary real estate property types.
- CMBS typically have many structural features that protect senior investors from credit losses while allowing flexibility for the senior portion of the capital structure to target narrow maturity windows.

EXHIBIT 27-14

Deterministic Model Logic Tree



- Impacts of prepayments can be somewhat muted given the prepayment restrictions of most mortgage loans.
- Given the idiosyncratic nature of commercial real estate within CMBS transactions, bottom-up loan and property level analysis is necessary to understand the underlying credit and extension risks.

CHAPTER

TWENTY-EIGHT

CREDIT CARD ASSET-BACKED SECURITIES

John McElravey, CFA
Managing Partner
First XV Partners

The securitization of credit card receivables began in 1987, but truly exploded onto the fixed income scene during the mid- to late 1990s. Credit card asset-backed securities (ABS) grew rapidly over the ensuing 20 years to become the largest nonmortgage ABS sector. Primary market volume increased rapidly as large commercial banks tapped a growing pool of capital. New specialty credit card lenders used ABS to fund expansion. Credit card ABS averaged $62.5 billion per year from 2000 to 2009, and credit cards became a consumer ABS staple (Exhibit 28-1).

Because of its liquidity, transparency, and relatively high-credit-quality sponsors, credit card ABS became the benchmark for most other kinds of securitizations, and something of a safe haven for ABS investors during periods of market volatility. Indeed, many investors making their initial foray into ABS would likely dip their toes into credit cards before wading into the many other asset classes available. This chapter summarizes the key structural features of credit card securitization and provides an overview of the credit card ABS market.

As a result of the growing use of securitization, credit card ABS outstanding grew from just $131 billion in 1995 and peaked at $325 billion in 2007 (Exhibit 28-2). The size of the credit card ABS market corresponded with the growth in the credit card lending market overall. Consumers came to rely on credit cards as a convenient method of payment for an expanding universe of goods and services, as well as an easy means of accessing credit. At the same time, credit card lenders viewed direct access to funding in the capital markets as a cost-effective alternative to gathering core deposits.

However, since 2009 the amount of credit card ABS outstanding has fallen precipitously. Commercial banks have come to rely less on ABS as a source of funding for credit card loans because of an abundance of lower-cost deposits. Furthermore, regulatory incentives have been put in place that encourage other kinds of corporate debt that count for capital purposes. ABS is not included for regulatory capital purposes. Issuance of credit card ABS seems likely to lag

EXHIBIT 28-1

Credit Card ABS Issuance: 1987–2018

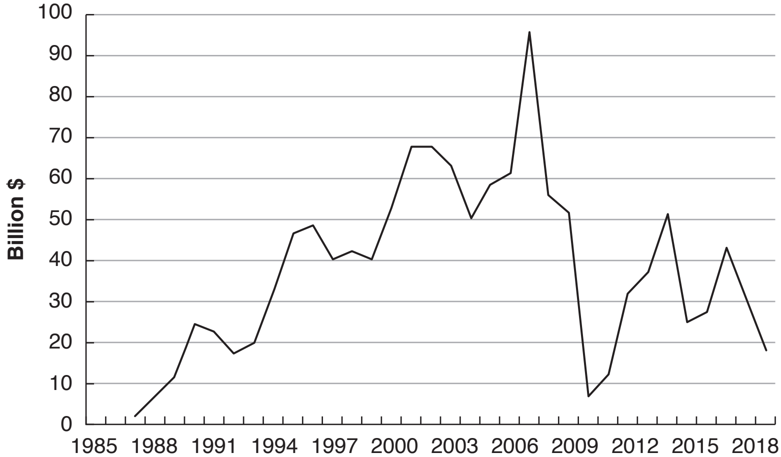
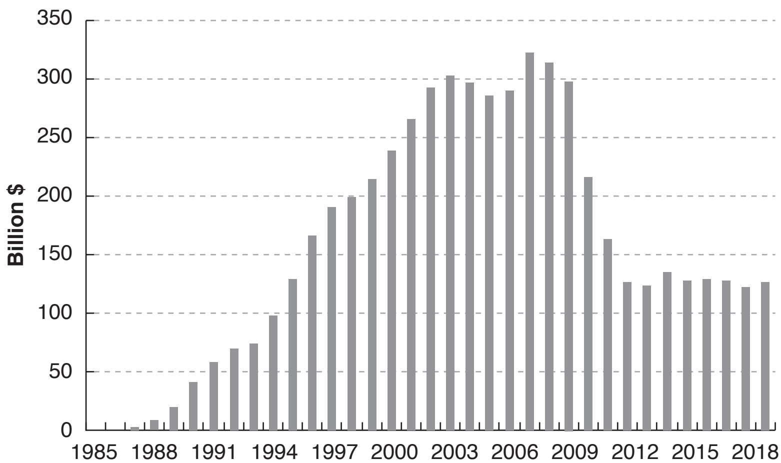


EXHIBIT 28-2

Credit Card ABS Outstanding



other sectors, such as auto loans and leases, unless receivables growth increases or other incentives for banks change. Nevertheless, credit spreads on credit card ABS remain low, and credit card spreads offer benchmark comparisons to other ABS sectors.

SECURITIZATION OF CREDIT CARD RECEIVABLES

Credit card securitizations began in the late 1980s and early 1990s by banks looking to diversify funding sources for their credit card businesses and as a way to remove assets from balance sheets. At that time, the banking industry faced the imposition of stricter capital standards by regulators. Securitization provided a vehicle to help meet these standards by reducing balance sheet assets and thereby improving regulatory capital ratios.

Beyond the beneficial capital treatment, securitization also allowed specialized credit card banks to enter the market and grow rapidly without having to rely heavily on attracting consumer deposits as a cheap funding source. These specialty banks, which included MBNA, First USA, and Capital One, were able to access the credit markets directly and achieve funding costs that were competitive with those of the established bankcard issuers. Much of the increased innovation and competition in the credit card market during the 1990s can be traced to these banks, which could not have grown as rapidly as they did without the benefits afforded by securitization.

Certain changes in accounting rules over time, namely FAS 166/167, forced most credit card securitizations back on the balance sheets of commercial banks. This move reduced or eliminated the advantageous capital treatment of securitization relative to other forms of on-balance-sheet funding. As a result, credit card ABS compete with equity, debt, and deposits to fund the credit card lending businesses of commercial banks. While it may be smaller than it was in the past, it seems likely that the credit card ABS market will remain a core segment of the consumer ABS market, and an important source of funding for some credit card lenders.

Basic Master Trust Structure

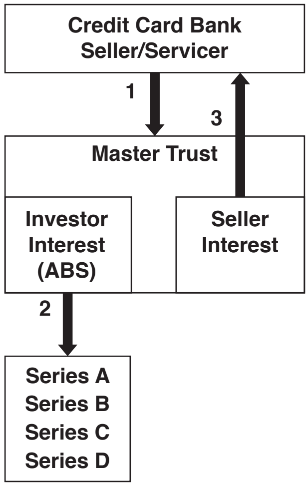
The structure used for credit card securitization until 1991 was a stand-alone trust with a dedicated pool of credit card accounts and the receivables generated by those accounts. Each securitization required a new trust and a new pool of collateral, and the securities were backed only by that collateral pool. Since 1991, the master trust has become the predominant structure in the market (Exhibit 28-3).

As the name implies, the issuer establishes a single trust that can accept periodic additions of accounts and issue multiple series of securities. All of the securities issued by the master trust are supported by the interest and principal collections from all of the receivables contributed to it. The collateral pool is not segmented to support any individual securities.

The credit card issuer, and seller/servicer of the accounts and receivables, pledges the accounts to the master trust (step 1). The master trust sells securities to investors (step 2) in various series. The investors are entitled to their share of interest and principal collections and are allocated their share of defaults and losses. At the same time, the seller/servicer maintains an interest in the master

EXHIBIT 28-3

Basic Master Trust Structure



trust called the seller interest. This seller interest is not credit enhancement for investors but is *pari passu* with investors. The seller interest receives its share of interest and principal collections and is allocated its share of defaults and losses. This is returned to the issuing bank (step 3).

For the issuer, the master trust structure reduces the cost of issuing ABS and provides greater flexibility. From the investor's point of view, assessing the credit quality of a new issue may require less analysis because there is only one pool of collateral to review. As the collateral pool in the trust grows, it generally becomes more diversified. While the characteristics of the collateral pool may change somewhat over time owing to changes in interest rates, underwriting criteria, industry competition, and so on, any change in the master trust would likely be more gradual than would the differences in stand-alone pools.

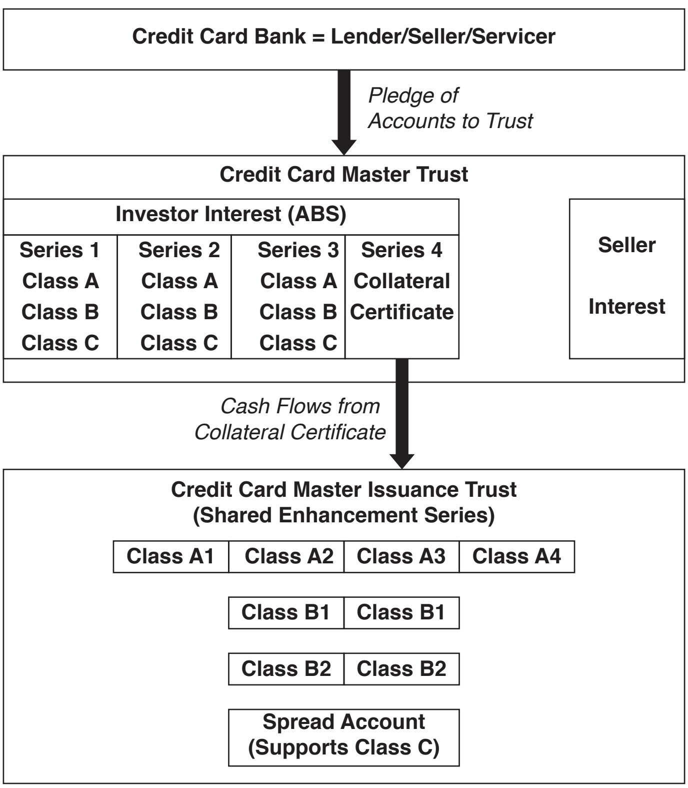
Master Note/Owner/Issuance Trust Structures

Credit card master trust structures evolved over time, and now most issuers utilize structures called master note or owner or issuance trusts. This chapter will refer to them as issuance trusts (IT). The bonds issued by an IT are still backed by a pool of revolving credit card accounts and receivables, and the credit analysis for investors is not affected in a meaningful way. However, there are important structural differences from older credit card master trusts using earlier technology. Perhaps most importantly, the IT structure provides the issuer with additional flexibility to meet investor demand for different maturities or types of bonds.

Because of consolidation in the credit card industry over time, many surviving credit card ABS issuers may have had more than one legacy credit card trust with its particular collateral pool. Exhibit 28-4 presents an example of an IT structured by an issuer active in the market with a legacy credit card master trust. Like our simple example above, the credit card bank pledges the accounts and receivables to its credit card master trust. This legacy trust has several series outstanding in the investor interest and each series has its own dedicated credit enhancement (Series 1–3). Then, the credit card bank decides to establish an MOT to take advantage of the state of the art in the securitization market. To accomplish this, the existing master trust issues a *collateral certificate* (Series 4). The collateral certificate represents an undivided interest in the assets of the legacy master trust and is allocated its proportionate share of principal collections, finance charges, defaults and losses, and servicing fees. For credit card banks with more than one legacy master trust, it is conceivable that each one could issue a collateral certificate that could be used to pass through to the IT.

EXHIBIT 28-4

Master Issuance Trust Structure



Credit card ABS issuers gravitated to the IT structure primarily for the increased flexibility that it allows when issuing new securities. Under the early master trust programs, issuers were required to issue subordinated bonds at the same time as the senior bonds. The senior and subordinated bonds were linked. However, the current credit card issuance trusts can be likened to a corporate medium-term note program. Different classes of securities can be issued at different times, in varying sizes, and with distinct maturities. This flexibility allows the issuer to be opportunistic with regard to the timing of new ABS securities, and to tailor those securities to the demands of its investor base.

This characteristic of the IT is sometimes referred to as a "delinked" issuance trust because the AAA-rated senior securities can be issued separately from the subordinated bonds that provide credit enhancement for the senior notes. The subordinated bonds are no longer directly linked to a specific series of senior bonds having the same maturity. In the IT structure, all of the outstanding subordinated classes act as credit enhancement for all the senior classes. These may be known as the *shared enhancement series*, and it can be seen in the lower section of Exhibit 28-4.

New senior bonds can only be issued to the extent that there is a sufficient amount of subordinated bonds already outstanding. For example, Class B bonds can only be issued if there is a sufficient amount of Class C bonds already outstanding to support them, and Class A bonds can only be issued to the extent there is an appropriate amount of Class B and Class C bonds. A "sufficient amount" is the amount of credit enhancement required by the rating agencies to maintain the desired credit ratings on the bonds.

Subordinated bonds may have different maturity dates than the Class A bonds. If a subordinated class matures prior to a senior class, then a replacement subordinated bond must be issued prior to the maturity to take its place. If a replacement bond cannot be issued in time to maintain the required credit enhancement, then principal collections would be deposited into an account that would support the senior bonds. Therefore, the senior bonds would always have an appropriate amount of credit enhancement outstanding. The senior bonds benefit from the subordination up to and including the required amount. They would not have the benefit of subordinated bonds issued in excess of the required amount.

The IT structure also became popular with issuers and investors because it allowed for an expansion of the potential investor base for credit card ABS, especially for the subordinated bonds. Securities could be issued as notes rather than as pass-through certificates. In doing so, all classes, including the subordinated classes, can achieve Employee Retirement Income Security Act (ERISA) eligibility. This feature is important because pension funds, a significant source of fixed income investor funds, can only buy securities that meet ERISA guidelines. In this way, the total investor base for credit card ABS was expanded, especially for subordinated bonds which very often could not achieve ERISA eligibility. Liquidity improved for subordinated bonds which had lagged the senior classes. In addition, the IT structure allows for easier and more timely execution of reverse inquiry issuance when an investor has a particular coupon or maturity need.

In practice, the issuance of subordinated bonds has stopped among the largest bank card issuers of credit card ABS. Those bank issuers have retained the subordinated bonds. Only a few issuers are continuing to make them available to outside investors, usually those without deposit taking networks. Relatively wide credit spreads on subordinated bonds in the credit card ABS sector means it is more economical for issuers to retain those securities.

Investor Interest and Seller Interest

Credit card master trusts allocate credit and cash flows between the ABS investors and the master trust sponsor. The sponsor is typically the seller/servicer of the accounts pledged to the trust. The *investor interest* is simply the aggregate principal amount owed to the ABS investors. The *seller interest* is a residual interest in the trust that the credit card issuer is required to maintain. The seller interest aligns the incentives of the credit card bank with those of the outside investors because the seller has a pari passu claim on the cash flows of the trust. As noted earlier, the seller interest receives its share of finance charge collections and principal repayments, as well as its allocation of defaults and net losses.

The minimum required seller interest for most master trusts tends to be in the 4% to 7% range of outstanding receivables balances. In practice, the seller interest is likely to be higher than the minimum required by the rating agencies depending on the sponsor's strategy toward using securitization for its funding needs relative to other forms of financing. In addition to aligning the interests of the issuer and the investors, the seller interest is in place to absorb the fluctuations in the amount of outstanding receivables.

For example, seasonal patterns of credit card usage mean that the receivables outstanding can change substantially from month to month. In addition, the seller interest would be allocated dilutions from purchases that have been reversed and any ineligible receivables to back the ABS. The seller interest does *not* provide credit enhancement for the ABS, at least not directly. Credit enhancement for the ABS, discussed more fully later, is provided by subordinated securities in the investor interest, or by other structural features of the master trust.

As an issuer's credit card business grows, new accounts that meet the eligibility criteria may be added to a master trust. An account addition normally requires rating agency approval, unless it would amount to a relatively low percentage of the current receivables balance (usually 10% to 15%). Sponsors may also withdraw accounts from the master trust, again with rating agency approval. Sellers are obligated to add accounts if the seller interest falls below the minimum level. If the seller is unable to add receivables, then an early amortization event is triggered, and investors begin to receive principal repayments immediately. The risk of an early amortization gives the seller a powerful incentive to support its credit card securitization because it is often a substantial portion of the funding for the credit card business. Early amortization and sponsor support will be addressed more fully later in the chapter.

THE CREDIT CARD ABS LIFE CYCLE

Under normal circumstances, the life cycle of credit card ABS can be divided into two main periods after it has been issued: the revolving period and the amortization period.

Revolving Period

During the revolving period, investors receive interest payments only. Principal collections on the receivables are used to purchase new receivables created from customer card usage, or to purchase a portion of the seller interest if there are not enough new receivables being generated by the designated accounts. The revolving period can be used by an issuer to finance short-term credit card loans over an extended period of time. Furthermore, the revolving period is a structural device used to maintain a stable average life on the credit card ABS, and to create more certainty for investors for the expected maturity of the bonds.

Amortization Period

After the end of the revolving period, the amortization period begins and principal collections are used to repay the ABS investors. The length of the amortization period may vary depending on the monthly payment rate (MPR) of outstanding principal of the accounts in the master trust. The MPR is the unannualized percentage of the principal receivables balance repaid each month. Trusts with slower MPRs would likely require longer amortization periods than those with faster MPRs. For example, credit card ABS with a five-year expected maturity might have a 48-month revolving period and then enter amortization for the final 12 months of its life. The amortization period of credit card ABS usually may be accomplished through either controlled amortization or controlled accumulation. Most trusts today favor a controlled accumulation of principal to pay off its maturing ABS.

In a *controlled amortization*, principal payments are made to ABS investors in equal payments during the amortization period (Exhibit 28-5). This simplified example assumes that one investor series has been issued out of the master trust. During the four-year revolving period, investors receive only interest payments and principal collections are used to purchase newly created credit card receivables. The total amount of receivables varies over time between \$1.5 billion and \$1.6 billion during the revolving period, and these fluctuations are absorbed by the seller interest. The seller interest percentage averages 23% through the first 48 months, well above the typical minimum levels. At the beginning of year 5, the revolving period ends, and the controlled amortization begins. In our example, investors receive principal payments in 12 equal installments, and principal collections not needed to repay ABS investors are used to purchase newly created receivables from the cardholders. Interest payments continue based on the declining principal balance of the ABS.

EXHIBIT 28-5

Controlled Amortization

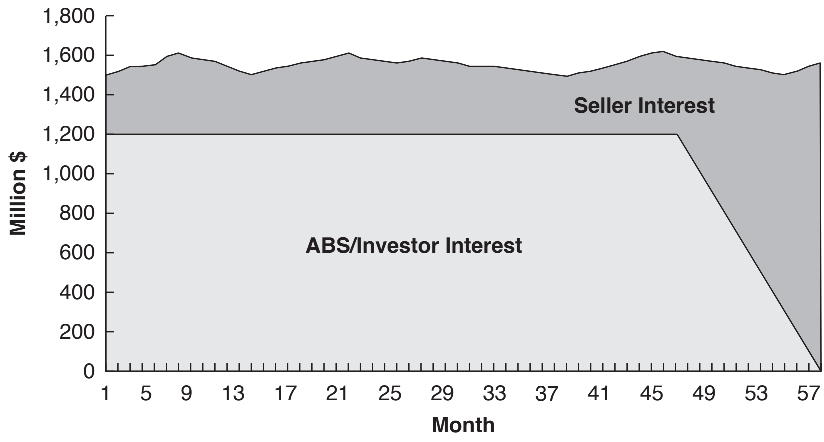
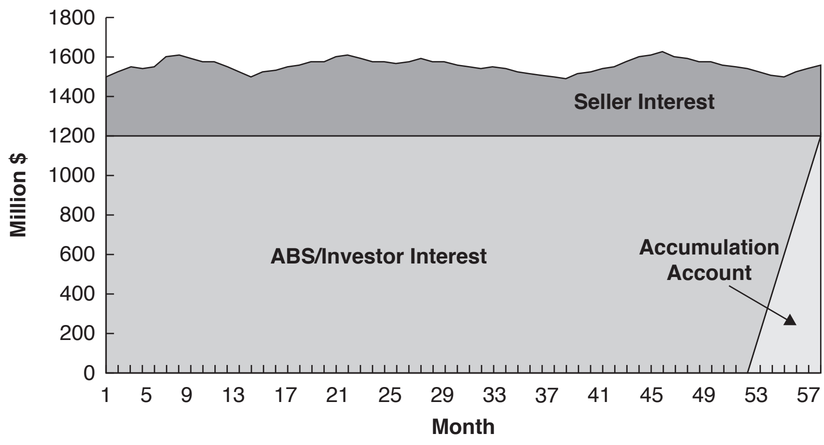


EXHIBIT 28-6

Controlled Accumulation



In a *controlled accumulation*, principal collections needed to repay ABS investors are deposited each month into a trust account and held until the expected maturity date (Exhibit 28-6). This example again assumes a five-year revolving period. As the end of the revolving period approaches, principal collections are collected in installments and excess principal collections are used to purchase new receivables. Interest payments to investors during the accumulation period are made based on the original outstanding invested amount. A single "bullet" payment of principal is made at maturity to the ABS investors.

In this example, principal is accumulated over six collection periods, which funds the repayment of ABS investors. This structural device developed as a way to emulate the cash-flow characteristics of a corporate bond. It is generally referred to as a "soft bullet" because, like most securitizations of consumer assets, the legal final maturity of the ABS bond is beyond the expected maturity date of the bond to account for potential variations in principal collections.

Early Amortization

Under certain circumstances, such as poor credit performance or a financially troubled servicer, an early amortization of the master trust could occur as a mechanism to pay off ABS investors early and minimize their potential credit losses. In most trusts, trigger events are put in place to reduce the length of time that investors would be exposed to a troubled collateral pool.

Exhibit 28-7 lists some common early amortization triggers found in credit card master trusts. If an early amortization trigger is hit, then a master trust with bonds still in their revolving periods would stop revolving and immediately begin to pass through principal collections to the ABS investors in order of priority. One structural enhancement available in most trusts to protect investors allows for principal to be passed through on an uncontrolled or rapid amortization basis. This mechanism diverts principal due to the seller interest toward payment of the ABS in order to get investors repaid more quickly.

EXHIBIT 28-7

Common Early Amortization Triggers

Collateral Pool Credit
Three-month average excess spread falls below zero
Seller interest less than the minimum required level
Collateral outstanding balance below the invested amount
Seller/Servicer Events
Failure to make required deposits or payments
Failure to transfer receivables to the trust when required
Events of default, bankruptcy, or insolvency of the seller/servicer
Breach of representations and warranties
Legal Events
Trust is reclassified as an "investment company under the Investment Company Act of 1940

CASH-FLOW ALLOCATIONS

The collection of principal and interest on the credit card accounts and passing it through to the ABS trust is relatively straightforward. The allocation of cash flows to investors and the sponsor can take on more complexity.

Groups

A credit card master trust may use the concept of a *group* to help allocate cash flow to different ABS issued by the trust. One or more groups may be established, and each series of securities issued to investors would be assigned to a group. At its highest level, the master trust allocates cash flows pro rata between the investor and seller interests. The investor interest would be divided further at the group level. While many trusts have only one group, others could have two or more. In trusts with more than one group, series of securities with similar characteristics would likely be grouped together. For example, all the fixed-rate coupon bonds could be in one group and all the floating-rate coupon bonds could be in another group. Any sharing of excess principal or finance charge collections, if called for in the cash flow waterfall of the master trust, would be determined at the group level.

Principal Collections

Principal collections are allocated on a pro rata basis to each series of ABS bonds in the same group based on the size of its outstanding principal balance. The allocation of principal to each series is determined by where that series is in its ABS life cycle. Series in their revolving period are allocated no principal collections. Their principal is reallocated and may be shared with other series that are amortizing to the extent it may be needed. The sharing of principal collections is a structural enhancement to ensure timely payment of principal to ABS investors. Principal collections that are not needed to repay investors are reinvested in new receivables.

For a series in its accumulation period, principal collections would be allocated to that series. The pro rata amount of principal allocated to that series would be determined and fixed by its original principal balance at the beginning of its accumulation period. An additional advantage of the sharing of principal collections between series means that the issuer would have less idle cash sitting in a collection account. The repayment of a maturing ABS series could be accomplished more quickly than the monthly payment rate might imply. For example, an MPR of 10% would imply a 10-month accumulation period. However, if there is only one maturity occurring, then excess principal collections could be used to shorten the accumulation period and reduce the negative carry of cash in a collection account for an issuer.

Finance Charge Collections and Allocations

The primary components of the finance charge collections by a credit card master trust include the monthly interest collected on the outstanding account balance (the APR), any annual or late fees, recoveries on charged-off accounts, interchange, and discounted principal receivables. When expressed as a percentage of the trust's receivables balance, finance charge collections are called the *portfolio yield*. The portfolio yield can be thought of as the top-line revenue number of the master trust.

Most master trusts in use today (master owner or issuance trusts) allocate finance charge collections on a *socialized* basis. In such a structure, finance charges are allocated to each series within a group based on need. Need is determined by the costs incurred by each series—the bond coupon, servicing fees, and allocated charge-offs based on the size of the series in the group. The expenses for the group are the weighted average of the expenses for each series. Since servicing and charge-offs are allocated on a pro rata basis, the series with higher coupon costs would receive a larger allocation of finance charge collections. The advantage of this method is that collections are combined to help support higher-cost series. However, the fates of all series are linked—all bonds will receive payments as expected, or the entire trust will enter early amortization together.

A few legacy master trusts with bonds still outstanding use older securitization technology that allocates finance charges based first on the size of the series outstanding rather than sharing according to need at the top of the cash-flow waterfall. These are known as *nonsocialized* master trusts. In these trusts, each series receives a "floating" allocation of finance charges based on the outstanding invested amount of each series. Excess finance charge collections may or may not be shared based on the cash-flow rules for the trust. A potential advantage of a nonsocialized trust is that the risk of early amortization can be more isolated at the series level rather than risking the unwinding of the entire trust. The disadvantage is that higher coupon series could be at relatively greater risk of early amortization if there is a shortfall in finance charge collections or charge-off rates increase sharply. The sharing of excess finance charges helps mitigate, but does not eliminate, this risk.

Principal Discounting, Interchange, and Recoveries

One of the key sources of support for credit card master trusts during the financial crisis of 2007–2009 was the discounting of principal receivables by the trust sponsors. This support mechanism had long been available to credit card ABS issuers, but it had rarely been used. Most master trust documents allow for the discounting of principal receivables, which are counted as finance charge collections. Discounting is a way to temporarily boost portfolio yield and excess spread. An issuer would most likely use this approach when a trust is under stress from lower finance charge collections and higher charge-off rates, and thus avoid an early amortization.

During the recession that began in December 2007, charge-off rates rose sharply and peaked in the 10% to 11% range by the middle of 2009. This weak credit performance reduced the excess spread substantially for most credit card master trusts. Since the level of excess spread is a major early amortization trigger, many issuers supported their trusts by discounting principal receivables. Many of the major credit card ABS issuers supported their master trusts in this way.

Two other parts of the finance charge collection calculation deserve some additional attention: recoveries on defaulted accounts and interchange. *Recoveries* are generally reported as part of finance charge collections, and so they are accounted for in the calculation of the portfolio yield. As a result, when reviewing charge-off rates, it would be more consistent to analyze the gross default rate rather than the net charge off rate. That way any double counting of recovery collections would be avoided in the calculation of excess spread. This calculation of excess spread is discussed in more detail in the next section. *Interchange* is a fee paid to the bank that issues the credit card. It compensates the bank for taking on credit risk and allowing a grace period before making a payment. Interchange is created when a bank discounts the amount paid to a merchant for a credit card transaction. It is shared by the merchant's bank, the bank issuing the credit card, and the clearing network (e.g., Visa or MasterCard) of the transaction.

CREDIT AND INVESTMENT CONSIDERATIONS

We analyzed above the key structural features and cash-flow allocations of a credit card master trust. In this section, we review some of the most important considerations for investors purchasing credit card ABS. Most investors in securitized products require an investment grade rating in order to add a security to a portfolio. Furthermore, many ABS investors focus more exclusively on bonds rated AAA by one or more credit rating agencies. Despite the moves by regulators to reduce the fixed income market's reliance on credit ratings, it seems likely that credit ratings will remain an important consideration for ABS investors for the foreseeable future because of a lack of a workable alternative.

In order to establish an investment grade rating on credit card ABS, credit enhancement is necessary to absorb potential losses on the collateral pool. The amount of credit enhancement needed will vary from one master trust to another based on the desired rating level and the credit performance of an issuer's credit card portfolio. In addition, the rating agencies will take into consideration the financial strength of the bank sponsoring the securitization. The credit rating of the bank sponsor has taken on even greater prominence in the rating agency review since the financial crisis of 2008–2009.

Credit Enhancement

Early credit card transactions carried letters of credit (LOCs) from commercial banks to guarantee the payment of the credit card ABS. However, the downgrades of the corporate ratings of a number of credit enhancers exposed ABS investors to downgrades on their investments. Over time, internal forms of credit enhancement that do not rely explicitly on the corporate credit rating of an outside entity have become the norm in the credit card ABS market.

Excess Spread

Excess spread is perhaps the most important measure of the health of a credit card master trust, and it is the first line of defense against losses to bondholders. It is also a key early amortization trigger if the credit performance of the collateral pool begins to deteriorate. Excess spread is the finance charge cash flow left over each month after the investor coupon, servicing fees, and charge-offs have been allocated to the investor interest and the seller interest. The calculation of excess spread is straightforward, as shown in Exhibit 28-8, with the values expressed as annualized percentages of the outstanding receivables balance.

In most credit card master trusts, an early amortization trigger is based on the three-month moving average of excess spread. If the three-month average falls below zero, then the revolving period stops, and all principal collections are used to pay off the outstanding ABS bonds. In a nonsocialized master trust, the excess spread trigger is applied at the series level, so an individual series could experience an early amortization without causing the entire master trust to wind down.

Cash Collateral Account

A *cash collateral account* (CCA) is a cash reserve funded at closing and held by the trust for the benefit of the ABS investors. In most trusts, the CCA is

EXHIBIT 28-8

Excess Spread Calculation

Gross Portfolio Yield	20%
Less:	
Charge-Off Rate	4%
Net Portfolio Yield	16%
Less:	
Investor Coupon	2%
Servicing Fee	1%
Excess Spread	13%

typically available as credit enhancement only to the lowest rated class of securities issued. For example, the Class C bonds in most master trusts (generally rated BBB) are supported by the excess spread and the CCA. The Class A and Class B bonds would have the Class C bonds and the excess spread as credit enhancement, but not the CCA. Investors should carefully note these types of structural features when reviewing credit card ABS. The cash to fund the CCA is usually lent by a third party and invested in high-grade short-term securities until needed to be drawn on against shortfalls in cash flow due to rising charge-offs. Any draws on the CCA would be reimbursed at a later date from future excess spread.

Collateral Invested Amount

An alternative to a cash reserve is a *collateral invested amount* (CIA), which is a privately placed subordinated tranche available as credit enhancement to the bondholders. The CIA is placed with a third-party investor that may or may not require its investment to be rated by one or more credit rating agencies. The CIA can generally be considered an improvement over the CCA from the viewpoint of the issuer because this tranche is backed by collateral from the master trust rather than cash. The CIA tranche normally has the benefit of any spread account. Draws on the CIA may also be reimbursed through future excess finance charge collections.

Subordination

As the credit card ABS market has evolved, structures have become more complex to provide greater flexibility to issuers and to meet the demand of investors. In the alphabet soup of credit card ABS, LOCs have given way to CCAs or CIAs, which in turn have been replaced in most cases by rated subordinated securities as the market for subordinated bonds became larger, deeper, and more liquid. The subordinated bonds are placed with outside investors and tend to be rated in the single-A and triple-B categories. The generalized capital structure of a credit card master trust may look like the example in Exhibit 28-9.

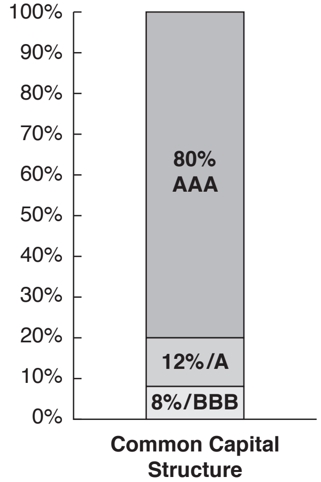
In our example, the rating agencies have determined that the AAA-rated securities are 80% of the capital structure and require 20% subordination in addition to the expected excess spread and the implied support provided by the bank sponsor. Likewise, the Class B and Class C bonds are 12% and 8% of the capital structure, respectively. Issuing subordinated tranches to investors allows the issuer to reach a wider investor audience. As indicated earlier, the issuance trust structure allows an issuer to offer senior bonds separately from the subordinated bonds with varying maturities and coupon types.

Master Trust Credit Analysis

While some of the structures may have changed over time, the credit analysis of credit card master trusts has not changed substantially. For example, most credit

EXHIBIT 28-9

Credit Card ABS Capital Structure



analysts stress the historical performance of critical variables related to the cash flows to test the structural integrity of credit card ABS. A long period of credit performance over several credit cycles would be ideal when analyzing credit card ABS. Credit data that spans the 2007–2010 period would pick up a severe economic downturn that caused charge-off rates and delinquencies to increase sharply and put substantial stress on the credit card ABS sector. In addition, static pool vintage data would be helpful to see how performance or underwriting standards may have changed over time.

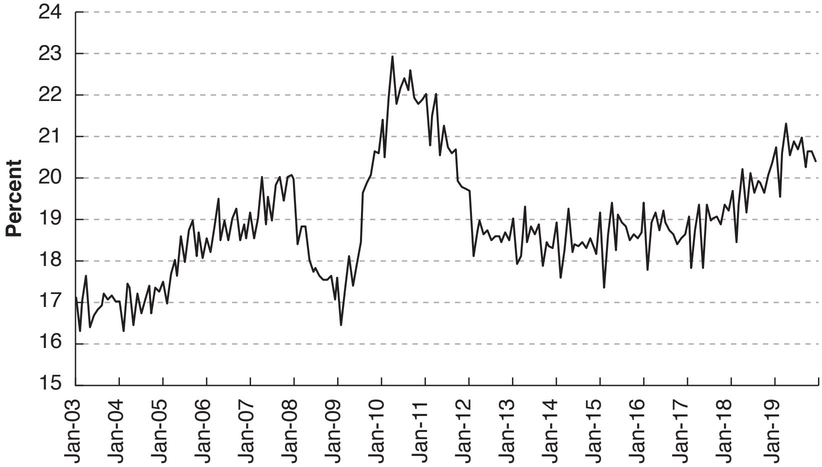
There are several key quantitative variables needed for analyzing credit card securitizations. They include portfolio yield, charge-off rate, delinquency rate, excess spread, monthly payment rate, monthly purchase rate, and the coupon paid to investors. Each of these variables is important for analyzing the ongoing health of a credit card master trust, and they play a role in analysis of a potential early amortization.

Portfolio Yield

As noted earlier, portfolio yield is a measure of the income generated by the credit card receivables. While portfolio yield is driven largely by the annual percentage rate (APR) paid by the cardholders, annual fees and late fees can also boost yield. Furthermore, usage by accountholders is also important. All else equal, a portfolio with proportionately more revolving accounts relative to convenience users will translate into a higher portfolio yield (Exhibit 28-10).

EXHIBIT 28-10

Portfolio Yield



Source: Wells Fargo Securities

Charge-Offs and Excess Spread

Excess spread has been discussed at length earlier in the chapter and is perhaps the most important measure of the health of a credit card master trust. Charge-offs are the credit losses experienced by the portfolio and normally are taken when an account becomes 180 days past due (Exhibit 28-11). Peak losses on static pools of credit card accounts have been observed at about 24 months of seasoning. The juxtaposition of excess spread and charge-offs can be a powerful analytical tool for determining tiering among various credit card issuers.

Serious Delinquency Rate

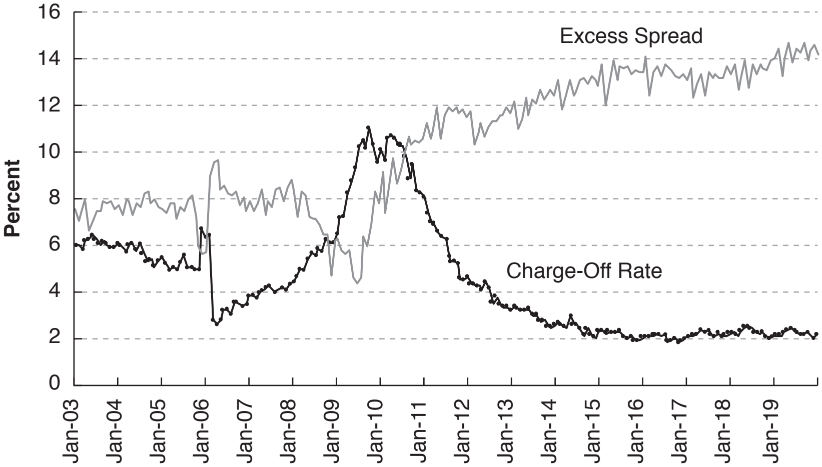
A good leading indicator of future charge-offs is the delinquency rate for accounts 60 days or more past due (60+ dpd). The direction of serious delinquencies can point to important credit trends in credit card master trusts. For example, during the recession of 2007–2009, changes in the direction of 60+ dpd provided an early warning signal for the rapid increase in the charge-off rate of most credit card ABS deals.

Monthly Payment Rate

The *monthly payment rate* (MPR) is an important, but often overlooked, variable in the analysis of credit card ABS because high MPRs can be a source of strength and implied credit enhancement when a portfolio comes under stress. For example, a large proportion of convenience users, while depressing portfolio

EXHIBIT 28-11

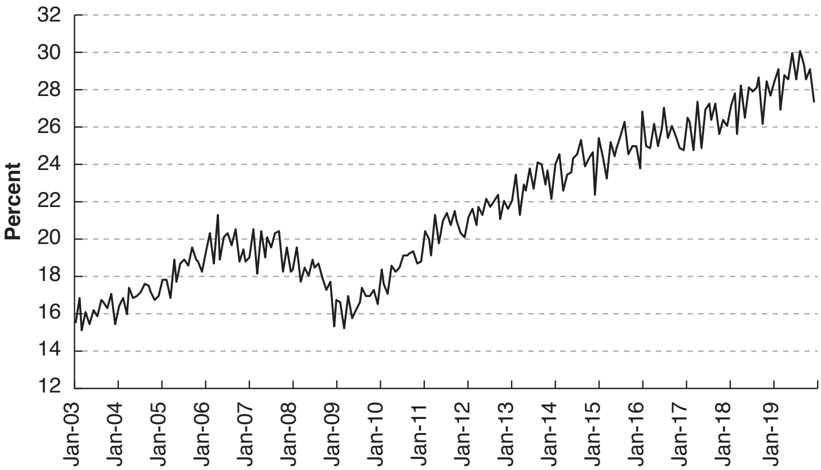
Credit Card ABS Charge-Off Rate and Excess Spread



Source: Wells Fargo Securities

EXHIBIT 28-12

Wells Fargo Securities Payment Rate Index



Source: Wells Fargo Securities

yield, can increase payment rates sharply (Exhibit 28-12). The faster turnover of the receivables means that investors can be repaid more quickly in the event of an early amortization. Since the recession of 2007–2009, the payment rate in credit card ABS trusts has increased significantly based on a strong account base of seasoned account holders using credit cards as a convenient method of payment rather than as a source of revolving credit.

Purchase Rate

Related to the payment rate is the purchase rate, which is generation of new receivables by the designated accounts. A higher purchase rate means that more receivables are being created to support the outstanding ABS. A bankruptcy or insolvency of the seller/servicer is the main risk with regard to the purchase rate because cardholders may stop using their cards as the utility declines. This risk can be particularly acute in private-label or department store cards, however, this event can happen with bank cards as well. As the amount of receivables declines, the credit quality of the portfolio is likely to deteriorate.

Investor Coupon

Floating-rate ABS may require more credit enhancement than fixed-rate bonds because the rating agencies assume in their stress scenarios that market interest rates increase dramatically. Higher funding costs for the ABS reduce the available excess spread to protect ABS investors.

Testing Master Trust Structures

In general, stress testing a credit card master trust structure would involve forcing portfolio yields, payment rates, and purchase rates down sharply at the same time that charge-off rates rise. This combination of factors compresses excess spread and causes an early amortization of the master trust. There have been only a few instances of early amortization, but in general charge-off rates do increase significantly while purchase rates fall and the payment rate drops to a minimal level of about 3%. Interestingly, portfolio yield has held up relatively well in these instances. In addition, early amortization tends to have hit weaker, less diversified issuers of credit card ABS.

There are also some important qualitative elements that should go into any analysis. For example, geographic concentration, the strategic objectives of the firm, seasoning of the accounts, and the type of card (general-purpose card or private-label card). The underwriting standards for new accounts can also play a role in the analysis. These types of qualitative factors can help to determine the degree of stress to apply to various quantitative factors.

As the credit card lending market has consolidated over the past decade, geographic concentration has probably become less of a concern. Most major credit card issuers of general-purpose cards, such as those banks that offer Visa, MasterCard, Discover, or American Express, try to source accounts from the general population. However, market pricing of credit card ABS often considers the corporate credit quality of the bank sponsor. Stronger banks can offer deeper pockets and more support to its credit card master trust in times of stress than a weaker bank. This tiering became more significant during the financial crisis of 2008–2009.

Credit card lenders have long used certain marketing programs to gain market share and to build brand loyalty among cardholders. These programs can play a role in the credit profile of the accounts backing the master trust.

Teaser Rates

For example, lenders may use offers with a low initial APR and no annual fee to lure customers away from competitors. This use of "teaser rates" may also allow borrowers to transfer existing balances from higher-rate cards to the new teaser rate. These teaser rate programs may be available for only a limited time, such as 6 to 12 months. One of the potential problems with this approach is that it can create adverse selection in the account base. Borrowers with a poor credit history may be more likely to respond to the cheaper terms of credit. Most banks tend to use these programs on a targeted base of potential applicants in order to mitigate the likelihood of lending to weaker borrowers.

Affinity and Co-Branded Programs

One of the major uses of the technological investment made by credit card issuers has been in the customer retention effort. A package of interest rates, credit limits, and other services can be offered to entice customers to stay once the teaser period ends. These packages can come in myriad combinations and can be offered based on the credit profile and usage patterns of the cardholder. This strategy of mass customization is made possible by sophisticated computer systems that search huge databases and track the credit history and profitability of existing customers.

Two products created by card issuers to differentiate themselves in the minds of cardholders are affinity and co-branded programs. Affinity cards are issued by a bank in association with a special interest group such as a college alumni association, professional group, or sports team. The group receives a fee from the bank, and the bank gets to market its card to a demographic that it wants to attract. Co-branded cards are programs that associate a bank's credit card with a commercial firm. Customers can earn certain rewards from the firm for making purchases with the card. Mileage awards with airlines, for example, are some of the most popular co-brand programs. However, gasoline companies and hotel chains also make use of these programs to build customer loyalty.

Private-Label Credit Cards

The objectives of private-label credit card issuers may be somewhat different from those of the general-purpose card programs. Private-label credit card programs are sponsored by retailers for use in their own stores as a means of boosting sales, though over the past several years the administration of these programs has moved from the retailers themselves to banks that specialize in private-label credit cards. Underwriting may be less stringent than that of a general-purpose card program, and losses would normally be expected to be higher for credit card ABS backed by private-label accounts. On the other hand, APRs and portfolio yields tend to be much higher to compensate for the greater risk. The market pricing of the ABS issued by private-label programs tends to be at a concession to that of benchmark, general purpose card programs. Good relative value can be found among private-label credit card ABS issuers by investors willing to investigate them.

KEY POINTS

- The securitization of credit card receivables began in 1987, and the credit card ABS market grew rapidly over the years to become one of the largest securitization sectors. many investors making their initial foray into ABS would likely dip their toes into credit cards before wading into the many other asset classes available.
- Credit card ABS are structured using a master trust structure. The credit card bank pledges certain accounts, and all of the receivables generated by the accounts, to the trust. The issuer establishes a single trust that can accept periodic additions of accounts and issue multiple series of securities. All of the securities issued by the master trust are supported by the interest and principal collections from all of the receivables contributed to it. The collateral pool is not segmented to support any individual securities.
- The revolving nature of credit card receivables created unique challenges for securitization. As a result, the master trust structure was developed to allow for a revolving period when only interest is paid to investors, and an amortization period when principal is allocated to pay bondholders.
- The master trust is segmented between the investor interest and the seller interest. The investor interest is the ABS sold to third-party investors. The seller interest is the bank's retained interest in the collateral pool. The seller interest aligns the incentives of the issuer with outside investors because they share in the collections and losses of the collateral pool.
- Bonds carrying credit ratings require credit enhancement to achieve investment grade ratings. Most credit card ABS utilize internal credit enhancement in the form of subordination and excess spread.

- The key variables needed to do credit analysis on a credit card master trust are charge-offs, delinquencies, monthly payment rate, purchase rate, portfolio yield, and excess spread. In the event of distress, an early amortization of the trust could occur. Stressing these variables in a cash-flow model can help determine the structural soundness of the master trust.
- The bank sponsor of the credit card master trust is an important element in the review of credit card ABS. During the financial crisis of 2008–2009, most sponsors of credit card securitizations came to the aid of their ABS trusts. The ability of the sponsor to support its trust should be one of the factors to consider when buying credit card ABS.

CHAPTER
TWENTY-NINE

SECURITIES BACKED BY AUTO LOANS AND LEASES, EQUIPMENT LOANS AND LEASES, AND STUDENT LOANS

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The securitization of nonmortgage financial assets has been providing firms with direct access to the capital markets since 1985. The asset-backed securities (ABS) market first began with a computer lease transaction sponsored by Sperry Lease Finance Corporation. Shortly thereafter, auto loans and credit cards were being financed through securitization. Many other types of consumer and commercial assets followed, and the nonmortgage ABS market grew from these humble beginnings to a peak of $871 billion outstanding by 2007.

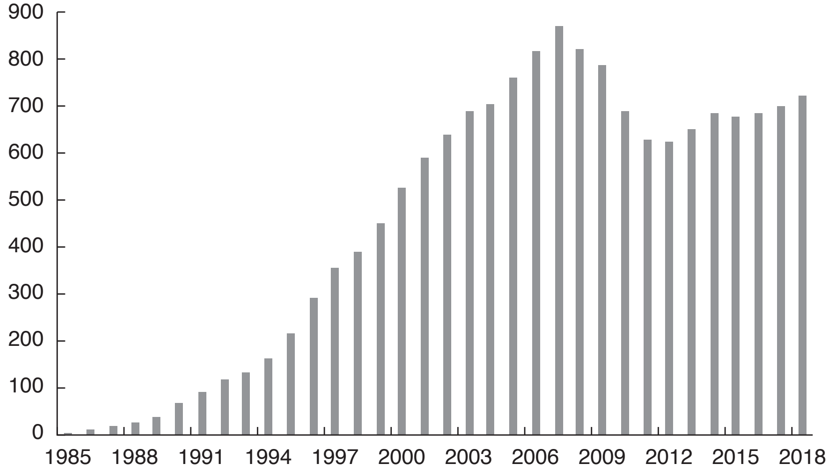
The financial crisis of 2008–2009 was unkind to consumer lending, and the ABS market shrunk from its peak to a recent low of $624 billion in 2012 (Exhibit 29-1). ABS recovered gradually since then and stood at about $720 billion in 2018. The composition of the ABS market has changed since the financial crisis, as well. Credit cards and government-guaranteed student loans, which had been the largest segments outstanding, have decreased and been replaced with credit-oriented sectors such as subprime auto loans, equipment loans and leases, unsecured personal loans, and private student loans. Nevertheless, ABS remain an important source of capital for the financial system. This chapter describes the securitization process and summarizes some of the key features of three of the larger ABS asset classes: auto loans and leases, equipment loans and leases, and student loans.

SECURITIZATION IN BRIEF

Securitization is a process where financial assets are sold to a special purpose vehicle (SPV) from the originator of the assets. Assets securitized are primarily loans and leases, but many other types of receivables and financial obligations, such as accounts receivable or utility charges, have found their way into the

EXHIBIT 29-1

Nonmortgage ABS Outstanding



Source: SIFMA, First XV Partners

asset-backed securities (ABS) market. The use of an SPV in securitization is a critical step because the assets need to be isolated from a potential bankruptcy of the originator.

This bankruptcy remoteness allows the debt of the SPV (the ABS bonds) to carry credit ratings that are likely to be higher than those of the originator of the loans or leases backing the securities that are sold to investors. The vast majority of ABS, roughly 80%, carries a AAA rating from one or more credit rating agencies. In the event of the insolvency or bankruptcy of the lender, the cash flows from the assets are designed to stand on their own to service the ABS debt. The assets backing the bonds would not be consolidated into the bankruptcy estate.

The SPV issues securities to investors that are backed by the cash flows generated by the assets. The assets are typically a diversified pool with hundreds or thousands of obligors. However, in some cases, there may be certain concentrations, either geographic, obligor, or industry, that may need to be mitigated in the structure or with additional credit enhancement. Interest collections on the assets are used to pay interest to the bondholders, and principal collections are used to repay principal to bondholders. As noted above, investors rely on the underlying pool of collateral for repayment and not on the creditworthiness of the originator, or seller of the assets.

This is not to say that the originator or servicer of the collateral pool does not matter. On the contrary, the lender's ability to originate high-quality collateral and service the loans effectively are critical to the success of a securitization. Indeed, the rating agencies explicitly take account of those abilities when determining the amount of the credit enhancement (i.e., referred to as sizing) required to achieve the desired credit rating on the ABS. In most cases, the originator of the loans will also be the servicer.

Exhibit 29-2 displays a generalized schematic of the securitization process. After the assets (loans, leases, receivables, or the like) are sold to the SPV, the transaction is structured and the securities sold to investors. Most ABS transactions offer a senior class of securities (Class A) that are usually rated AAA by one or more credit rating agencies. Subordinated securities, usually rated in the investment-grade categories (AA to BBB), may also be offered to investors, or they may be retained by the issuer

The key to receiving credit ratings on ABS backed by a pool of unrated assets is the credit enhancement required. The level of credit enhancement required will be related to the amount of expected credit losses on the collateral pool. For example, a pool of auto loans to prime quality borrowers might be expected to generate credit losses of just 1% of the original balance of the loan pool. Alternatively, a pool of auto loans to subprime borrowers might be expected to generate losses of 15%. The ABS deal backed by the subprime loans would require substantially more credit enhancement to achieve the same rating than would the ABS deal backed by prime auto loans.

Credit Enhancement

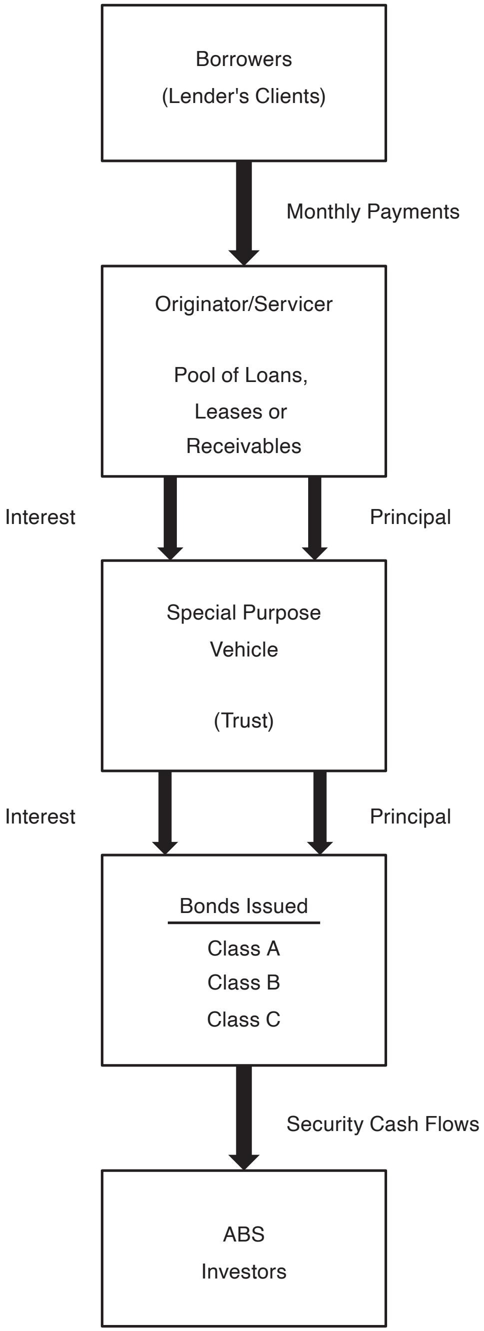
The major types of credit enhancement for ABS transactions include internal sources and external sources. External sources are mainly bond insurance and corporate guarantees, which link the rating of the ABS directly to the corporate credit rating of the guarantor. This method of credit enhancement came under severe stress during the 2008–2009 financial crisis and has fallen out of favor since then with issuers and investors. Internal sources of credit enhancement include excess spread, cash reserve account, overcollateralization, and subordination. Some combination of them is found in every ABS deal.

Excess spread is the amount of interest collected above and beyond that needed to pay interest to bondholders and pay the ongoing expenses of the transaction. This is the first line of defense against losses in most ABS because it can absorb credit losses in each period. The excess interest usually goes back to the servicer if it is not used in a particular payment period, or in some cases it is trapped in an account for the benefit of the bondholders.

A *cash reserve* account may be fully funded at the closing of the ABS transaction, or it may be added to or funded over time by retaining (i.e., trapping) the excess spread. The reserve account is available to provide the deal with additional liquidity in the event that interest or principal collections are less than expected. Cash reserve accounts may also come with a floor on them that allow funds to be distributed to the originator if credit performance meets certain objectives in terms of quantitative tests. Individual ABS transactions should be reviewed for the details of any reserve release conditions.

EXHIBIT 29-2

Securitization Flowchart



Overcollateralization (OC) is the amount of collateral in the pool that is in excess of the ABS bonds issued. For example, if the total collateral pool is $500 million and the ABS issued is $450 million, then the initial OC would be $50 million, or 10% of the collateral pool. This form of credit enhancement may be preferred by an originator that does not want to tie up cash in a reserve fund. OC may also be preferred by investors because it represents the first loss piece in the transaction. The lender holds this equity position, and it helps align the interests of the lender and ABS investors to mitigate risk.

Subordination is the issuance of other classes of securities that would be junior in priority for receiving principal repayment. Many ABS transactions have rated subordinated classes that are sold to third-party investors. Most structures have ratings on these securities from AA to BBB, but it is not unusual to see a BB-rated class at the bottom of the capital structure. This allows an issuer to receive a higher advance rate against its pool of receivables, and it can satisfy investors with differing risk profiles.

Credit Analysis of ABS

The credit analysis of ABS is mainly focused on the performance of the collateral pool. Due diligence of the originator of the loans and its servicing capabilities are still an important component of any credit analysis, but for purposes of this chapter the focus remains on the collateral. Here we simply mention the key data needed to track performance.

Delinquency rates provide a signal of future losses, and in particular serious delinquencies of more than 60 days past due. Defaults, net losses, and loss severity/recovery rates are used by the rating agencies to help determine credit enhancement levels. This data is tracked over time to see if credit performance is in line with expectations. Prepayment rates should be followed because most financial obligations can be repaid early, and almost every ABS deal is priced based on some expected level of loan prepayments. The extent to which prepayments vary from expectations can have significant effects on the valuation of ABS.

Finally, most ABS transactions give the issuer the right, though not the obligation, to exercise a clean-up call of the collateral when the pool balance reaches some predetermined level. The call is usually set at 10% of the original collateral balance, though it is not unusual to see clean-up calls in the 5% to 15% range. It is important to note that the call is on the collateral pool, and not on the outstanding ABS bonds directly. The call is in place because the fixed costs of loan servicing increase as the pool balance declines and the call allows the servicer to manage its securitization costs. The history of an issuer's clean-up call efficiency should be followed because the ability and willingness to exercise the call can have an impact on the valuation of ABS securities.

AUTO LOANS AND LEASES

Auto ABS is one of the earliest and most active securitization sectors beginning in 1986. It has proven to be an attractive and efficient source of funding for auto finance companies. Auto loans and leases offer a steady stream of issuance that has been running roughly $80 billion per year since 2012, and it has become the largest new issue segment. Auto ABS is predominantly based on loans to prime quality borrowers originated by captive finance companies of large automakers. Meanwhile, as investors have increased exposure to ABS, the economics of it has brought new issuers, including commercial banks, specialty finance companies, and lenders to subprime borrowers. Furthermore, consumers opted to lease new cars in increasing numbers over time, and this led to more auto lease ABS transactions. Auto ABS issuers can be divided into five broad groups: the Detroit Three, foreign automakers from Asia and Europe, U.S. bank lenders, independent finance companies, and subprime lenders.

Auto ABS outstanding nearly doubled to $162 billion in 2018 from the near-term low point of $82 billion in 2011 (Exhibit 29-3). The amount of prime auto loan ABS outstanding reached $84.6 billion in 2018, which was still well below the 2003 peak of $102.6 billion. A robust corporate bond market has kept funding costs more competitive in unsecured corporate credit relative to ABS. The increase in auto ABS has been a result of the rise of subprime auto lenders funding in the ABS market, and an increase in auto lease deals as leasing has become a more affordable option for many consumers. Subprime auto loan ABS outstanding reached $52.3 billion in 2018 from $16.3 billion in 2011. Auto lease ABS outstanding rose to $25.0 billion in 2018 from $12.7 billion in 2011.

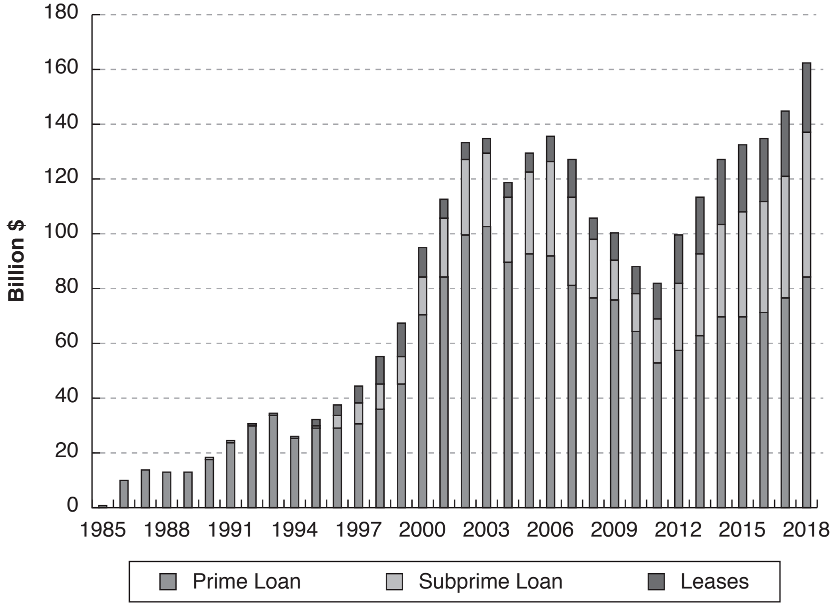
One of the major elements of credit analysis in auto ABS is based on consumer credit scores. The primary method is to use FICO scores of the obligor pool as a way of gauging credit risk. Subprime borrowers are generally viewed as those with FICO scores of 620 or lower. Prime borrowers have FICO scores of 680 or higher. Scores between 620 and 680 are a narrow group often described as nonprime. These break points should be thought of as general guidelines rather than as hard rules. For example, bank regulators use 660 as the demarcation between prime and subprime borrowers. Market participants may have varying levels of risk tolerance for collateral pools with exposures to subprime borrowers. Subprime auto ABS deals have substantially higher levels of credit enhancement because of the higher risk of default and net loss.

Auto ABS Structure

Auto loan ABS are typically issued using an owner trust structure, which is a legal form that allows for a time tranching of the senior class, as well as credit tranching of subordinated debt. The sequential senior bonds allow lenders to tailor issuance to meet the different maturity preferences of fixed-income investors. For example, an auto owner trust usually has a senior class that may be divided into three or four sequential classes as shown in Exhibit 29-4. The Class

EXHIBIT 29-3

Auto ABS Outstanding



Source: SIFMA, First XV Partners

EXHIBIT 29-4

Example Auto ABS Structure

Class	Weighted Avg. Life (Years)	Pricing Benchmark	Rating (S&P/Mdy)	Prin. Payment Window (Mos.)
A1	0.3	Interp. LIBOR	A1/P1	1–8
A2	1.0	EDSF	AAA/Aaa	8–16
A3	2.0	Swaps	AAA/Aaa	16–34
A4	3.0+	Swaps	AAA/Aaa	34–48
B	3 to 4	Swaps	AA/Aa2	48–51
C	4.0+	Swaps	A/A2	51–51
D	4.0+	Swaps	BBB/Baa2	51–51

Other Internal Credit Enhancment:

Overcollateralization below the rated bonds (first loss equity)

Cash Reserve Account

Excess Spread

Classes C & D subject to the clean-up call.

EDSF used to price fixed-rate bonds with WAL < 2.0 years.

WAL and payment windows are for illustrative purposes.

A1 tranche is structured with a short average life that would typically meet the requirements for Rule 2a-7 eligibility for money market investors to buy it.

There are also classes with one-year and two-year average lives, as well as a last cash flow (LCF) senior bond, with an average life of three years or more. The LCF senior bond tends to have a more limited investor base than the other senior bonds because this class may have greater variability in its expected maturity from prepayments or the clean-up call. It is usually the smallest of the senior class, as well. One or more subordinated classes also may be offered, usually with ratings from AA to BBB. Many issuers offer just the AAA classes. The average lives of auto loan ABS have been lengthening as loan terms to borrowers have been extended to keep monthly payments affordable. The days of the 48-month loan have been replaced by the 60-month or 72-month loan because the cost of vehicles has increased over time.

The pricing benchmarks for fixed-rate auto ABS depend on the weighted-average life (WAL) of the bond. For example, the money market tranche would be priced against an interpolated LIBOR rate. If the WAL is 0.30 years, then the yield would be based on an interpolated LIBOR rate between three months and four months. For bonds with average lives of 2.0 years or longer, the swap curve normally would be used as the pricing benchmark for the auto ABS. Bonds with average lives less than 2.0 years use the Eurodollar synthetic forward rate (EDSF), which is the rate implied by the prices of Eurodollar futures. This curve may deviate from the interpolated LIBOR rate implied by the cash market.

Since the underlying loans make payments of principal on a monthly basis, the principal is returned to investors also on a monthly basis. This structural artifact creates a "payment window" for each of the bonds. For example, Class A2 has a principal payment window from month 8 to month 16—a nine-month payment window. This feature is unlike credit card ABS, where the bonds are structured with a bullet payment of principal at the expected maturity date.

Investors generally prefer tighter principal payment windows that allow for less uncertainty as to WAL and bond valuation. The return of principal to investors can be affected by prepayments and defaults by borrowers, as well as the exercise of the clean-up call option by the issuer. The Class A2 bonds tend to be the largest class in an auto loan ABS deal, and the majority of the total amount of the bonds issued tends to be in the top of the capital structure to minimize the cost of issuance.

Subprime Auto ABS

As mentioned earlier, loans to subprime credit borrowers have become more common and a larger portion of the ABS market overall. The risk profile of the underlying borrowers means much higher credit enhancement levels to achieve a desired credit rating compared to that of prime auto loans. For example, better-quality pools with somewhat higher-weighted average FICO scores may need original credit enhancement of 35% to be graded AAA. However, it can take as much as 65% to achieve a AAA rating for certain issuers depending on the credit profile of the pool. In general, subprime auto loan ABS deals have three senior sequential classes with the longest being a two-year average life security. The sizes of the subordinated classes can be quite large, and the market prices the credit and liquidity risk at wider spreads compared to prime auto loans. Prepayment rates tend to be secondary in consideration to credit risk and default timing in subprime auto loan ABS pools.

In addition to the usual collateral credit risks in auto loan ABS, servicer risk plays a more important role in subprime auto loan deals because the lenders that service the loans tend to be smaller specialty finance companies that rely more heavily on the ABS market for funding. They may not have ready access to other liquidity or the capital markets. A higher degree of servicer risk should translate into wider credit spreads and more tiering among issuers as the market prices that risk.

Auto Lease ABS

Auto leasing has become more important as new vehicle prices and financing costs have increased. Leasing can be a more affordable option for many consumers needing auto credit because the lease payment can be as much as $100/month lower compared to loan payments for the same vehicle. Lease penetration rates, the proportion of leases to all financings, increased to roughly 30% in 2018 and 2019 from less than 20% before the recession in 2008.

Unlike loans, where the main credit risk is default by the borrower, the primary credit risk in auto lease ABS is the residual value realizations of the vehicles at the end of the lease term. Lease residual collections are generally more than 50% of the cash flows being securitized, with the remainder being the periodic lease payments from the consumer. The maturity distribution of the leases during the securitization and the composition of the vehicles are main drivers of the cash flows.

The risk is that the market price of the vehicle at the term of the lease will be significantly less than the expected value at the time that the lease was written, usually three years earlier. This risk can be captured in the variability of used car prices over time. The largest short-term downside moves in used car prices have been 11% to 12%. The rating agencies will build into their stress scenarios a serious decline in residual values to size credit enhancement. Auto lease ABS will normally price at a concession to auto loan ABS because of the risk of exposure to future moves in auto residual values.

EQUIPMENT LOANS AND LEASES

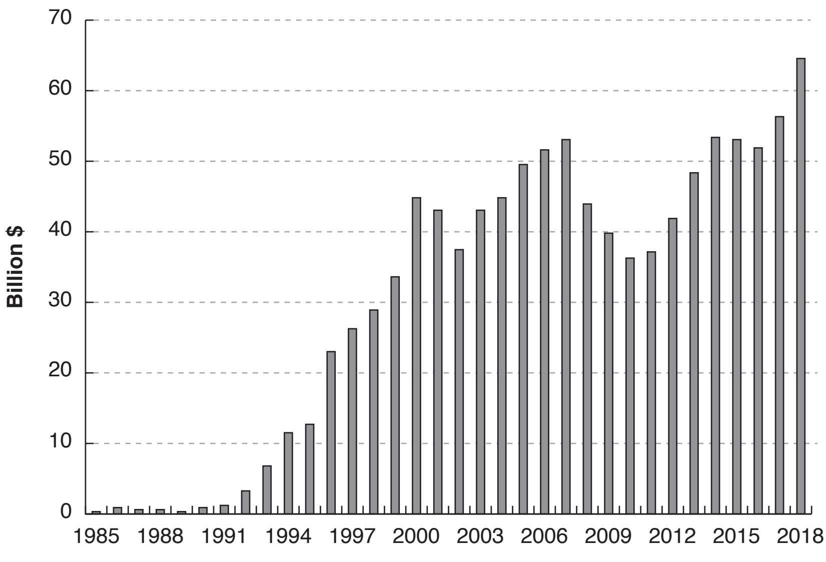
Equipment loans and leases were some of the earliest nonmortgage assets to be securitized. Equipment ABS outstanding has accelerated along with issuance since 2011, rising to $64.3 billion from $37.1 billion (Exhibit 29-5). These deals tend to be structured in a similar way to those in the auto ABS sector, displayed in the example in Exhibit 29-4. Furthermore, trading in equipment ABS securities generally use the auto ABS market as a benchmark for pricing, with equipment deals normally offering a concession to benchmark auto ABS securities.

Equipment loan transactions tend to look much like other types of securitizations where interest from the loans is used to pay interest to bondholders and principal is used to repay principal. The securitization of lease receivables presents a different problem for structuring because leases do not carry an explicit interest rate. As a result, the lease collateral pool is discounted at the weighted average coupon of the securities plus any servicing fees and other expenses to create an interest component on the collateral.

Equipment securitizations may be backed by loans or leases of different types of equipment that fall into three broad categories based on the original cost of the equipment. Small ticket equipment pools, such as telephone systems, computers, or copying machines, are reasonably diverse across geographies and industries, and have an original cost of less than $100,000; mid-ticket equipment pools, such medical or larger printing equipment, heavy duty trucks, trailers, and busses (that may have some obligor concentrations) have an original cost between $100,000 and $500,000; and large ticket equipment pools, such as agricultural or construction equipment with relatively low net loss rates, have an original cost of greater than $500,000.

EXHIBIT 29-5

Equipment ABS Outstanding



Source: SIFMA, First XV Partners

From a credit perspective, analysis of equipment ABS may be relatively labor intensive because of the specialized nature of many types of equipment. In addition, residual values of the equipment are important in lease deals because some items, especially certain types of small ticket equipment, may depreciate more quickly than others. The degree to which any residual value realizations have been securitized and included in the cash flows of the transaction can have a critical impact, particularly for tranches that pay later in the priority of the capital structure.

Equipment ABS issuers and sponsors in some cases may also be smaller, specialty finance firms without a corporate credit rating that use securitization for the bulk of their term funding. Like subprime auto deals, servicer risk can be an important risk in equipment ABS deals when the sponsor is a smaller company. In other cases, the issuers are large manufacturers with their own corporate credit ratings that use securitization as one method of funding to diversify their sources of credit in the capital markets.

STUDENT LOANS

Student loan ABS became the largest individual sector of the ABS market in 2010 at $242 billion. This amount compared to $217 billion for credit cards and $115 billion for autos. The largest source of collateral was government-guaranteed student loans financed by third-party lenders, which accounted for roughly 90% of all student loans. However, the Department of Education ended that program in favor of making loans directly to students. The character of the student loan market has shifted over time as funding for student loans migrated from the private market to direct government lending, which is unlikely to be securitized. Student loan ABS outstanding declined to $171 billion in 2018 and is likely to fall further as older deals amortize.

The student loan ABS market became so large in the first place because education costs have increased faster than the ability of students and parents to pay tuition. Some of this funding gap has been filled by student loans made by private lenders and guaranteed by the government, and also by private student loans with no guarantee. The student loan ABS market follows these two broad categories.

Government-Guaranteed Student Loans

The Federal Family Education Loan Program (FFELP) provided loans to students and parents for postsecondary education. FFELP loans were originated by a lender such as a bank, insurance company, state agency, or not-for-profit student loan company. The loans carry a guarantee from the federal government that covers interest on the loan and repayment of principal up to 97% of the original loan balance. There are four different types of loans available under the FFELP plan: subsidized Stafford, unsubsidized Stafford, PLUS, and consolidation loans. Subsidized Stafford loans are made to students who meet a financial needs test. Unsubsidized Stafford loans are available to students who do not qualify for the subsidized loans or have needs beyond the subsidized loan limits. PLUS loans are made to parents of students. Student borrowers can combine Stafford and PLUS loans into one consolidation loan and make one monthly payment.

A student's status in the school/repayment life cycle is a key factor determining the cash flows in student loan ABS. When a Stafford loan is made and the student is enrolled in school, the borrower's status is "in school." The *in-school period* does not have a time limit, but it would typically be one to four years depending on when the loan was made, the type of school, and the degree pursued. The in-school period is followed by a six-month *grace period* before the loan enters its *repayment period*. During the repayment period, the borrower is responsible for full payments of interest and principal on the student loans.

Borrowers with subsidized Stafford loans do not pay interest or principal during the in-school or grace periods, and the Department of Education makes the interest payments on behalf of the student during these periods. For unsubsidized Stafford loans, accrued interest is capitalized into the unpaid loan balance at the end of the status period. PLUS and consolidation loans enter into repayment of interest and principal 60 days after the funds are distributed to the student.

Once a borrower is in repayment, a loan can go into deferment or forbearance, which allows a borrower to delay payments of interest and principal. *Deferment* allows a borrower to postpone payments due to unemployment, economic hardship, or entering public service or the military. In these circumstances, deferment can be one to three years in length. For a borrower that goes on to further educational programs, there is usually no time limit on their deferment status. *Forbearance* may be used for borrowers that have lost a job or are having some other type of economic hardship. Forbearance may be granted in 6-month or 12-month periods, but the total time in forbearance cannot exceed three years. Different types of schools may carry different credit or prepayment risks. School types include two-year, four-year, graduate, and proprietary or for-profit schools.

Private Student Loans

The federal government has replaced FFELP loans with direct lending from the government. Over time, the student loan ABS market has migrated toward more private loan deals. Private student loan ABS has generally been a very small sector; however, as the cost of college rises, students and parents may need to tap other sources of funds to close the gap between cost and savings. Private student loans carry no federal government guarantee to compensate investors against defaults. In this regard, private student loans are more similar to other kinds of consumer credit, and pools of student loans are likely to be originated and serviced like other types of consumer ABS. One important difference, however, is that, unlike other kinds of consumer credit, student loan debt cannot be discharged in bankruptcy. This factor provides some additional level of protection in terms of potential recovery on defaulted loans.

Private student loans may be disbursed directly to the student rather than through the financial aid office of the school. Direct-to-consumer (DTC) loans may show higher loss rates because the money never makes it to pay tuition, or because of the potential for fraud. Nevertheless, like government-guaranteed student loans, the collateral performance of private student loans depend on a number of characteristics. Investors should look for issuers that provide collateral pool information on the key risk factors in order to make an informed investment decision.

Like FFELP loans, the most significant collateral characteristics include the type of loan made for undergraduate, graduate school, proprietary/for profit, or a consolidation loan. The credit quality of the borrower very often using the FICO score is taken under consideration, as is whether the loan is co-signed by a parent or another party that may take responsibility for repaying the loan. As noted above, if the borrower receives the loan directly from the lender, then it may have a higher risk profile than a loan that is channeled through the school. The type of school plays a role in the credit profile if it is a two-year, four-year, or for-profit school. Like other kinds of consumer credit, the loan seasoning can be an indicator of risk. Generally, a pool of loans with more seasoning tends to be less risky than a pool of loans with little or no seasoning. The loan status—in-school, grace, repayment, deferment, or forbearance—with their differing cash flows may create different risk profiles for a transaction.

Student Loan ABS Structure and Risks

Student loan ABS structures, like all securitizations, are designed to mitigate risks and create a situation where investors can be repaid and the rating agencies can achieve investment-grade ratings on the securities. In student loan ABS, the major risks are credit losses, liquidity, servicing, and interest rate and basis risk. Credit risk can be mitigated through credit enhancement that protects investors against principal writedowns. Excess spread is the first line of defense against credit losses, and it is generated when the yield on the loans is greater than the cost of the liabilities in the securitization. Credit enhancement may be in the form of overcollateralization or subordination that is in a position to absorb losses ahead of rated securities.

Liquidity risk can be particularly acute in student loan ABS because pools of student loans may have a substantial number of loans that are not yet in repayment status. Loans that are in-school, grace, deferment, or forbearance may not pay principal or interest and therefore can decrease the cash flow available for ABS investors. Liquidity support may be provided by a capitalized interest account that can be used to interest to bondholders before loans enter their repayment status. In addition, a reserve account may be part of the deal structure to provide liquidity as well as credit enhancement, much as it would in any other sort of ABS deal. Such a reserve account would be funded at closing and have a minimum level to protect investors against losses.

Interest rate risk and basis risk may be higher in student loan ABS than in most other segments of the ABS market. The reason is that the borrower's interest rate may be either fixed or floating, and if floating it may be linked to a number of benchmarks, including the prime rate, Treasury bill, one-month LIBOR, or three-month LIBOR. In most cases, the interest rate on the ABS is based on one-month or three-month LIBOR. When both sides of the equation are floating, the interest rate risk can be mitigated. However, there may be a mismatch in the timing when the interest rates on the loans reset compared with the reset on the ABS. This situation leads to the potential for the collateral pool to provide sufficient excess spread.

Servicer risk is an important component of a securitization because the lender originates the collateral, is responsible for adequate underwriting, and then must have the capabilities to collect the interest and principal from borrowers and minimize the losses from defaults. On a student loan ABS deal backed by FFELP loans, the collateral pool has the benefit of the government guarantee, so losses would be mitigated through the guarantee. However, the servicer must comply with the rules and regulations set down by the Department of Education in order to get the full benefit of the guarantee for the ABS investors. Private student loans do not have the benefit of a government guarantee, so the underwriting and servicing of the loans must stand on the lender/servicer ability to collect on the loans. The ability of borrowers to delay repayment through various stages of the student loan life cycle suggests that the capability of the servicer can play an important role in the long-run quality of student loan ABS.

Prepayment risks, rather than credit risks, in legacy FFELP student loans have become particularly acute. An uneven economic recovery since 2009 and slow growth in household incomes has made it difficult for many borrowers to make full payments of interest and principal. The Department of Education put in place a number of programs to help borrowers manage their debt loads. This has included income-based repayment (IBR) plans that reduce the monthly payments based on the current income of the borrower.

In the extreme, the payment can be zero, but the loan may still be considered current because of the IBR plan it is in. Payment rates of principal have slowed considerably, and the average lives of the ABS bonds have extended. This extension risk has translated into wider spreads on FFELP student loan ABS to compensate for the longer payment window on legacy bonds. Trading in FFELP student loan ABS has become concentrated in the hands of a few investors and dealers willing to take the extension and prepayment risks.

KEY POINTS

- Securitization is a process where the cash flows from financial assets—interest and principal—are used to back payments on securities sold to investors.

- Assets securitized are primarily loans and leases, but many other types of receivables and financial obligations, such as accounts receivable or utility charges, have found their way into the ABS market.
- Securitizations are usually structured as bankruptcy-remote vehicles to isolate the assets from any potential bankruptcy of the originator. This bankruptcy remoteness allows the ABS debt to carry credit ratings that may be higher than those of the originator of the assets backing the securities sold to investors. The vast majority of ABS sold to investors, in fact, carries a AAA rating from one or more credit rating agencies.
- Credit enhancement in the form of overcollateralization, excess spread, subordination, and/or cash reserve accounts may be used in combination to protect investors against credit writedowns on their bonds.
- The structures of different ABS asset classes will depend upon the cash-flow profile of different kinds of loans or leases. Structures will be put together to mitigate risks that may be unique to each different type of asset class.
- Outside of the credit card ABS sector, the largest segments of the market are auto loans and leases, equipment loans and leases, and student loans.
- Auto ABS has become the largest nonmortgage sector, with rapid expansion in subprime loans and prime leases. Used car prices and lease residual values have become a major focus for those analyzing the sector.
- Equipment ABS consists of several subsectors with their own unique risks. Smaller issuers mean servicer risk is an important component of credit analysis.
- Student loan ABS outstanding has been shrinking after the end of the FFELP government program. Income-based repayment plans have slowed principal collections and extended maturities on many bonds. Private student loans are growing as tuition costs continue to rise.

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CHAPTER
THIRTY

COLLATERALIZED LOAN OBLIGATIONS

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A collateralized debt obligation (CDO) is a structured financial product backed by a diversified pool of one or more types of debt obligations. The pool is usually managed by an asset manager. A CDO issues debt and equity and utilizes the proceeds received to acquire a portfolio of debt obligations. The cash flows from the pool of debt obligations are distributed to the holders of the CDO's various liabilities in prescribed ways that consider the relative seniority of those liabilities.

Issuance of CDOs backed by pools of corporate bonds, residential mortgage-backed securities, commercial mortgage-backed securities, and asset-backed securities has ceased, and few market observers believe these types of CDOs will be issued in the future. A CDO backed by a pool of bank loans is called a *collateralized loan obligation* (CLO). This type of CDO continues to be issued and is the subject of this chapter.

The terminology regarding what is a CLO can be confusing. A CLO is a distinct legal entity that, as explained later, is established as a bankruptcy-remote entity and is the issuer of the securities that investors can purchase. The confusion is that the CLO is the issuer of securities and the securities issued are also referred to as CLOs. That is, a CLO can mean both the issuer and the securities issued by the CLO. The context in which CLO is used in the chapter will make it clear how the term is used.

There are four key attributes of a CLO: assets, capital structure, purpose for creation, and credit structure. We briefly describe each in this chapter.[1]

1. For a more detailed discussion of CLOs, see Stephen J. Antczak, Douglas J. Lucas, and Frank J. Fabozzi, *Leveraged Finance: Concepts, Methods, and Trading of High-Yield Bonds, Loans, and Derivatives* (Hoboken, NJ: John Wiley & Sons, 2009).

ASSETS

The assets of a CLO are corporate loans, most always performing leveraged loans that sit senior in a firm's capital structure and that historically have had recovery values much higher than unsecured debt of the same bankrupt firm. As explained in Chapter 11, leveraged bank loans are loans to corporations with a speculative-grade rating. There are two types of loans currently being used in the CLO market, broadly syndicated loans and middle markets loans. Broadly syndicated loans (BLS) are the most common type of loans, making up a majority of CLO collateral. BLS are larger loans that exceed $500 million or more and trade more actively than middle market loans, which represent smaller loan amounts for smaller, less well-known companies.

The dynamic between the CLO market and the loan market is well understood. As credit spreads tighten and loan prices increase, the amount of the spread they offer to investors decreases, thereby reducing the CLO profit via arbitrage. This condition will cause the new issue market for CLOs to slow or cease.

Only when credit markets fall or liability investors accept a tighter spread will the creation of new issue CLO continue.

CAPITAL STRUCTURE

A CLO's capital structure includes senior debt, mezzanine debt, subordinated debt, and equity. The securities issued by a CLO are commonly referred to as *tranches* and labeled in an offering as Class A, Class B, Class C, and so forth, going from top (in terms of payment seniority) to the bottom of the capital structure. They range from the most secured triple-A rated tranche with the greatest amount of subordination beneath it, to the most levered, unrated equity tranche. This structure is commonly referred to as "the stack." A simplified tranche structure for a CLO backed by a pool of leveraged loans is shown in Exhibit 30-1.

A CLO is created so as to be a "bankrupt remote entity," and this is accomplished by establishing a special purpose entity (SPE) that affords that protection. A very important aspect of a CLO's bankruptcy remoteness is the absolute seniority and subordination of the CLO's debt tranches to one another. Even if it is a certainty that some holders of the CLO's debt will not receive their full principal and interest, cash flows from the CLO's assets are still distributed according to the distribution rules dictated by seniority. The CLO cannot go into bankruptcy, either voluntarily or through the action of an aggrieved creditor. In fact, the need for bankruptcy is obviated because the distribution of the CLO's cash flows, even if the CLO is insolvent, has already been determined in detail at the origination of the CLO. But within the stipulation of strict seniority, there is great variety in the features of CLO debt tranches. The driving force in creating a CLO structure is to raise funds at the lowest possible liability cost. This is done so that the CLO's equity holder, who is at the bottom of the chain of seniority, can get the most residual cash flow.

EXHIBIT 30-1

Simple, Typical CLO Tranche Structure

Tranche	Percent of Capital Structure	Rating	Coupon
Class A	67.50	AAA	LIBOR + 30
Class B	10.00	AA	LIBOR + 40
Class C	9.00	A	LIBOR + 80
Class D	2.75	BBB	LIBOR + 190
Class E	2.75	BB	LIBOR + 480
Equity	8.00	NR	Residual Cash Flow

CREATION PURPOSE

Prior to the passage of Dodd-Frank and the Volcker Rule, CLOs were created for one of two purposes: balance sheet or arbitrage. With banks no longer able to warehouse large amounts of bank loans, balance sheet trades are no longer viable.

The motivation for an arbitrage CLO is that an asset manager specializing in loans seeks to augment assets under management and management fees. It is the asset manager who assembles the initial portfolio into a warehouse facility months before the actual CLO is created. The hope is the weighted average coupon of the asset pool will exceed the weighted average cost of the liabilities. This creates a positive arbitrage CLO that is then managed according to prescribed guidelines set forth in the CLO's indenture. Investors wish to have the expertise of an asset manager specializing in leveraged loan portfolio management. Loans are purchased in the marketplace by the asset manager from many different sellers and put into the CLO.

The difference is that instead of all the investors sharing the fund's return in proportion to their investment, investor returns are also determined by the seniority of the CLO tranches they purchase.

From the perspective of CLO investors, all CLOs have a number of common purposes. One such purpose is the partitioning and allocation of the credit risk of the pool of loans among investor groups that have different risk appetites. Thus, both a triple-A investor and a double-B investor can invest in leveraged loans. Often, CLO debt provides a higher spread than comparable investments.

For the equity investor, a CLO provides a leveraged return on a diversified portfolio of leveraged loans without the need to obtain borrowing via repurchase agreements (repos) from a bank. It allows the investor to obtain nonrecourse long-term financing at a fixed spread to LIBOR (the weighted average of the liabilities above them in the capital structure).

CREDIT STRUCTURES

CLOs have additional structural credit protections beyond the protection afforded by seniority and subordination of the CLO's capital structure. These credit structures fall into the category of either *cash-flow* or *market-value* protections. We will only discuss the cash-flow credit structure here because it is the dominant credit enhancement mechanism in CLOs, being roughly 95% of all CLOs. The specifics of a CLO's cash-flow structure determine the risks taken on by various classes of CLO debt and equity and therefore the return profiles of those classes.

It is necessary to understand a CLO's *cash-flow waterfalls* in order to understand the cash-flow credit structure. There are two waterfalls in a cash flow CLO: one for collateral interest and another for collateral principal. It is the cash-flow waterfalls that dictate the payment priority to the holders of the CLO tranches and thus enforce the seniority of one creditor in the structure over another. The cash-flow waterfalls specify *coverage tests*, and the failure of such tests can result in the diversion of collateral cash flow from subordinated CLO creditors to senior CLO creditors. The most important of these are the *par coverage tests*:

Class A par coverage test = Asset par/Class A par
Class B par coverage test = Asset par/(Class A par + Class B par)

and so on, for all of the CLO debt tranches.

The par of defaulted loans is reduced or excluded from Asset Par in the numerator of par coverage tests.

Here is a simple, typical *interest waterfall* in which collateral interest is applied to CLO creditors in the following order:

1. To the trustee for base fees and expenses
2. To the asset manager for base fees
3. To Class A for interest expense
4. If Class A coverage tests are failed, to Class A for principal repayment until Class A coverage tests are met
5. To Class B for interest expense
6. If Class B coverage tests are failed, to the senior-most outstanding tranche (which could be Class A or, if Class A has been paid in full, Class B) for principal repayment until Class B coverage tests are met
7. To Class C for interest expense
8. If Class C coverage tests are failed, to the senior-most outstanding tranche for principal repayment until Class C coverage tests are met

(Steps 7 and 8 are repeated for remaining debt tranches.)

9. An additional coverage test that determines whether an amount of collateral interest must be reinvested in additional collateral

10. Additional fees to the trustee
11. Additional fees to the asset manager
12. To the equity tranche, in accordance with any profit-sharing agreement with the asset manager

Note that coverage tests force a decision to be made about whether to pay interest to a class or pay down principal on the senior-most outstanding class.

Here is a simple, typical *principal waterfall* in which collateral principal is applied to CLO creditors in the following order:

1. Amounts due in 1 through 8 of the interest waterfall that were not met with collateral interest
2. During the CLO's reinvestment period, to purchase new collateral assets
3. After the reinvestment period, for principal repayment of tranches in order of their priority
4. Amounts due in 9 through 12 of the interest waterfall

The purpose of the diversion of collateral interest is to provide greater protection to senior CLO tranches. The CLO's debt tranches can receive all their principal and interest even if collateral losses exceed the amount of subordination below them in the capital structure. The benefit of coverage tests to senior tranches depends on how soon the tests are breached. The earlier the diversion of interest to senior tranches occurs, the greater the collateral interest diverted over the remaining life of the collateral. The amount of cash that can be diverted is smaller if tests fail late in the CLO's life.

However, there are strategies that a CLO manager can employ to circumvent the protection of cash-flow diversion. "Par building" trades artificially improve par coverage tests by replacing relatively high-price collateral with relatively low-price collateral. For example, suppose that a CLO manager sells \$6 million of loans at par and with the proceeds from the sale acquires \$7 million par of loans selling at 85%. This action would inflate Asset Par by \$1 million in the numerator of the par coverage test. Done in enough size, it could prevent a CLO from violating par coverage tests and keep cash flowing down the CLO's waterfall to the manager and equity holders.

MARKET SIZE, TRADING

As of 2019, the outstanding CLO market is approximately \$600 billion, which accounts for half of the \$1.2 trillion leveraged loan market. Annual new issuance volume averaged \$100 billion from 2014–2019, with a large number of new CLO asset managers appearing since 2018 as risk-retention rules were turned back by the courts.

CLO trading is still completed in a very decentralized, over-the-counter market. Due to the extensive work that must be completed by each potential buyer with respect to documentation, no electronic marketplace has yet developed for CLO's. In fact, most lower-rated CLO tranches and CLO equity trade in a multiday BWIC (bid wanted in competition) format to allow for the exchange of documentation between buyers and bidders.

HOW A CLO IS CREATED

The origins of a new CLO begin with a lengthy syndicate process that may last as long as six months to complete. The issuer (who in this case is the SPV represented by the asset manager teams) with an investment bank help find buyers for both the liabilities (funding) and the equity.

Months before a CLO is priced and created, the investment bank and the manager start the process by opening a warehouse facility that will allow the manager to begin purchasing collateral for the upcoming CLO. This process of purchasing collateral in anticipation of a new CLO deal is called the "ramp-up period."

As the investment banker and investment manager begin to collect orders for the liabilities, the deal becomes more likely to be finalized, or "printed." Normally, it is the two ends of the capital structure (AAA or equity) that are the most difficult to place, depending on market conditions. As soon as both parties agree that a deal is likely, the amount of assets in the warehouse will grow closer to the expected final size of the deal. Most CLO deals are in the range of $350 to $600 million.

On the final day the spreads for all liabilities are locked, and the funds are transferred from the liability buyers to the SPV. Simultaneously, the assets previously purchased in the warehouse are transferred into the SPV. The asset manager must then hurry to purchase the remaining amount of the needed collateral since the cash in the SPV may create a negative arbitrage between the assets and liabilities.

FEES

CLO fees are divided into three classes. The first is the Senior Management Fee, which is paid after administration and trustee fees but before interest on the liabilities. The next fee is the Junior Management Fee, which is paid after the liabilities but before any payments to the equity class. The last fee is the Equity Class Incentive Fee, which has properties like a hedge fund fee with a hurdle rate and fixed percentage of profits.

The sum of the first two fees is in a range of 30 to 35 basis points of deal assets as measured by liabilities. However, certain arrangements called "side letters" are offered to critical investors that have the effect of lowering these fees.

BUYERS

It is easy to think of the CLO stack in three parts. The senior, which includes the AAA and AA tranches; the subordinate, which includes the BBB and BB tranches; and last the equity, which is unrated.

Senior tranches are purchased by money center banks, endowments, and pension funds. Hedge funds will only purchase senior tranches by applying a great deal of leverage.

Subordinate tranches are usually purchased by mutual funds or hedge funds looking to diversify away from BBB corporate credit while hoping to obtain similar or higher returns for the same ratings.

Equity tranches are purchased by a special class of buyers, most often structured products experts working within a credit hedge fund or other investment manager with structured product experience.

TRADING OF CLO COLLATERAL

The trading of bank loans by CLO managers depends on three factors: (1) liquidity of the issuer, (2) size of the sale amount and number of names, and (3) style of the manager.

For a well-known name (e.g., Charter or Sprint), a good buy-side loan trader should know the market and understand the bid side. For lesser-known names, the trader has two options: (1) give a broker an order at an agreed-upon level and let the broker canvas the market on behalf of the buy-side trader, or (2) go the BWIC route, asking many dealers for a bid.

If the number of names to be sold is small and less liquid, the trader may go to two or three other possible dealers—so, a mini-BWIC, because some dealers are either going to be asked to buy or sell a particular name on a specific day. A good trader needs to figure this out. The CLO trader cannot expect that every dealer desk will want to buy the bank loan that the trader wants to sell. If, in contrast, the BWIC contained a large number of names, let's say $100 million or more, a BWIC with six or seven dealers is usually the way to go. During a BWIC, dealers can either search for buyers or bid on their own. A good broker/dealer could either need the loans on an order for another account or need the loans for inventory. This leads to some loans being sold on the BWIC as a broker transaction (dealer passes loans to another account immediately and collects the bid/offer) or a principal transaction where the loans simply go into the dealer's inventory.

As for style, some CLO managers like to talk to many broker/dealers and show no favors. Others have favorites based on different metrics and do a considerable percentage of their business with a few dealers. There is no right or wrong practice.

Also what should be kept in mind is that CLO managers cannot be just sellers. The yield on the CLO portfolio cannot sustain being in cash after a sale but must be reinvested in another bank loan. Consequently, many trades are effectively swaps. A good CLO trader is looking for the best sale-to-purchase net price, so a BWIC/OWIC (offer wanted in competition) may or may not accomplish that investment objective.

KEY POINTS

- A CLO is a type of CDO in which the pool of assets consists of levered, secured bank loans.
- A CLO's capital structure includes senior debt, mezzanine debt, subordinated debt, and equity.
- From a CLO investor's perspective, the purpose is the partitioning and allocation of the credit risk of the pool of loans among investor groups that have different risk appetites.
- CLOs rely on both an initial positive arbitrage and strong active portfolio management for the life of the deal to provide investors their expected returns.
- In addition to the protection afforded by seniority and subordination of the CLO's capital structure, there is another structural credit protection that allows the diversion of cash flow to the senior-most tranche outstanding if prescribed coverage tests are not satisfied.
- A new issue CLO can only exist when there is a positive arbitrage between the loans (collateral) and the notes (liabilities).

PART
FIVE

THE YIELD CURVE AND THE TERM STRUCTURE

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CHAPTER
THIRTY-ONE

OVERVIEW OF FORWARD RATE ANALYSIS

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Over the years, advances have been made in both the theoretical and the empirical analysis of the term structure of interest rates. However, such analysis is often very quantitative, and it rarely emphasizes practical investment applications. In this chapter we briefly describe the computation of par, spot, and forward rates; present a framework for interpreting the forward rates by identifying their main determinants; and develop practical tools for using the information in forward rates in active bond portfolio management.

The three main influences on the Treasury yield-curve shape are (1) the market's expectations of future rate changes, (2) bond risk premiums (expected return differentials across bonds of different maturities), and (3) convexity bias. Conceptually, it is easy to divide the yield-curve (or the term structure of forward rates) into these three components. It is much harder to interpret real-world yield-curve shapes, but the potential benefits are substantial. For example, investors often wonder whether the curve steepness reflects the market's expectations of rising rates or a positive risk premium. The answer to this question determines whether a duration extension increases expected returns. It also shows whether we can view forward rates as the market's expectations of future spot rates. In addition, in this chapter we will explain how the market's curve reshaping and volatility expectations influence the shape of today's yield-curve. These expectations determine the cost of enhancing portfolio convexity via a duration-neutral yield-curve trade.[1]

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1. Details on each of the three influences on the yield-curve can be found at Antti Ilmanen, "Market's Rate Expectations and Forward Rates," *Journal of Fixed Income* (September 1996), pp. 8–22; Antti Ilmanen, "Does Duration Extension Enhance Long-Term Expected Returns?" *Journal of Fixed Income* (September 1996), pp. 23–36; and Antti Ilmanen, "Convexity Bias in the Yield Curve," Chapter 3 in Narasimgan Jegadeesh and Bruce Tuckman (eds.), *Advanced Fixed-Income Valuation Tools* (New York: Wiley, 2000).

Forward rate analysis also can be valuable in direct applications. Forward rates may be used as break-even rates to which subjective rate forecasts are compared or as relative-value tools to identify attractive yield-curve sectors.[2]

COMPUTATION OF PAR, SPOT, AND FORWARD RATES

At the outset, it is useful to review the concepts yield-to-maturity, par yield, spot rate, and forward rate to ensure that we are using our terms consistently. Appendix 31A is a reference that describes the notation and definitions of the main concepts used in this chapter. Our analysis focuses on government bonds that have known cash flows (no default risk, no embedded options). *Yield-to-maturity* is the single discount rate that equates the present value of a bond's cash flows to its market price. *A yield-curve* is a graph of bond yields against their maturities. (Alternatively, bond yields may be plotted against their durations, as we do in many of the exhibits presented in this chapter.) The best-known yield-curves are the on-the-run Treasury curve and the interest-rate-swap curve. On-the-run bonds are the most recently issued government bonds at each maturity sector. Since these bonds are always issued with price near par (100), the on-the-run curve often resembles the *par yield-curve,* which is a curve constructed for theoretical bonds whose prices equal par. The swap curve based on receive-fixed, pay-floating contracts is by construction a par curve.

While the yield-to-maturity is a convenient summary measure of a bond's expected return—and therefore a popular tool in relative-value analysis—the use of a single rate to discount multiple cash flows can be problematic unless the yield-curve is flat. First, all cash flows of a given bond are discounted at the same rate, even if the yield-curve slope suggests that different discount rates are appropriate for different cash-flow dates. Second, the assumed reinvestment rate of a cash flow paid on a given date can vary across bonds because it depends on the yield of the bond to which the cash flow is attached. In this chapter we will show how to analyze the yield-curve using simpler building blocks—single cash flows and one-period discount rates—than the yield-to-maturity, an *average* discount rate of multiple cash flows with various maturities.

A coupon bond can be viewed as a bundle of zero-coupon bonds (zeros). It can be unbundled to a set of zeros that can be valued separately. Then these can be bundled back together into a more complex bond whose price should equal the

2. For a discussion of how to analyze many aspects of yield-curve trades, such as barbell-bullet trades, and a presentation of empirical evidence about their historical behavior, see Antti Ilmanen and Ray Iwanowski, "Dynamics of the Shape of the Yield Curve," *Journal of Fixed Income* (September 1997), pp. 47–60; and Chapter 32.

sum of the component prices.[3] The *spot rate* is the discount rate of a single future cash flow such as a zero. Equation (31-1) shows the simple relation between an n-year zero's price P_n and the annualized n-year spot rate s_n.

$$P_n = \frac{100}{(1+s_n)^n} \tag{31-1}$$

A single cash flow is easy to analyze, but its discount rate can be unbundled even further to one-period rates. A multiyear spot rate can be decomposed into a product of *one-year forward rates,* the simplest building blocks in a term structure of interest rates. A given term structure of spot rates implies a specific term structure of forward rates. For example, if the m-year and n-year spot rates are known, the annualized forward rate between maturities m and n, that is, $f_{m,n}$, is easily computed from Eq. (31-2).

$$(1+f_{m,n})^{n-m} = \frac{(1+s_n)^n}{(1+s_m)^m} \tag{31-2}$$

The forward rate is the interest rate for a loan between any two dates in the future, contracted today. Any forward rate can be "locked in" today by buying one unit of the n-year zero at price $P_n = 100/(1 + s_n)^n$ and by shortselling P_n/P_m units of the m-year zero at price $P_m = 100/(1 + s_m)^m$. (Such a weighting requires no net investment today because both the cash inflow and cash outflow amount to P_n.) The one-year forward rate ($f_{n-1,n}$ such as $f_{1,2}, f_{2,3}, f_{3,4}, \ldots$) represents a special case of Eq. (31-3) where $m = n - 1$. The spot rate represents another special case where $m = 0$; thus $s_n = f_{0,n}$.

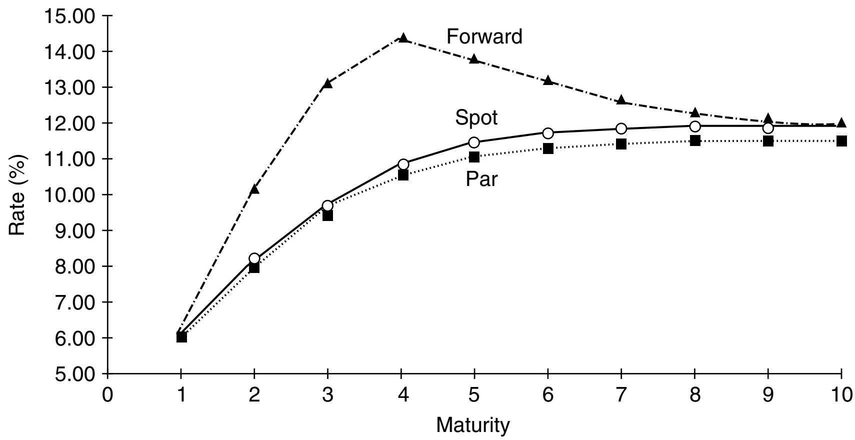
To summarize, a par rate is used to discount a set of cash flows (those of a par bond) to today, a spot rate is used to discount a single future cash flow to today, and a forward rate is used to discount a single future cash flow to another (nearer) future date. The par yield-curve, the spot-rate curve, and the forward-rate curve contain the same information about today's term structure of interest rates.[4]

3. Arbitrage activities ensure that a bond's present value is very similar when its cash flows are discounted using the marketwide spot rates as when its cash flows are discounted using the bond's own yield-to-maturity. However, some deviations are possible because of transaction costs and other market imperfections. In other words, the term structure of spot rates gives a consistent set of discount rates for all government bonds, but all bonds' market prices are not exactly consistent with these discount rates. Individual bonds may be rich or cheap relative to the curve because of bond-specific-liquidity, coupon, tax, or supply effects.

4. These curves can be computed directly by interpolating between on-the-run bond yields (approximate par curve) or between zero yields (spot curve). Because these assets have special liquidity characteristics, these curves may not be representative of the broad Treasury market. Therefore, the par, spot, or forward rate curve is typically estimated using a broad universe of coupon Treasury bond prices. There are many different curve-fitting techniques, but a common goal is to fit the prices well with a reasonably shaped curve. This chapter does not focus on yield-curve estimation but on the interpretation and practical uses of the curve once it has been estimated.

EXHIBIT 31-1

Par, Spot, and One-Year Forward Rate Curves



If one set of rates is known, it is easy to compute the other sets.[5] Exhibit 31-1 shows a hypothetical example of the three curves. In Appendix 31B, we show how the spot and forward rates were computed based on the par yields.

In this example, the par and spot curves are monotonically upward-sloping, whereas the forward rate curve[6] is first upward-sloping and then inverts (because of the flattening of the spot curve). The spot curve lies above the par curve, and the forward rate curve lies above the spot curve. This is always the case if the spot curve is upward-sloping. If it is inverted, the ordering is reversed: The par curve is highest, and the forward curve lowest. Thus loose characterizations of one curve (e.g., steeply upward-sloping, flat, inverted, humped) generally are applicable to the other curves. However, the three curves are identical only if they are horizontal. The forward rate curve magnifies any variation in the slope of the spot curve. One-year forward rates measure the *marginal* reward for lengthening the maturity of the investment by one year, whereas the spot rates measure an investment's *average* reward from today to maturity n. Therefore, spot rates are (geometric) averages of one or more forward rates. Similarly, par rates are averages of one or more spot rates; thus par curves have the flattest

5. Further, one can use today's spot rates and Eq. (31-2) to back out implied spot curves for any future date and implied future paths for the spot rate of any maturity. It is important to distinguish the implied spot curve one year forward ($f_{1,2}, f_{1,3}, f_{1,4}, \ldots$), a special case of Eq. (31-2) where $m = 1$, from the one-year forward rate curve ($f_{1,2}, f_{2,3}, f_{3,4}, \ldots$). Today's spot curve can be subtracted from the former curve to derive the yield changes implied by the forwards. (This terminology is somewhat misleading because these "implied" forward curves/paths do not reflect only the market's expectations of future rates.)

6. Note that all one-year forward rates actually have a one-year maturity even though in the x axis of Exhibit 31-1 each forward rate's maturity refers to the final maturity. For example, the one-year forward rate between $n - 1$ and n ($f_{n-1,n}$) matures n years from today.

shape of the three curves. In Appendix 31C, we discuss further the relation between spot and forward rate curves.

It is useful to view forward rates as *break-even rates*. The implied spot rates one year forward ($f_{1,2}$, $f_{1,3}$, $f_{1,4}$, . . .) are, by construction, equal to such future spot rates that would make all government bonds earn the same return over the next year as the (riskless) one-year zero. For example, the holding-period return of today's two-year zero (whose rate today is s_2) will depend on its selling rate (as a one-year zero) in one year's time. The implied one-year spot rate one year forward ($f_{1,2}$) is computed as the selling rate that would make the two-year zero's return [the left-hand side of Eq. (31-3)] equal to the one-year spot rate [the right-hand side of Eq. (31-3)]. Formally, Eq. (31-3) is derived from Eq. (31-2) by setting $m = 1$ and $n = 2$ and rearranging.

$$\frac{(1+s_2)^2}{1+f_{1,2}} = 1+s_1 \tag{31-3}$$

Consider an example using numbers from Exhibit 31B–1 in Appendix 31B, where the one-year spot rate (s_1) equals 6% and the two-year spot rate (s_2) equals 8.08%. Plugging these spot rates into Eq. (31-3), we find that the implied one-year spot rate one year forward ($f_{1,2}$) equals 10.20%. If this implied forward rate is exactly realized one year hence, today's two-year zero will be worth 100/1.1020 = 90.74 next year. Today, this zero is worth $100/1.0808^2 = 85.61$; thus its return over the next year would be 90.74/85.61 − 1 = 6%, exactly the same as today's one-year spot rate. Thus 10.20% is the break-even level of the future one-year spot rate. In other words, the one-year rate has to increase by more than 420 basis points (10.20% − 6.00%) before the two-year zero underperforms the one-year zero over the next year. If the one-year rate increases, but by less than 420 basis points, the capital loss of the two-year zero will not fully offset its initial yield advantage over the one-year zero.

More generally, if the yield changes implied by the forward rates are realized subsequently, all government bonds, regardless of maturity, earn the same holding-period return. In addition, all self-financed positions of government bonds (such as long a barbell versus short a bullet) earn zero return; that is, they break even. However, if the yield-curve remains unchanged over a year, each n-year zero earns the corresponding one-year forward rate $f_{n-1,n}$. This can be seen from Eq. (31-2) when $m = n - 1$; $1 + f_{n-1,n}$ equals $(1 + s_n)^n/(1 + s_{n-1})^{n-1}$, which is the holding-period return from buying an n-year zero at rate s_n and selling it one year later at rate s_{n-1}. Thus the one-year forward rate equals a zero's horizon return for an unchanged yield-curve. See Appendix 31C for details.

MAIN INFLUENCES ON THE YIELD-CURVE SHAPE

In this section we describe some economic forces that influence the term structure of forward rates or, more generally, the yield-curve shape. The three main influences are the market's rate expectations, the bond risk premiums (expected return differentials across bonds), and the so-called convexity bias. In fact, these three components fully determine the yield-curve; it can be shown that the difference between each one-year forward rate and the one-year spot rate is approximately equal to the sum of an expected spot-rate change, a bond risk premium, and the convexity bias.[7] We first discuss separately how each component alone influences the curve shape and then analyze their combined impact.

Expectations

It is clear that the market's expectations of future rate changes are one important determinant of the yield-curve shape. For example, a steeply upward-sloping curve may indicate market expectations of near-term Fed tightening or of rising inflation. However, it may be too restrictive to assume that the yield differences across bonds with different maturities *only* reflect the market's rate expectations. The well-known pure expectations hypothesis has such an extreme implication. The *pure expectations hypothesis* asserts that all government bonds have the same near-term expected return (as the nominally riskless short-term bond) because the return-seeking activity of risk-neutral traders removes all expected return differentials across bonds. Near-term expected returns are equalized if all bonds that have higher yields than the short-term rate are expected to suffer capital losses that offset their yield advantage. When the market expects an increase in bond yields, the current term structure becomes upward-sloping so that any long-term bond's yield advantage and expected capital loss (owing to the expected yield increase) exactly offset each other. Stated differently, if investors expect that their long-term bond investments will lose value owing to an increase in interest rates, they will require a higher initial yield as a compensation for duration extension. Conversely, expectations of yield declines and capital gains will lower current long-term bond yields below the short-term rate, making the term structure inverted.

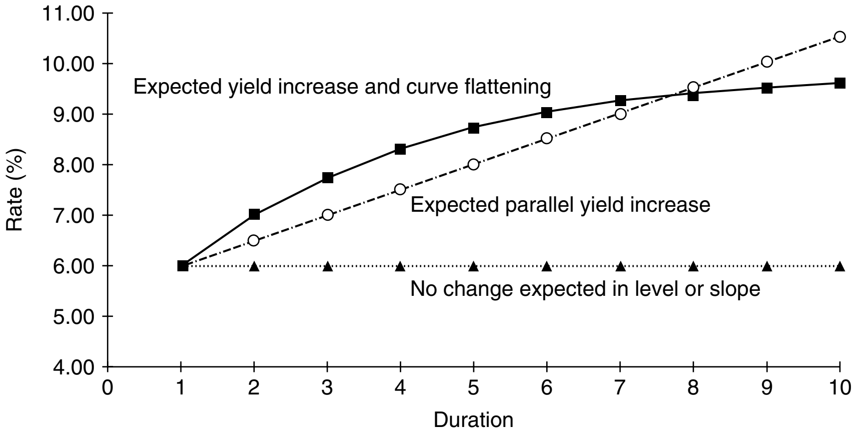
The same logic—that positive (negative) initial yield spreads offset expected capital losses (gains) to equate near-term expected returns—also holds for combinations of bonds, including duration-neutral yield-curve positions. One example is a trade that benefits from the flattening of the yield-curve between 2- and 10-year maturities: selling a unit of the 2-year bond, buying a duration-weighted amount (market value) of the 10-year bond, and putting the remaining proceeds from the sale to "cash" (very short-term bonds). Given the typical concave yield-curve shape, such a curve-flattening position earns a negative carry.[8] The trade will be profitable only if the curve flattens enough to offset the impact of the negative carry. Implied forward rates indicate how much

7. The proof is provided in the appendix to Chapter 37.

8. A concave shape means that the (upward-sloping) yield-curve is steeper in the front end than in the long end. The yield loss of moving from the two-year bond to cash is greater than the yield gain of moving from the two-year bond to the ten-year bond. Thus the yield earned from the combination of cash and tens is lower than the forgone yield from twos.

EXHIBIT 31-2

Yield-Curves Given the Market's Various Rate Expectations



flattening (narrowing of the two- to ten-year spread) is needed for the trade to break even.

In the same way as the market's expectations regarding the future level of rates influence the *steepness* of today's yield-curve, the market's expectations regarding the future steepness of the yield-curve influence the *curvature* of today's yield-curve. If the market expects more curve flattening, the negative carry of the flattening trades needs to be larger (to offset the expected capital gains), which makes today's yield-curve more concave (curved). Exhibit 31-2 illustrates these points. This figure plots coupon bonds' yields against their durations or, equivalently, zeros' yields against their maturities, given various rate expectations. Ignoring the bond risk premium and convexity bias, if the market expects no change in the level or slope of the curve, today's yield-curve will be horizontal. If the market expects a parallel rise in rates over the next year (but no reshaping), today's yield-curve will be linearly increasing (as a function of duration). If the market expects rising rates *and* a flattening curve, today's yield-curve will be increasing and concave (as a function of duration).[9]

Bond Risk Premium

A key assumption in the pure expectations hypothesis is that all government bonds, regardless of maturity, have the same expected return. In contrast, many theories and empirical evidence suggest that expected returns vary across bonds. We define the *bond risk premium* as a longer-term bond's expected one-period return in excess of the one-period bond's riskless return. A positive bond risk

9. For a detailed treatment of these issues, see Ilmanen, "Market's Rate Expectations and Forward Rates," *op. cit.*

premium would tend to make the yield-curve slope upward. Various theories disagree about the sign (+/−), the determinants, and the constancy (over time) of the bond risk premium. The classic liquidity premium hypothesis argues that most investors dislike short-term fluctuations in asset prices; these investors will hold long-term bonds only if they offer a positive risk premium as a compensation for their greater return volatility. Also, some modern asset-pricing theories suggest that the bond risk premium should increase with a bond's duration, its return volatility, or its covariance with market wealth. In contrast, the preferred-habitat hypothesis argues that the risk premium may decrease with duration; long-duration liability holders may perceive the long-term bond as the riskless asset and require higher expected returns for holding short-term assets. While academic analysis focuses on risk-related premiums, market practitioners often emphasize other factors that cause expected return differentials across the yield-curve. These include liquidity differences between market sectors, institutional restrictions, and supply and demand effects. We use the term *bond risk premium* broadly to encompass all expected return differentials across bonds, including those caused by factors unrelated to risk.

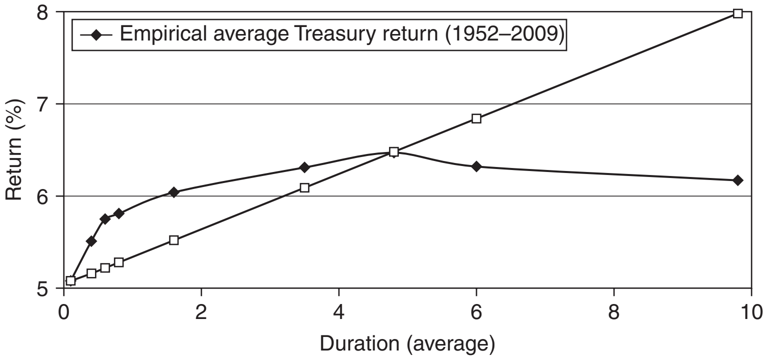
Historical data on U.S. Treasury bonds provide evidence about the empirical behavior of the bond risk premium. For example, the fact that the Treasury yield-curve has been upward-sloping more than 90% of the time in recent decades may reflect the impact of positive bond risk premiums. Historical average returns provide more direct evidence about expected returns across maturities than do historical yields. Even though weekly and monthly fluctuations in bond returns are mostly unexpected, the impact of unexpected yield rises and declines should wash out over a long sample period. Therefore, the *historical average returns* of various maturity sectors over a relatively trendless sample period should reflect the *long-run expected returns*.

Exhibit 31-3 shows the empirical average return curve as a function of average duration and contrasts it with a popular theoretical expected return curve, one that increases linearly with duration. The theoretical bond risk premiums are measured in the exhibit by the difference between the annualized expected returns at various duration points and the annualized return of the riskless one-month bill (the leftmost point on the curve). Similarly, the empirical bond risk premiums are measured by the historical average bond returns (at various durations) in excess of the one-month bill.[10] Historical experience suggests that the bond risk premiums are not linear in duration but that they increase steeply with duration in the

10. The empirical bond risk premiums are based on the compound average returns of various maturity-subsector portfolios of Treasury bills, notes, and bonds between 1952 and 2009. This period does not have an obvious bullish or bearish bias because long-term yields were at broadly similar levels at the beginning and end of the sample. Moreover, the sample period begins just after the "Treasury-Fed accord" ended a decade of regulated (capped) bond yields. Arithmetic average returns would be somewhat higher than these compound average returns (at the long-est maturities 0.2-0.4% higher). This evidence is from Chapter 9 in Antti Ilmanen, *Expected Return* (Hoboken, NJ: John Wiley & Sons, 2011), which discusses bond risk premiums but focuses mainly on forward-looking measures of such premiums.

EXHIBIT 31-3

Theoretical and Empirical Bond Risk Premiums



front end of the curve and much more slowly after two years. The concave shape may reflect the demand for long-term bonds from pension funds and other long-duration liability holders.

Exhibit 31-3 may give us the best empirical estimates of the long-run average bond risk premiums at various durations. However, empirical studies also suggest that the bond risk premiums are not constant but vary over time. That is, it is possible to identify in advance periods when the near-term bond risk premiums are abnormally high or low. These premiums tend to be high after poor economic conditions when the yield-curve is steep, amid high inflation expectations and related inflation uncertainty. These premiums tend to be lower and even turn negative when Treasury prices benefit from safe-haven premiums (amid equity market weakness and negative stock-bond correlation, as in 1998 and 2002) or from scarcity premiums (amid fiscal surpluses and expectations of dwindling government bond markets, as in 2000).[11]

Convexity Bias

The third influence on the yield-curve—convexity bias—is probably the least well known. Different bonds have different convexity characteristics, and the convexity differences across maturities can give rise to (offsetting) yield differences. In particular, long-term bonds exhibit very high convexity (see panel *a* of

11. Long-run average return differentials across bonds with different maturities are discussed in Ilmanen, "Does Duration Extension Enhance Long-Term Expected Returns?" *op. cit*. Near-term expected return differentials across bonds and the time variation in the bond risk premiums are discussed in Antti Ilmanen, "Forecasting U.S. Bond Returns," *Journal of Fixed Income* (June 1997), pp. 22–37. A more recent study, Antti Ilmanen, "Stock-Bond Correlations," *Journal of Fixed Income* (September 2003), pp. 55–66, focuses on stock-bond correlation as a determinant of bond risk premium but also discusses other determinants.

EXHIBIT 31-4 (a)

Illustration of Convexity Bias

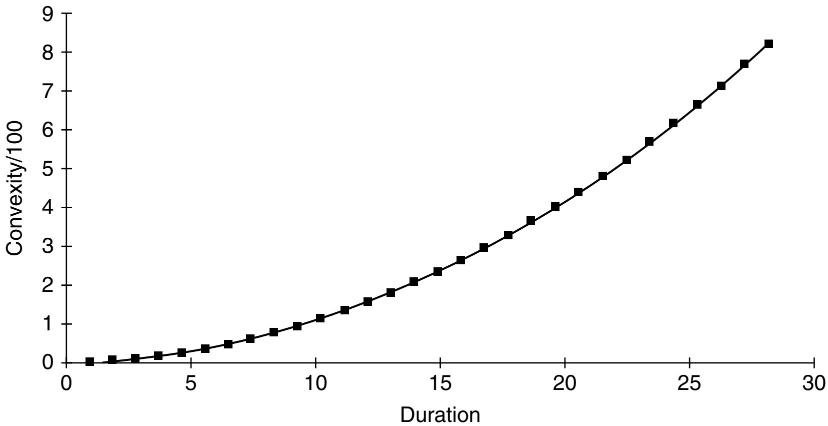


Exhibit 31-4), which tends to depress their yields. *Convexity bias* refers to the impact these convexity differences have on the yield-curve shape.

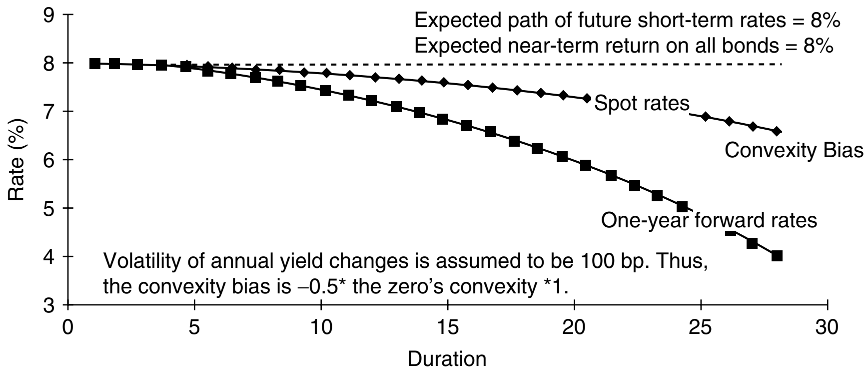
Convexity is closely related to the nonlinearity in the bond price–yield relationship. All noncallable bonds exhibit positive convexity; their prices rise more for a given yield decline than they fall for a similar yield increase. All else being equal, positive convexity is a desirable characteristic because it increases bond return (relative to return in the absence of convexity) whether yields go up or down—as long as they move somewhere. Because positive convexity can only improve a bond's performance (for a given yield), more convex bonds tend to have lower yields than less convex bonds with the same duration.[12] In other words, investors tend to demand less yield if they have the prospect of improving their returns as a result of convexity. Investors are primarily interested in expected returns, and these high-convexity bonds can offer a given expected return at a lower yield level.

Panel *b* of Exhibit 31-4 illustrates the pure impact of convexity on the curve shape by plotting the spot-rate curve and the curve of one-year forward rates when all bonds have the same expected return (8%) and the short-term rates are expected to remain at the current level. With no bond risk premiums and no expected rate

12. The degree of convexity varies across bonds, mainly depending on their option characteristics and durations. Embedded short options decrease convexity. For bonds without embedded options, convexity increases roughly as a square of duration (see Exhibit 31-4). There also are convexity differences between bonds that have the same duration. A barbell position (with very dispersed cash-flows) exhibits more convexity than a duration-matched bullet bond. The reason is that a yield rise reduces the relative weight of the barbell's longer cash-flows (because the present values decline more than those of the shorter cash-flows) and thereby shortens the barbell's duration. The inverse relation between duration and yield level increases a barbell's convexity, limiting its losses when yields rise and enhancing its gains when yields decline. Of all bonds with the same duration, a zero has the smallest convexity because its cash-flows are not dispersed, so its Macaulay duration does not vary with the yield level.

EXHIBIT 31-4 (b)

Pure Impact of Convexity on the Yield-Curve Shape



changes, one might expect these curves to be horizontal at 8%. Instead, they slope down at an increasing pace because lower yields are needed to offset the convexity advantage of longer-duration bonds and thereby to equate the near-term expected returns across bonds.[13] Short-term bonds have little convexity, so there is little convexity bias at the front end of the yield-curve, but convexity can have a dramatic impact on the curve shape at very long durations. Convexity bias can be one of the main reasons for the typical concave yield-curve shape (i.e., for the tendency of the curve to flatten or invert at long durations).

The value of convexity increases with the magnitude of yield changes. Therefore, increasing volatility should make the overall yield-curve shape more concave (curved) and widen the spreads between more and less convex bonds (duration-matched coupon bonds versus zeros and barbells versus bullets).[14]

Putting the Pieces Together

Of course, all three forces influence bond yields simultaneously, making the task of interpreting the overall yield-curve shape quite difficult. A steeply upward-sloping curve can reflect either the market's expectations of rising rates or a high required risk premium. A strongly humped curve (i.e., high curvature) can reflect

13. Convexity bias is closely related to the distinction between different versions of the pure expectations hypothesis. Earlier we referred to *the* pure expectations hypothesis. In fact, there are alternative versions of this hypothesis that are not exactly consistent with each other. The local-expectations hypothesis (LEH) assumes that "all bonds earn the same expected return over the next period" whereas the unbiased-expectations hypothesis (UEH) assumes that "forward rates equal expected spot rates." In panel *b* of Exhibit 31-4, the LEH is assumed to hold; thus UEH is not exactly true. The expected future short rates are flat at 8% even though the curve of one-year forward rates is inverted. In yield terms, the difference between the LEH and the UEH is the convexity bias.

14. For detailed discussion of this topic, see Ilmanen, "Convexity Bias in the Yield Curve," *op. cit.*

the market's expectations of either curve flattening or high volatility (which makes convexity more valuable) or even the concave shape of the risk premium curve.

In theory, the yield-curve can be neatly decomposed into expectations, risk premiums, and convexity bias. In reality, exact decomposition is not possible because the three components vary over time and are not observable directly but need to be estimated.[15] Even though an exact decomposition is not possible, the analysis in this chapter should give investors a framework for interpreting various yield-curve shapes. Furthermore, our survey of earlier literature and our new empirical work evaluate which theories and market myths are correct (consistent with data) and which are false. The main conclusions are as follows:

- We often hear that "forward rates show the market's expectations of future rates." However, this statement is true only if no bond risk premiums exist and the convexity bias is very small.[16] If the goal is to infer expected short-term rates one or two years ahead, the convexity bias is so small that it can be ignored. In contrast, our empirical analysis shows that the bond risk premiums are important at short maturities. Therefore, if the forward rates are used to infer the market's near-term rate expectations, some measures of bond risk premiums should be subtracted from the forwards, or the estimate of the market's rate expectations will be strongly upward-biased.
- The traditional term-structure theories make the assumption of a zero risk premium (pure expectations hypothesis) or of a nonzero but *constant* risk premium (liquidity premium hypothesis, preferred-habitat hypothesis), which is inconsistent with historical data. According to the pure expectations hypothesis, an upward-sloping curve should predict increases in long-term rates so that a capital loss offsets the long-term bonds' yield advantage. However, empirical evidence shows that, on average, small declines in long-term rates, which *augment* the long-term bonds' yield advantage, follow upward-sloping curves. The steeper the yield-curve, the higher is the expected bond risk premium. This finding clearly vio-

15. We show in other studies how interest-rate expectations can be measured using survey data, how bond risk premiums can be estimated using historical return data, and how the convexity bias can be inferred using option prices; see Ilmanen, "Market's Rate Expectations and Forward Rates," *op. cit.*; Ilmanen, "Does Duration Extension Enhance Long-Term Expected Returns?" *op. cit.*; and Ilmanen, "Convexity Bias in the Yield Curve," *op. cit.* Alternatively, all three components could be estimated from the yield-curve if one is willing to impose the structure of some term-structure model.

16. A related assertion claims that if near-term expected returns were not equal across bonds, it would imply the existence of *riskless arbitrage opportunities*. This assertion is erroneous. It is true that if forward contracts were traded assets, arbitrage forces would require their pricing to be consistent with zero prices according to Eq. (31-2). However, the arbitrage argument says nothing about the economic determinants of the zero prices themselves, such as rate expectations or risk premia. The experience of 1994 and 1999 shows that buying long-term bonds is not riskless even if they have higher expected returns than short-term bonds.

lates the pure expectations hypothesis and supports hypotheses about time-varying risk premiums.

- Modern term-structure models make less restrictive assumptions than the traditional theories just mentioned. Yet many popular one-factor models assume that bonds with the same duration earn the same expected return. Such an assumption implies that duration-neutral positions with more or less convexity earn the same expected return (because any convexity advantage is *exactly* offset by a yield disadvantage). However, if the market values very highly the insurance characteristics of positively convex positions, more convex positions may earn lower expected returns. Our analysis of the empirical performance of duration-neutral barbell-bullet trades will show that, in the long run, barbells tend to marginally underperform bullets.

USING FORWARD RATE ANALYSIS IN YIELD-CURVE TRADES

Recall that if the local expectations hypothesis holds, all bonds and bond positions have the same near-term expected return. In particular, an upward-sloping yield-curve reflects expectations of rising rates and capital losses, and convexity is priced so that a yield disadvantage exactly offsets the convexity advantage. In such a world, yields do not reflect value, no trades have favorable odds, and active management can add value only if an investor has truly superior forecasting ability. Fortunately, the real world is not quite like this textbook case because expected returns do vary across bonds (see Exhibit 31-3). The main reason is probably that most investors exhibit risk aversion and preferences for other asset characteristics; moreover, investor behavior may not always be fully rational. Therefore, yields reflect value, and certain relative value trades have favorable odds.

The preceding section provided a framework for thinking about the term-structure shapes. In this section we describe practical applications, that is, different ways to use forward rates in yield-curve trades. The first approach requires strong subjective rate views and faith in one's forecasting ability.

Forwards as Break-Even Rates for Active Yield-Curve Views

The forward rates show a path of break-even future rates and spreads. This path provides a clear yardstick for an active portfolio manager's subjective yield-curve scenarios and yield-path forecasts. It incorporates directly the impact of carry on the profitability of the trade. For example, a manager should take a bearish portfolio position only if she expects rates to rise by more than what the forwards imply. However, if she expects rates to rise, but by less than what the forwards imply (i.e., by less than what is needed to offset the positive carry), she should take a bullish portfolio position. If the manager's forecast is correct, the position will be profitable. In contrast, managers who take bearish portfolio positions whenever they expect bond yields to rise—ignoring the forwards—may find that their positions lose money, because of the negative carry, even though their rate forecasts are correct.

One positive aspect about the role of forward rates as break-even rates is that they do not depend on assumptions regarding expectations, risk premiums, or convexity bias. The rules are simple. If forward rates are realized, all positions earn the same return. If yields rise by more than the forwards imply, bearish positions are profitable, and bullish positions lose money. If yields rise by less than the forwards imply, the opposite is true. Similar statements hold for any yield spreads and related positions, such as curve-flattening positions.

Exhibit 31-5 shows the dollar-swap (par) yield-curve and the implied-swap curves 3 months forward and 12 months forward as of April 2004. If we believe that forward rates only reflect the market's rate expectations, a comparison of these curves tells us that the market expects rates to rise and the curve to flatten over the next year. Alternatively, the implied yield rise may reflect a bond risk premium, and the implied curve flattening may reflect the value of convexity. Either way, the forward yield-curves reflect the break-even levels between profits and losses.

The information in the forward rate structure can be expressed in several ways. Exhibit 31-5 is useful for an investor who wants to contrast his subjective view of the future yield-curve with an objective break-even curve at some future horizon. Another graph may be more useful for an investor who wants to see the break-even future path of any given-maturity yield (instead of the

EXHIBIT 31-5

Current and Forward Par Yield Curves Based on the Dollar-Swap Curve in April 2004

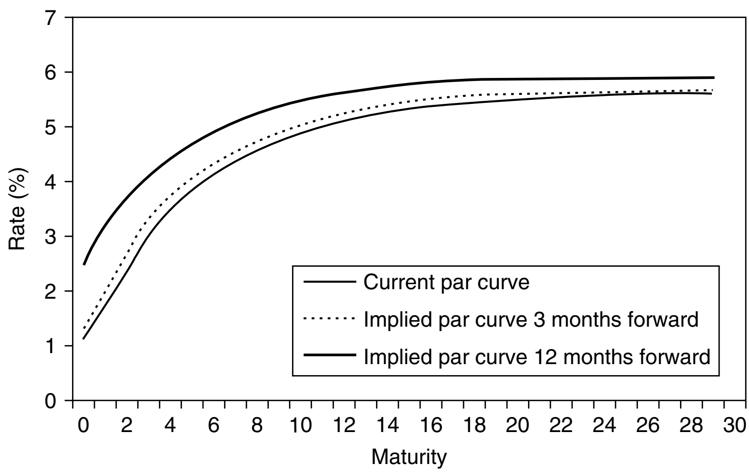
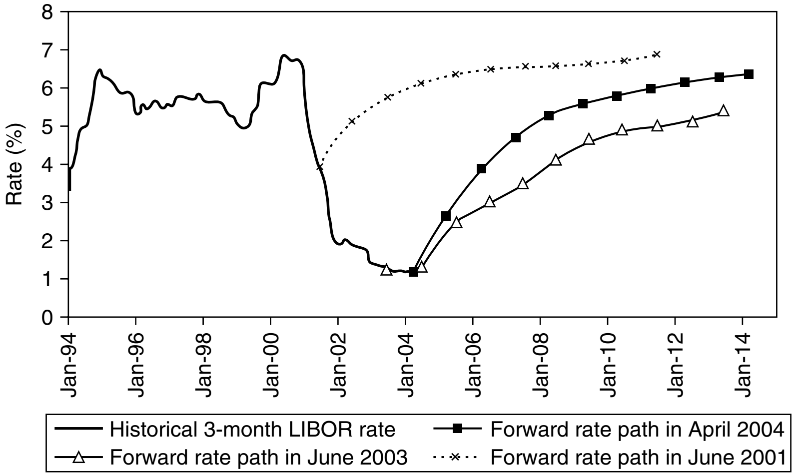


EXHIBIT 31-6

Historical Three-Month Rates and Implied Forward Rate Path Based on the Dollar Swap Curve in April 2004, June 2003, and June 2001



whole curve) and contrast it with his own forecast, which may be based on a macroeconomic forecast or on the subjective view about the speed of Fed tightening. As an example, Exhibit 31-6 shows such a break-even path of future three-month rates in April 2004. Note that the first point in each implied forward par curve in Exhibit 31-5 is the implied forward three-month rate at a given future date. Therefore, the forward path in Exhibit 31-6 can be constructed by tracing through the three-month points in the three curves of Exhibit 31-5 and through similar curves at other horizons. Because Exhibit 31-6 depicts a rate path over time, the horizontal axis is calendar years and not maturity.

To add perspective, the graph also contains the historical path of the three-month rate over the past decade and the break-even path of the future three-month rates in June 2003 when monetary policy expectations were much more bullish and in June 2001 when market's policy tightening expectations proved immature.

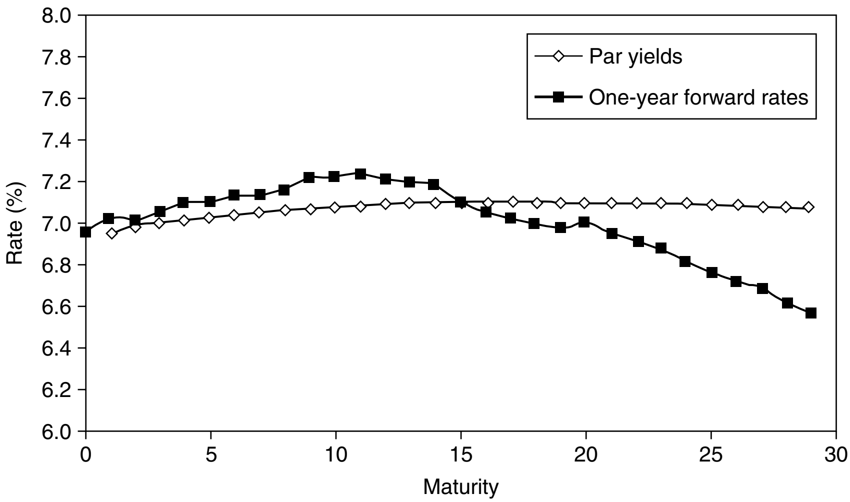
Forwards as Indicators of Cheap Maturity Sectors

The other ways to use forwards require less subjective judgment than the first one. As a simple example, the forward rate curve can be used to identify cheap maturity sectors visually. Abnormally high forward rates are more visible than high spot or par rates because the latter are averages of forward rates.

Exhibit 31-7 shows one real-world example from year 2000 when the par yield-curve was extremely flat (although forwards may be equally useful when the par curve is not flat). Even though the par yield-curve was almost horizontal (all par

EXHIBIT 31-7

Par Yields and One-Year Forward Rates Based on the Dollar-Swap Curve in August 2000



yields were within 15 basis points), the range of one-year forward rates was almost 100 basis points because the forward rate curve magnifies the cheapness/richness of different maturity sectors. High forward rates identify the 9- to 12-year sector as cheap. Forward rates are very low at the long maturities, but this characteristic probably reflects the convexity bias. Recall that forward rates are downward-biased estimates of expected returns because they ignore the convexity advantage, which is especially large at long maturities.

Once an investor has identified a sector with abnormally high forward rates (e.g., between 9 and 12 years), she can exploit the cheapness of this sector by buying a bond that matures at the end of the period (12 years) and by selling a bond that matures at the beginning of the period (9 years). If equal market values of these bonds are bought and sold, or received and paid fixed in swaps, the position captures the cheap forward rate (in this case the 3-year rate 9 years forward). In par-curve terms, the position is exposed to a general increase in rates and a steepening yield-curve. More elaborate trades can be constructed (e.g., by selling both the 9- and 15-year bonds against the 12-year bonds with appropriate weights) to retain level and slope neutrality. To the extent that bumps and kinks in the forward curve reflect temporary local cheapness, the trade will earn capital gains when the forward curve becomes flatter and the cheap sector richens (in addition to the higher yield and rolldown the position earns).

Forwards as Relative-Value Tools for Yield-Curve Trades

Thus far in this chapter forwards are used quite loosely to identify cheap maturity sectors. A more formal way to use forwards is to construct quantitative cheapness indicators for duration-neutral flattening trades, such as barbell-bullet trades. We first introduce some concepts with an example of a market-directional trade.

When the yield-curve is upward-sloping, long-term bonds' yield advantage over the riskless short-term bond provides a cushion against rising yields. In a sense, duration extensions are "cheap" when the yield-curve is very steep and the cushion (positive carry) is large. These trades only lose money if capital losses caused by rising rates offset the initial yield advantage. Moreover, the longer-term bonds' rolling yield advantage[17] over the short-term bond is even larger than their yield advantage. The one-year forward rate ($f_{n-1,n}$) is, by construction, equal to the n-year zero's rolling yield (see Appendix 31C). Thus it is a direct measure of the n-year zero's rolling yield advantage. [Another forward-related measure, the change in the $(n-1)$-year spot rate implied by the forwards ($f_{1,n} - s_{n-1}$) tells how much the yield-curve has to shift to offset this advantage and to equate the holding-period returns of the n-year zero and the one-year zero.]

Because one-period forward rates measure zeros' near-term expected returns, they can be viewed as indicators of cheap maturity sectors. The use of such cheapness indicators does not require any subjective interest-rate view. Instead, it requires a belief, motivated by history, that an unchanged yield-curve is a good base-case scenario.[18] If this is true, long-term bonds have higher (lower) near-term expected returns than short-term bonds when the forward rate curve is upward-sloping (downward-sloping). In the long run, a strategy that adjusts the portfolio duration dynamically based on the curve shape should earn higher average return than constant-duration strategies.[19]

Similar analysis holds for curve-flattening trades. Recall that when the yield-curve is concave as a function of duration, any duration-neutral flattening trade earns a negative carry. Higher concavity (curvature) in the yield-curve indicates less attractive terms for a flattening trade (larger negative carry) and more "implied flattening" by the forwards (that is needed to offset the negative carry).

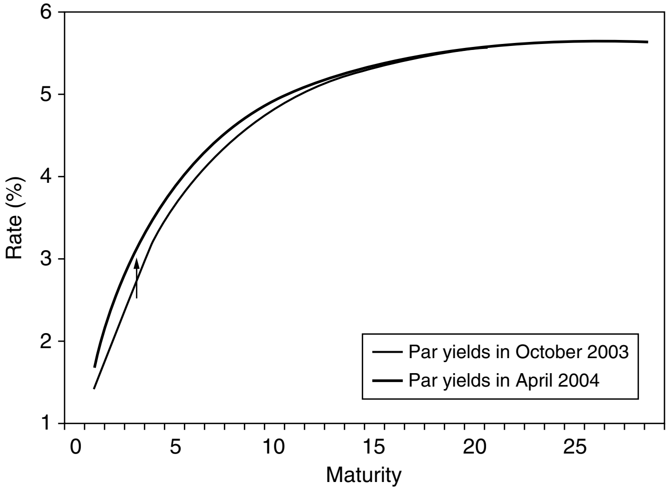
17. As bonds age, they roll down the upward-sloping yield-curve and earn some rolldown return (capital gain owing to this yield change) if the yield-curve remains unchanged. A bond's rolling yield, or horizon return, includes both the yield and the rolldown return given a scenario of no change in the yield-curve.

18. The one-period forward rate can proxy for the near-term expected return—albeit with a downward bias because it ignores the value of convexity—*if* the current yield-curve is not expected to change. Empirical studies show that the assumption of an unchanged curve is more realistic than the assumption that forward rates reflect expected future yields. Historically, current spot rates predict future spot rates better than current forward rates do because the yield changes implied by the forwards have not been realized, on average.

19. The historical performance of dynamic strategies that exploit the predictability of long-term bonds' near-term returns is evaluated in Antti Ilmanen, "Forecasting U.S. Bond Returns," *Journal of Fixed Income* (June 1997), pp. 22–37. The dynamic strategies have consistently outperformed static strategies that do not actively adjust the portfolio duration.

EXHIBIT 31-8

Dollar-Swap Curves in October 2003 and in April 2004



Therefore, the amount of spread change implied by the forwards is a useful cheapness indicator for yield-curve trades at different parts of the curve. If the implied change is wide historically, the trade is expensive, and vice versa.

Exhibit 31-8 shows a recent example of negative carry making curve-flattening positions expensive to hold. In October 2003, high yield-curve curvature indicated strong flattening expectations—forwards implied a 50 basis point decline in the 2- to 30-year spread over the coming six months—or high expected volatility (high value of convexity). The barbell (of the 30-year bond and six-month bill) over the duration-matched two-year bullet would become profitable only if the curve flattened even more than the forwards implied or if a sudden increase in volatility occurred. Purely on yield grounds, the two-year bullet (a steepening position) appeared cheap to the barbell. With the benefit of hindsight, we know that the carry/cheapness indicator gave a correct signal in this case. Exhibit 31-8 plots the dollar-swap curves in October 2003 and in April 2004; it is perhaps surprising that a steepening position outperformed amid curve flattening. Even though the yield-curve did flatten (the 2- to 30-year spread actually narrowed by 38 basis points by April 2004), the realized flattening did not match the forward-implied flattening. A steepener's (bullet's) initial carry and rolldown advantage did more than offset the capital losses owing to subsequent curve flattening.[20]

20. We show how to use forward rate analysis to evaluate opportunities like this in Ilmanen, "Market's Rate Expectations and Forward Rates," *op. cit.*; and Ilmanen and Iwanowski, "Dynamics of the Shape of the Yield Curve," *op. cit.*

APPENDIX 31A

Notation and Definitions

P	market price of a bond
P_n	market price of an n-year zero
C	coupon rate (in percent; other rates are expressed as a decimal)
y	annualized yield-to-maturity (YTM) of a bond
n	time-to-maturity of a bond (in years)
s_n	annualized n-year spot rate; the discount rate of an n-year zero
s_{n-1}	annualized (n – 1)-year spot rate next period; superscript * denotes next period's (year's) value
Δs_{n-1}	realized change in the (n – 1)-year spot rate between today and next period ($= s^*_{n-1} - s_{n-1}$)
$f_{m,n}$	annualized forward rate between maturities m and n
$f_{n-1,n}$	one-year forward rate between maturities (n – 1) and n; also, the n-year zero's rolling yield
$f_{1,n}$	annualized forward rate between maturities 1 and n; also called the implied (n – 1)-year spot rate one year forward
Δf_{n-1}	implied change in the (n – 1)-year spot rate between today and next period ($= f_{1,n} - s_{n-1}$); also called the break-even yield change (over the next period) implied by the forwards
Δfz_n	implied change in the yield of an n-year zero, a specific bond, over the next period ($= f_{1,n} - s_n$)
FSP	forward-spot premium ($\text{FSP}_n = f_{n-1,n} - s_1$)
h_n	realized holding-period return of an n-year zero [over one period (year)]

Rolling yield	a bond's horizon return given a scenario of unchanged yield-curve; sum of yield and rolldown return
Bond risk premium (BRP)	expected return of a long-term bond over the next period (year) in excess of the riskless one-period bond; for the n-year zero, $\text{BRP}_n = E(h_n - s_1)$
Realized BRP	realized one-year holding-period return of a long-term bond in excess of the one-year bond; also called excess bond return; realized $\text{BRP}_n = h_n - s_1$
Persistence factor (PF)	slope coefficient in a regression of the annual realized BRP_n on FSP_n
Term spread	yield difference between a long-term bond and a short-term bond; for the n-year zero, $= s_n - s_1$
Real yield	difference between a long-term bond yield and a proxy for expected inflation; our proxy is the recently published year-on-year consumer price inflation rate

Inverse wealth	ratio of exponentially weighted past wealth to the current wealth; we proxy wealth W by the stock market level; $= (W_{t-1} + 0.9^*W_{t-2} + 0.9^{2*}W_{t-3} + \cdots)^*0.1/W_t$
Duration (Dur)	measure of a bond price's interest rate sensitivity; Dur = $-(dP/\mathrm{d}y)^*(1/P)$
Convexity (Cx)	measure of the nonlinearity in a bond's P/y relation; Cx = $(d^2P/\mathrm{d}y^2)^*(1/P)$
Convexity bias (CB)	impact of convexity on the forward rate curve; $\mathrm{CB}_n = -0.5^*\mathrm{C}x_n{}^*(\text{volatility of } \Delta s_n)^2$

APPENDIX 31B

Calculating Spot and Forward Rates When Par Rates Are Known

A simple example illustrates how spot rates and forward rates are computed on a coupon date when the par curve is known (and coupon payments and compounding frequency are annual). The basis of the procedure is the fact that a bond's price will be the same, the sum of the present values of its cash flows, whether it is priced via yield-to-maturity—Eq. (31B.1)—or via the spot-rate curve—Eq. (31B.2).

$$P = \frac{C}{1+y} + \frac{C}{(1+y)^2} + \cdots + \frac{C+100}{(1+y)^n} \tag{31B.1}$$

$$P = \frac{C}{1+s_1} + \frac{C}{(1+s_2)^2} + \cdots + \frac{C+100}{(1+s_n)^n} \tag{31B.2}$$

where P is the bond price, C is the coupon rate (in percent), y is the annual yield-to-maturity (expressed as a decimal), s is the annual spot rate (expressed as a decimal), and n is the time-to-maturity (in years). We show only the computation for the first two years, which have par rates of 6% and 8%. For the first year, par, spot, and forward rates are equal (6%). Longer spot rates are solved recursively using known values of the par bond's price and cash flows and the previously solved spot rates. Every par bond's price is 100 (par) by construction, so its yield (the par rate) equals its coupon rate. Because the two-year par bond's market price (100) and cash flows (8 and 108) are known, as is the one-year spot rate (6%), it is easy to solve for the two-year spot rate as the only unknown in the following equation:

$$100 = \frac{C}{1+s_1} + \frac{C+100}{(1+s_2)^2} = \frac{8}{1.06} + \frac{108}{(1+s_2)^2} \tag{31B.3}$$

A little manipulation shows that the solution for s_2 is 8.08%. Equation (31B.3) also can be used to compute par rates when only spot rates are known. If the

EXHIBIT 31B–1

Par, Spot, and One-Year Forward Rate Curves

Maturity	Par Rate	Spot Rate	Forward Rate
1	6.00	6.00	6.00
2	8.00	8.08	10.20
3	9.50	9.72	13.07
4	10.50	10.86	14.36
5	11.00	11.44	13.77
6	11.25	11.71	13.10
7	11.38	11.83	12.55
8	11.44	11.88	12.20
9	11.48	11.89	11.97
10	11.50	11.89	11.93

spot rates are known, the coupon rate C—which equals the par rate—is the only unknown in Eq. (31B.3).

The forward rate between one and two years is computed using Eq. (31B.3) and the known one-year and two-year spot rates.

$$(1+f_{1,2}) = \frac{(1+s_2)^2}{1+s_1} = \frac{(1.0808)^2}{1.06} = 1.1020 \tag{31B.4}$$

The solution for $f_{1,2}$ is 10.20%. The other spot rates and one-year forward rates ($f_{2,3}$, $f_{3,4}$, etc.) in Exhibit 31B–1 are computed in the same way. These numbers are shown graphically in Exhibit 31-1.

APPENDIX 31C

Relations Between Spot Rates, Forward Rates, Rolling Yields, and Bond Returns

Investors often want to make quick "back of the envelope" calculations with spot rates, forward rates, and bond returns. In this appendix we discuss some simple relations between these variables, beginning with a useful approximate relation between spot rates and one-year forward rates.[21] Equation (31-2) showed exactly how the forward rate between years *m* and *n* is related to *m*- and *n*-year spot rates. Equation (31C.1) shows the same relation in an approximate but simpler form; this equation ignores nonlinear effects such as the convexity bias. The relation is exact if spot rates and forward rates are continuously compounded.

$$f_{m,n} \approx \frac{ns_n - ms_m}{n-m} \tag{31C.1}$$

For one-year forward rates ($m = n - 1$), Eq. (31C.1) can be simplified to

$$f_{n-1,n} \approx s_n + (n-1)(s_n - s_{n-1}) \tag{31C.2}$$

Equation (31C.2) shows that the forward rate is equal to an *n*-year zero's one-year horizon return given an unchanged yield-curve scenario: a sum of the initial yield and the rolldown return [the zero's duration at horizon ($n - 1$) multiplied by the amount the zero rolls down the yield-curve as it ages]. This horizon return is often called the *rolling yield.* Thus the one-year forward rates proxy for near-term expected returns at different parts of the yield-curve if the yield-curve is expected to remain unchanged. We can gain intuition about the equality of the one-year forward rate and the rolling yield by examining the *n*-year zero's realized holding-period return h_n over the next year, in Eq. (31C.3). The zero earns its initial yield s_n plus a capital gain/loss that is approximated by the product of the zero's year-end duration and its realized yield change.

$$h_n \approx s_n + (n-1) \times (s_n - s_{n-1}^*) \tag{31C.3}$$

where s_{n-1}^* is the ($n - 1$)-year spot rate next year. If the yield-curve follows a random walk, the best forecast for s_{n-1}^* is (today's) s_{n-1}. Therefore, the *n*-year zero's expected holding period return is exactly the one-year forward rate in Eq. (31C.2). The key question is whether it is more reasonable to assume that the current spot rates are the optimal forecasts of future spot rates than to assume that forwards are the optimal forecasts. Empirical evidence suggests that the "random walk" forecast of an unchanged yield-curve is more accurate than the forecast implied by the forwards.

Equation (31C.2) shows that the (one-year) forward rate curve lies above the spot curve as long as the latter is upward-sloping (and the rolldown return is positive). Conversely, if the spot curve is inverted, the rolldown return is negative, and the forward rate curve lies below the spot curve. If the spot curve is first rising and then declining, the forward rate curve crosses it from above at its peak. Finally, the forward rate curve can become downward-sloping even when the spot curve is upward-sloping if the spot curve's slope is first steep and then flattens

21. These relations are discussed in more detail in the appendix to Ilmanen, "Market's Rate Expectations and Forward Rates," *op. cit.*

(reducing the rolldown return). The following calculations illustrate this point and show that the approximation is good—within a few basis points from the correct values (10.20 – 13.07 – 14.36 – 13.77) in Exhibit 31B–1.

$$f_{1,2} \approx 8.08 + 1 * (8.08 - 6.00) = 8.08 + 2.08 = 10.16;$$

$$f_{2,3} \approx 9.72 + 2 * (9.72 - 8.08) = 9.72 + 3.28 = 13.00;$$

$$f_{3,4} \approx 10.86 + 3 * (10.86 - 9.72) = 10.86 + 3.42 = 14.28; \text{ and}$$

$$f_{4,5} \approx 11.44 + 4 * (11.44 - 10.86) = 11.44 + 2.32 = 13.76.$$

KEY POINTS

- Yield-curve or the term structure of interest rates can be depicted in several interchangeable ways, including the par curve, the spot curve, and the forward rate curve.
- The main drivers of the yield-curve are the market's rate expectations, required bond risk premiums, and convexity bias.
- A steeply upward-sloping yield-curve may reflect the market forecast of rising future short-term rates, or exceptionally high bond risk premiums, or some combination of these two. The pure expectations hypothesis assumes the first term drives yield-curve fluctuations, while empirical evidence suggests that the second term matters more. In reality, both matter.
- Forward rates can be useful tools for bond investors in break-even analysis (how much yields need to shift over a given horizon to just offset certain assets' initial yield advantage?) and in relative value analysis (what is the expected return of a zero-coupon bond if the curve remains unchanged?).
- Treasury analysis can focus on duration extensions and yield level changes or on duration-neutral strategies and yield-curve shape changes.

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CHAPTER

THIRTY-TWO

A FRAMEWORK FOR ANALYZING YIELD-CURVE TRADES

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In Chapter 31 it was explained that the shape of the yield-curve depends on three main determinants: the market's rate expectations, the required bond risk premia, and the convexity bias. In this chapter we show how to decompose the forward rate curve into these three determinants. Even though we cannot observe these determinants directly, the decomposition can clarify our thinking about the yield-curve.

Our analysis also produces direct applications—it provides a systematic framework for relative-value analysis of noncallable government bonds. Analogous to the decomposition of forward rates, the total expected return of any government bond position can be viewed as the sum of a few simple building blocks: (1) the yield income, (2) the rolldown return, (3) the value of convexity, and (4) the duration impact of the rate view. A further term should be added for bonds that trade "special" in the repo market and for bonds that trade very rich or cheap against the fitted curve.

The following observations motivate this decomposition. A bond's near-term expected return is a sum of its horizon return given an unchanged yield-curve and its expected return from expected changes in the yield-curve. The first item, the horizon return, is also called the *rolling yield* because it is a sum of the bond's yield income and the rolldown return (the capital gain that the bond earns because its yield declines as its maturity shortens and it "rolls down" an upward-sloping yield-curve). The second item, the expected return from expected changes in the yield-curve, can be approximated by duration and convexity effects. The duration impact is zero if the yield-curve is expected to remain unchanged, but it may be the main source of expected return if the rate predictions are based on an investor's or economist's market view or on a quantitative forecasting model.

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The value of convexity is always positive and depends on the bond's convexity and on the perceived level of yield volatility.

We argue that both prospective and historical relative-value analysis should focus on near-term expected-return differentials across bond positions instead of on yield spreads. The former measures are more comprehensive in the sense that they take into account all sources of expected return. Moreover, they provide a consistent framework for evaluating all types of government bond positions. We also show, with practical examples, how various expected-return measures are computed and how our framework for relative-value analysis is related to the better-known scenario analysis.

FORWARD RATES AND THEIR DETERMINANTS

Chapter 31 shows that the yield-curve can be represented in either par rates, spot rates, or forward rates. Whichever representation is used, there are three main determinants of the yield-curve that we discuss next.

How Do the Main Determinants Influence the Yield-Curve Shape?

We describe here how the market's rate expectations, the required bond risk premia,[1] and the convexity bias influence the term structure of interest rates. The market's expectations regarding the future interest-rate behavior probably are the most important influences on today's term structure. Expectations for parallel increases in yields tend to make today's term structure linearly upward sloping, and expectations for falling yields tend to make today's term structure inverted. Expectations for future curve flattening induce today's spot- and forward-rate curves to be concave (functions of maturity), and expectations for future curve steepening induce today's spot- and forward-rate curves to be convex.[2] These are the facts, but what is the intuition behind these relationships?

The traditional intuition is based on the pure expectations hypothesis. In the absence of risk premia and convexity bias, a long rate is a weighted average of the expected short rates over the life of the long bond. If the short rates are expected to rise, the expected average future short rate (i.e., the long rate) is

1. The *bond risk premium* is defined as a bond's expected (near-term) holding-period return in excess of the riskless short rate. Historical experience suggests that long-term bonds command some risk premium because of their greater perceived riskiness. However, our term *bond risk premium* also covers required return differentials across bonds that are caused by other reasons than risk, such as liquidity differences, supply effects, or the market sentiment.

2. A concave (but upward-sloping) curve has a steeper slope at short maturities than at long maturities; thus a line connecting two points on the curve is always below the curve. A convex (but upward-sloping) curve has a steeper slope at long maturities than at short maturities; thus a line connecting two points on the curve is always above the curve.

higher than the current short rate, making today's term structure upward-sloping. A similar logic explains why expectations of falling rates make today's term structure inverted. However, this logic gives few insights about the relation between the market's expectations regarding future curve reshaping and the curvature of today's term structure.

Another perspective to the pure expectations hypothesis may provide a better intuition. The absence of risk premia means that all bonds, independent of maturity, have the same near-term expected return. Recall that a bond's holding-period return equals the sum of the initial yield and the capital gains/losses that yield changes cause. Therefore, if all bonds are to have the same expected return, initial yield differentials across bonds must offset any expected capital gains/losses. Similarly, each bond portfolio with expected capital gains must have a yield disadvantage relative to the riskless asset. If investors expect the long bonds to gain value because of a decline in interest rates, they accept a lower initial yield for long bonds than for short bonds, making today's spot- and forward-rate curves inverted. Conversely, if investors expect the long bonds to lose value because of an increase in interest rates, they demand a higher initial yield for long bonds than for short bonds, making today's spot- and forward-rate curves upward-sloping. Similarly, if investors expect the curve-flattening positions to earn capital gains because of future curve flattening, they accept a lower initial yield for these positions. In such a case, barbells would have lower yields than duration-matched bullets (to equate their near-term expected returns), making today's spot- and forward-rate curves concave. A converse logic links the market's curve-steepening expectations to convex spot- and forward-rate curves.

The preceding analysis presumes that all bond positions have the same near-term expected returns. In reality, investors require higher returns for holding long bonds than short bonds. Many models that acknowledge bond risk premia assume that they increase linearly with duration (or with return volatility) and that they are constant over time. Empirical evidence contradicts both assumptions.[3] Historical average returns increase substantially with duration at the front end of the curve but only modestly beyond intermediate durations. Thus the bond risk premia make the term structure upward-sloping and concave, on average. Moreover, it is possible to forecast when the required bond risk premia are abnormally high or low. Thus the time variation in the bond risk premia can cause significant variation in the shape of the term structure.

Convexity bias refers to the impact that the nonlinearity of a bond's price/yield-curve has on the shape of the term structure. This impact is very small at the front end but can be quite significant at very long durations. A positively convex price/yield-curve has the property that a given yield decline raises the bond price more than a yield increase of equal magnitude reduces it. All else

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3. This evidence is discussed in Antti Ilmanen, "Does Duration Extension Enhance Long-Term Expected Returns?" *Journal of Fixed Income* (September 1996), pp. 23–36; and Antti Ilmanen, "Forecasting U.S. Bond Returns," *Journal of Fixed Income* (June 1997), pp. 22–37.

equal, this property makes a high-convexity bond more valuable than a low-convexity bond, especially if the volatility is high. It follows that investors tend to accept a lower initial yield for a more convex bond because they have the prospect of enhancing their returns as a result of convexity. Because a long bond exhibits much greater convexity than a short bond, it can have a lower yield and yet offer the same near-term expected return. Thus, in the absence of bond risk premia, the convexity bias would make the term structure inverted. In the presence of positive bond risk premia, the convexity bias tends to make the term structure humped—because the negative effect of convexity bias overtakes the positive effect of bond risk premia only at long durations. An increase in the interest-rate volatility makes the bias stronger and thus tends to make the term structure more humped.

The three determinants influence the shape of the term structure simultaneously, making it difficult to distinguish their individual effects. Despite a widespread misconception, the shape of the term structure does not reflect only the market's rate expectations. Forward rates are good measures of the market's rate expectations only if the bond risk premia and the convexity bias can be ignored. This is hardly the case, even though a large portion of the short-term variation in the shape of the curve probably reflects the market's changing expectations about the future level and shape of the curve. The steepness of the curve on a given day depends mainly on the market's view regarding the rate direction, but in the long run, the impact of positive and negative rate expectations largely washes out. Therefore, the average upward slope of the yield-curve is mainly attributable to positive bond risk premia. The curvature of the term structure may reflect all three components. On a given day, the spot-rate curve is especially concave (humped) if market participants have strong expectations of future curve flattening or of high future volatility. In the long run, the reshaping expectations should wash out, and the average concave shape of the term structure reflects the concavity of the risk premium curve and the convexity bias.

Decomposing Forward Rates into Their Main Determinants

Conceptually, each one-period forward rate can be decomposed to three parts: the impact of rate expectations, the bond risk premium, and the convexity bias. So far this statement is just an assertion. In this subsection we show intuitively why this relationship holds between the forward rates and their three determinants. We provide a more formal derivation in Appendix 32A (where we take into account the fact that the analysis is not instantaneous but that yield changes occur over a discrete horizon, during which invested capital grows). In Appendix 32B we tie some loose strings together by summarizing various statements about the forward rates and by clarifying the relations between these statements.

EXHIBIT 32-1

Splitting a Zero-Coupon Bond's One-Period Yield Change into Two Parts

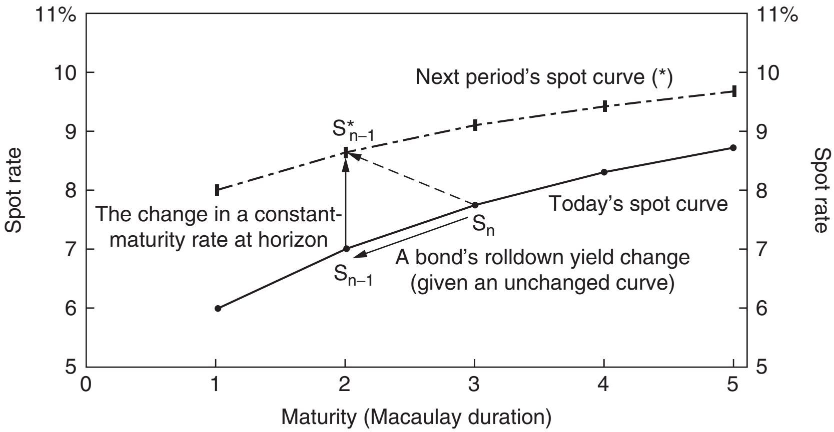


Exhibit 32-1 shows how the yield change of an n-year zero-coupon bond over one period (dashed arrow) can be split to the rolldown yield change and the one-period change in an $n - 1$ year constant-maturity spot rate $s_{n-1}(\Delta s_{n-1} = s^*_{n-1} - s_{n-1})$ (two solid arrows).[4] A zero-coupon bond's price can be split in a similar way (see Appendix 32A). Thus an n-year zero's holding-period return over the next period h_n is

$$\begin{aligned} h_n &= \text{return if the curve is unchanged} + \text{return from the curve changes} \\ &= \text{rolling yield} + \text{percentage price change (at horizon)} \\ &\approx \text{(one-period) forward rate} + [(-\text{duration} \times \Delta s_{n-1}) \\ &\quad + (0.5 \times \text{convexity} \times \Delta s_{n-1})^2] \end{aligned} \tag{32-1}$$

Equation (32-1) is based on the following relations. First, a bond's one-period horizon return given an unchanged yield-curve is called the *rolling yield*. A zero-coupon bond's rolling yield equals the one-period forward rate ($f_{n-1,n}$). For example, if the four-year (five-year) constant-maturity rate remains unchanged at 9.5% (10%) over the next year, a five-year zero bought today at 10% can be sold next year at 9.5% as a four-year zero; then the bond's horizon return is $1.10^5/1.095^4 - 1 = 0.1202 = 12.02\%$, which is the one-year forward rate between four- and five-year maturities [see Eq. (32-11) in Appendix 32B]. The second source of a zero's holding-period return, the price change caused by the yield-curve

4. All rates and returns in this chapter are expressed in percentage terms (200 basis points = 2%).

shift, is approximated very well by duration and convexity effects for all but extremely large yield-curve shifts.

It is more interesting to relate the forward rates to expected returns and expected rate changes than to the realized ones. We take expectations of both sides of Eq. (32-1), split the bond's expected holding-period return into the short rate and the bond risk premium, and recall that $E(\Delta s_{n-1})^2 \approx [\text{vol}(\Delta s_{n-1})]^2$. Then we can rearrange the equation to express the one-period forward rate as a sum of the other terms:

$$\begin{aligned}\text{Forward rate} \approx\ &\text{short rate} + \text{duration} \times E(\Delta s_{n-1}) \\ &+ \text{bond risk premium} + \text{convexity bias}\end{aligned} \tag{32-2}$$

where bond risk premium $= E(h_n - s_1)$, and convexity bias $\approx -0.5 \times$ convexity $\times$ $[\text{vol}(\Delta s_{n-1})]^2$.

If we move the short rate to the left-hand side of the equation, we decompose the "forward-spot premium" $(f_{n-1,n} - s_1)$ into a rate-expectation term, a risk-premium term, and a convexity term (see Eq. 32-10 in Appendix 32A). We interpret the expectations in Eq. (32-2) as the market's rate and volatility expectations and as the expected risk premium that the market requires for holding long-term bonds. The market's expectations are weighted averages of individual market participants' expectations.

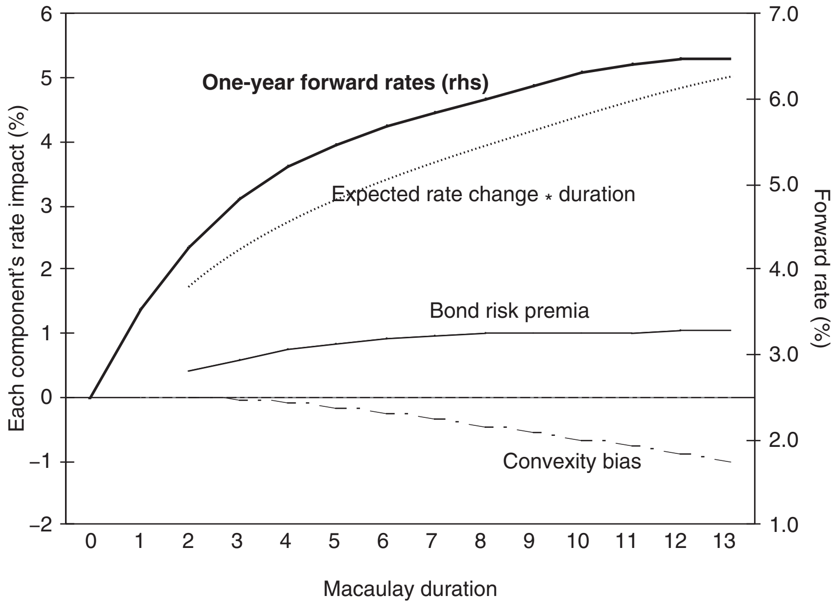
Some readers may wonder why our analysis deals with forward rates and not with the more familiar par and spot rates. The reason is the simplicity of the one-period forward rates. A one-period forward rate is the most basic unit in term-structure analysis, the discount rate of one cash flow over one period. A spot rate is the average discount rate of one cash flow over many periods, whereas a par rate is the average discount rate of many cash flows—those of a par bond—over many periods. All the averaging makes the decomposition messier for the spot rates and the par rates than it is for the one-period forward rate in Eq. (32-2). However, because the spot and the par rates are complex averages of the one-period forward rates, they too can be decomposed conceptually into the three main determinants.

Because the approximate decomposition in Eq. (32-2) is derived mathematically without making specific economic assumptions, it is true in general. In reality, however, it is hard to make this decomposition because the components are not observable and because they vary over time. Further assumptions or proxies are needed for such a decomposition. In Exhibit 32-2 we use historical average returns to compute the bond risk premia and historical rate volatilities to compute the convexity bias—together with the observable market forward rates (as of April 2004)—and back out the only unknown term in Eq. (32-2): the expected spot-rate change times duration. We also could divide this term by duration to infer the market's rate expectations. The rate expectations that we back out in Exhibit 32-2 suggest that the market expects rising short rates but less than forwards imply.

If bond risk premia vary over time, the use of historical average risk premia may be misleading. As an alternative, we can use survey data or rate predictions

EXHIBIT 32-2

Decomposing Forward Rates into Their Components Using Historical Average Risk Premia and Volatilities



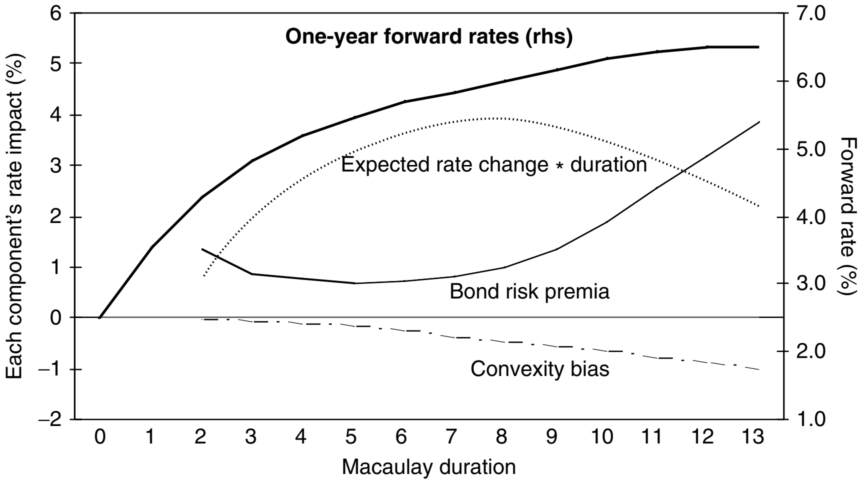
Note: The one-year forward rates are based on the dollar swap curve in April 2004. The bond risk premia are based on the historical arithmetic average returns of various maturity-subsector bond portfolios between 1972–2001, expressed in excess of the riskless one-year return. The convexity bias is based on the historical volatilities of various maturity swaps in 2004. The rate expectation term for each duration is then backed out as the difference—one-year forward rate – one-year spot rate – bond risk premium – convexity bias.

based on a quantitative forecasting model to proxy for the market's rate expectations. In Exhibit 32-3, we use a hypothetical consensus interest-rate forecast that predicts a bear flattening (yields rising 100 basis points at the two-year maturity and 20 basis points at 10 years). In addition, we use implied volatilities from swaption prices to compute the convexity bias. These components can be used together with the one-year forward rates to back out estimates of the unobservable bond risk premia.

A comparison of Exhibits 32-2 and 32-3 shows that the two decompositions look similar at short durations but different at intermediate and long durations. The similarity of the convexity bias components in these two exhibits suggests that the use of historical or implied volatilities makes little difference, at least in this case. The hypothetical survey's yield-curve view implies a relatively poor performance of intermediate-duration assets (low expected excess return) and a good performance by the longest assets (whose yields are expected to be stable). Because the forward-rate curve is the same

EXHIBIT 32-3

Decomposing Forward Rates into Their Components Using Hypothetical Survey Rate Expectations and Implied Volatilities



Note: The one-year forward rates are based on the dollar swap curve in April 2004. The market's rate expectations are proxied by a hypothetical consensus interest-rate forecast. The convexity bias is based on the implied basis point volatilities from swaption prices. The bond risk premium for each duration is then backed out as the difference—one-year forward rate – one-year spot rate – expected rate change × duration – convexity bias.

in both exhibits, any smaller predicted rate increases lead to higher bond risk premia in Exhibit 32-3 than in Exhibit 32-2.[5]

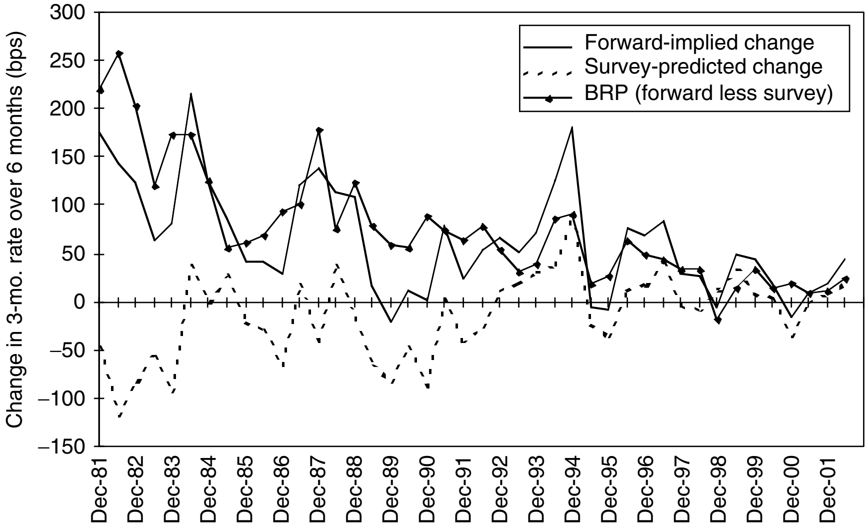
Exhibits 32-2 and 32-3 are snapshots of the forward rates and their components on one date. A comparison of similar decompositions over time would provide insights into the relative variability of each component. In Exhibit 32-4, we try to illustrate the impact of changing rate expectations and risk premia on the steepness of the U.S. Treasury bill curve based on a semiannual survey of economists' rate forecasts. The exhibit shows that the forwards almost always implied larger increases in the three-month rate than the market expected, based on surveys of bond market analysts. The difference is proportional to the required bond risk premium of longer bills over shorter bills (because bills exhibit negligible convexity, its impact can be ignored). This difference clearly varies over time.

The time variation in the survey-based bond risk premium in Exhibit 32-4 appears economically reasonable. It fell secularly from the early 1980s to late 1990s, perhaps reflecting the trend decline in inflation expectations and in level-dependent

5. We hasten to point out that these calculations are quite imprecise, especially at long durations. Even an error of a couple of basis points in our proxy for the market's rate expectation will have a large impact on any long bond's expected return (and thus on the estimated bond risk premium) because the expected yield change is scaled up by duration. Such sensitivity reduces the usefulness of this decomposition at long durations.

EXHIBIT 32-4

Forward-Implied Yield Changes versus Survey-Expected Yield Changes in the Treasury Bill Market, 1981–2002



Note: Forward-implied yield change is the difference between the implied three-month rate six months forward ($f_{0.5,\,0.75}$) and the current three-month rate ($s_{0.25}$) based on market data (fitted Treasury yield-curves). Survey-expected yield change is the difference between the expected three-month rate six months ahead [$E(s_{0.25})$] and the current three-month rate, where the market's rate expectation is proxied by the mean in the *Wall Street Journal's* semiannual survey of economist forecasts. The difference between the forward-implied yield change and the survey-expected yield change is proportional to the bond risk premium.

inflation uncertainty. Besides the lower inflation risk premium, improving fiscal prospects likely contributed to this trend decline. The bond risk premium also exhibited cyclic fluctuations that are related to the direction of consensus rate predictions and thus the central bank's policy tightening and easing cycles. Finally, the bond risk premium turned slightly negative during the flight to quality in late 1998, arguably reflecting government bonds' role as safe-haven assets.[6]

DECOMPOSING EXPECTED RETURNS OF BOND POSITIONS

Our framework for decomposing the yield-curve also provides a framework for systematic relative-value analysis of government bonds with known cash-flows. We can evaluate all bond positions' expected returns comprehensively yet with simple and intuitive building blocks. We emphasize that relative-value

6. Here we analyze the bond risk premium at money market maturities, but we find similar patterns for the 10-year Treasury in Antti Ilmanen, "Stock-Bond Correlations," *Journal of Fixed Income* (September 2003), pp. 55–66.

analysis should be based on near-term expected return differentials, not on yield spreads, which are only one part of them. That is, total-return investors should care more about expected returns than about yields. Thus our approach brings fixed income investors closer to mean-variance analysis in which various positions are evaluated based on the trade off between their expected return and return volatility.

Five Alternative Expected-Return Measures

Equation (32-1) shows that a zero's holding-period return is a sum of its return given an unchanged yield-curve and its return caused by the changes in the yield-curve. The return given an unchanged yield-curve is called the *rolling yield* because it is a sum of the zero's yield and the rolldown return. The return caused by changes in the yield-curve can be approximated well by duration and convexity effects. Taking expectations of Eq. (32-1) and splitting the rolling yield into yield income and rolldown return, the near-term expected return of a zero is

$$\begin{aligned}\text{Expected return} &= \text{yield income} + \text{rolldown return} + \text{value of convexity}\\ &\quad + \text{expected capital gain from the rate “view”}\end{aligned}$$

[For details, see Eq. (32-8) in Appendix 32A or the notes below Exhibit 32-5.] A similar relation holds approximately for coupon bonds, and we will describe the three-month expected return of some on-the-run Treasury bonds as the sum of the four preceding components.[7]

This framework is especially useful when evaluating positions of two or more government bonds, such as duration-neutral barbells versus bullets. We first compute expected return separately for each component and then compute the portfolio's expected return by taking a market-value weighted average of all the components' expected returns.

7. However, certain modifications are needed when we analyze coupon bonds' instead of zeros' expected returns—and the approximation will be somewhat worse. We use each bond's rolling yield to measure the horizon return given an unchanged yield-curve; this measure no longer equals the one-period forward rate. We also use the end-of-horizon duration and convexity, as well as the change in the constant-maturity rate of a constant-coupon curve at horizon, and we adjust the duration and convexity effects for the fact that the bond's value increases to (1 + rolling yield/100) by the end of the horizon. Besides the approximation error of ignoring higher-order terms than duration and convexity effects, another source of error exists for coupon bonds: The reinvestment-rate assumptions vary across bonds. Recall that the calculation of the yield-to-maturity implicitly assumes that all cash flows are reinvested at the bond's yield-to-maturity. This fact may lead to exaggerated estimates of yield income for long-term bonds if the yield-curve is upward-sloping, a problem common to all expected-return measures that use the concept of yield-to-maturity. Even though our approach of using bond-specific yields does not ensure internal consistency of the reinvestment-rate assumptions across bonds, any inconsistencies should have a relatively small impact on the overall level of bonds' expected returns.

It may be helpful to show step by step how the expected-return measures are improved, starting from simple yields and moving toward more comprehensive measures:

- A bond's *yield income* includes coupon income, accrued interest, and the accretion/amortization of price toward par value. Yield-to-maturity is the correct return measure if all interim cash flows can be reinvested at the yield and the bond can be sold at its purchasing yield.[8] Yield ignores the rolldown return the bond earns if the yield-curve stays unchanged.
- *Rolling yield* is a better expected-return proxy if an unchanged curve is a reasonable base case. Yet it ignores the value of convexity and thus implicitly assumes no rate uncertainty. Thus the rolling yield measures expected return if no curve change and no volatility are expected.
- Combining the rolling yield with the value of convexity improves the expected-return measure further. This is so because it can be shown that a bond's convexity-adjusted expected return equals the sum of the rolling yield and the value of convexity. This measure recognizes the impact of rate uncertainty but implies that no change is expected in the yield-curve.[9] Empirical evidence suggests that an unchanged yield-curve is often a reasonable base "view."[10]
- If investors want, they can replace the prediction of an unchanged curve with some other rate (or spread) "view." One possibility is to use survey-based information of the market's current rate forecasts; such an approach may be useful for backing out the market's required return for each bond. Alternatively, investors may ignore the market view and input either their own rate views or an economist's subjective rate forecasts or rate predictions from some quantitative model.[11] The impact of any rate view is approximated by the expected yield change scaled by duration [see Eq. (32-10) in Appendix 32A], which may be added

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8. The yield-to-maturity of a single cash flow is unambiguous, whereas the yield of a portfolio of multiple cash flows is a more controversial measure. The duration-times-market-value weighted yield is a good proxy for a portfolio's true yield-to-maturity (internal rate of return). Capital gains are well-approximated by the product of minus duration and the change in such a yield measure. However, a portfolio's market-value weighted yield may be a better estimate of the portfolio's *likely yield income over a short horizon* (its near-term expected return) than is its yield-to-maturity. The yield-to-maturity weighs longer cash flows more heavily and is more influenced by the built-in reinvestment-rate assumptions.

9. See Antti Ilmanen, "Convexity Bias in the Yield Curve," Chapter 3 in Narasimgan Jegadeesh and Bruce Tuckman (eds.), *Advanced Fixed-Income Valuation Tools* (New York: Wiley, 2000).

10. See Antti Ilmanen, "Market's Rate Expectations and Forward Rates," *Journal of Fixed Income* (September 1996), pp. 8–22.

11. For example, one can use the predictors identified in Antti Ilmanen, "Forecasting U.S. Bond Returns," *Journal of Fixed Income* (June 1997), pp. 22–37.

to the convexity-adjusted expected return. The sum gives us the "expected return with a view"—the four-term expected return measure in Eq. (32-3). However, this equation is a perfect description of expected returns only for bonds that lie on the fitted curve. Thus the preceding relative-value measures ignore "local" or bond-specific richness or cheapness relative to the curve.

- Many technical factors can make a specific bond "locally" rich or cheap (relative to adjacent-maturity bonds), or they can make a whole maturity sector rich or cheap relative to the fitted curve. Such factors include supply effects (temporary price pressure on a sector caused by new issuance), demand effects (maturity limitations or preferences of important market participants—for example, the richness of quarter-end bills), liquidity effects (lower transaction costs for on-the-runs versus off-the-runs, for 10-year bonds versus 8-year bonds, for Treasury bills versus duration-matched coupon bonds, etc.), coupon effects (motivated by tax benefits, accounting rules, etc.), and above all, the financing effects (the "special" repo income that is common for on-the-runs).[12] Fortunately, it is easy to add to the four-term expected-return measures the financing advantage and two local cheapness measures—the spread off the fitted curve and the expected cheapening toward the fitted curve. The five-term expected-return measures are comprehensive measures of total expected returns—ignoring small approximation errors, they incorporate all sources of expected return for noncallable government bonds.[13]

As a numerical illustration, Exhibit 32-5 shows the various expected-return measures for three bonds (the three-month Treasury bill and the 5- and 10-year on-the-run Treasury notes) and for the barbell combination of the three-month bill and the 10-year bond. In this example we use as much market-based data as

12. Whether such local cheapness effects appear as deviations from a fitted yield-curve or as "wiggles" or "kinks" in the fitted curve depends on the curve-estimation technique. Recall that all curve-estimation techniques try to fit bond prices well while keeping the curve reasonably shaped. If the goodness of fit is heavily weighted, all bonds have small or no deviations from the fitted curve. However, a close fit may lead to "unreasonably" jagged forward-rate curves. Based on Eq. (32-2), the forward-rate curve should be smooth rather than jagged because maturity-specific expectations of rate or volatility behavior are hard to justify and because arbitrageurs presumably are quick to exploit any abnormally large expected-return differentials between adjacent-maturity bonds.

13. In our analysis we include the local effects into the expected bond returns separately as a fifth term. As an alternative, we could include the financing advantage (repo income) and the spread off the curve in the yield income, and we could include the expected cheapening in the rolldown return. "Rich" bonds, such as the on-the-runs, are unlikely to roll down the fitted curve if the overall curve remains unchanged. More likely, they eventually will lose their relative richness. It may be reasonable to assume that an on-the-run bond's yield advantage and *expected* cheapening roughly offset its *expected* financing advantage. For other issues than on-the-runs, it is often reasonable to assume (or better, estimate) some reversal toward the issue's "normal" cheapness spread versus the fitted curve.

EXHIBIT 32-5

Three-Month Expected Return Measures and Their Components, as of April 2004

Maturity	0.25	5	10	Barbell
Yield income	**0.259%**	**0.881%**	**1.128%**	**0.742%**
+ *Rolldown return*	*0.000*	*0.321*	*0.281*	*0.156*
= **Rolling yield**	**0.259**	**1.203**	**1.409**	**0.898**
+ *Value of convexity*	*0.000*	*0.047*	*0.129*	*0.072*
= **Convexity-adj. expected return**	**0.259**	**1.250**	**1.538**	**0.970**
+ *Duration impact of the "view"*	*0.000*	*–1.315*	*–1.579*	*–0.879*
= **Expected return with a view**	**0.259**	**–0.065**	**–0.041**	**0.092**
+ *Total local rich/cheap effect*	*0.000*	*0.023*	*0.010*	*0.006*
= **Total expected return**	**0.259**	**–0.042**	**–0.031**	**0.097**
Background Information				
Par yield	1.05	3.59	4.600	NA
Rolldown yield change	NA	–0.074	–0.036	NA
Duration now	0.249	4.54	7.94	4.53
Duration at horizon	0.000	4.33	7.79	4.33
Convexity now	0.002	0.24	0.76	0.42
Convexity at horizon	0.000	0.22	0.73	0.40
Yield volatility	NA	0.656	0.592	NA
Yield change "view"	+0.20	+0.30	+0.20	NA
On-the-run yield	1.00	3.56	4.46	NA
Financing advantage	NA	0.175	0.225	0.13
Spread to the par curve	NA	–0.007	–0.035	–0.02
Expected cheapening return	NA	–0.145	–0.180	–0.10

NA, not available.

Note: Barbell is a combination of 0.56 unit of the ten-year par bond and 0.44 unit of the three-month bond; these weights duration-match the barbell with the five-year par bond bullet. Yield income is the return that a par bond earns over three months if it can be sold at its yield and if any cash flows are reinvested at the yield. The yields are compounded semiannually and based on the Citigroup Treasury Model's par yield-curve. Rolldown return is the capital gain that a bond earns from the rolldown yield change. Rolling yield is a bond's horizon return given an unchanged yield-curve. Value of convexity is approximated by 0.5 × convexity at horizon × (yield volatility)^2 × (1 + rolling yield/100), where yield volatility is the basis-point yield volatility over a three-month horizon. The latter is computed by multiplying the on-the-run bond's relative yield volatility—implied volatility based on the price of a three-month OTC option written on this bond—by its yield level and dividing by two (for deannualization). For the three-year bond, we interpolate between the implied volatilities of on-the-run twos and fives. Duration impact of the "view" is (– duration at horizon) × (expected change in a constant-maturity rate over the next three months) × (1 + rolling yield/100). In this example, the "view" reflects the market's yield-curve expectations, broadly based on a *Consensus Forecasts* report. The "expected return with a view" measures the expected return for a hypothetical par bond that lies exactly on the model curve, ignoring any local cheapness or financing advantage of actual bonds. We can add to this four-term measure a fifth component called the *total local rich/cheap effect*. It is the sum of three additional sources of return for specific bonds: (1) the financing advantage (the difference between the three-month term repo rate for general collateral and the three-month special term repo rate for the on-the-run bond, divided by four for deannualization), (2) the spread between the on-the-run bond yield and the model par yield, divided by four for deannualization, and (3) the bond's expected cheapening as it loses the richness associated with the on-the-run status.

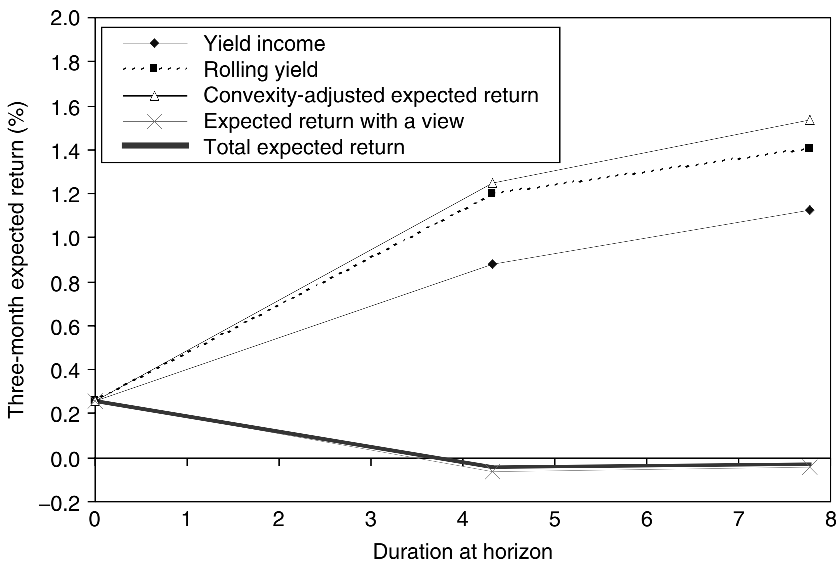
possible, for example, implied volatilities, not historical, to estimate the value of convexity and the "view" (rate predictions) based on survey evidence of the market's rate expectations, not on a quantitative forecasting model. All the numbers are based on the market prices as of April 22, 2004.

The top panel of Exhibit 32-5 shows how nicely the different components of expected returns can be added to each other. Moreover, the barbell's expected return measures are simply the market-value weighted averages of its components' expected returns. In this case, the yield income, the rolldown return, and the value of convexity are all higher for the longer bonds. In contrast, the duration impact of the market's rate view is negative because the consensus forecast indicates that the market expected rising rates over the next quarter. The local rich/cheap effect is marginally positive for the 5- and 10-year notes; the reason is that the negative yield spread and the expected cheapening are not sufficient to offset the high repo market advantage. Based on "viewless" expected-return measures, the five-year bullet looks more attractive than the barbell, thanks to its carry and rolldown advantage. However, if we impose a consensus curve-flattening view (30 basis point rise in 5-year rates versus 20 basis point rise in 10-year rates), the broad expected-return measures favor the barbell over the bullet.

Exhibit 32-6 shows the five different expected-return curves plotted on the three bonds' durations. In this case, the simplest expected-return measure (yield income) and the most comprehensive measure (total expected return) look very

EXHIBIT 32-6

Expected Returns of a Three-Month Bill, a 5-Year Bond, and a 10-Year Bond, in April 2004



different, thanks to the strong bear-flattening view on yield-curve reshaping. In general, the relative importance of the five components may be dramatically different from that in Exhibit 32-5. The longer the asset's duration and the shorter the investment horizon, the greater is the relative importance of the duration impact and the smaller is the impact of yield income. It is worth noting that realized returns can be decomposed in the same way as the expected returns and that the duration impact typically dominates the realized returns even more.[14]

The total expected returns, if estimated carefully, should produce the most useful signals for relative-value analysis because they include all sources of expected returns. Yield spreads may be useful signals, but they are only a part of the picture. Therefore, we advocate the monitoring of broader expected-return measures relative to their history as cheapness indicators—just as yield spreads often are monitored relative to their history.

The components of expected returns just discussed are not new. However, few investors have combined these components into an integrated framework and based their historical analysis on broad expected-return measures. An additional useful feature of this framework is that all types of government bond trades can be evaluated consistently within it: the portfolio-duration decision (market-directional view), the maturity-sector positioning and barbell-bullet decision (curve-reshaping view), and the individual-issue selection (local cheapness view). With small modifications, the framework can be extended to include the cross-country analysis of currency-hedged government bond positions. Other possible future extensions include the analysis of foreign-exchange exposure and the analysis of spread positions between government bonds and other fixed income assets.

We finish with some reservations. Even if two investors use the same general framework and the same type of expected-return measure, they may come up with different numbers because of different data sources and different estimation techniques. The whole analysis can be made with any raw material; we emphasize the importance of good-quality inputs. Various candidates for the raw material include on-the-run and off-the-run government bonds, STRIPS, Eurodeposits, swaps, and Eurodeposit futures. [This multitude, of course, opens the possibility of trading between these curves if we can assess how various characteristics (say, convexity) are priced in each curve.] The most common approach is first to estimate the spot curve (or discount function) using a broad universe of coupon government bonds as the raw material and then to compute the forward rates and other relevant numbers. In European bond markets, the liquid swap curve (using cash Eurodeposits and swaps as the raw material) has gained more of a benchmark status. Of course, some credit and tax-related

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14. Realized returns can be split into an expected part and an unexpected part, and both parts can be decomposed further. Equation (32-3) describes the decomposition of the expected part, while the unexpected part can be split into duration and convexity effects. This type of return attribution can have a useful role in risk management and performance evaluation, but these two activities are not our focus in this chapter.

spread may exist between the swap curve and the government bond yield-curve. Recently, yet another approach has become popular: Eurodeposit futures prices are used as the raw material. In this case, the forward rates are computed by adjusting for the convexity difference between a futures contract and a forward contract, and only then are spot rates computed from the forwards. Some components of expected returns are easier to measure—and less debatable—than others. The yield income is relatively unambiguous. The rolldown return and the local rich/cheap effects depend on the curve-fitting technique. The value of convexity depends on the volatility input and thus on the volatility estimation technique. The rate "view," the fourth term, can be based on various approaches, such as quantitative modeling or subjective forecasting, that rely on fundamental or technical analysis. Even the quantitative approach is not purely objective because infinitely many alternative forecasting models and estimation techniques exist. Forecasting rate changes is, of course, the most difficult task, as well as the one with greatest potential rewards and risks. Forecasting changes in yield spreads may be almost as difficult. The short-term returns of most bond positions depend primarily on the duration impact (rate changes or spread changes). However, even if investors cannot predict rate changes, they may earn superior returns in the long run—and with less volatility—by systematically exploiting the more stable sources of expected-return differentials across bonds: yields, rolldown returns, value of convexity, and local rich/cheap effects. More generally, while the total expected return differentials are, in theory, better relative-value indicators than the yield spreads, in practice, measurement errors conceivably can make them so noisy that they give worse signals. Therefore, it is important to check with historical data that any supposedly superior relative value tools would have enhanced the investment performance, at least in the past.

Link to Scenario Analysis

Many active investors base their investment decisions on subjective yield-curve views, often with the help of scenario analysis. Our framework for relative-value analysis is closely related to scenario analysis. It may be worthwhile to explore the linkages further.

An investor can perform the scenario analysis of noncallable government bonds in two steps. First, the investor specifies a few yield-curve scenarios for a given horizon and computes the total return of her bond portfolio—or perhaps just a particular trade—under each scenario. Second, the investor assigns subjective probabilities to the different scenarios and computes the probability-weighted expected return for her portfolio. Sometimes the second step is not completed, and investors only examine qualitatively the portfolio performance under each scenario. However, we advocate performing this step because investors can gain valuable insights from it. Specifically, the probability-weighted expected return is the "bottom line" number a total return manager should care about. By assigning probabilities to scenarios, investors also can explicitly back out their implied views about the yield-curve reshaping and about yield volatilities and correlations.

In scenario analysis, investors define the mean yield-curve view and the volatility view implicitly by choosing a set of scenarios and by assigning them probabilities. In contrast, our framework for relative-value analysis involves explicitly specifying one yield-curve view (which corresponds to the probability-weighted mean yield-curve scenario) and a volatility view (which corresponds to the dispersion of the yield-curve scenarios). Either way, the yield-curve view determines the duration impact, and the volatility view determines the value of convexity.

Exhibit 32-7 presents a portfolio that consists of five equally weighted zero-coupon bonds with maturities of one to five years and (annually compounded) yields between 6% and 7%. The portfolio's maturity—and its Macaulay duration—initially

EXHIBIT 32-7

Scenario Analysis and Expected Bond Returns

						Bond Portfolio
Initial maturity	1	2	3	4	5	3
Horizon maturity	0	1	2	3	4	2
Initial yield	6.00%	6.25%	6.50%	6.75%	7.00%	
Yield-change scenarios (of 1–5 year constant-maturity rates)						
Bear	1.00	1.00	1.00	1.00	1.00	
Bull	–1.00	–1.00	–1.00	–1.00	–1.00	
Neutral	0.00	0.00	0.00	0.00	0.00	
Bear-flattener	1.00	0.875	0.75	0.625	0.50	
Bull-steepener	–0.50	–0.375	–0.25	–0.125	0.00	
One-year returns in each scenario						
Bear	6.00	5.51	5.02	4.53	4.05	5.02
Bull	6.00	7.51	9.04	10.59	12.15	9.06
Neutral	6.00	6.50	7.00	7.50	8.01	7.00
Bear-flattener	6.00	5.51	5.26	5.26	5.51	5.51
Bull-steepener	6.00	7.01	7.76	8.26	8.51	7.51
Assign equal probability (0.2) to each scenario and back out various statistics						
Mean return	6.00	6.41	6.82	7.23	7.65	6.82
Vol. of return	0.00	0.80	1.52	2.17	2.78	1.45
Mean yield change	0.10	0.10	0.10	0.10	0.10	
Vol. of Yield Change	0.80	0.76	0.72	0.69	0.66	

is three. Over a one-year horizon, each zero's maturity shortens by one year. We specify five alternative yield-curve scenarios over the horizon: parallel shifts of +100 basis points and –100 basis points, no change, a yield increase combined with a curve flattening, and a yield decline combined with a curve steepening (see Exhibit 32-8). We compute the one-year holding-period returns for each asset and for the portfolio under each scenario. In particular, the neutral scenario shows the rolling yield that each zero earns if the yield-curve remains unchanged. We can evaluate each scenario separately. However, such analysis gives us limited insight—for example, the last column in Exhibit 32-7 shows just that bearish scenarios produce lower portfolio returns than bullish scenarios.

In contrast, if we assign probabilities to the scenarios, we can back out many numbers of potential interest. We begin with a simple example in which we use only the two first scenarios, parallel shifts of 100 basis points up or down. If we assign these scenarios equal probabilities (0.5), the expected return of the portfolio is 7.04% (= 0.5 × 5.02 + 0.5 × 9.06). On average, these scenarios have no view about curve changes, yet this expected return is 4 basis points higher than the expected portfolio return given no change in the curve (i.e., the 7% rolling yield computed in the neutral scenario). This difference reflects the value of convexity. If we use only one scenario, we implicitly assume zero volatility, which leads to downward-biased expected-return estimates for positively convex bond positions. If we use the two first scenarios (bear and bull), we implicitly assume a 100 basis point yield volatility; this assumption may or may not be reasonable, but it certainly is more reasonable than an assumption of no volatility. This example highlights the importance of using multiple scenarios to recognize the value of convexity. (The value is small here, however, because we focus on short-duration assets that have little convexity.)

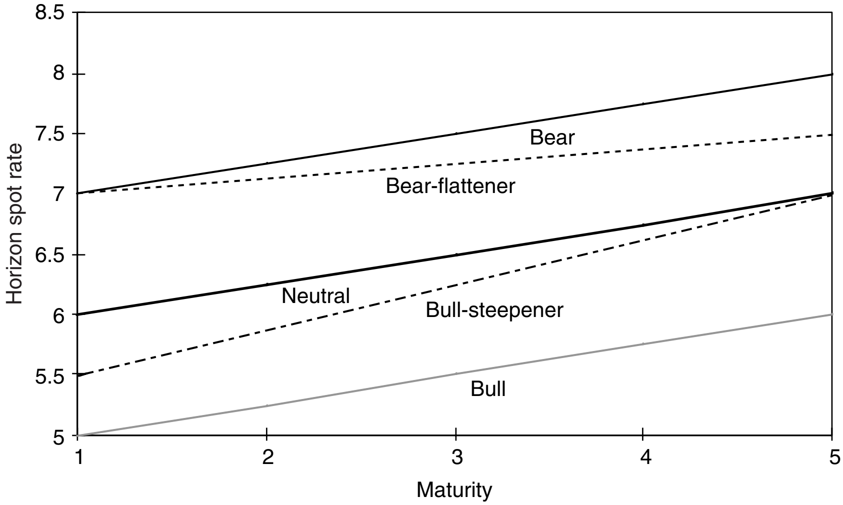
Now we return to the example with all five yield-curve scenarios in Exhibit 32-8. As an illustration, we assign each scenario the same probability (p_i = 0.2). Then it is easy to compute the portfolio's probability-weighted expected return:

$$E(h_p) = \sum_{i=1}^{5} p_i \times h_i = 0.2 \times (5.02 + 9.06 + 7.00 + 5.51 + 7.51) = 6.82 \tag{32-3}$$

Given these probabilities, we can compute the expected return for each asset, and it is possible to back out the implied yield-curve views. The lower panel in Exhibit 32-7 shows that the mean yield change across scenarios is +10 basis points for each rate (because the bear-flattener and the bull-steepener scenarios are not quite symmetric in magnitude in this example), implying a mild bearish bias but no implied curve-steepness views. In addition, we can back out the implied basis point yield volatilities (or return volatilities) by measuring how much the yield-change (or return) outcomes in each scenario deviate from the mean. These yield volatility levels are important determinants of the value of convexity. The last line in Exhibit 32-7 shows that the volatilities range from 80 to 66 basis points, implying an inverted term structure of volatility. Finally, we can compute implied correlations between

EXHIBIT 32-8

Various Yield-Curve Scenarios



various maturity-yield changes; the curve behavior across the five scenarios is so similar that all correlations are 0.92 or higher (not shown). Note that all correlations would equal 1.00 if only the first three scenarios were used; the imperfect correlations arise from the bear-flattener and the bull-steepener scenarios.

Whenever an investor uses scenario analysis, he should back out these implicit curve views, volatilities, and correlations—and check that any biases are reasonable and consistent with his own views. Without assigning the probabilities to each scenario, this step cannot be completed; then the investor may overlook hidden biases in his analysis, such as a biased curve view or a very high or low implicit volatility assumption that makes positive convexity positions appear too good or too bad. If investors use quantitative tools—such as scenario analysis, mean-variance optimization, or the approach outlined in this chapter—to evaluate expected returns, they should recognize the importance of their rate views in this process. Strong subjective views can make *any* particular position appear attractive. Therefore, investors should have the discipline and the ability to be fully aware of the views that are input into the quantitative tool.

In addition to the implied curve views, we can back out the four components of expected returns discussed earlier. In this example, we only analyze bonds that lie "on the curve" and thus can ignore the fifth component, the local rich/cheap effects. First, we measure the yield income from the portfolio by a market-value weighted-average yield of the five zeros, which is 6.50%. Second, each asset's rolldown return is the difference between the horizon return given an unchanged yield-curve and the yield income. Exhibit 32-7 shows that the horizon return for the portfolio is 7% in the neutral scenario; thus the portfolio's (market-value weighted average) rolldown return is 50 basis points (= 7% – 6.5%). Note that the rolldown return is larger for longer bonds, reflecting the fact that the same rolldown yield change (25 basis points) produces larger capital gains for longer bonds. Third, the value of convexity for each zero can be approximated by 0.5 × convexity at horizon × (basis point yield volatility)^2 × (1 + rolling yield/100). Using the implicit yield volatilities in Exhibit 32-7, this value varies between 0.6 and 4.5 basis points across bonds. The portfolio's value of convexity is a market-value weighted average of the bond-specific values of convexity, or roughly 2 basis points. Fourth, the duration impact of the rate "view" for each bond equals (– duration at horizon) × (expected yield change) × (1 + rolling yield/100). The last term is needed because each invested dollar grows to (1 + rolling yield/100) by the end of horizon when the repricing occurs. The core of the duration impact is the product of duration and expected yield change. The expected yield change refers to the change (over the investment horizon) in a constant-maturity rate of the bond's horizon maturity. In Exhibit 32-7, all rates are expected to increase by 10 basis points, and the duration impact on specific bonds' returns varies between 0 and –40 basis points. The portfolio's duration impact is a market-value weighted average of bond-specific duration impacts, or about –20 basis points.

The four components add up to the total probability-weighted expected return of 6.82% (= 6.50% + 0.50% + 0.02% – 0.20%). Decomposing expected returns into these components should help investors to better understand their own investment positions. For example, they can see what part of the expected return reflects static market conditions and what part reflects their subjective market view. Unless they are extremely confident about their market view, they can emphasize the part of expected-return advantage that reflects static market conditions. In our example, the duration effect is small because the implied rate view is quite mild (10 basis points), and the one-year horizon is relatively long (the "slower" effects need time to accrue). With a shorter horizon and stronger rate views, the duration impact easily would dominate the other effects.

APPENDIX 32A

Decomposing the Forward Rate Structure into Its Main Determinants

In this appendix we show how the forward rate structure is related to the market's rate expectations, bond risk premia, and convexity bias. In particular, the holding-period return of an n-year zero-coupon bond can be described as a sum of its horizon return given an unchanged yield-curve and the end-of-horizon price change that is caused by a change in the n – 1 year constant-maturity spot rate (Δs_{n-1}). The horizon return equals a one-year forward rate, and the end-of-horizon price change can be approximated by duration and convexity effects. These relations are used to decompose near-term expected bond returns and the one-period forward rates into simple building blocks. All rates and returns used in the following equations are compounded annually and expressed in percentage terms

$$\frac{h_n}{100} = \frac{P^*_{n-1} - P_n}{P_n} = \frac{(P^*_{n-1} - P_{n-1}) + (P_{n-1} - P_n)}{P_n}$$
$$= \left(\frac{\Delta P_{n-1}}{P_{n-1}} \times \frac{P_{n-1}}{P_n} - 1\right) + \left(\frac{P_{n-1}}{P_n} - 1\right) \tag{32-4}$$

where h_n is the one-period holding-period return of an n-year bond, P_n is its price (today), P^*_{n-1} is its price in the next period (when its maturity is $n-1$), and $\Delta P_{n-1} = P^*_{n-1} - P_{n-1}$. The second term on the right-hand side of Eq. (32-4) is the bond's rolling yield (horizon return). The first term on the right-hand side of Eq. (32-4) is the instantaneous percentage price change of an $n-1$ year zero multiplied by an adjustment term P_{n-1}/P_n.[15]

Equation (32-5) shows that the zero's rolling yield (P_{n-1}/P_n) equals, by construction, the one-year forward rate between $n-1$ and n. Moreover, the adjustment term equals one plus the forward rate.

$$1 + \frac{f_{n-1,n}}{100} = \frac{\left(1 + \frac{s_n}{100}\right)^n}{\left(1 + \frac{s_{n-1}}{100}\right)^{n-1}} = \frac{P_{n-1}}{P_n} \tag{32-5}$$

Equation (32-6) shows the well-known result that the percentage price change ($\Delta P/P$) is closely approximated by the first two terms of a Taylor series expansion, duration and convexity effects

$$100 \times \frac{\Delta P}{P} \approx -\text{dur} \times (\Delta s) + 0.5 \times Cx \times (\Delta s)^2 \tag{32-6}$$

where

$$\text{dur} \equiv -\frac{dP}{ds} \times \frac{100}{P} \qquad \text{and} \qquad Cx \equiv \frac{d^2P}{d^2s} \times \frac{100}{P}$$

Plugging Eqs. (32-5) and (32-6) into Eq. (32-4), we get

$$h_n \approx f_{n-1,n} + \left(1 + \frac{f_{n-1,n}}{100}\right)[-\text{dur}_{n-1}(\Delta s_{n-1}) + 0.5Cx_{n-1}(\Delta s_{n-1})^2] \tag{32-7}$$

15. The adjustment term is needed because the bond's instantaneous price change occurs at the end of horizon, not today. The value of the bond position grows from one to P_{n-1}/P_n at the end of horizon if the yield-curve is unchanged. The end-of-horizon value (P_{n-1}/P_n) would be subject to the yield shift at horizon.

Even if the yield-curve shifts occur during the horizon, for performance calculation purposes, the repricing takes place at the end of horizon. This disparity causes various differences between the percentage price changes in Eqs. (32-6) and (32-7). First, the amount of capital that experiences the price change grows to $(1 + f_{n-1,n}/100)$ by the end of horizon. Second, the relevant yield change is the change in the $n - 1$ year constant-maturity rate, not in the n-year zero's own yield (the difference is the rolldown yield change).[16] Third, the end-of-horizon (as opposed to the current) duration and convexity determine the price change.

The realized return can be split into an expected part and an unexpected part. Taking expectations of both sides of Eq. (32-7) gives us the n-year zero's expected return over the next year:

$$E(h_n) \approx f_{n-1,n} + \left(1 + \frac{f_{n-1,n}}{100}\right)[-\text{dur}_{n-1}E(\Delta s_{n-1}) + 0.5Cx_{n-1}E(\Delta s_{n-1})^2] \tag{32-8}$$

Recall from Eq. (32-5) that the one-period forward rate equals a zero's rolling yield, which can be split to yield and rolldown return components. In addition, the expected yield change squared is approximately equal to the variance of the yield change or the squared volatility $E(\Delta s_{n-1})^2 \approx [\text{vol}(\Delta s_{n-1})]^2$. This relation is exact if the expected yield change is zero. Thus the zero's near-term expected return can be written (approximately) as a sum of the yield income, the rolldown return, the value of convexity, and the expected capital gains from the rate "view" (see Eq. 32-3).

We can interpret the expectations in Eq. (32-8) to refer to the market's rate expectations. Mechanically, the forward rate structure and the market's rate expectations on the right-hand side of Eq. (32-8) determine the near-term expected returns on the left-hand side. These expected returns should equal the required returns that the market demands for various bonds if the market's expectations are internally consistent. These required returns, in turn, depend on factors such as each bond's riskiness and the market's risk-aversion level. Thus it is more appropriate to think that the market participants, in the aggregate, *set the bond market prices* to be such that given the forward rate structure and the consensus rate expectations, each bond is expected to earn its required return.[17]

16. If we used bonds' own yield changes in Eq. (32-7), these yield changes would include the rolldown yield change. In this case, we should not use the forward rate (which includes the impact of the rolldown yield change on the return, in addition to the yield income) as the first term on the right-hand side of Eq. (32-7). Instead, we would use the spot rate.

17. Individual investors also can use Eq. (32-8), but the interpretation is slightly different because most of them are so small that they cannot influence the market rates; thus they are "price takers." Any individual investor can plug her subjective rate expectations into Eq. (32-8) and back out the expected return given these expectations and the market-determined forward rates. These expected returns may differ from the required returns that the market demands; this discrepancy may prompt the investor to trade on her view.

Subtracting the one-period riskless rate (s_1) from both sides of Eq. (32-8), we get

$$E(h_n - s_1) \approx (f_{n-1,n} - s_1) + \left(1 + \frac{f_{n-1,n}}{100}\right)[-\text{dur}_{n-1}E(\Delta s_{n-1}) + 0.5Cx_{n-1}\text{vol}(\Delta s_{n-1})^2] \quad (32\text{-}9)$$

We define the bond risk premium as $BRP_n \equiv E(h_n - s_1)$ and the forward-spot premium as $FSP_n \equiv f_{n-1,n} - s_1$. The forward-spot premium measures the steepness of the one-year forward rate curve (the difference between each point on the forward rate curve and the first point on that curve), and it is closely related to simpler measures of yield-curve steepness. Rearranging Eq. (32-9), we obtain

$$FSP_n \approx BRP_n + \left(1 + \frac{f_{n-1,n}}{100}\right)[\text{dur}_{n-1}E(\Delta s_{n-1}) - 0.5Cx_{n-1}\text{vol}(\Delta s_{n-1})^2] \quad (32\text{-}10)$$

In other words, the forward-spot premium is approximately equal to a sum of the bond risk premium, the impact of rate expectations (expected capital gain/loss caused by the market's rate "view"), and the convexity bias (expected capital gain caused by the rate uncertainty). Unfortunately, none of the three components is directly observable.

The analysis thus far has been very general, based on accounting identities and approximations, not on economic assumptions. Various term-structure hypotheses and models differ in their assumptions. Certain simplifying assumptions lead to well-known hypotheses of the term-structure behavior by making some terms in Eq. (32-10) equal zero—although fully specified term-structure models require even more specific assumptions. First, if constant-maturity rates follow *a random walk,* the forward-spot premium mainly reflects the bond risk premium but also the convexity bias [$E(\Delta s_{n-1}) = 0 \Rightarrow FSP_n \approx BRP_n + CB_{n-1}$]. Second, if the *local-expectations hypothesis* holds (all bonds have the same near-term expected return), the forward-spot premium mainly reflects the market's rate expectations but also the convexity bias [$BRP_n = 0 \Rightarrow FSP_n \approx \text{dur}_{n-1}E(\Delta s_{n-1}) + CB_{n-1}$]. Third, if the *unbiased-expectations hypothesis* holds, the forward-spot premium only reflects the market's rate expectations [$BRP_n + CB_{n-1} = 0 \Rightarrow FSP_n \approx \text{dur}_{n-1}E(\Delta s_{n-1})$]. The last two cases illustrate the distinction between two versions of the pure expectations hypothesis.

APPENDIX 32B

Relating Various Statements About Forward Rates to Each Other

We make several statements about forward rates—describing, interpreting, and decomposing them in various ways. The multitude of these statements may be confusing; therefore, we now try to clarify the relationships between them.

We refer to the spot curve and the forward curves on a given date as if they were unambiguous. In reality, different analysts can produce somewhat different estimates of the spot curve on a given date if they use different curve-fitting techniques or different underlying data (asset universe or pricing source). We acknowledge the importance of these issues—having good raw material is important to any kind of yield-curve analysis—but here we ignore these differences. We take the estimated spot curve as given and focus on showing how to interpret and use the information in this curve.

In contrast, the relations between various depictions of the term structure of interest rates (par, spot, and forward rate curves) are unambiguous. In particular, once a spot curve has been estimated, any forward rate can be computed mathematically by using Eq. (32-11):

$$\left(1+\frac{f_{m,n}}{100}\right)^{n-m} = \frac{\left(1+\frac{s_n}{100}\right)^n}{\left(1+\frac{s_m}{100}\right)^m} \tag{32-11}$$

where $f_{m,n}$ is the annualized $n - m$ year interest rate m years forward and s_n and s_m are the annualized n-year and m-year spot rates, expressed in percent. Thus a one-to-one mapping exists between forward rates and *current* spot rates. The statement "the forwards imply rising rates" is equivalent to saying that "the spot curve is upward sloping," and the statement "the forwards imply curve flattening" is equivalent to saying that "the spot curve is concave." Moreover, an unambiguous mapping exists between various types of forward curves, such as the implied spot curve one year forward ($f_{1,n}$) and the curve of constant-maturity one-year forward rates ($f_{n-1,n}$).

The forward rate can be the agreed interest rate on an *explicitly* traded contract, a loan between two future dates. More often the forward rate is defined *implicitly* from today's spot curve based on Eq. (32-11). However, arbitrage forces ensure that even the explicitly traded forward rates would equal the implied forward rates and thus be consistent with Eq. (32-11). For example, the implied one-year spot rate four years forward (also called the one-year forward rate four years ahead, $f_{4,5}$) must be such that the equality $(1 + s_5/100)^5 = (1 + s_4/100)^4(1 + f_{4,5}/100)$ holds. If $f_{4,5}$ is higher than this, arbitrageurs can earn profits by short selling the five-year zeros and buying the four-year zeros and the one-year forward contracts four years ahead, and vice versa. Such activity should make the equality hold within transaction costs.

Forward rates can be viewed in many ways: the arbitrage interpretation, the break-even interpretation, and the rolling yield interpretation. According to the arbitrage interpretation, implied forward rates are such rates that would ensure the absence of riskless arbitrage opportunities between spot contracts (zeros) and forward contracts if the latter were traded. According to the break-even interpretation of forward rates, implied forward rates are such *future* spot rates that would equate holding-period returns across bond positions. According to the rolling-yield interpretation, the one-period forward rates show the one-period horizon returns that various zeros earn if the yield-curve remains unchanged. Each interpretation is useful for a certain purpose: active view taking relative to the forwards (break-even), relative-value analysis given no yield-curve views (rolling yield), and valuation of derivatives (arbitrage).

All these interpretations hold by construction (from Eq. 32-11). Thus they are not inconsistent with each other. For example, the one-period forward rates can be interpreted and used in quite different ways. The implied one-year spot rate four years forward ($f_{4,5}$) can be viewed as either the break-even one-year rate *four years into the future* or the rolling yield of a five-year zero *over the next year*. Both interpretations follow from the equality $(1 + s_5/100)^5 = (1 + s_4/100)^4(1 + f_{4,5}/100)$. This equation shows that the forward rate is the break-even one-year reinvestment rate that would equate the returns between two strategies (holding the five-year zero to maturity versus buying the four-year zero and reinvesting in the one-year zero when the four-year zero matures) over a five-year horizon. [Rewriting the equality as $(1 + s_4/100)^4 = (1 + s_5/100)^5/(1 + f_{4,5}/100)$ gives a slightly different viewpoint; the forward rate also is the break-even selling rate that would equate the returns between two strategies (holding the four-year zero to maturity versus buying the five-year zero and selling it after four years as a one-year zero) over a four-year horizon.] Finally, rewriting the equality as $1 + f_{4,5}/100 = (1 + s_5/100)^5/(1 + s_4/100)^4$ shows that the forward rate is the horizon return from buying a five-year zero at rate s_5 and selling it one year later as a four-year zero at rate s_4 (thus the constant-maturity four-year rate is unchanged from today). Our analysis focuses on the last (rolling-yield) interpretation.

Interpreting the one-period forward rates as rolling yields enhances our understanding about the relation between the curve of one-year forward rates ($f_{0,1}, f_{1,2}, f_{2,3}, \ldots, f_{n-1,n}$) and the implied spot curve one year forward ($f_{1,2}, f_{1,3}, f_{1,4}, \ldots, f_{1,n}$). The latter "break-even" curve shows how much the spot curve needs to shift to cause capital gains/losses that exactly offset initial rolling-yield differentials across zeros and thereby equalize the holding-period returns. Thus a steeply upward-sloping curve of one-period forward rates requires, or "implies," a large offsetting increase in the spot curve over the horizon, whereas a flat curve of one-period forward rates only implies a small "break-even" shift in the spot curve.[18] A similar link exists for the rolling-yield differential between a duration-neutral barbell versus bullet and the break-even yield-spread change (curve-flattening) that is needed to offset the bullet's rolling-yield advantage. These examples provide insight as to why an upward-sloping spot curve implies rising rates and why a concave spot curve implies a flattening curve.

18. In Chapter 31 we describe one common way to use the break-even forward rates. Investors can compare their subjective views about the yield-curve at some future date (or about the path of some constant-maturity rate over time) to the forward rates and directly determine whether bullish or bearish strategies are appropriate. If the rate changes that the forwards imply are realized, all bonds earn the riskless return [because $(1 + s_n/100)^n/(1 + f_{1,n}/100)^{n-1} = 1 + s_1/100$]. If rates rise by more than that, long bonds underperform short bonds. If rates rise by less than that, long bonds outperform short bonds because their capital losses do not quite offset their initial yield advantage.

Appendix 32A showed that forward rates can be decomposed conceptually into three main determinants (rate expectations, risk premia, and convexity bias). One might hope that the arbitrage, break-even, or rolling-yield interpretations could help us in backing out the relative roles of rate expectations, risk premia, and convexity bias in a given day's forward rate structure. However, such hope is in vain. The three interpretations hold quite generally because of their mathematical nature. Thus they do not guide us in decomposing the forward rate structure.

Therefore, even when two analysts agree that today's forward rate structure is an approximate sum of three components, they may disagree about the relative roles of these components. We can try to address this question empirically. It is closely related to the question about the forward rates' ability to forecast future rate changes and future bond returns. Ignoring convexity bias, if the forwards primarily reflect rate expectations, they should be unbiased predictors of future spot rates (and they should tell little about future bond returns). However, if the forwards mainly reflect required bond risk premia, they should be unbiased predictors of future bond returns (and they should tell little about future rate changes).[19,20]

Finally, our analysis does not reveal the fundamental economic determinants of the required risk premia or the market's rate expectations—nor does it tell us to what extent the nominal rate expectations reflect expected inflation and expected real rates. Macroeconomic news about economic growth, inflation rates, budget deficits, and so on can influence both the required risk premia and the market's rate expectations. More work clearly is needed to improve our understanding about the mechanisms of these influences.

19. We present some empirical evidence indicating that the forward rates are better predictors of future bond returns than of future rate changes in Antti Ilmanen, "Market's Rate Expectations and Forward Rates," *Journal of Fixed Income* (September 1996), pp. 8–22. This evidence also suggests that the current spot curve is a better predictor of the next-period spot curve than is the implied spot curve one period forward. These findings imply that the rolling yields are reasonable proxies for the near-term expected bond returns—although even rolling yields capture a very small part of the short-term realized bond returns. Note that the poorer the forwards are in predicting future rate changes, the better they are in predicting bond returns—because then the implied rate changes that would offset initial yield advantages tend to occur more rarely. Note also that some investors may not care whether the forwards' ability to predict bond returns reflects rational risk premia or the market's inability to forecast rate changes; they want to earn any predictable profit irrespective of its reason.

20. One common misconception is that the forward rates are used in the valuation of swaps, options, and other derivative instruments *because* the forwards are good predictors of future spot rates. In fact, the forwards' ability to predict future spot rates has nothing to do with their usefulness in derivatives pricing. Unlike forecasting returns, the valuation of derivatives is based on arbitrage arguments. For example, traders theoretically can construct, by dynamic hedging, a riskless combination of a risky long-term bond and an option written on it. The price of the option should be such that the hedged position earns the riskless rate—otherwise, a riskless arbitrage opportunity arises. The forward rates are central in this valuation because the traders can lock in these rates for future periods in their hedging activity. This arbitrage argument implies that the yield-curve option pricing models should be calibrated to be consistent with the market forward rates *in spite of* the fact that the forwards are quite poor predictors of future spot rates.

KEY POINTS

- Yield-curve or forward rates can be decomposed into three main determinants: the market's rate expectations, required bond risk premiums, and convexity bias.
- In an analogous fashion, the expected return of a position in a (default-free) bond—or in a long-short position across such bonds—can be decomposed into a few building blocks: the yield income and so-called rolldown return, the value of convexity, and the duration impact of a curve view.
- The first three components of the expected return amount to the reasonably predictable "viewless" part, while the last component is the least certain but dominates realized returns.
- The above decompositions provide a useful framework for analyzing the attractiveness of yield-curve trades. For analyzing the attractiveness of individual issues, the local richness of a bond relative to the curve and its richness in the repo market are important additional considerations.

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CHAPTER
THIRTY-THREE

EMPIRICAL YIELD-CURVE DYNAMICS AND YIELD-CURVE EXPOSURE

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While there are many factors that can influence the return on a specific bond, one of the most important influences—especially for high-quality bonds—is the behavior of the benchmark (Treasury) yield curve. Individual bond yields tend to move along with the yield curve. For example, if the 10-year Treasury yield moves up or down, other high-quality bonds with maturities close to 10 years will tend to follow suit. This sensitivity to yield-curve changes is referred to as the yield-curve exposure or the interest rate risk of a bond or a portfolio of bonds; in order to measure and manage this risk, we first need to understand the ways in which the yield curve can move.

The goals of this chapter are therefore as follows. First, to explain how most yield-curve movements can be empirically captured by a small number of standard yield-curve shifts. Second, to discuss the theoretical reasons why yield curves behave in this way, that is, how the standard shifts arise. Third, to sketch the implications for risk management of a bond portfolio, and when the usual concept of bond duration is—or is not—applicable. And along the way, to illustrate some techniques in exploratory data analysis that are helpful in interpreting the data and applying the results of the analysis appropriately.

Before diving into the analysis, some intuition may be helpful. The yield curve is determined by Treasury bonds of different maturities, which are closely linked to each other: nearby bonds have similar cash flows and should therefore behave in a similar way—they should be correlated with each other, and the yield curve as a whole should be somewhat "rigid." What could this mean?

In the physical world, rigid bodies do not vibrate in arbitrary ways, but tend to have "vibration modes" or "natural frequencies." For example, consider a thin plank on wheels (i.e., a *dolly*) rolling over rough ground. As it is shaken around, it will tend to vibrate in a few specific ways: up and down, tilting back and forth,

The author thanks Henry Schellhorn and Tom Hollenberg for their useful comments.

and flexing in the middle, as shown in Exhibit 33-1. It will also have additional vibration modes, but these will be much smaller. Compare this to a thin beam with one end fixed to a wall (i.e., a *cantilever*), as shown in Exhibit 33-2. Parallel up-and-down movements are now impossible, and the beam will only be able to tilt and flex. We will see that the first situation is roughly comparable to a yield curve that can shift freely, while the second situation resembles a yield curve whose short end is pinned down by monetary policy.

EXHIBIT 33-1

Vibration Modes of a Plank on Wheels

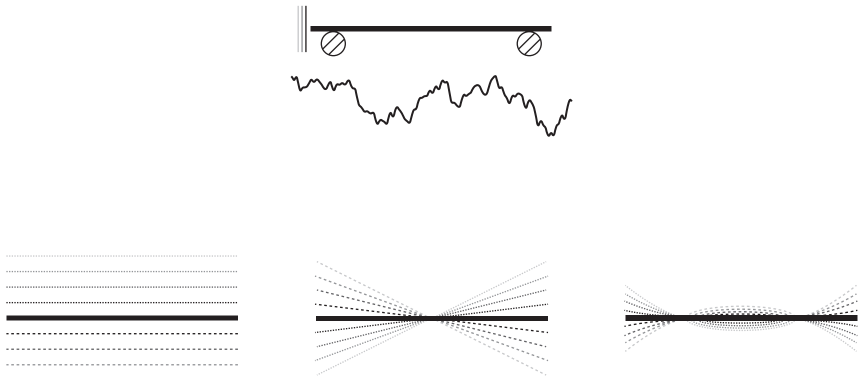
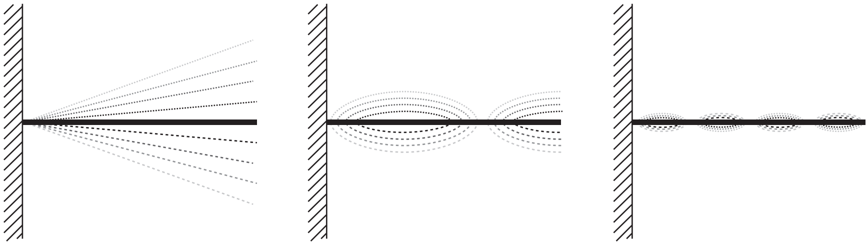


EXHIBIT 33-2

Vibration Modes of a Thin Beam Attached to a Wall



Note that if the plank (or beam) can only vibrate in one way, all the points on the plank will be perfectly correlated, but if it has several vibration modes, the correlations between different points will be less than one; for example, the endpoints of the plank in Exhibit 33-1 will not be perfectly correlated with the middle, since when the plank tilts back and forth, the endpoints move but the middle doesn't. This suggests that the correlations encode information about the vibration modes.

EMPIRICAL ANALYSIS OF YIELD-CURVE DYNAMICS

The "vibration modes" of the yield curve can be identified using a statistical method known as *principal component analysis*, invented in 1901 by Pearson.[1] It was first applied to analyze yield-curve dynamics in 1991 by Litterman and Scheinkman.[2] Since the method is completely standard,[3] we give only a brief description here before moving on to the results.

The intuition is as follows. Given a predefined shift in the yield curve (such as a parallel shift), any observed shift can be written as a multiple of the predefined shift plus some residual. Define the shift in order to make these residuals—measured over some historical data set of yield-curve observations—as small as possible. The resulting yield-curve shift is referred to as the first principal component: it can be regarded as the "first vibration mode," that is, the most important type of shift. We can proceed iteratively to define the second, third, and so on, principal components.

It turns out that there is a simple way to calculate these principal components: they are simply the eigenvectors of the correlation matrix. The first principal component is the eigenvector corresponding to the biggest eigenvalue the second principal component is the eigenvector corresponding to the second biggest eigenvalue, and so on.[4]

Since a correlation matrix is positive definite, all its eigenvalues are real and positive. The relative size of the eigenvalues indicates the relative contribution of each principal component to the overall variance of yields along the yield curve. Usually there are just a few eigenvalues that are much bigger than all the rest. Also, note that since the eigenvectors are orthogonal, they can be regarded as describing independent factors. This means that one can take a large and unpromising correlation matrix, like the ones shown in Exhibit 33-3, and extract a small number of independent risk factors that capture most of the information in it.

We should note at this point two features of principal component analysis that can be regarded as both limitations and advantages. First, it assumes that each factor is symmetric (i.e., up and down shifts have the same shape, and the same

1. Karl Pearson, "On Lines and Planes of Closest Fit to Systems of Points in Space," *Philosophical Magazine* 2(11), pp. 559–572.

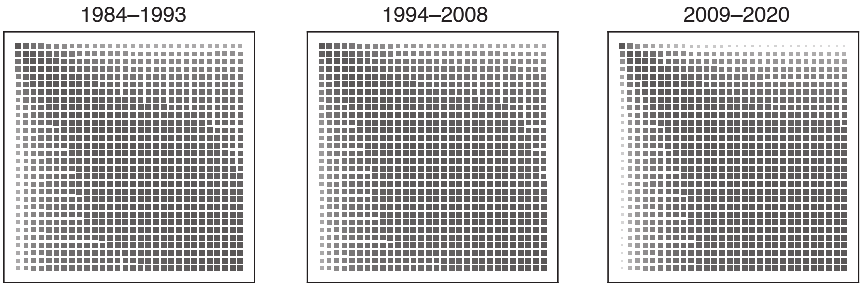
2. Robert Litterman and José Scheinkman, "Common Factors Affecting Bond Returns," *Journal of Fixed Income* 1(1), pp. 54–61.

3. Ian Jolliffe and Jorge Cadima, "Principal Component Analysis: A Review and Recent Developments," *Philosophical Transactions of the Royal Society* A 374 (2016):20150202.

4. There is a subtlety here about whether to use the correlation matrix, which implicitly weights different points on the yield curve equally, or the covariance matrix, which weights them by their volatilities. The convention—adopted in many statistical software packages—is to use the former, which is appropriate when different units of measurement are involved. The calculations in this chapter use the covariance matrix, which has some theoretical advantages but leads to similar results. See Mike Tipping and Christopher Bishop, "Probabilistic Principal Component Analysis," *Journal of the Royal Statistical Society* B 61(3), 1999, pp. 611–622.

EXHIBIT 33-3

Correlation Matrices for 1-Year to 30-Year U.S. Treasury Yields



loadings).[5] Second, it assumes that the shape of each factor is independent of the level of the yield curve—which, as we will see below, is not true when yields are near the lower bound. These oversimplifications are clearly limitations, but they are also advantages in practice, because the results are easy to interpret and use—as we'll see at the end of this chapter.

Principal Component Analysis of Yield-Curve Shifts

Exhibit 33-4 shows the results of applying principal component analysis to daily U.S. Treasury yield date from 1984 to 2020, covering evenly spaced maturities from 1 year to 30 years.[6]

- Most of the observed variance in bond yields is explained by the first four principal components: the 1st principal component explains about 92%,[7] the 2nd explains about 5%, the 3rd about 1%, the 4th explains 0.5%, and the rest very little.
- The first line plot shows the first four principal components. The first two principal components look quite intuitive: the 1st (solid line) is a nearly parallel shift in the level of the yield curve, while the 2nd (dashed line) is a change in the slope of the yield curve, that is, a steepening or flattening.

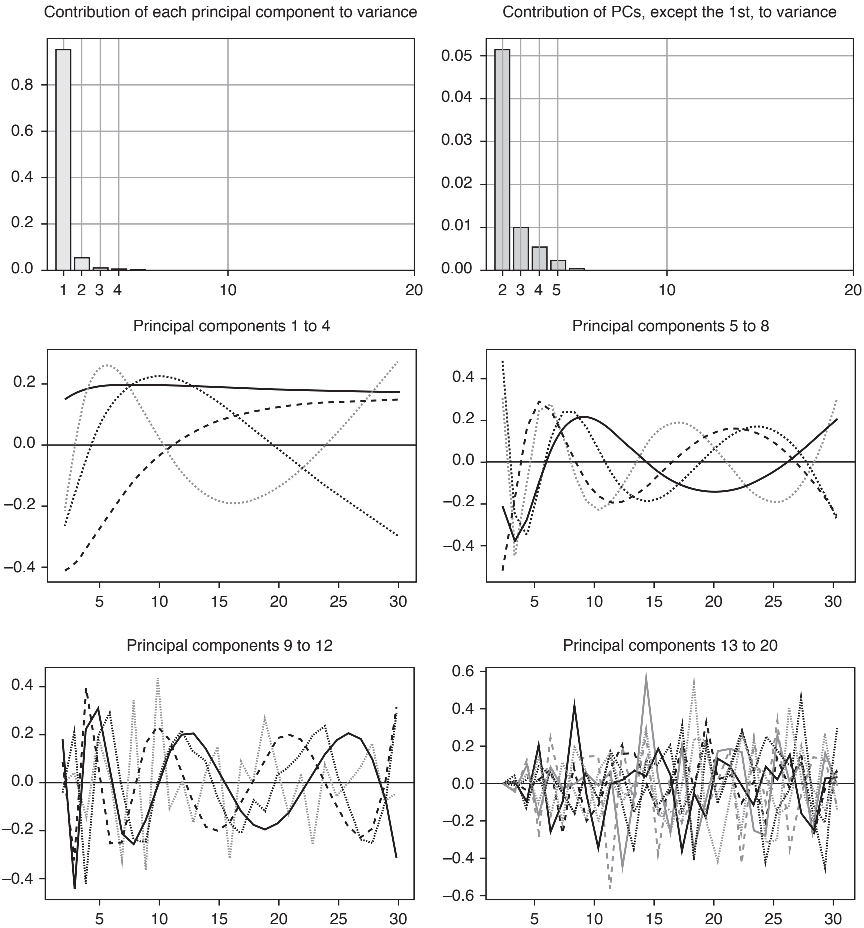
5. Thanks to Henry Schellhorn for noting the potential importance of asymmetry.

6. All U.S. yield-curve data are from the Federal Reserve Board. See Refet Gurkaynak, Brian Sack an,d Jonathan Wright, "The U.S. Treasury Yield-Curve: 1961 to the Present," *FEDS Working Paper* 2006-28 (2006).

7. It can be hard for finance practitioners, who are used to thinking in terms of volatility, to interpret statements like "explains 92% of variance." A simple example may help. Suppose a security's returns are driven by two uncorrelated factors, with volatilities of 3% and 1%, respectively. Then even though the first factor is only 3× as volatile, it explains $\frac{0.03^2}{0.03^2+0.01^2} = 90\%$ of the variance in returns.

EXHIBIT 33-4

Principal Component Analysis, U.S. Treasury Yields, 1984–2020



- The 3rd principal component (dark dotted line) is a hump-shaped shift with the peak of the hump at around the 10-year maturity point; the 4th (light dotted line) is a "snake shift," which seems less intuitive.
- The remaining three line plots show the remaining principal components up to the twentieth. The next half dozen look vaguely like Fourier modes, while the remainder appear to be just noise. None seem intuitive or meaningful.

The 1st principal component is particularly interesting, since it vindicates the notion of bond duration. When we compare the interest rate risk of different bonds by comparing their durations, we are implicitly assuming that all their yields move one-for-one; that is, the duration of a bond is its sensitivity to a parallel shift in the yield curve, which affects all bonds equally. This is almost the same thing as its sensitivity to the 1st principal component, that is, to the empirically most important kind of yield-curve shift.

Beyond the 1st, though, which of these principal components are meaningful and useful? The answer is more subtle than it seems, but we begin with a very important observation: *The principal components you identify will depend on the set of maturities you look at.*[8]

This is illustrated by Exhibit 33-5, which shows the results of a principal component analysis to data from the same historical time period, but considering only intermediate Treasuries, that is, those with maturities of 10 years or less.

- Again, only the first four principal components look significant.
- The first two principal components again look like a level shift and a slope shift, and have similar weights, explaining about 93% and 5% of variance, respectively.
- The 3rd principal component is a hump-shaped shift, but this time peaking at around the 2.5-year maturity point, and it now has a 2% weight; the 4th is a snake shift, but peaking around the one-year point.
- The next three or so principal components look like wavy Fourier modes, and the rest once again look like noise.

Here is our first indication that, while the first two principal components are fairly robust, the shape and significance of the third (often called the "curvature shift") are much more dependent on the data we choose to focus on. That is, while the level shift and slope shift seem to have some universal significance, the other shifts we identify can vary depending on the maturities we include.[9]

Another robustness check is to compare the results of analyzing yield-curve shifts observed in different historical periods. Exhibit 33-6 splits the 1962–2020 data into five different periods.[10]

---

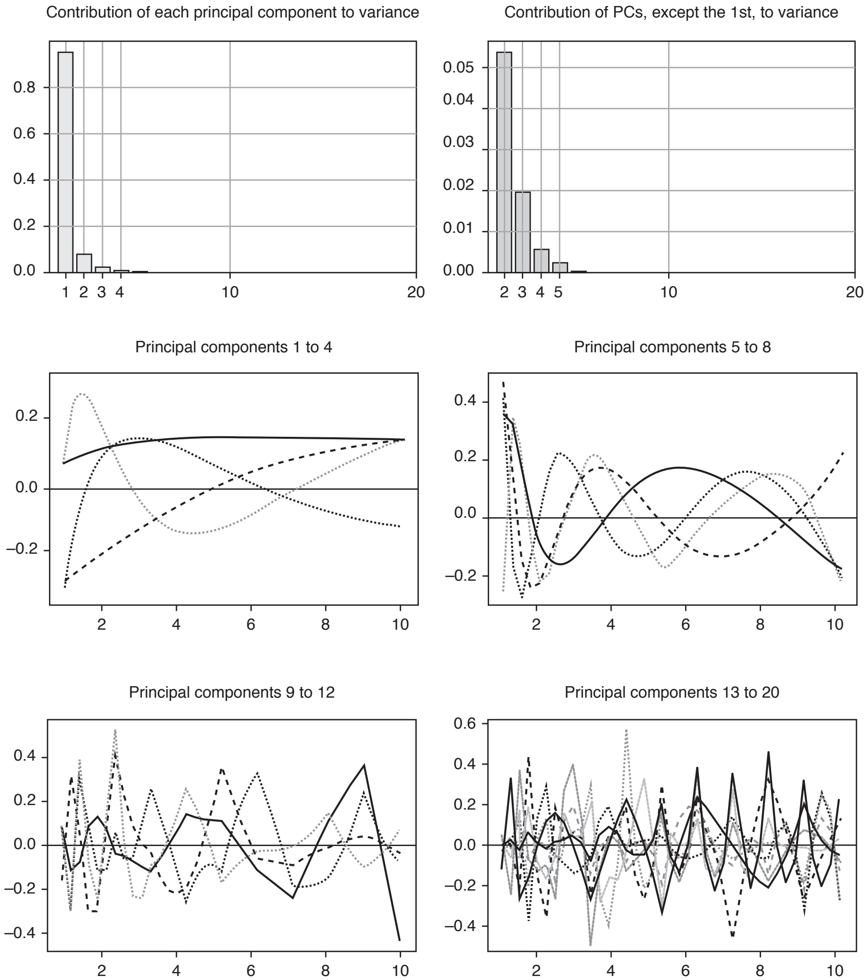
8. So do the weights. If the data set includes large gaps between maturities, the 1st and 2nd principal components will appear relatively more important. Since diversified bond portfolios tend to populate the full range of maturities rather than leaving gaps, the analysis in this chapter uses equally spaced maturities.

9. Many empirical studies of interest rate dynamics have focused solely on Treasury bill yields or Eurodollar futures yields. A principal component analysis of these data only sheds light on the dynamics at the short end of the yield curve, and the results may have little relevance for an investor in intermediate or long maturity bonds.

10. These were chosen to correspond to different monetary policy regimes: 1962–1979 is the early period; 1979–1983 is the period when the Fed targeted the money supply; 1984–1993, when it targeted the Fed funds rate but did not disclose the target; 1994–2008, when it had a public target for the Fed funds rate; and 2009–2020, when Fed funds was near the zero bound and it employed quantitative easing.

EXHIBIT 33-5

Principal Component Analysis, U.S. Treasury Yields (Intermediate Maturities Only), 1984–2020



- In most periods, the 1st principal component is a level shift. The exception is the most recent period 2009–2020, where it looks like a flattened-out slope shift, with no movement in short maturities. We will return to this observation later.
- In most periods, the 2nd principal component is a slope shift. However, it seems to change shape over time, becoming more "linear." The exceptions are the early period where it is parallel beyond the one-year

point, and the QE period where it looks like a slope shift for maturities two years and longer, but is pinned near zero at the very short end.

- The hump of the 3rd principal component has moved around in different periods, as has the peak of the 4th principal component, which seems to have been even less stable.

A further check, which is independently useful, is to analyze yield-curve data from other countries, shown in Exhibit 33-7.[11] We observe the following:

- Canada and the United Kingdom show similar results to the United States.
- The level shift in Germany is similar, but is not parallel at maturities shorter than two years. The slope shift is also somewhat different, as are the 3rd and 4th principal components, though there is a qualitative resemblance.
- For Japan, where yields have been low for much longer, the 1st principal component looks a little more like a slope shift (cf. the QE period results for the United States). The 2nd principal component looks like Germany's. The 3rd and 4th principal components are completely different.
- In all four countries, the relative importance of the 1st principal component is a little lower than it is in the United States. That is, duration does a slightly worse job of capturing overall yield-curve risk in other countries, especially Japan, than it does in the United States.

It is also possible to use principal component analysis to study the *joint* dynamics of yield curves in different countries. For example, it turns out that in a data set spanning advanced economies, the 1st principal component is a "global level shift."[12]

Is the Analysis Vacuous?

At this point, we might feel some satisfaction for identifying a small number of important yield-curve shifts that explain most interest rate risk: the level shift, which justifies the traditional notion of duration; the slope shift, which suggests an additional, important risk measure (see the end of this chapter); and the third/fourth principal components, which may be important as well. After all, a priori these principal components could all have turned out to have complicated and unintuitive shapes—like the less significant ones actually do.

11. U.K. data is from the Bank of England; Canadian data from the Bank of Canada; German and Japanese data from Bloomberg.

12. Wesley Phoa, "Yield-Curve Risk factors: Domestic and Global Contexts," in Lev Borodovsky and Marc Lore (eds.), *The Practitioner's Handbook of Financial Risk Management*, Butterworth-Heinemann (2000).

EXHIBIT 33-6

Principal Component Analysis, Intermediate U.S. Treasury Yields, Different Time Periods

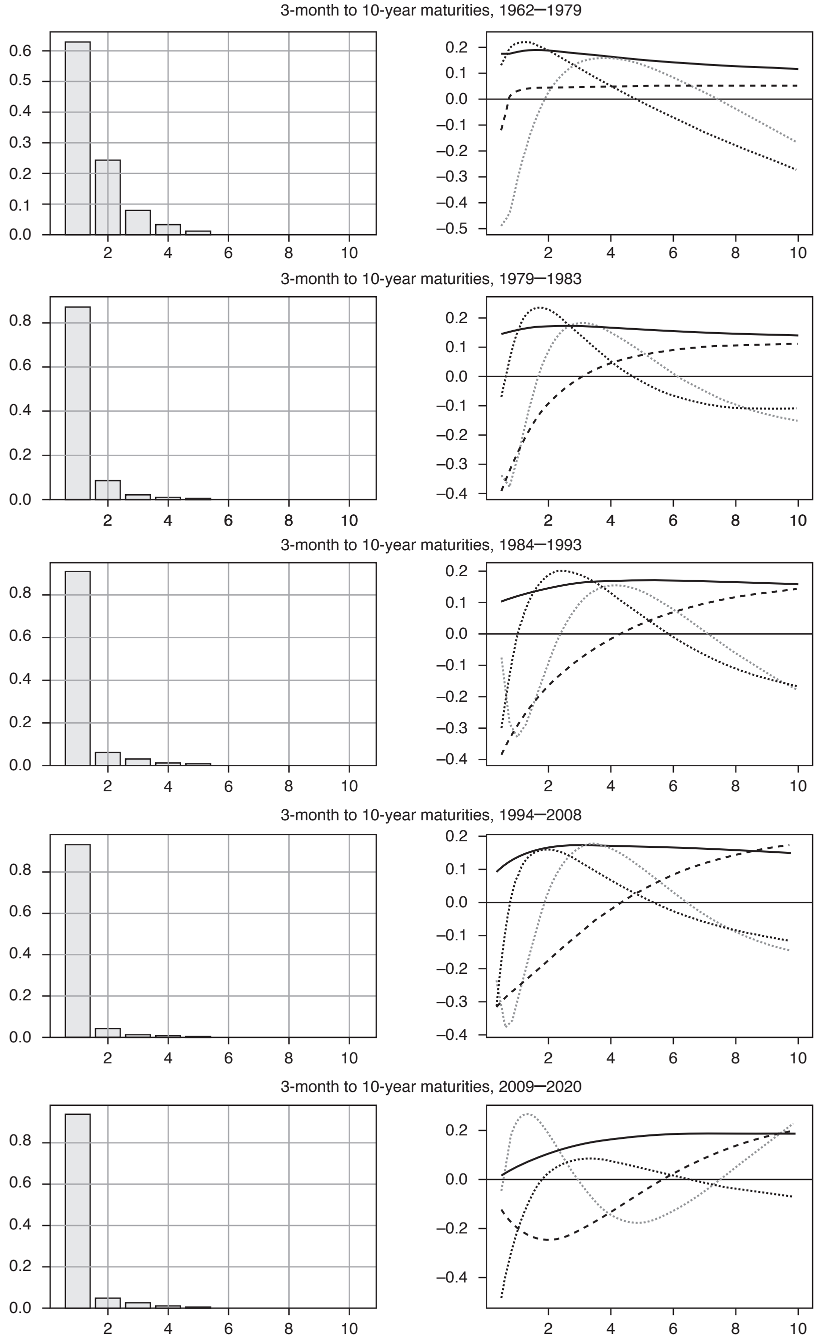
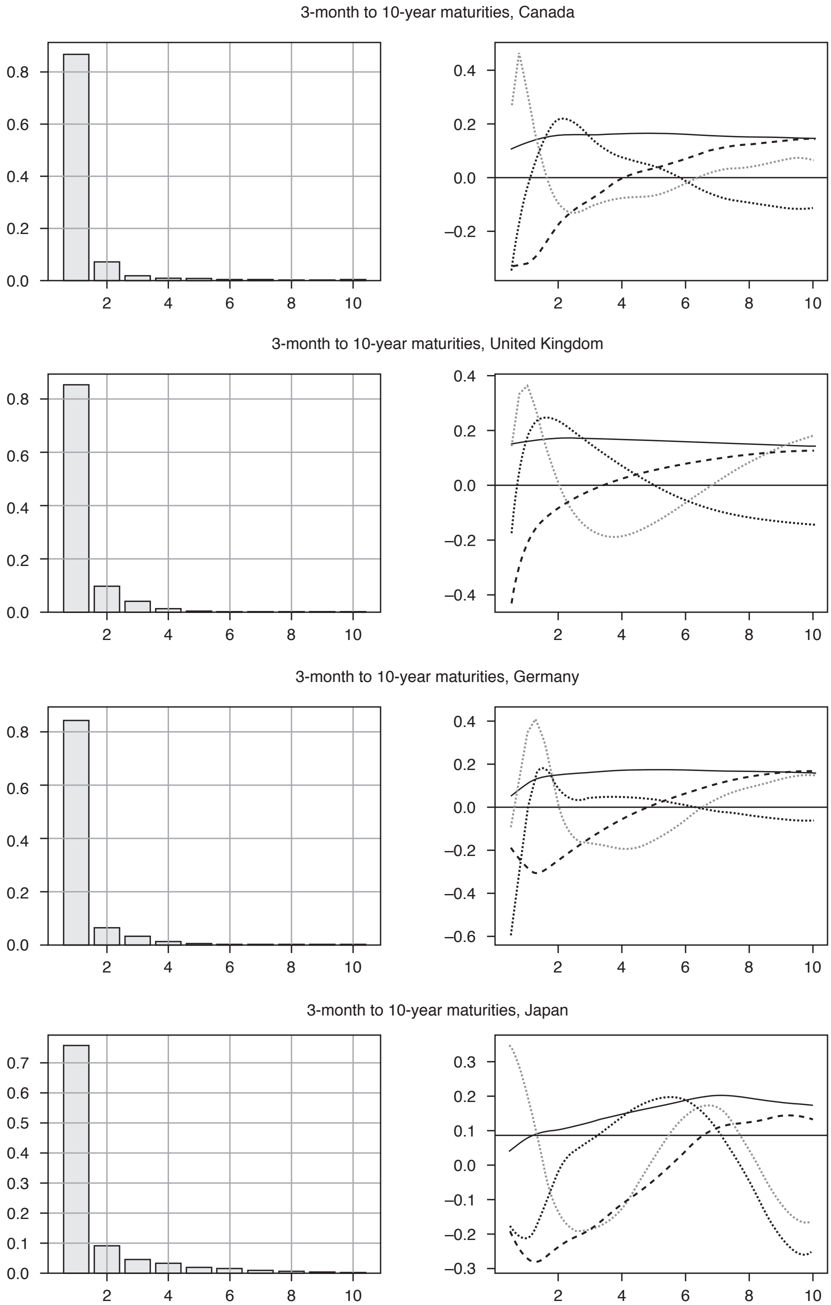


EXHIBIT 33-7

Principal Component Analysis, Other Countries



But we should first ask ourselves whether this really was a discovery emerging from hidden, special features of the data, or whether it was a statistical artefact—whether the principal components *must* look like that, for general reasons; that is, whether there are theorems that dictate their form.

The answer is somewhere in between. Lord and Pelsser describe the general characteristics of a correlation matrix that ensure that a principal component analysis *must* generate level, slope, and curvature shifts.[13] To explain their results, fix a data set and define the *correlation curve* for a specified maturity M to consist of the correlation between each maturity point of the yield curve and the specified M-year yield. It is simply the corresponding row of the correlation matrix, interpreted as a function of maturity (e.g., see the solid lines in Exhibit 33-20 later in this chapter).

Lord and Pelsser define a yield-curve shift to be a *level shift* if it does not change sign, that is, yields at all maturities move in the same direction; it is a *slope shift* if it changes sign exactly once, and a *curvature shift* if it changes sign exactly twice. Then they prove precise versions of the following theorems:

- The 1st principal component will look like a *level shift* provided every entry in the correlation matrix is strictly positive.
- The 2nd principal component will look like a *slope shift* provided each correlation curve is flatter on the right than on the left.
- The 3rd will look like a *curvature shift* provided the "derivative" of each correlation curve is flatter on the right than on the left.

A glance at Exhibit 33-20 shows that the first two conditions hold for the full Treasury yield curve in various time periods. The third condition is harder to visualize, but we can also verify that it holds in all the time periods shown. The same is true for most other yield-curve data sets.

We should not interpret this negatively, as saying that yield-curve principal component analysis is simply a tautology. Viewed more positively, these results show that the first few principal components are qualitatively robust, in the sense that their form is not overly dependent on the specific details of the correlation matrix, but on its general features.

Also, note that a "level shift" in Lord and Pelsser's sense need not be a parallel shift, and indeed empirically the 1st principal component is not always parallel. This illustrates that, even though yield-curve correlation matrices usually satisfy the general conditions spelled out in their paper, the principal components analysis still yields necessary quantitative information about the precise form of the shifts.

13. Roger Lord and Antoon Pelsser, "Level-Slope-Curvature: Fact or Artefact?" *Applied Mathematical Finance* 14(2), 2007, 105–130.

Time Variation and Other Sources of Uncertainty

Let's take a closer look at the stability of the principal components—or, to put it differently, their time variation. Exhibit 33-8 overlays a principal component analysis for each individual year in the period 1984-2020, to show how much the results varied; Exhibit 33-9 does the same, but for maturities up to 10 years.

- The 1st principal component varied quite a bit from being nearly parallel to being distinctly sloped at the short end. It was generally flat, or slightly downward-sloping, for maturities longer than five years.
- The 2nd principal component had a surprisingly consistent shape over time, but occasionally deviated quite a bit—though never for long.
- The 3rd and 4th principal components had the same general form over time but tended to peak at different maturities in different periods.
- The remaining principal components seem less meaningful, and inconsistent over time.

This is a strong indication that the first two principal components are fairly stable and therefore meaningful; that the 3rd, and perhaps the 4th, may be relevant, but should be interpreted with caution due to their instability; and that the rest should probably be ignored.[14]

Now that we've observed that the 1st principal component is not always a parallel shift, it's reasonable to ask what determines its shape. A reasonable guess would be: when bond yields are well above zero, the yield curve is free to move (like the plank/dolly), and parallel shifts are possible; whereas when short-term interest rates are static, the yield curve is anchored at one end (like the beam/cantilever), and the 1st principal component cannot be parallel.[15]

Evidence for this is shown in Exhibit 33-10, which plots the short-term interest rate in the United States and the slope of the 1st principal component, again measured over one-year periods. In the period prior to 2008, short-term interest rates remained well above zero, and the 1st principal component was quite flat on average. By contrast, once short-term interest rates reached the zero lower bound and remained there, the 1st principal component became upward-sloping. Note that when short-term rates started to rise above zero in 2016–2019, the 1st principal component started to flatten; if this had continued, it might have returned to being parallel.

14. However, more components may be relevant when analyzing forward rates rather than coupon yields: Ilias Lekkos, "A Critique of Factor Analysis of Interest Rates," *Journal of Derivatives* 8(1), 2000, pp. 72–83.

15. One might also suspect that the fundamental shifts might not be symmetric in nature, e.g., because it is possible to have a parallel yield-curve shift upward but not downward. As noted earlier, principal component analysis is not able to capture this kind of asymmetry. Practitioners tend to use more ad hoc methods to analyze it.

EXHIBIT 33-8

Variation in Shapes of Principal Components, U.S. Treasury Yields

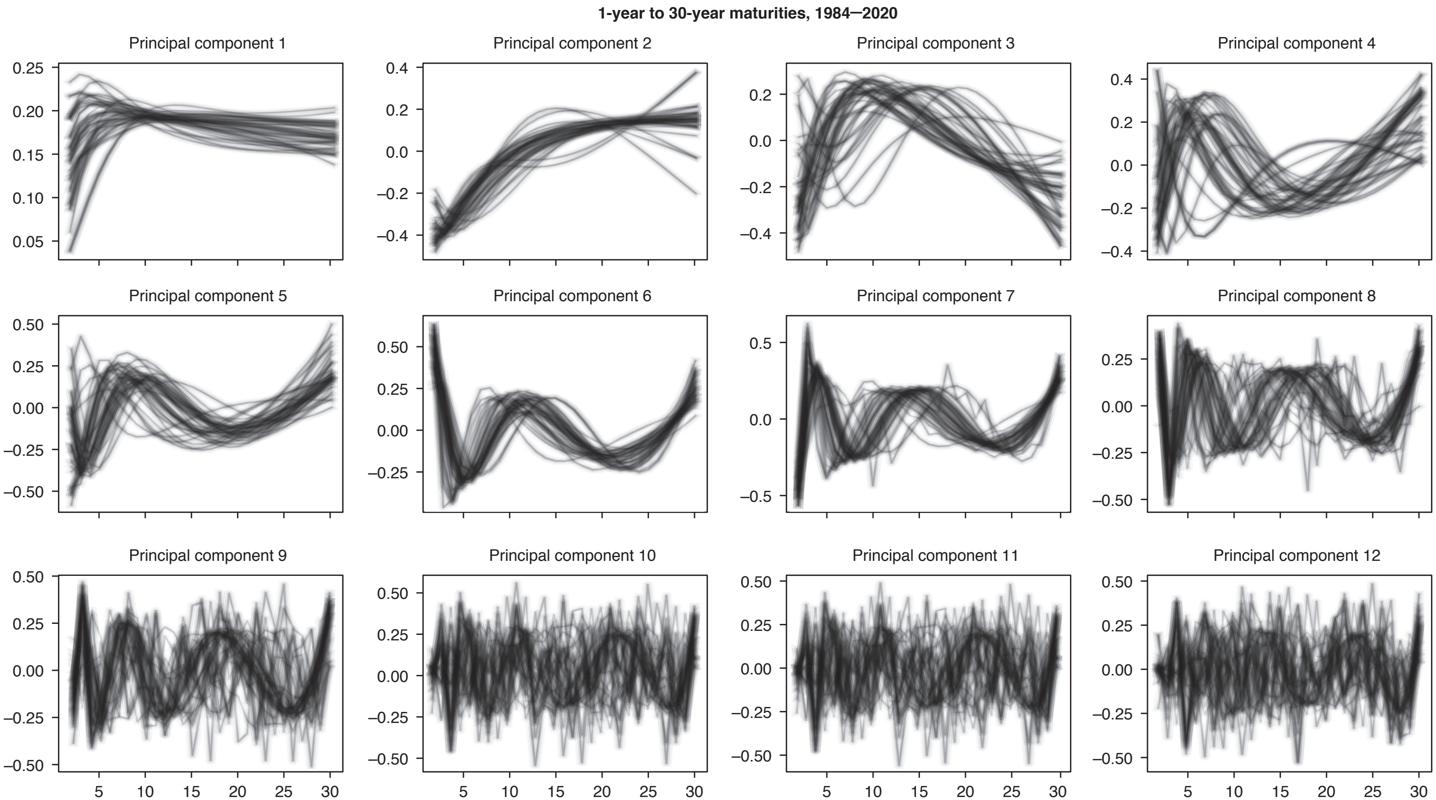


EXHIBIT 33-9

Variation in Shapes of Principal Components, Intermediate U.S. Treasury Yields

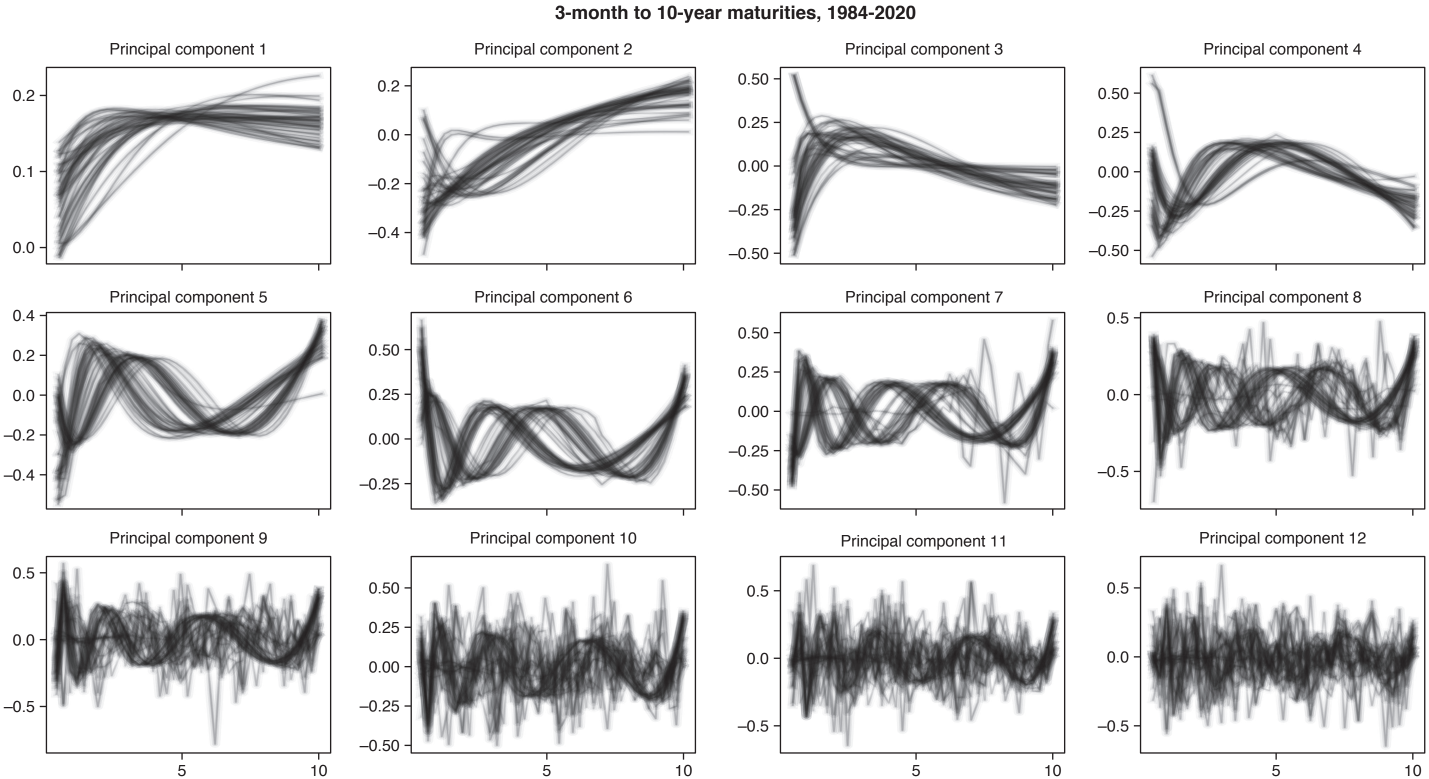
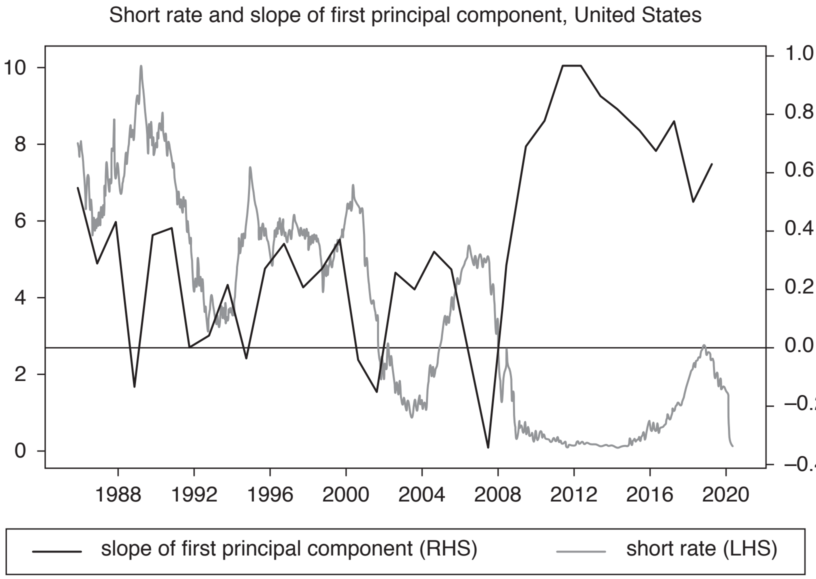


EXHIBIT 33-10

Historical Variation in 1st Principal Component, United States



However, this simple story, linking the nature of the 1st principal component with the zero lower bound on short-term rates, is unfortunately a bit too simple, as Exhibit 33-11 shows. In the United Kingdom, the 1st principal component started to exhibit a distinct upward slope in the mid-1990s, more than a decade before short-term interest rates approached zero. In Canada, the slope of the 1st principal component was trending upward from around 2004, again well before short-term rates approached zero.

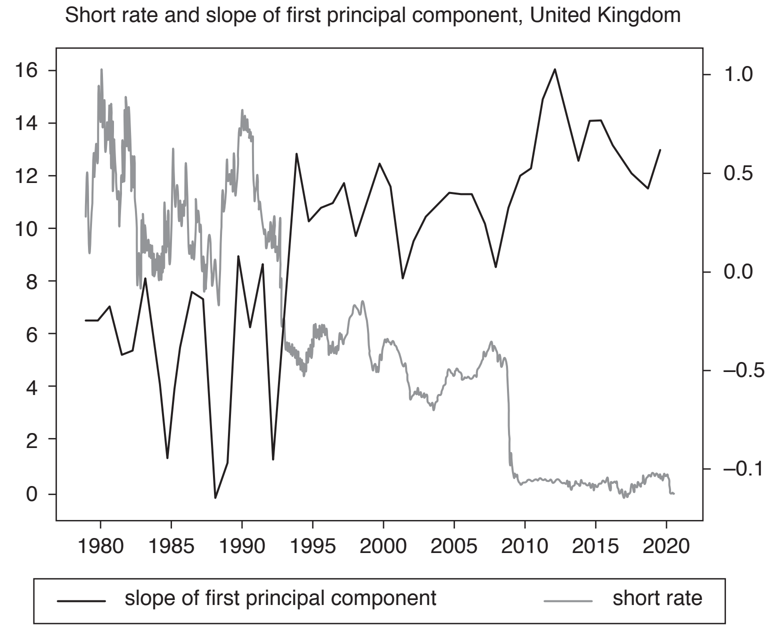
In both cases there is a possible explanation. The Bank of England became independent in 1998; the monetary policy regime in Canada may have changed in 2004.[16] However, it is difficult to make a rigorous connection between these less clear-cut regime switches and the change in yield-curve dynamics.

Another aspect of time variation involves the relative importance of each principal component. Exhibit 33-12 shows that, for the full U.S. Treasury yield curve, the importance of each principal component was somewhat stable during the 1984–2020 period: for example, the 1st principal component accounted for 86% to 97% of variation in yields throughout that period, while the 2nd principal component accounted for 2% to 9%.

16. David Andolfatto and Paul Gomme, "Estimating Canadian Monetary Policy Regimes, preprint (2008).

EXHIBIT 33-11

Historical Variation in 1st Principal Component, Other Countries



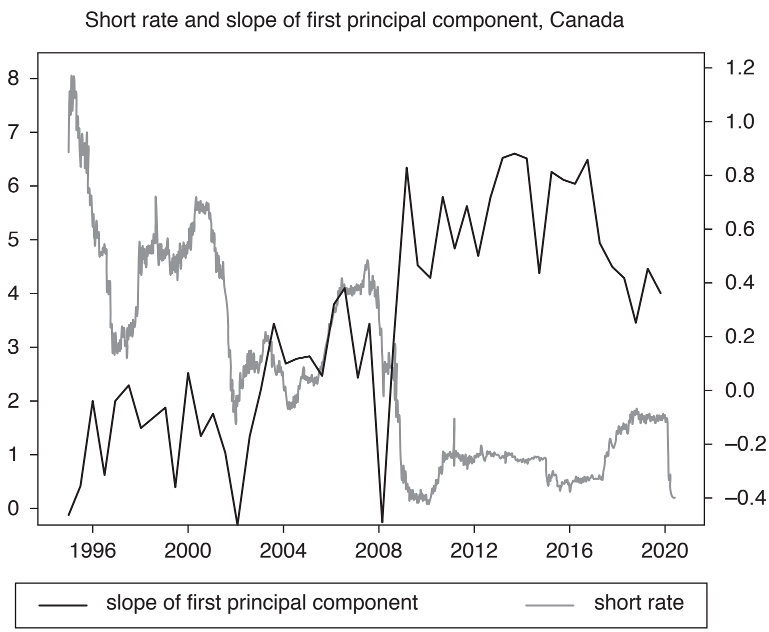
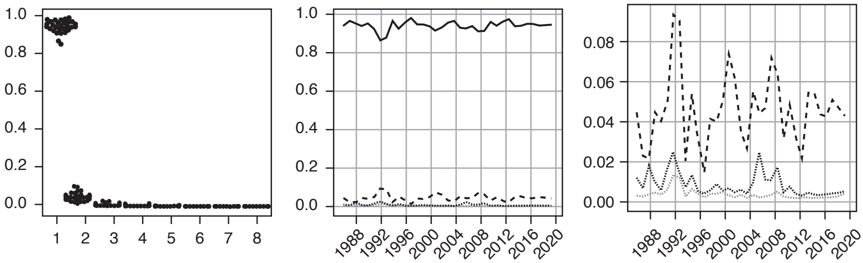


EXHIBIT 33-12

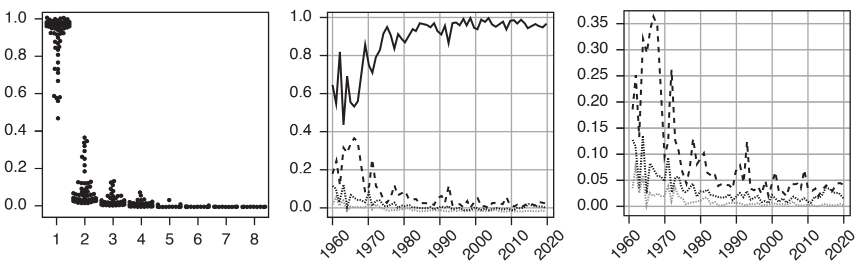
Variation in Importance of Principal Components, U.S. Treasury Yields



Looking at the longer 1962–2020 period, using intermediate Treasury yields, reveals a different picture (see Exhibit 33-13). Prior to the mid-1980s, the 1st principal component was much less important, initially accounting for only 60% of variation in yields on average. It seemed to become more important as Fed policy acquired more independence and clarity between the mid-1970s and the mid-1980s. At the same time, the importance of the 2nd, 3rd, and 4th principal components gradually declined.

EXHIBIT 33-13

Variation in Importance of Principal Components, Intermediate U.S. Treasury Yields



At this point, one might wonder about the relationship between any two principal components. Are they substitutes, with one gaining importance as the other loses it? Conversely, are they linked, both becoming more or less important together? Or are they just unrelated? The answer to these questions is relevant to risk management, once we acknowledge that the importance of each shift is not static.

Exhibit 33-14 shows that the answer is, unfortunately, not simple. It looks at both the full yield curve (upper charts) and maturities up to 10 years (lower chart), again for the 1984–2020 period.

- The 1st and 2nd principal components seem to be substitutes: when level shifts are more important, slope shifts are less important, and vice versa.
- For the analysis using intermediate maturities, the 3rd and 4th principal components seem to be linked: they tend to be more (or less) important at the same time. However, this is less clear in the analysis using all maturities; remember that this analysis identifies different 3rd and 4th principal components.
- The relationship between the 2nd and 3rd principal components is unclear in both data sets.

A final practical remark. The 3rd and 4th principal components are each significantly less important than the 2nd, but their combined importance is comparable. It can be useful to combine them into the shift shown in Exhibit 33-15, which is a hump shift peaking at intermediate maturities, and fairly flat beyond 15 years maturity. While this combined shift has no special significance—it is not itself a principal component—it can be a useful tool. When fixed income risk models incorporate a "curvature" or "hump" shift like this, it is often defined to roughly involve no shift at long maturities; this can be straightforward to specify using standard parametric yield-curve models.[17]

THEORETICAL DETERMINANTS OF YIELD-CURVE DYNAMICS

Now that we have empirically identified the different kinds of yield-curve shifts that dominate the dynamics of the yield curve, we should ask where they come from, and what this means for bond risk management and bond investing. This is a theoretical, rather than empirical, question.

Macroeconomic Determinants

Economic expectations are a key driver of yield-curve fluctuations; this is obvious from the fact that the yield-curve responds to economic surprises. Can we interpret level and slope shifts in terms of economic expectations? Do level and slope shifts emerge naturally from an economic account of the yield curve? Is this what distinguishes them from the other principal components? We sketch an affirmative answer to these questions as follows.

17. Ram Willner, "A New Tool for Portfolio Managers: Level, Slope and Curvature Durations," *Journal of Fixed Income* 6(1), 1996, pp. 48–59.

E X H I B I T 33-14

Historical Relationship Between Importance of Principal Components, U.S. Treasury Yields

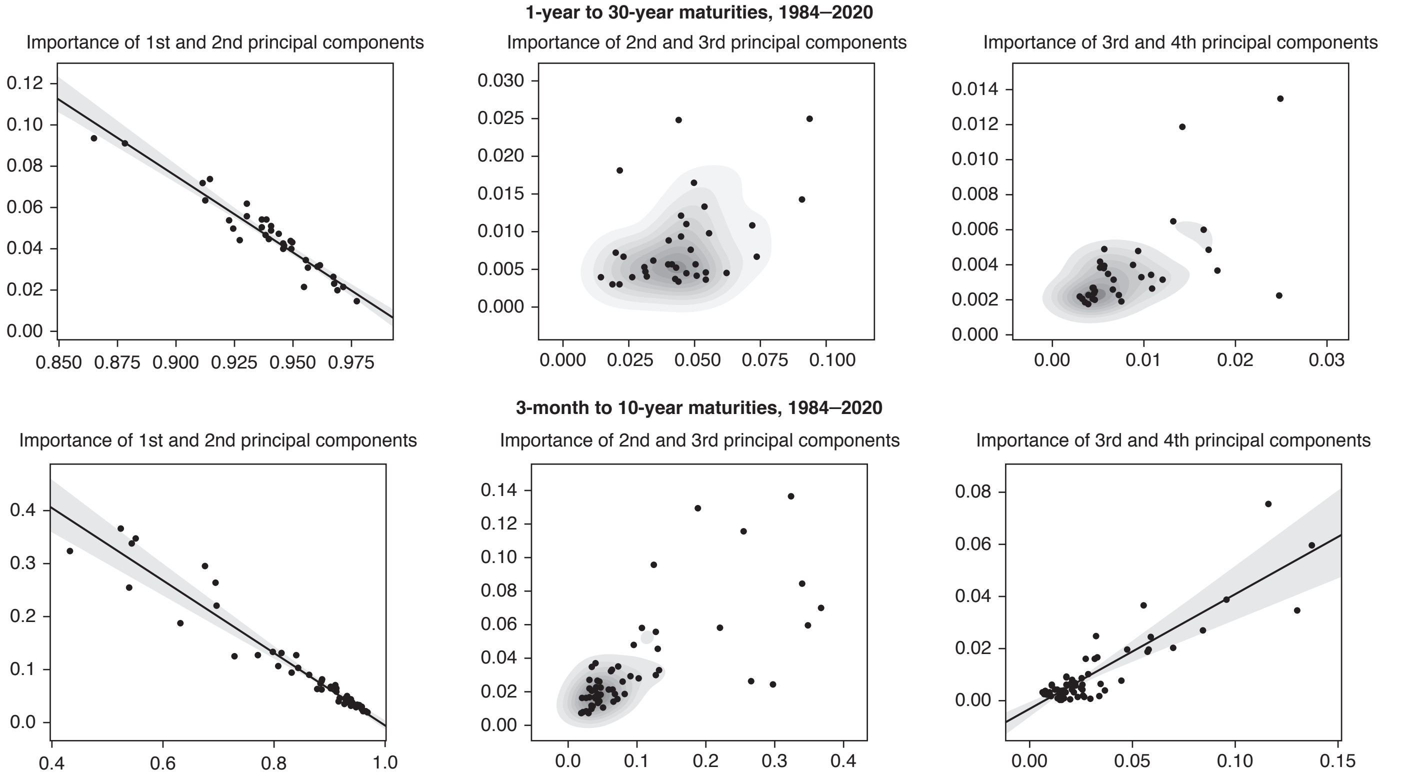
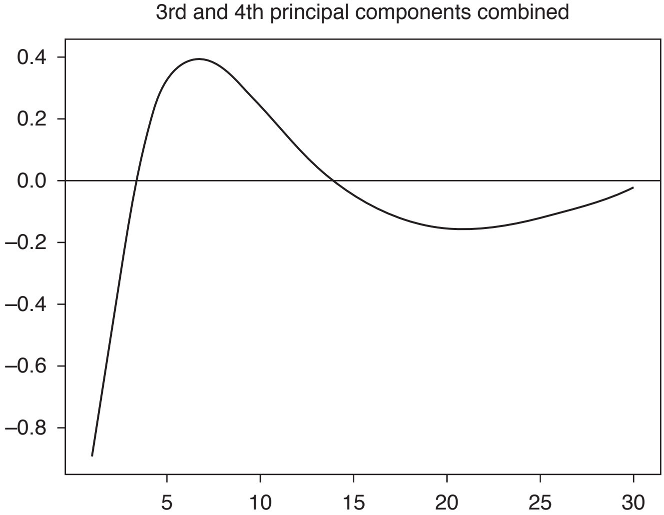


EXHIBIT 33-15

Combining the Problematic Principal Components



The simple intuition is shown schematically in Exhibit 33-16. Nominal yields are determined by expected real interest rates plus expected inflation. These both have long-run expected values but can deviate from those in the short run. The yield curve shifts whenever there is a change in either long-run or short-run expectations, about either future real interest rates or future inflation. (Note that in the long run, real interest rates are generally thought to be determined by the real growth rate of the economy.)

That intuition can be made a bit more formal: Let r_0 be the current short-term nominal interest rate, let $\overline{\pi}$ be the expected long-term inflation rate, and let $\overline{e}$ be the expected long-term real interest rate. Then the expected long-term nominal interest rate is $\overline{\pi}+\overline{e}$. This usually differs from the current short-term rate r_0, but it seems reasonable to assume that investors expect the future short-term rate $r = r_t \ (t > 0)$ to approach $\overline{\pi}+\overline{e}$ as time passes, at least in the absence of future shocks. In fact, under some simple assumptions about how the economy works, one can show that there is a constant κ such that, in expectation,

$$\frac{dr}{dt} = -\kappa\left(r - \left(\overline{\pi}+\overline{e}\right)\right)$$

More precisely, we can derive this from a formal macroeconomic model. The simple model that Frankel used to derive this relationship[18] is shown in

18. Jeffrey Frankel, *Financial Markets and Monetary Policy*, MIT Press (1995).

EXHIBIT 33-16

Economic Determinants of the (Short-Run Equilibrium) Nominal Rate

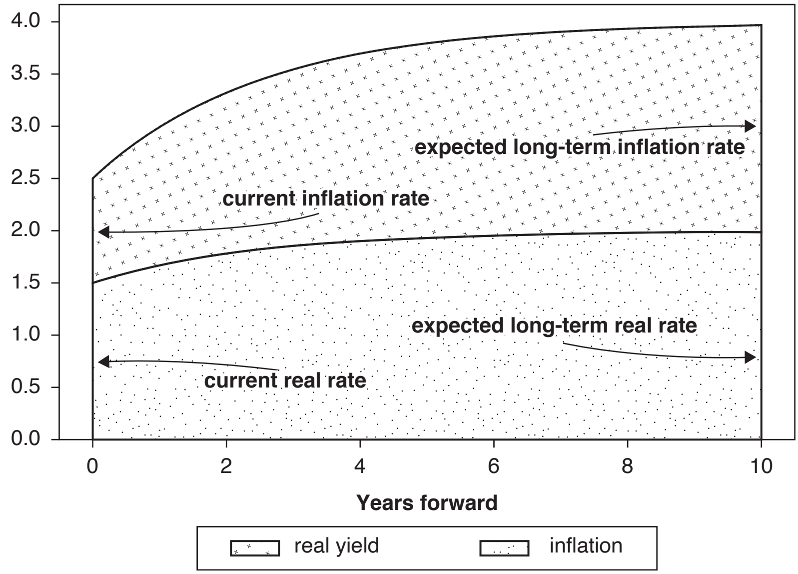


Exhibit 33-17; it corresponds fairly closely to "standard undergraduate macroeconomics." In that model, some algebraic manipulation yields the above formula with $\kappa = \dfrac{\rho\gamma}{\omega\gamma + \lambda}$, where $\gamma := \dfrac{\psi}{1 - \psi\rho}$.

This result is not special: a similar relationship appears to hold in a fairly wide variety of models of the economy, including more complex ones that permit random shocks to the level and trend of the money supply. Thus, the conclusion seems to be quite general. The basic intuition is that interest rates take time to adjust to their expected long-term level, since output and prices take time to adjust.

Given the above expression for the expected rate of change $\dfrac{dr}{dt}$ of the short-term interest rate, it is easy to derive a formula for the expected short-term interest rate at time t:

$$E\left[r_t\right] = \left(1 - \exp\left(-\kappa t\right)\right)\left(\bar{\pi} + \bar{e}\right) + r_0 \exp\left(-\kappa t\right)$$

It is convenient to write this in the form:

$$E\left[r_t\right] = \left(\bar{\pi} + \bar{e}\right) - \exp\left(-\kappa t\right)\left(\left(\bar{\pi} + \bar{e}\right) - r_0\right)$$

That is, a rational investor with conventional beliefs about how the economy works would expect the short-term interest rate to asymptotically approach some

EXHIBIT 33-17

Macroeconomic Model of the Nominal Interest Rate

Constants

$\bar{\pi}$	expected long-term rate of inflation
$\bar{e}$	expected long-term real interest rate

Time-varying quantities

r	short-term nominal interest rate
$\bar{y}$	log of potential output (i.e., capacity)
y	log of actual output (i.e., utilization)
m	log of the money supply
p	log of the price level

Equations

IS

$$y - \bar{y} = -\psi\left(\left(r - \frac{dp}{dt}\right) - \bar{e}\right)$$

"the current output gap is determined by the current real interest rate gap"

LM

$m - p = y - \lambda r$

"real money demand is determined by real income and the nominal interest rate"

CU

$$\frac{dp}{dt} = \rho(y - \bar{y}) + \bar{\pi}$$

"current inflation is determined by the current output gap and long-run inflation"

MP

$$\frac{dm}{dt} = \bar{\pi} + \frac{d\bar{y}}{dt}$$

"money supply growth is determined by potential output growth and long-run inflation"

long-term equilibrium level $\bar{\kappa} + \bar{e}$, and the expected future path of short-term rates can be described by a simple exponential curve. There are also other ways to arrive at this functional form, via arbitrage arguments rather than economic arguments.[19] The coefficient κ determines the shape of the yield curve, and could thus be estimated empirically by looking at observed yield curves.

We can see from the above expression that the model predicts two kinds of observable shifts in the yield curve due to changes in economic expectations:

19. Herbert F. Ayres and John Y. Barry, "The Equilibrium Yield Curve for Government Securities," *Financial Analysts Journal* 35(3), 1979, pp. 31–39.

1. *Level shifts*, which arise either from a change in the expected long-term rate of inflation $\overline{\pi}$, or in the expected long-term real rate $\overline{e}$. Thus, level shifts are linked to the expected long-run behavior of the economy.
2. *Slope shifts*, which result from short-term changes in r—in terms of the model, this might occur because an economic shock creates a sudden change in the output gap $y-\overline{y}$. Thus, slope shifts are linked to the cyclical behavior of the economy.

These can be regarded as separate economic factors because changes to long-run expectations and short-run shocks to the output gap can happen at different times for separate reasons.[20]

In addition, if investors expect that κ has changed (e.g., because the structural parameters ψ, λ, ρ have changed), then this would imply a change in the curvature of the yield–curve, that is, a hump-shaped shift resembling the 3rd empirical principal component. However, in practice, hump-shaped shifts in the yield curve mainly occur for quite different reasons.

Other Determinants

In practice we know that the yield curve is not determined entirely by economic expectations (long-term inflation and real rates) and current economic conditions (the output gap and current inflation). There are usually more factors at play. Two particularly important factors are:

- The *term premium*. This is the compensation that bond investors require for assuming interest rate risk, that is, for being willing to invest for a fixed term of years rather than continually rolling over short-term investments.[21] The term premium was positive during most periods in history, but can be negative if investors actually prefer locking in yields.
- The central bank's *policy bias*. This refers to the fact that the short-term interest rate is controlled by the central bank's discretionary policy, rather than being determined by a simple economic model. Over a horizon of a year or two, the expected policy rate can thus differ from what the model says it "should" be.

(Note that the term premium should not be confused with the "term spread," which is the observable difference between long-term and short-term yields. The term spread is the sum of two unobservable quantities: the market's

20. A *caveat* is that the first two principal components are orthogonal by construction, but the two economic factors just described need not be uncorrelated. So the relationship is a bit more subtle than implied here.

21. Don Kim, "The Bond Market Term Premium: What Is It, and How Can We Measure It?" *BIS Quarterly Review*, June 2007: 27–40.

expected change in short-term yields between now and the future, and the term premium. See the reference cited for a more detailed explanation.)

An interesting case of negative term premium is when the central bank is buying bonds aggressively, that is, engaging in quantitative easing, so that net supply is negative. An interesting case of policy bias is when the model says the short-term nominal rate should be large and negative. In many countries the policy rate cannot fall below zero, and in the remaining countries it can only be modestly negative. Thus, in this situation there will be a positive policy bias.

Exhibit 33-18 shows two conceptual illustrations of how economic and other determinants fit together to determine the overall nominal yield curve. In each row in Exhibit 33-18, the left-hand plot shows the economic determinants only (see Exhibits 33-16 and 33-17), while the right plot chart shows the adjustments due to the term premium and policy bias. The upper row illustrates the situation in the mid-2000s, when the term premium was positive; the lower row illustrates the early 2020s, with a negative term premium.

The term premium and policy bias are important for yield-curve dynamics because they are both time-varying. For example, the previous discussion noted that central bank policy actions can affect both the term premium (e.g., via quantitative easing) and the policy bias (e.g., via forward guidance).

Note that the term premium is a problematic concept, because—like other market risk premia—it is not directly observable. Therefore, the term premium must be estimated using a model, and different models can give quite different results. That problem is beyond the scope of this chapter, so we simply note that some central banks publish their own estimates of the term premium, which are a useful resource for investors who are not in a position to build and maintain these models themselves.

If a model is used to decompose the observed yield curve into short rate expectations (i.e., the economic model plus the policy bias) plus the term premium, then we can ask how the principal components can be interpreted in terms of this decomposition. For example, if there is a slope shift in the yield curve, how was this driven by changes in expected short rates, and in (the term structure of) the term premium? What about a curvature shift?

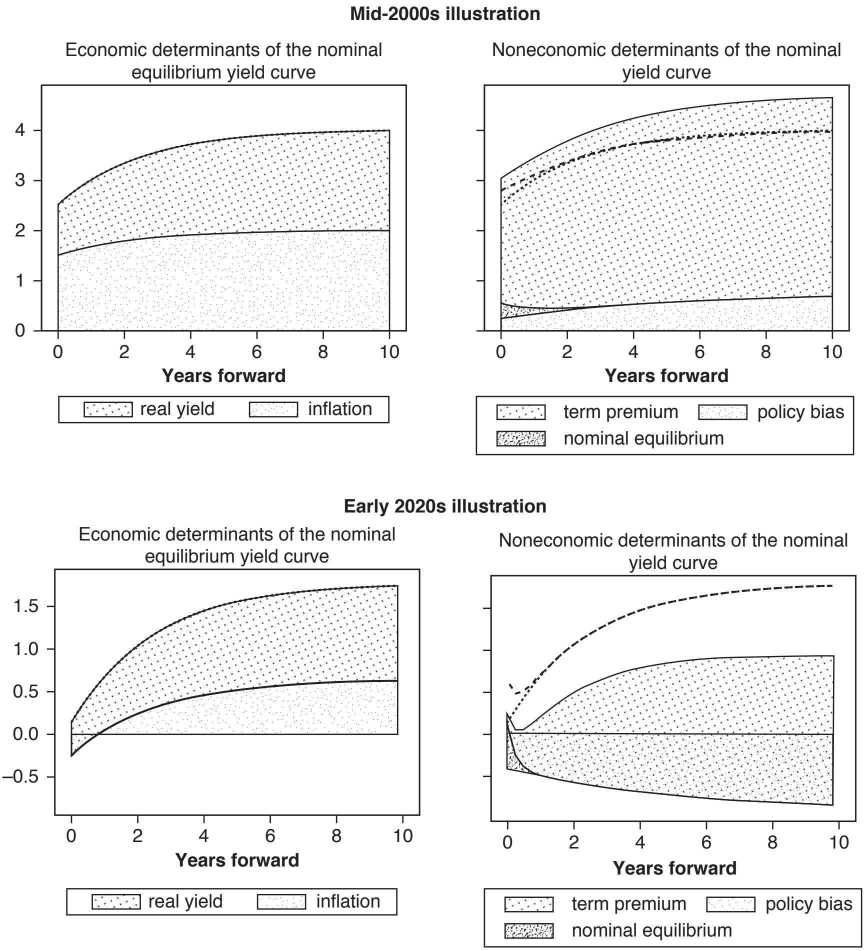
Exhibit 33-19 shows the results based on (a proprietary version of) a well-known term premium model.[22] The model decomposes slope and curvature shifts into their separate impact on short rate expectations and on the term structure of term premia.

- A slope shift (2nd factor) is decomposed into a bull steepening of the expected short rate curve, plus a bear steepening of the term premium curve.

22. Don Kim and Jonathan Wright, "An Arbitrage-Free Three-Factor Term Structure Model and Recent Behavior of Long-Term Yields and Distant Horizon Forward Rates," *FEDS Working Paper* 2005-33 (2005).

EXHIBIT 33-18

Economic and Other Determinants of the Yieldurve

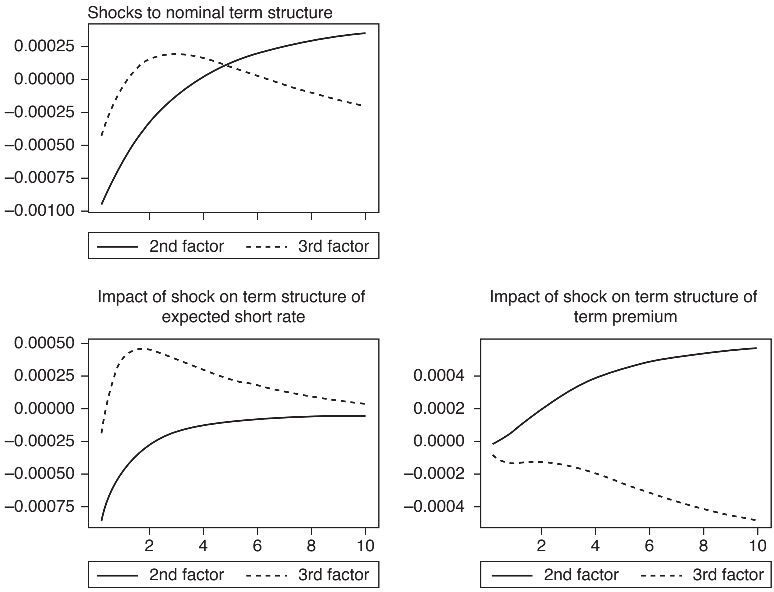


- A curvature shift (3rd factor) is decomposed into a hump shift of the expected short rate curve, plus a bull flattening of the term premium curve (for maturities over three years).

While this kind of decomposition is not so important for pure risk management, it can have investment implications: it affects whether we interpret an observed shift as due to changing expectations or changing compensation for risk. For example, it suggests that a slope shift generally leads to lower expected returns on longer maturity bonds, while a hump shift generally leads to higher expected returns.

EXHIBIT 33-19

Decomposition of Model-Implied Shocks to Nominal Yields



YIELD-CURVE DYNAMICS AND RISK MANAGEMENT

What does all this mean for the practical risk management of a bond portfolio? The analysis has shown that the first two principal components—interpreted as level and slope shifts—capture 80% or more of the variance in bond yields along the yield curve.

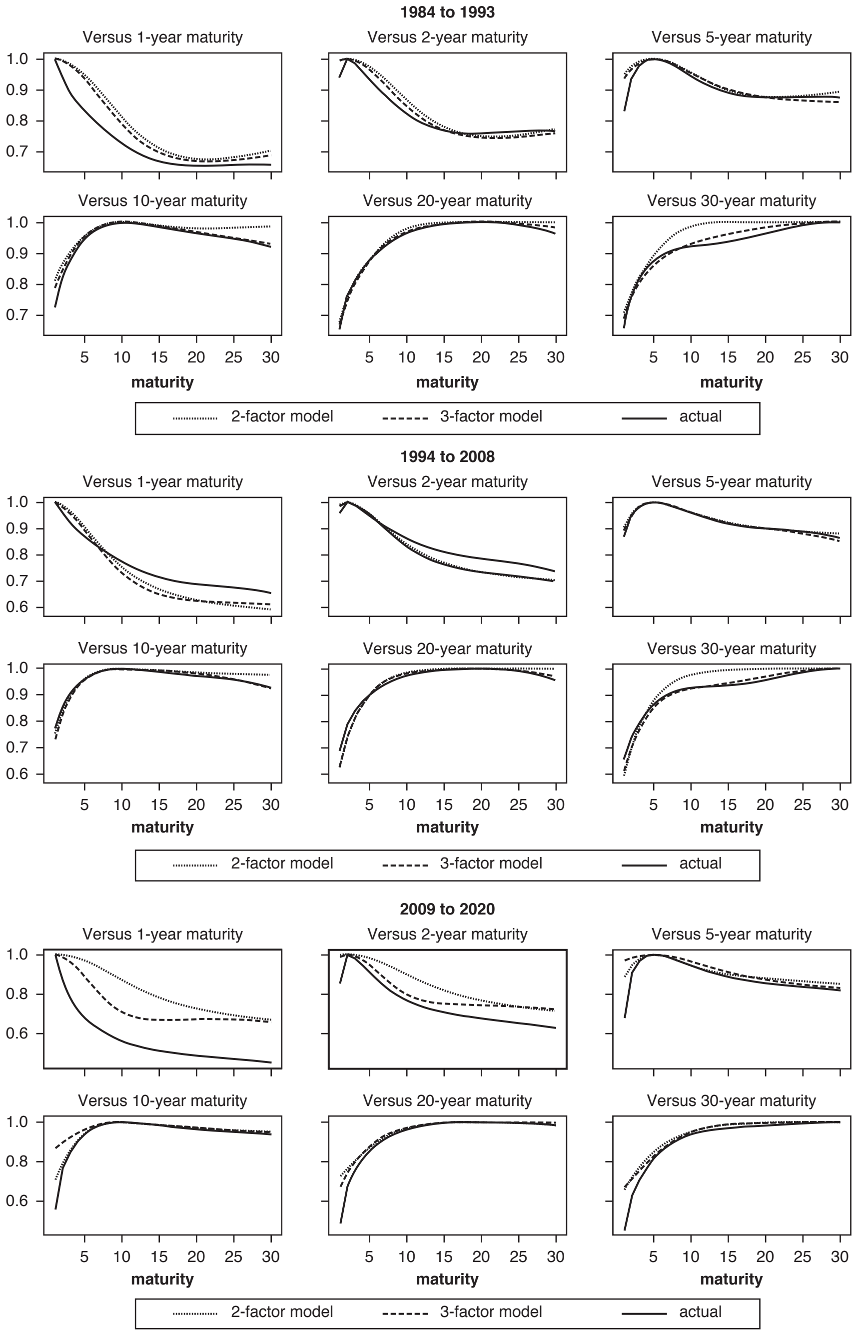
This has two important implications. First, it suggests that just two risk measures—the sensitivities to level and slope shifts—can capture most of the yield-curve risk in a bond or a portfolio. Second, it suggests that only two instruments (e.g., two different Treasury futures contracts) suffice to hedge most of that risk. But these conclusions must be heavily qualified. While the residual risk may seem small, it may be extremely important to investors who are very sensitive to relative returns or who have highly leveraged yield-curve positions. And importantly, this residual risk can change over time: for some investors, it has risen substantially in recent years.

Correlation Structure

One way to see this is to compare the actual correlations between different maturities with the correlations that we would have seen if only the first two (or the first three) principal components mattered. This is illustrated, for three different historical time periods, by the correlation curves show in Exhibit 33-20.

EXHIBIT 33-20

Empirical Correlation Curves vs. Those Implied by Risk Model



For example, for each period the top middle chart shows the correlation between the two-year yield and the yields at other maturity points. The solid line shows the actual correlations, while the dotted (dashed) line shows what they would have been if yields had been driven entirely by the first two (first three) principal components.

- In most cases, the solid, dashed, and dotted lines are close: the actual correlation structure of the Treasury yield curve was well captured by just three or even two factors.
- This is not true for the one-year maturity point, whose correlations with longer maturity bonds drop off much more rapidly in all three time periods. This illustrates the fact that the behavior of the short end of the yield curve can be very idiosyncratic.
- During 1984–2008, a two-factor model overstated the correlation between 10-year and 30-year yields, that is, understated the risk of a long-short position. However, this has been much less the case since 2009.
- On the other hand, since 2009, the two-factor and three-factor models have overstated the correlation between 2-year yields and 5–30-year yields. The idiosyncratic behavior that was formerly confined to the very short end of the yield curve seemed to extend to the two-year maturity point.[23]

It has been known for a long time that the empirical correlation structure of the yield curve cannot be fully reconstructed from just two or three kinds of yield curve shift.[24] Investors need to focus on specific data sets, and compare time periods, to understand the practical implications of this. For example, the results will vary depending on the relevant range of maturities.

Bond Risk Measures

We close this chapter by illustrating how to apply the analysis to the practical activity of managing the yield-curve risk of a high-quality bond portfolio. Exhibit 33-21 shows a typical yield-curve risk report for an illustrative portfolio of bonds, including U.S. Treasuries and TIPS, agency mortgage-backed securities, corporate bonds, asset-backed securities, and municipal bonds.[25] The risk measures shown are:

23. Perhaps due to the Fed's adoption of forward guidance.
24. Riccardo Rebonato and Ian Cooper, "The Limitations of Simple Two-Factor Interest Rate Models," *Journal of Financial Engineering* 5(1), 1996, pp. 1–16.
25. Bond risk measures are from BlackRock Solutions (Aladdin), except for slope duration, which is based on the author's calculations.

EXHIBIT 33-21

Yield-Curve Risk Measures for a Portfolio of Bonds

CUSIP	Security Description	Coupon	Mat	Dur	Slope Dur	3M	1Y	2Y	3Y	5Y	7Y	10Y	15Y	20Y	25Y	30Y	40Y	50Y	Cvxty
912828YZ7	TREASURY	1.625	31-Dec-21	1.57	–0.62	0.00	0.65	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
912828VB3	TREASURY	1.75	15-May-23	2.89	–1.11	0.00	0.02	0.14	2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
912828ZT0	TREASURY (OTR)	0.25	31-May-25	4.97	–1.34	0.00	0.00	0.00	0.02	4.92	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27
912828ZN3	TREASURY (OLD)	0.5	30-Apr-27	6.79	–1.11	0.00	0.00	0.01	0.02	0.32	6.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
912828ZQ6	TREASURY (OTR)	0.625	15-May-30	9.64	–0.35	0.00	0.01	0.01	0.03	0.06	0.23	9.29	0.00	0.00	0.00	0.00	0.00	0.00	0.99
912810RJ9	TREASURY	3	15-Nov-44	18.2	1.99	0.00	0.02	0.04	0.11	0.22	0.39	0.87	1.42	3.05	12.06	0.00	0.00	0.00	4.03
912810SN9	TREASURY (OTR)	1.25	15-May-50	24.47	9.19	0.00	0.01	0.03	0.06	0.13	0.23	0.52	0.85	1.03	1.30	20.32	0.00	0.00	6.90
912828YL8	TREASURY (CPI)	0.125	15-Oct-24	3.05	–0.93	0.00	0.00	0.00	0.95	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
912810QP6	TREASURY (CPI)	2.125	15-Feb-41	12.2	1.31	0.00	0.01	0.02	0.05	0.1	0.19	0.45	0.77	9.16	1.44	0.00	0.00	0.00	3.46
912810SM1	TREASURY (CPI)	0.25	15-Feb-50	19.93	8.21	0.00	0.00	0.00	0.01	0.02	0.03	0.07	0.12	0.16	1.29	18.22	0.00	0.00	8.43
3140Q9XN8	FNMA 30YR	4.5	1-Mar- 48	1.3	–0.52	0.11	0.30	0.32	0.36	0.27	0.15	–0.13	–0.07	0.10	0.05	–0.04	–0.06	–0.07	–0.16
3140H6SD2	FNMA 30YR	4	1-Dec-47	1.75	–0.55	0.09	0.29	0.36	0.42	0.33	0.23	–0.11	0.02	0.29	0.11	–0.07	–0.10	–0.12	–1.00
3138YWEU7	FNMA 15YR	3.5	1-Aug-30	2.35	–0.68	0.08	0.24	0.32	0.46	0.57	0.60	0.10	–0.06	0.00	0.01	0.01	0.01	0.01	–0.05
3140HLPE0	FNMA 15YR	3	1-Jun-33	3.59	–0.72	0.05	0.19	0.31	0.5	0.66	0.78	0.92	0.13	0.00	0.01	0.01	0.01	0.01	–0.36
3140JVQM7	FNMA 15YR UMBS	2.5	1-Aug-34	4.35	–0.69	0.05	0.18	0.27	0.44	0.65	0.90	1.44	0.37	0.00	0.01	0.01	0.01	0.02	–0.78
00206RCT7	AT&T INC	4.125	17-Feb-26	4.96	–1.24	0.01	0.03	0.07	0.17	3.51	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25

(Continued)

EXHIBIT 33-21

Yield-Curve Risk Measures for a Portfolio of Bonds (*Continued*)

CUSIP	Security Description	Coupon	Mat	Dur	Slope Dur	3M	1Y	2Y	3Y	5Y	7Y	10Y	15Y	20Y	25Y	30Y	40Y	50Y	Cvxty
00206RJY9	AT&T INC	2.75	1-Jun-31	9.48	–0.30	0.00	0.03	0.05	0.13	0.24	0.42	7.07	1.55	0.00	0.00	0.00	0.00	0.00	1.00
00206RKA9	AT&T INC	3.65	1-Jun-51	18.16	4.61	0.01	0.03	0.07	0.17	0.32	0.54	1.12	1.66	1.80	1.82	9.79	0.84	0.00	4.55
34531BAA0	FORDR_16–2 A	2.03	15-Dec-27	1.03	–0.39	0.01	0.98	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
34532RAA4	FORDR_18–1 A	3.19	15-Jul-31	5.12	–1.24	0.01	0.03	0.06	0.25	3.07	1.73	–0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.24
167505PC4	CHICAGO BRD ED	5.5	1-Dec-39	6.71	–0.36	0.01	0.26	0.47	0.41	0.53	0.65	0.90	1.67	1.8	0.00	0.00	0.00	0.00	–10.81
167505QR0	CHICAGO BRD ED	5.25	1-Dec-39	10.03	–0.33	0.01	0.05	0.11	0.44	1.26	1.14	2.19	2.67	2.18	0.00	0.00	0.00	0.00	6.96

- *Effective duration*, which measures the sensitivity of the bond's price to a parallel shift in the yield curve—roughly corresponding to the 1st principal component.[26]
- *Slope duration*, which measures the sensitivity of the bond to a change in the slope of the yield curve—corresponding to the 2nd principal component.[27]
- *Key rate durations* for the 3-month, 1-year, 2-year, . . . 50-year points, which measure the sensitivity of the bond to shifts at specific points in the yield-curve.[28]
- *Convexity*, which is negative for most mortgages and callable bonds, such as callable municipals.

Not all risk management systems provide slope duration by default, but it is easily calculated from the key rate durations.[29] Note that since the 2nd principal component is a twist around the 10-year point on the yield curve, the slope duration is positive for bonds with longer durations, but negative for bonds with shorter durations (see Exhibit 33-22). Also, two bonds with the same duration can have different slope durations if their cash flows are different. Finally, while the slope shift is monotonic, the slope duration is most negative for bonds with around a five-year duration; these are the bonds whose price rises (falls) the most when the yield-curve steepens (flattens).

Key rate durations have relevance beyond being used to calculate derived risk measures such as slope duration. As noted above, two-factor or even three-factor yield-curve modeling overstates the correlation between different points on the yield curve, that is, the idiosyncrasies of specific maturities. Investors who are especially sensitive to yield-curve risks—for example, investors implementing asset-liability matching strategies—need to monitor key rate durations independently.

There are several important caveats to bear in mind when interpreting this kind of report:

- Duration is not a perfect measure of a bond's sensitivity to the 1st principal component, since it is not precisely a parallel shift. This discrepancy was relatively minor before 2009, but has become more significant

26. It would be a mistake to think that because the 1st principal component explains 95% of variance in yields, duration is the only risk measure that is important. Recall our earlier example in footnote 7, of a security whose returns are driven by two uncorrelated factors, with volatilities of 3% and 1%, respectively. The first factor accounts for 90% of variance, but hedging it out only reduces volatility from 3.2% to 1%, i.e., by only two-thirds. So the second factor is important too!

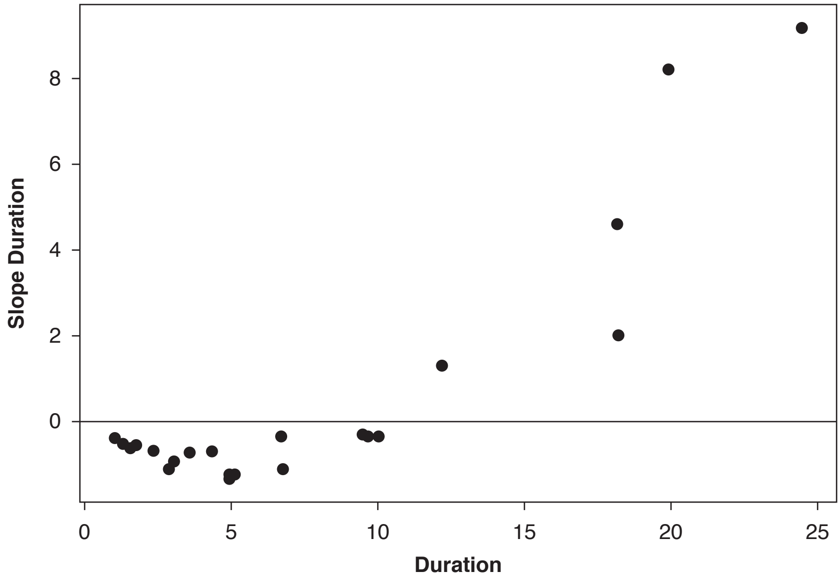
27. Note that defining the slope duration measure involves an arbitrary scaling (and shifting), which should be borne in mind when comparing results from different vendor systems.

28. Thomas Ho, "Key Rate Durations: Measures of Interest Rate Risks," *Journal of Fixed Income* 2(2), 1992, pp. 29–44. Key rate durations are sometimes called partial durations.

29. Wesley Phoa and Michael Shearer, "A Note on Arbitrary Yield-Curve Reshaping Sensitivities Using Key Rate Durations," *Journal of Fixed Income* 7(3), 1997, pp. 67–71.

EXHIBIT 33-22

Duration and Slope Duration of Selected Bonds



in recent years when the 1st principal component has been far from parallel (see Exhibit 33-6). Using standard duration will overstate the yield-curve risk of short maturity bonds.

- The above yield-curve risk measures overstate the yield-curve risk of TIPS. Yields on TIPS are not sensitive to changes in the expected long-term rate of inflation, but only the expected long-term real rate (see Exhibit 33-16).
- Similarly, they may overstate the yield-curve risk of municipal bonds. Under normal conditions, a shift in Treasury yields affects municipal bond yields less than one-for-one, since yields must be compared on an after-tax basis.
- Most importantly, yield-curve risk is not the only relevant risk that bond investors must manage. For example, corporate bonds have credit spread risk, MBS have prepayment uncertainty, TIPS are subject to a varying illiquidity premium, and so on. A full risk report would contain many other risk measures in addition to the ones shown.

KEY POINTS

- Yield-curve shifts are not always parallel. It is thus inadvisable to use the conventional notion of duration as the sole measure of interest rate risk.
- Both empirical and theoretical analyses suggest that the two most important kinds of yield-curve shifts are parallel shifts and slope shifts.
- The forms and relative importance of these shifts can be identified using principal component analysis. They are more or less uniform over time, except during periods when short-term interest rates are at the zero bound.
- The risk measures corresponding to these two kinds of yield-curve shifts are conventional (parallel) duration and slope duration. Taken together, these capture most, but not all, of a portfolio's yield-curve risk exposure.
- "Curvature shifts" appear to be important, but do not have a clear economic interpretation and are less uniform over time; a more practical way to monitor exposure to more complex yield-curve shifts is via key rate durations.
- In a period of structural change in bond markets, overreliance on off-the-shelf risk analytics can lead to blind spots in risk management. Investors should supplement standardized risk measures with exploratory data analysis and conceptual analysis that can shed light on the possibility of structural changes in yield-curve dynamics.

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CHAPTER
THIRTY-FOUR

TERM STRUCTURE MODELING WITH NO-ARBITRAGE INTEREST RATE MODELS

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Interest rate models are important tools used by practitioners for purposes including pricing of fixed income securities, pricing interest rate contingent claims, and evaluation of interest rate risk. Although there are many interest rate models, the models vary by their assumptions regarding interest rate dynamics and their degree of specificity. Due to differing assumptions about the interest rate process, each model has different properties that have important implications for their use in valuation. The models range from fairly simplistic to highly mathematical and complex, reflecting the tradeoff between analytical tractability and how closely the model captures interest rate dynamics.

The focus in this chapter is on *no-arbitrage* interest rate models. This term means that the models are fit to the current term structure so that valuing bonds with the model results in prices that are consistent with market prices. In addition to no-arbitrage models, another class of interest rate models called *equilibrium models,* begin with a stochastic differential process and develop pricing mechanisms under a general equilibrium framework. Our focus on no-arbitrage models stems from the fact that these models seem to be the most widely accepted among practitioners.

In general, interest rate models begin with a stochastic differential equation (SDE) to describe the dynamics of an interest rate. One-factor models represent the short rate of interest, whereas multifactor models incorporate a SDE for additional interest rates. Obtaining closed-form solutions to interest rate models requires the use of stochastic calculus. Instead of assuming the reader is versed in stochastic calculus, we present the models in the most tractable way possible.

In this chapter, we illustrate several no-arbitrage interest rate models. Our presentation focuses on the important characteristics of each model with an emphasis on the key assumptions driving the models and the properties of the models that reflect these assumptions. Although more sophisticated models exist, the models presented in this chapter are built on the same intuition and algebraic properties as more sophisticated models.

For interest rate models to be useful for practical purposes, it is helpful to adapt them to a recombining lattice structure. This usually translates into binomial or trinomial trees. After presenting the models and highlighting their important properties, we illustrate the models using lattices. The lattice approach is a useful tool for pricing interest rate contingent claims such as callable bonds and swaptions and for evaluating interest rate risk exposure.

INTRODUCTION TO MODELS OF THE SHORT RATE

We present five no-arbitrage models of the short rate in this section. Our focus is on the assumptions behind each of the models and the implications of those assumptions on the resulting rate scenarios. In the next section we build on these ideas by presenting the models fit to binomial lattices to illustrate the important properties.

Ho-Lee Model

The first no-arbitrage interest rate model was that of Ho and Lee.[1] The model assumes that the short-rate follows the stochastic process:

$$dr = \theta(t)dt + \sigma dz \tag{34-1}$$

This continuous-time process expresses the short-rate dynamics as a combination of an expected component and a random shock. The term $\theta(t)dt$ is the expected change component that is also referred to as the drift in the short rate. This component is the source of important characteristics, such as mean reversion, driving the expected change in interest rates. The drift parameter is a function of time and its value comes from the current term-structure through the process of fitting the model to the no-arbitrage constraints, which we will illustrate below.

The second component in the continuous time process is the source of risk and is the product of σ and dz. This component is important since it drives the distributional characteristics of the interest rate. The Ho-Lee interest rate model assumes the level of risk is constant through time and is referred to as a normal process since z is a Weiner process that is distributed normally. The term $dz = \varepsilon\sqrt{dt}$ is distributed normally since ε comes from a standard normal distribution with zero mean and unit standard deviation. Thus, the Ho-Lee process models the short

1. Thomas Ho and Sang Lee, "Term Structure Movements and Pricing Interest Rate Contingent Claims," *Journal of Finance* (1986), pp. 1011–1029.

rate as normally distributed. As we will see shortly, this means that negative interest rates are possible in the model.

We develop a discrete numerical approximation to generate approximate interest rates. Denoting the exact solution to the stochastic differential equation at time t_k as $r(t_k)$, the numerical algorithm generates solutions denoted r_k that approximate the exact solutions $r(t_k)$. For very small discrete time steps, where Δt is close to zero, we have $dt \approx \Delta t = t_{k+1} - t_k$. This leads to an approximation for the interest rate where $dr \approx \Delta r = r(t_{k+1}) - r(t_k) \approx r_{k+1} - r_k$. Using the discrete approximation, we are able to write the approximation for the Ho-Lee model for the interest rate movement from time k to $k + 1$ as:

$$r_{k+1} = r_k + \theta_k \tau + \sigma_k \Delta z_k \tag{34-2}$$

where $t_k = k\tau$, and Δz_k is a numerical (discrete) approximation of dz. Substituting $dz = \varepsilon\sqrt{dt}$, the equation becomes:

$$r_{k+1} = r_k + \theta_k \tau + \sigma_k \varepsilon_k \sqrt{\tau} \tag{34-3}$$

where ε_k is a random number drawn from the standard normal distribution $N(0,1)$. We denote the time step between time t_k and the starting point as τ. Examining the above equation, it is clear that the short rate's mean may grow very large over time; this happens for certain θ where $\theta_k \tau$ can become large. Additionally, it is clear that for large volatility shocks, the short rate dynamics can be heavily influenced by volatility and the random shock component may be very large. Thus, the Ho and Lee allows for interest rates to grow without bound.

Hull-White Model

The stochastic process for the Hull-White interest rate model is[2]:

$$dr = (\theta - \phi r)dt + \sigma dz \tag{34-4}$$

The process in (34-4) is similar to the Ho-Lee process in (34-1) in that the volatility is assumed to be constant through time and the rates are distributed normally. Additionally, negative interest rates are also possible in the Hull-White model. The drift term in the Hull-White process differs from Ho-Lee process. Note that if θ equals zero, then the Hull-White model reduces to the Ho-Lee model. The drift term in the Hull-White model captures the mean-reversion property of interest rates and is an attempt to control the uncontrolled growth of the short rate that is possible in the Ho-Lee model.

2. John Hull and Alan White, "Pricing Interest Rate Derivative Securities," *Review of Financial Studies* (1990), 3, pp. 573–592, and "One Factor Interest Rate Models and the Valuation of Interest Rate Derivative Securities," *Journal of Financial and Quantitative Analysis* (1993), pp. 235–254.

If we define the long run target short rate as $\mu = \theta/\phi$, then we can rearrange the drift term in equation (34-4) to be $\phi(\mu - r)$. When the short rate is below the target rate μ, then in future periods the rate drifts upward toward that target rate. Conversely, in periods when the short rate is greater than the target rate, the drift term pulls future rates back toward the target rate. The parameter ϕ controls the speed of mean reversion. If ϕ is close to zero, the speed at which the short rate tends toward the target rate is slower than cases in which ϕ is close to one. Positive mean reversion occurs when ϕ takes a positive value. Negative mean reversion is possible when ϕ takes a negative value, but results in exponential growth in the short rate through time. Another important feature of mean reversion is that the drift toward the target rate is determined partially by how far the short rate is from the target rate, the drift being larger when the short rate is further from the target. In the case of negative mean reversion, this second effect amplifies the exponential growth of the short rate.

Applying the discrete approximation for the Hull-White stochastic process, as described for the Ho-Lee model, we obtain the following approximation:

$$r_{k+1} = r_k + (\theta_k - \phi_k r_k)\tau + \sigma_k \varepsilon_k \sqrt{\tau} \tag{34-5}$$

The numerical approximation for the Hull-White process, like the Ho-Lee process, models the short rate as normally distributed. The normality assumption is evident since ε_k is a random number drawn from the standard normal distribution $N(0,1)$. Additionally, it is clear that short rates can become negative, particularly when the assumed level of volatility is large.

Due to the additional parameters of the model, the algebra required to fit the Hull-White process to the lattice involves a variable time step. The variable time step is an undesirable property, requiring a spline methodology to engineer equal time steps. Using a trinomial lattice instead of a binomial lattice will introduce an additional degree of freedom allowing the solutions to have fixed time steps between nodes. Thus, when we present the model lattices, we will present the trinomial model for the Hull-White model.

Kalotay-Williams-Fabozzi Model

The Kalotay-Williams-Fabozzi (KWF) model is analogous to the Ho-Lee model as the stochastic process has a constant drift, does not include mean reversion, and exhibits constant volatility.[3] However, the incremental distinction is that the model treats the natural logarithm of the interest rate as normally distributed. Although the natural logarithm of the short rate may be negative, the short rate itself does not turn negative in this model, unlike the Ho-Lee and Hull-White models. Specifically, the differential process for the KWF model is:

$$d\ \ln(r) = \phi dt + \sigma dz \tag{34-6}$$

3. Andrew Kalotay, George Williams, and Frank J. Fabozzi, "A Model for the Valuation of Bonds and Embedded Options," *Financial Analysts Journal* (May-June 1993), pp. 35-46.

We can see that this equation is identical to the Ho-Lee model if $\mu = \ln(r)$ and we re-write the process as:

$$d\mu = \phi dt + \sigma dz \tag{34-7}$$

Since μ follows a normal process, $\ln(r)$ follows a normal process, implying that r follows a lognormal process. Although μ may become negative as in the Ho-Lee and Hull-White processes, r may not become negative. To illustrate, note that since $\mu = \ln(r)$ then $r = e^{\mu}$, which shows that r is always positive and the KWF model does not allow for negative interest rates like the Ho-Lee or the Hull-White models.

The discrete form approximation for the KWF model is:

$$\mu_{k+1} = \mu_k + \theta_k \tau + \sigma_k \varepsilon_k \sqrt{\tau} \tag{34-8}$$

Since $\mu = \ln(r)$ we re-write the equation as:

$$r_{k+1} = r_k e^{\theta_k \tau + \sigma_k \varepsilon_k \sqrt{\tau}} \tag{34-9}$$

From this equation, we see that when θ is positive, the short rate grows through time and is unbounded. Similarly, if θ is negative, the short rate decays toward zero. Like the Ho-Lee model, short rates in the KWF model exhibit potential unbounded growth, but the KWF model circumvents the negative short rates plaguing the Ho-Lee and Hull-White models. Additionally, the short rate is distributed log normally as opposed to normally.

Black-Karasinski Model

The interest rate process in the Black-Karasinski model takes the following form[4]:

$$d\ \ln(r) = (\theta - \phi\ \ln(r))dt + \sigma dz \tag{34-10}$$

If we again let $\mu = \ln(r)$ and re-write the process, we obtain:

$$d\mu = (\theta - \phi\ \mu)dt + \sigma dz \tag{34-11}$$

Note that this expression is the Hull-White interest rate process, and that since μ has those same properties as the rate in the Hull-White model, it is distributed normally and r is distributed log normally. Since $r = e^{\mu}$, the interest rate in the Black-Karasinski process is greater than zero, which is the advantage of this model over the Hull-White model.

4. F. Black and P. Karasinski, "Bond and Option Pricing when Short Rates are Lognormal," *Financial Analyst Journal* (July-August 1991), pp. 52–59.

Compared with the Kalotay-Williams-Fabozzi model, the Black-Karasinski model also includes mean reversion of the interest rate. Similar to the Hull-White model's extension of the Ho-Lee model, the Black-Karasinski model is an extension of the log normal KWF model to incorporate the mean-reversion property of interest rates. Similar to the Hull-White model, the parameter ϕ controls the growth of the short rate. The drift in the short term rate from each period to the next is determined by the speed of mean-reversion parameter and the distance of the rate from the target rate.

Next, we discretize the process using the same approach illustrated above for the other models:

$$\mu_{k+1} = \mu_k + (\theta_k - \phi_k r_k)\tau + \sigma_k \varepsilon_k \sqrt{\tau} \tag{34-12}$$

Since $\mu = \ln(r)$ we re-write the equation as:

$$r_{k+1} = r_k e^{(\theta_k - \phi_k \ln r_k)\tau + \sigma_k \varepsilon_k \sqrt{\tau}} \tag{34-13}$$

Note the similarity of these equations and Equation (34-5) for the Hull-White model. Both models incorporate mean reversion in the drift term but the main difference comes from the distributional assumption since the Hull-White is normal and Black-Karasinski is lognormal.

Black-Derman-Toy Model

Similar to the Black-Karasinski model, the Black-Derman-Toy (BDT) interest rate model combines mean reversion and the lognormal distribution of the short rate.[5] The important incremental contribution is that in the BDT model, mean reversion is determined endogenously, which is to say that it is determined based on the model's input parameters. The mathematics behind this model make it the most complicated of the models we present. The short rate in the model follows the following process:

$$d\ \ln(r) = \left(\theta(t) + \frac{\sigma'(t)}{\sigma(t)}\ln(r)\right)dt + \sigma(t)dz \tag{34-14}$$

If we again let $\mu = \ln(r)$ and re-write the process, we obtain:

$$\mu = \left(\theta(t) + \frac{\sigma'(t)}{\sigma(t)}\mu\right)dt + \sigma(t)dz \tag{34-15}$$

Equation (34-15) is strikingly similar to the Black and Karasinski model in Equation (34-11), and the only difference between the two comes from the mean

5. Fischer Black, Emanuel Derman, and William. Toy, "A One Factor Model of Interest Rates and Its Application to the Treasury Bond Options," *Financial Analyst Journal* (January-February 1990), pp. 33–39.

reversion parameter. In this model, mean reversion is endogenous to the model since it is determined by the assumed volatility of the short rate. The mechanics of mean reversion in this model should be similar, where the short rate is mean reverting when the term $\sigma'(t)$ is less than zero. Conversely, when $\sigma'(t)$ is positive, implying $\sigma(t)$ is increasing, the short rate grows without mean reverting. Note that if the volatility is constant, the derivative is zero and the mean-reversion term is zero. In the case of constant volatility, the KWF model is a special case of the BDT model.

Next, we discretize the BDT interest rate process using the same approach as for the other models:

$$\mu_{k+1} = \mu_k + \left(\theta_k - \frac{\sigma'(t)}{\sigma(t)} r_k\right)\tau + \sigma_k \varepsilon_k \sqrt{\tau} \tag{34-16}$$

Since $\mu = \ln(r)$ we re-write the equation as:

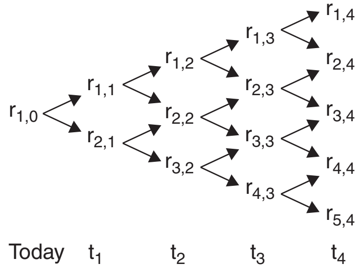
$$r_{k+1} = r_k e^{\left(\theta_k - \frac{\sigma'(t)}{\sigma(t)} \ln r_k\right)\tau + \sigma_k \varepsilon_k \sqrt{\tau}} \tag{34-17}$$

BINOMIAL INTEREST RATE LATTICES

In this section, we present binomial lattice representations of the interest rate models. In the binomial lattice, the interest rate may make one of two possible moves over discrete points in time. For our purposes, we present lattices where the length of each time step is six months. Exhibit 34-1 illustrates a four-period binomial tree. Note that at each node the interest rate takes either an up-step or a down-step. The size of each step is determined by the properties of the interest rate model. Additionally, notice that the tree recombines, meaning that an up-step followed by a down-step produces the same rate as a down-step followed by an up-step. Recombination is a common assumption in binomial trees and results from the imposition of additional algebraic constraints. The numerical methods required to fit the interest rate models to binomial trees are beyond the scope of

EXHIBIT 34-1

The Binomial Lattice of Forward Rates



this chapter, but we present binomial lattice representations of the model to illustrate the important features of the interest rate models. Buetow and Sochacki present a thorough discussion of the numerical methodologies involved with fitting the models to binomial trees.[6]

The no-arbitrage property of the term structure models presented in this chapter comes from the fact that the model rates match the properties of the current term structure. For example, denoting the current one-period (six-month) spot rate as $r_{1,0}$, the two-period spot rate as z, and the implied forward rate as f_1, we can illustrate the no-arbitrage property using the binomial lattice. The two possible values for the interest rate next period in the binomial lattice are $r_{1,1}$ and $r_{2,1}$, and the no-arbitrage property is satisfied by the following constraint, which requires the one-period spot rate, followed by the one-period rate at the next time step, $r_{1,1}$ or $r_{2,1}$, to be equal to the two-period spot rate:

$$\left(1+\frac{1}{2}z\right)^2 = \left(1+\frac{1}{2}r_{1,0}\right)\left[p_u\left(1+\frac{1}{2}r_{1,1}\right)+p_d\left(1+\frac{1}{2}r_{2,1}\right)\right] \tag{34-18}$$

where p_u and p_d are the probabilities of the up and down move, respectively. Imposing the no-arbitrage constraint ensures that pricing straight bonds using the interest rate lattice generates prices that are consistent with the observed spot curve produced from market prices. Due to this property, the no-arbitrage models have practical appeal and are useful for pricing and risk-management purposes.

Exhibit 34-2 presents the Ho-Lee binomial lattice where the term structure is flat at 2% and volatility is constant. In panel A of the exhibit, volatility is 1% and in panel B, volatility is 10%. There are several important features of the Ho-Lee model evident in the binomial lattices. First, the one-period interest rate may be negative, which results from the fact that in the Ho-Lee process, the rate is distributed normally and is unbounded. In fact, it can be demonstrated that the spread between the high and low rates in the Ho-Lee lattice equals $2\times k\times\sigma\sqrt{\tau}$, where k is time (in years) and τ is the length of the time step. This algebraic relation demonstrates that the spread, or distance, between the highest possible rate and the lowest at each time step is an increasing function of time and often produces negative rates. Additionally, the level of volatility drives the spread. To illustrate, panel B of Exhibit 34-2 presents the Ho-Lee lattice where volatility is 10%. The greater dispersion of rates resulting from the greater volatility is immediately evident and illustrates that rates in this model may be very large and frequently negative. Despite the undesirable economic interpretation of negative rates, they are not detrimental to the model since bond prices computed from the binomial trees are the average over the possible future short paths, averaging across all rates.

6. See Gerald W. Buetow and James Sochacki, *Binomial Interest Rate Models*, AIMR Research Foundation, 2001.

EXHIBIT 34-2

The Ho-Lee Binomial Interest Rate Lattice

Panel A: Flat Term Structure at 2% and 1% Constant Volatility

										8.48%
									7.75%	
								7.02%		7.06%
							6.29%		6.33%	
						5.57%		5.60%		5.65%
					4.85%		4.88%		4.92%	
				4.14%		4.16%		4.19%		4.23%
			3.42%		3.44%		3.47%		3.50%	
		2.71%		2.72%		2.74%		2.78%		2.82%
	2.00%		2.01%		2.02%		2.05%		2.09%	
		1.30%		1.31%		1.33%		1.36%		1.40%
			0.59%		0.61%		0.64%		0.67%	
				−0.11%		−0.08%		−0.05%		−0.01%
					−0.80%		−0.78%		−0.74%	
						−1.50%		−1.47%		−1.42%
							−2.19%		−2.15%	
								−2.88%		−2.84%
									−3.57%	
										−4.25%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-2

The Ho-Lee Binomial Interest Rate Lattice (*Continued*)

Panel B: Flat Term Structure at 2% and 10% Constant Volatility

										76.72%
									67.44%	
								58.40%		62.58%
							49.61%		53.30%	
						41.06%		44.26%		48.44%
					32.75%		35.46%		39.16%	
				24.70%		26.92%		30.12%		34.30%
			16.88%		18.61%		21.32%		25.01%	
		9.32%		10.55%		12.77%		15.98%		20.15%
	2.00%		2.74%		4.47%		7.18%		10.87%	
		–4.82%		–3.59%		–1.37%		1.83%		6.01%
			–11.40%		–9.67%		–6.96%		–3.27%	
				–17.73%		–15.51%		–12.31%		–8.13%
					–23.82%		–21.10%		–17.41%	
						–29.65%		–26.45%		–22.27%
							–35.25%		–31.55%	
								–40.59%		–36.41%
									–45.70%	
										–50.56%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

The Ho-Lee process models the short rate as distributed normally. This is evident in the binomial lattice representation since the rates are symmetrical around the mean rate. For example, the distance between rates $r_{1,2}$ and $r_{2,2}$ is identical to the distance between $r_{2,2}$ and $r_{3,2}$.

Another important property of the Ho-Lee model is that the drift term is related to the slope of the current term structure. This property is illustrated in panel A of Exhibit 34-3 where the term structure slopes upward and the forward curve is increasing by 15 basis points each period and volatility is constant at 10%. This example corresponds to a "normal" term structure since it is positively sloped. The positive drift term is evident and we note that the spread or dispersion between the nodes is identical to that in panel B of Exhibit 34-2. The difference comes from the positive drift term. In some cases, since the drift is proportional to time and grows unboundedly, this term can become quite large. Correspondingly, when the drift term is positive, there are fewer negative interest rates in the lattice. Panel B of Exhibit 34-3 presents the Ho-Lee model for an inverted term structure where the forward curve decreases by 15 basis points each period and volatility is again 10%. Again, the spread between the highest and lowest rate is identical since the volatility is 10% and volatility drives the spread in the Ho-Lee model. Additionally, we can see that the drift term is negative and all rates in the Ho-Lee model shift down by that negative drift term compared with the flat or normal term structure scenarios.

We now turn to the KWF binomial lattice. Recall that this model is analogous to a log-normal version of the Ho-Lee model. It is also a special case of the BDT model when volatility is assumed to be positive and constant. Panel A of Exhibit 34-4 presents the KWF binomial lattice for the scenario where the term structure is flat at 2% and volatility is a constant 10%. This scenario is directly comparable to the scenario is Exhibit 34-2 panel B for the Ho-Lee model and there are two important distinctions between the two lattices. First, the log-normal distribution in the KWF model restrains the interest rate paths from becoming negative. Since the Ho-Lee model is distributed normally, negative rates are possible, but the log-normal distribution of the KWF model restricts rates to be positive. Second, the spread of possible rates at the same volatility level are smaller than in the Ho-Lee model. Whereas the rates are distributed normally around the center nodes in the Ho-Lee model, in the KWF model the rates are distributed asymmetrically around the center node and are skewed toward higher rates. This property illustrates the importance of the distributional assumptions stemming from the models' differential processes.

Exhibit 34-5 presents the KWF lattices for two additional scenarios to cover a normal term structure and an inverted term structure. Panel A presents the normal term structure scenario in which rates are increasing at 15 basis points per period and volatility is constant at 10%. Note that the rates grow larger over time, which is the impact of the drift term. Panel B presents the lattice for the inverted term structure scenario in which the rates decrease by 10 basis points per period and volatility is again constant at 10%. Note that the rates

EXHIBIT 34-3

Ho-Lee Binomial Lattice Under Normal and Inverted Term Structures

Panel A: Normal Term Structure and 10% Constant Volatility

									79.33%
								69.77%	
							60.45%		65.18%
						51.38%		55.63%	
					42.54%		46.31%		51.04%
				33.94%		37.23%		41.49%	
			25.59%		28.40%		32.17%		36.90%
		17.48%		19.80%		23.09%		27.34%	
	9.62%		11.45%		14.25%		18.03%		22.76%
2.00%		3.34%		5.66%		8.95%		13.20%	
	–4.52%		–2.69%		0.11%		3.89%		8.61%
		–10.80%		–8.48%		–5.19%		–0.94%	
			–16.84%		–14.03%		–10.26%		–5.53%
				–22.62%		–19.33%		–15.08%	
					–28.17%		–24.40%		–19.67%
						–33.48%		–29.22%	
							–38.54%		–33.81%
								–43.37%	
									–47.95%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-3

Ho-Lee Binomial Lattice Under Normal and Inverted Term Structures (*Continued*)

Panel B: Inverted Term Structure and 10% Constant Volatility

									74.13%
								65.12%	
							56.36%		59.99%
						47.84%		50.98%	
					39.58%		42.21%		45.85%
				31.57%		33.70%		36.84%	
			23.80%		25.44%		28.07%		31.71%
		16.29%		17.42%		19.56%		22.69%	
	9.02%		9.66%		11.29%		13.93%		17.56%
2.00%		2.14%		3.28%		5.42%		8.55%	
	–5.12%		–4.48%		–2.85%		–0.21%		3.42%
		–12.00%		–10.86%		–8.73%		–5.59%	
			–18.63%		–16.99%		–14.35%		–10.72%
				–25.00%		–22.87%		–19.73%	
					–31.13%		–28.50%		–24.86%
						–37.01%		–33.88%	
							–42.64%		–39.00%
								–48.02%	
									–53.15%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-4

The Kalotay-Williams-Fabozzi Binomial Interest Rate Lattice

Panel A: Flat Term Structure at 2% and 10% Constant Volatility

										3.71%
									3.46%	
								3.23%		3.22%
							3.02%		3.00%	
						2.82%		2.80%		2.79%
					2.63%		2.62%		2.61%	
				2.45%		2.44%		2.43%		2.42%
			2.29%		2.28%		2.27%		2.26%	
		2.14%		2.13%		2.12%		2.11%		2.10%
	2.00%		1.99%		1.98%		1.97%		1.96%	
		1.86%		1.85%		1.84%		1.83%		1.83%
			1.73%		1.72%		1.71%		1.70%	
				1.61%		1.60%		1.59%		1.58%
					1.49%		1.49%		1.48%	
						1.39%		1.38%		1.38%
							1.29%		1.28%	
								1.20%		1.19%
									1.11%	
										1.04%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-4

The Kalotay-Williams-Fabozzi Binomial Interest Rate Lattice (*Continued*)

Panel B: Flat Term Structure at 2% and 20% Constant Volatility

										6.64%
									5.80%	
								5.07%		5.00%
							4.43%		4.36%	
						3.88%		3.81%		3.76%
					3.39%		3.34%		3.28%	
				2.97%		2.92%		2.87%		2.83%
			2.60%		2.56%		2.51%		2.47%	
		2.28%		2.24%		2.20%		2.16%		2.13%
	2.00%		1.96%		1.93%		1.89%		1.86%	
		1.72%		1.69%		1.66%		1.63%		1.60%
			1.48%		1.45%		1.42%		1.40%	
				1.27%		1.25%		1.22%		1.20%
					1.09%		1.07%		1.05%	
						0.94%		0.92%		0.90%
							0.81%		0.79%	
								0.69%		0.68%
									0.60%	
										0.51%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-5

Kalotay-Williams-Fabozzi Binomial Lattice; Normal and Inverted Term Structures

Panel A: Normal Term Structure and 10% Constant Volatility

Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5
										8.75%
									7.64%	
								6.64%		7.59%
							5.74%		6.63%	
						4.93%		5.76%		6.59%
					4.21%		4.98%		5.75%	
				3.56%		4.28%		5.00%		5.72%
			2.98%		3.65%		4.32%		4.99%	
		2.46%		3.09%		3.72%		4.34%		4.96%
	2.00%		2.59%		3.17%		3.75%		4.33%	
		2.14%		2.68%		3.23%		3.76%		4.30%
			2.25%		2.75%		3.26%		3.76%	
				2.33%		2.80%		3.27%		3.73%
					2.39%		2.83%		3.26%	
						2.43%		2.84%		3.24%
							2.45%		2.83%	
								2.46%		2.81%
									2.46%	
										2.44%

(Continued)

EXHIBIT 34-5

Kalotay-Williams-Fabozzi Binomial Lattice; Normal and Inverted Term Structures (*Continued*)

Panel B: Inverted Term Structure and 10% Constant Volatility										0.38%
									0.70%	
								0.97%		0.33%
							1.21%		0.60%	
						1.41%		0.84%		0.28%
					1.58%		1.05%		0.52%	
				1.72%		1.22%		0.73%		0.25%
			1.83%		1.37%		0.91%		0.45%	
		1.93%		1.49%		1.06%		0.63%		0.21%
	2.00%		1.59%		1.19%		0.79%		0.39%	
		1.67%		1.30%		0.92%		0.55%		0.18%
			1.38%		1.03%		0.69%		0.34%	
				1.12%		0.80%		0.48%		0.16%
					0.90%		0.59%		0.30%	
						0.69%		0.41%		0.14%
							0.52%		0.26%	
								0.36%		0.12%
									0.22%	
										0.10%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

grow smaller over time, illustrating the impact of negative drift under the inverted term structure. Additionally, we notice that the spread from the highest to the lowest rate on the lattice at each time step is noticeably smaller for the inverted term structure scenario than for the normal term structure. This observation is in stark contrast to the Ho-Lee model in which the spread is determined solely by volatility.

Next, we turn to the BDT binomial lattice. Recall that the differential process in this model is lognormal and incorporates endogenous mean reversion in which the slope of the volatility curve drives mean reversion in the model. Exhibit 34-6 presents the binomial lattice for the normal interest rate tree scenario where the current rate is 2% and the rate increases by 0.15 basis points each period. Panels A, B, and C present three scenarios for a normal term structure across different volatility structures. In panel A, the volatility structure is decreasing from 20% by 0.5% each period, in panel B it is increasing from 20% by 0.5% each period, and in panel C it is constant. When volatility is constant, the model reduces to the KWF model. Note that the rates are all positive and are not extreme as in the normally distributed Ho-Lee model.

The shape of the volatility curve drives the model's mean reversion. This is evident in panels A, B, and C of Exhibit 34-6 since the only change across the panels is the shape of the volatility structure. Comparing panel A to panel C, it is clear that the decreasing volatility structure has the effect of increasing mean-reversion. Note that the upward drift and the spread from high to low rates at each time step are different. The upward drift is checked by the mean reversion when the volatility structure is decreasing and similarly the spread is lower. Comparing panel B to panel C, it is clear that under the positively sloped volatility structure, the upward drift is larger and the spread at each time step is greater.

Exhibit 34-7 presents the BDT interest rate lattices for an inverted term structure where the current short rate is 2% and decreases by 10 basis points each period. The pattern that emerges is similar to the previous exhibit. Comparing panel A to panels B and panel C, it is clear that the mean reversion from the decreasing volatility structure has the effect of reducing the spread across rates at each time step.

Turning to the Black-Karasinski model, Exhibit 34-8 presents the interest rate lattice for this model for a flat term structure of rates when volatility is initially 20% but decreases by 0.5% each period. To illustrate the importance of mean reversion in this model, the table contains two panels; panel A illustrates the lattice with the mean-reversion parameter equal to 0.015 and panel B illustrates the lattice when the mean-reversion parameter equals 0.005. The figures illustrate that larger mean reversion impacts the rates by narrowing the spread between the rates at each time step. Additionally, it must be noted that in order to fit the model to a binomial lattice the ttime step must be allowed to vary for this model. Interpolation is necessary to adjust this tree to equally spaced time steps. The larger mean reversion leads to a decreasing time step. One way to circumvent the uneven time step in this model is to use a trinomial lattice since it allows for an extra degree of freedom.

EXHIBIT 34-6

Black-Derman-Toy Binomial Lattice: Normal Term Structure and Varying Volatility Structures

Panel A: Normal Term Structure and Decreasing Volatility

										10.61%
									9.44%	
								8.28%		8.79%
							7.15%		7.74%	
						6.08%		6.71%		7.29%
					5.08%		5.73%		6.35%	
				4.17%		4.82%		5.44%		6.04%
			3.35%		3.98%		4.59%		5.20%	
		2.62%		3.22%		3.82%		4.41%		5.01%
	2.00%		2.56%		3.11%		3.68%		4.26%	
		1.98%		2.49%		3.02%		3.58%		4.15%
			1.95%		2.44%		2.95%		3.50%	
				1.93%		2.39%		2.90%		3.44%
					1.91%		2.37%		2.87%	
						1.90%		2.35%		2.86%
							1.90%		2.35%	
								1.90%		2.37%
									1.93%	
										1.96%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-6

Black-Derman-Toy Binomial Lattice: Normal Term Structure and Varying Volatility Structures (*Continued*)

Panel B: Normal Term Structure and Increasing Volatility										23.66%
									17.55%	
								13.16%		16.03%
							9.96%		12.06%	
						7.59%		9.17%		10.86%
					5.81%		7.04%		8.29%	
				4.46%		5.43%		6.39%		7.36%
			3.42%		4.21%		4.97%		5.70%	
		2.62%		3.27%		3.89%		4.46%		4.98%
	2.00%		2.55%		3.05%		3.51%		3.92%	
		1.98%		2.40%		2.78%		3.11%		3.38%
			1.89%		2.21%		2.48%		2.69%	
				1.76%		1.99%		2.16%		2.29%
					1.60%		1.75%		1.85%	
						1.42%		1.51%		1.55%
							1.24%		1.27%	
								1.05%		1.05%
									0.87%	
										0.71%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-6

Black-Derman-Toy Binomial Lattice: Normal Term Structure and Varying Volatility Structures (*Continued*)

Panel C: Normal Term Structure and Constant Volatility

										15.91%
									12.92%	
								10.47%		11.94%
							8.46%		9.71%	
						6.80%		7.87%		8.96%
					5.44%		6.37%		7.29%	
				4.31%		5.12%		5.92%		6.72%
			3.39%		4.09%		4.79%		5.48%	
		2.62%		3.25%		3.86%		4.45%		5.04%
	2.00%		2.55%		3.08%		3.60%		4.12%	
		1.98%		2.45%		2.90%		3.35%		3.78%
			1.92%		2.32%		2.71%		3.09%	
				1.84%		2.19%		2.52%		2.84%
					1.75%		2.04%		2.32%	
						1.65%		1.89%		2.13%
							1.54%		1.74%	
								1.42%		1.60%
									1.31%	
										1.20%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-7

Black-Derman-Toy Binomial Lattice: Inverted Term Structure and Varying Volatility Structures

Panel A: Inverted Term Structure and Decreasing Volatility

									0.30%
								0.73%	
							1.14%		0.30%
						1.48%		0.66%	
					1.75%		0.97%		0.30%
				1.93%		1.23%		0.59%	
			2.04%		1.41%		0.83%		0.30%
		2.08%		1.53%		1.01%		0.53%	
	2.06%		1.59%		1.14%		0.71%		0.29%
2.00%		1.59%		1.21%		0.84%		0.48%	
	1.56%		1.23%		0.92%		0.61%		0.29%
		1.22%		0.96%		0.69%		0.43%	
			0.96%		0.74%		0.52%		0.29%
				0.76%		0.57%		0.38%	
					0.60%		0.44%		0.29%
						0.48%		0.34%	
							0.38%		0.28%
								0.31%	
									0.28%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-7

Black-Derman-Toy Binomial Lattice: Inverted Term Structure and Varying Volatility Structures

Panel B: Inverted Term Structure and Increasing Volatility

									2.68%
								2.51%	
							2.46%		1.51%
						2.42%		1.58%	
					2.36%		1.63%		0.86%
				2.29%		1.66%		0.99%	
			2.21%		1.66%		1.08%		0.48%
		2.14%		1.64%		1.13%		0.62%	
	2.06%		1.61%		1.16%		0.72%		0.27%
2.00%		1.59%		1.18%		0.78%		0.39%	
	1.56%		1.18%		0.82%		0.47%		0.15%
		1.18%		0.84%		0.53%		0.25%	
			0.86%		0.57%		0.31%		0.09%
				0.61%		0.36%		0.16%	
					0.40%		0.21%		0.05%
						0.25%		0.10%	
							0.14%		0.03%
								0.06%	
									0.02%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

(Continued)

EXHIBIT 34-7

Black-Derman-Toy Binomial Lattice: Inverted Term Structure and Varying Volatility Structures (*Continued*)

Panel C: Inverted Term Structure and Constant Volatility

										0.67%
									1.16%	
								1.52%		0.50%
							1.77%		0.87%	
						1.94%		1.14%		0.38%
					2.03%		1.33%		0.66%	
				2.08%		1.46%		0.86%		0.28%
			2.08%		1.53%		1.00%		0.49%	
		2.05%		1.57%		1.10%		0.65%		0.21%
	2.00%		1.57%		1.16%		0.76%		0.37%	
		1.55%		1.18%		0.83%		0.49%		0.16%
			1.18%		0.87%		0.57%		0.28%	
				0.89%		0.62%		0.37%		0.12%
					0.66%		0.43%		0.21%	
						0.47%		0.28%		0.09%
							0.32%		0.16%	
								0.21%		0.07%
									0.12%	
										0.05%
Time in Years		0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-8

Black-Karasinski Binomial Lattice: Inverted Term Structure

Panel A: Flat Term Structure, Mean Reversion = 0.015

										3.71%
									3.68%	
								3.59%		3.21%
							3.46%		3.13%	
						3.28%		3.01%		2.78%
					3.06%		2.85%		2.67%	
				2.82%		2.66%		2.52%		2.41%
			2.67%		2.44%		2.35%		2.27%	
		2.22%		2.20%		2.15%		2.11%		2.08%
	2.00%		1.98%		1.94%		1.93%		1.93%	
		1.72%		1.72%		1.74%		1.77%		1.80%
			1.47%		1.54%		1.59%		1.65%	
				1.35%		1.41%		1.48%		1.56%
					1.23%		1.31%		1.40%	
						1.14%		1.24%		1.35%
							1.08%		1.19%	
								1.04%		1.17%
									1.02%	
										1.01%
Time in Years		0.50	0.99	1.48	1.96	2.43	2.89	3.35	3.81	4.25

(Continued)

EXHIBIT 34-8

Black-Karasinski Binomial Lattice: Inverted Term Structure (*Continued*)

Panel B: Flat Term Structure, Mean Reversion = 0.005

									4.01%
								3.92%	
							3.78%		3.41%
						3.60%		3.29%	
					3.37%		3.12%		2.91%
				3.12%		2.92%		2.76%	
			2.85%		2.70%		2.58%		2.47%
		2.65%		2.46%		2.38%		2.31%	
	2.24%		2.21%		2.17%		2.13%		2.10%
2.00%		1.97%		1.94%		1.94%		1.94%	
	1.74%		1.72%		1.74%		1.76%		1.79%
		1.46%		1.53%		1.58%		1.62%	
			1.34%		1.39%		1.45%		1.52%
				1.21%		1.28%		1.36%	
					1.11%		1.20%		1.30%
						1.04%		1.14%	
							0.99%		1.10%
								0.96%	
									0.94%
Time in Years	0.50	1.00	1.49	1.99	2.48	2.96	3.45	3.93	4.41

TRINOMIAL LATTICE

Turning to the Hull-White model, Exhibit 34-9 presents the Hull-White trinomial lattice. The trinomial structure is identical to the binomial lattice except there are three possible time steps from each node instead of two. Similar to the binomial lattice, the solutions impose restrictions to ensure that the trinomial lattice recombines and that the rates in the tree satisfy the necessary conditions. Exhibit 34-9 presents the Hull-White trinomial lattice when the term structure is flat at 2%, 10% constant volatility, and zero mean reversion. The important properties of the Hull-White process are evident in the lattice: Interest rates become negative for the bottom nodes, the spread between high and low rates at each time step is large, and the rates are distributed normally. Additionally, an upward drift is evident in the middle nodes.

Since the Hull-White model incorporates mean reversion, Exhibit 34-10 presents the Hull-White model with the same term structure and volatility as Exhibit 34-9, but incorporates 5% mean reversion. We expect the mean reversion will have the effect of pulling rates back toward the mean, or that the lattice tree should be "pruned." The mean-reversion property is evident as the spread at each time step is reduced and each rate is pulled back toward the target rate, compared to the tree in Exhibit 34-9.

In summary, the lattice representations of the no-arbitrage interest rate models discussed in this chapter demonstrate the importance of the model assumptions about the short-rate process on the model output. It is of critical importance that users of these models understand the model assumptions and the impact those assumptions have on any results (pricing or risk metrics) based on model outputs.

EXHIBIT 34-9

Hull-White Trinomial Lattice: Flat Term Structure, 10% Volatility, No Mean Reversion

									123.63%
								109.06%	111.38%
							94.77%	96.81%	99.13%
						80.74%	82.52%	84.57%	86.89%
					66.98%	68.50%	70.27%	72.32%	74.64%
				53.48%	54.73%	56.25%	58.03%	60.07%	62.39%
			40.23%	41.23%	42.49%	44.00%	45.78%	47.82%	50.14%
		27.24%	27.99%	28.99%	30.24%	31.75%	33.53%	35.58%	37.90%
	14.50%	14.99%	15.74%	16.74%	17.99%	19.51%	21.28%	23.33%	25.65%
2.00%	2.25%	2.74%	3.49%	4.49%	5.75%	7.26%	9.04%	11.08%	13.40%
	–10.00%	–9.50%	–8.76%	–7.76%	–6.50%	–4.99%	–3.21%	–1.17%	1.15%
		–21.75%	–21.00%	–20.00%	–18.75%	–17.24%	–15.46%	–13.41%	–11.09%
			–33.25%	–32.25%	–31.00%	–29.48%	–27.71%	–25.66%	–23.34%
				–44.50%	–43.24%	–41.73%	–39.95%	–37.91%	–35.59%
					–55.49%	–53.98%	–52.20%	–50.16%	–47.84%
						–66.23%	–64.45%	–62.40%	–60.08%
							–76.70%	–74.65%	–72.33%
								–86.90%	–84.58%
									–96.83%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

EXHIBIT 34-10

Hull-White Trinomial Lattice: Flat Term Structure, 10% Volatility, 5% Mean Reversion

									121.55%
								107.60%	109.30%
							93.78%	95.35%	97.05%
						80.12%	81.54%	83.10%	84.81%
					66.62%	67.88%	69.29%	70.85%	72.56%
				53.30%	54.38%	55.63%	57.04%	58.61%	60.31%
			40.16%	41.05%	42.13%	43.38%	44.79%	46.36%	48.06%
		27.22%	27.91%	28.80%	29.88%	31.13%	32.55%	34.11%	35.82%
	14.50%	14.97%	15.67%	16.56%	17.63%	18.89%	20.30%	21.86%	23.57%
2.00%	2.25%	2.73%	3.42%	4.31%	5.39%	6.64%	8.05%	9.62%	11.32%
	–10.00%	–9.52%	–8.83%	–7.94%	–6.86%	–5.61%	–4.20%	–2.63%	–0.93%
		–21.77%	–21.08%	–20.19%	–19.11%	–17.86%	–16.44%	–14.88%	–13.17%
			–33.32%	–32.43%	–31.36%	–30.10%	–28.69%	–27.13%	–25.42%
				–44.68%	–43.60%	–42.35%	–40.94%	–39.37%	–37.67%
					–55.85%	–54.60%	–53.19%	–51.62%	–49.91%
						–66.85%	–65.43%	–63.87%	–62.16%
							–77.68%	–76.12%	–74.41%
								–88.36%	–86.66%
									–98.90%
Time in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5

KEY POINTS

- Interest rate models are important tools for practitioners and are useful for pricing fixed income securities, valuing interest-rate contingent claims, and risk management purposes.
- There exist many interest rate models. One-factor models of the short rate make important assumptions about its dynamics through time. Understanding these assumptions and their implications is critical for practitioners.
- Interest rate models specify a stochastic differential equation to capture the dynamics of the models.
- Early models (Ho-Lee and Hull-White) assume the short rate is distributed normally. Interest rates in those models may be negative. Other models (Kalotay-Williams-Fabozzi, Black-Derman-Toy, and Black-Karasinski models) assume the short rate is distributed log-normally, restricting the short rate to be positive.
- Mean reversion is the tendency for interest rates to tend toward a long-term target rate. Absent mean reversion, an interest rate model may allow the short rate to grow unbounded.
- The no-arbitrage models incorporate the information in the current term structure and produce identical prices for option-free bonds.
- When pricing bonds with embedded option features, the interest rate model assumptions are critically important and may result in meaningful differences across different models.

PART

SIX

VALUATION AND RELATIVE VALUE

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CHAPTER

THIRTY-FIVE

RELATIVE VALUE TRADING

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Relative value (RV) trading has been a cornerstone of fixed income trading. However, in the current low interest rate environment, RV trading has proliferated to become an even more important tool for investors to boost their returns. The beauty of RV trading is that it is less dependent on the absolute level of yields compared to traditional investing methods. The result is that investors are now less reliant on the general market environment to generate alpha.

Traditional strategies like macro trading tend to require high leverage and often result in large risk exposure to the market. In contrast, RV trading exploits the opportunity between securities, and because the risk exposure of an RV trade is the spread between securities, an investor is exposed to less tail risk to worry about than on a traditional directional trade.

In this chapter, we help define RV in the investment sense in fixed income securities and show how traders and portfolio managers look at it to generate alpha in any market environment.

WHAT IS FIXED INCOME RELATIVE VALUE?

Relative value analysis relies on creating different models and fair value baselines in which an investor can compare assets. Having a fair value baseline is essential in creating an RV measure to ensure that you can compare these assets relatively to each other.

Building an RV trading model in the fixed income space is fairly challenging as there are many moving parts. First, an effective trading model must calibrate to the market in real time so that an investor can trade off it. This requires an accurate live data feed. On top of that, an investor needs reliable historical data to see how the strategy has performed as well as to calculate some performance metric. On top of that, there is also no one perfect model to look at RV as all models have their own assumptions along with their pros and cons. Most traders use multiple models simultaneously to inform each trading decision. The hallmark of a good trading model is one that can consistently identify rich and cheap securities with strong mean reversion.

An even greater challenge besides sourcing for data and building the right model is that the financial markets tend toward being more and more efficient. As each trading model propagates through the industry and is used by more people, security prices tend to converge to fair value. Therefore, models must consistently be tweaked and refined, and new models built if an investor intends to consistently generate positive returns.

In the 1980s, the largest bond trading house Salomon Brothers created the "2+ term structure fair value model" to quantify the richness and cheapness of U.S. government bonds. In a period where mathematical models were practically absent on trading floors, they made a fortune. Over time, as older models have become less effective, newer ones have become more numerous and more sophisticated in nature.

Building a Fair Value Baseline Curve

RV measures involve building a baseline and looking at the spread of each security to this baseline. In fixed income, a fair value curve can be created that represents this baseline. Much like running a regression on two variables and looking at the spread from the current position (residual) to the regression curve to get an idea of whether the point is an outlier, the spread in yield from the security in question to this baseline curve gives investors an idea of the richness or cheapness of these securities.

In the fixed income world, the yield curve derived from all of a country's government bonds is commonly used in this fair value analysis. A bootstrapped curve is derived from carefully selecting multiple instruments.[1] This term structure of yields is created from bond yields by solving for them recursively, by forward substitution, in ascending order of maturity.

Recent Practice of Curve Construction

The number of curve-building choices are consistently increasing in the industry. Before the 2008 Global Financial Crisis, the LIBOR curve was used as both the forward curve and discounting curve for swap traders. However, in the post-crisis

1. Ken Adams, "Smooth Interpolation of Zero Curves," *Algo Research Quarterly*, 4(1/2), 2001, pp. 11–22.
Patrick S. Hagan and Graeme West, "Methods for Constructing a Yield Curve," *Wilmott Magazine*, 3, 2008, pp. 70–81.

period, a new "multi-curve and collateral" framework has become more common. The overnight index swap (OIS) curve has proven to be a better choice for the discounting curve since it is the rate paid on the collateral posted by counterparties on most Credit Support Annexes (CSAs).

There are multiple listed indices that market participants think would be good discounting curves, such as the Secured Overnight Financing Rate (SOFR) in the United States, the Euro Short Term Rate (€STR) in Europe, and the Sterling Overnight Interbank Average Rate (Sonia) in Britain.

Besides having different curves to choose from, the curve construction methodologies are also evolving. In 2006, Hagan and West introduced a new "Monotone Convex Spline Interpolation" of the forward rates as a curve construction method.[2] This spline method uses piecewise quadratic polynomials chosen carefully to preserve the geometric properties such as local monotonicity and convexity.

Now that we understand how to construct a curve, we next look at how a security is valued against the chosen baseline curve.

Z-SCORE, MEAN REVERSION, AND EXPECTED RETURN

Bond prices move inversely to yields. In order to compare bond values relative to each other, their yields should be compared as prices largely differ depending on when they were issued. In the previous section, we discussed how to construct a curve. We can then use this methodology to create a fair value curve based on where all the bonds are currently trading. Because the live prices are always changing, the spread to the fair value curve, or RV spread, is constantly changing as well. What is important is this distance to the fair value curve, as well as its standard deviation from the curve, which gives an investor a good idea of how rich or cheap a bond is. If the yield is higher than the fair value curve, the bond is cheap relative to its estimated fair value curve, and if the yield is lower than the estimated fair value curve, the bond is richer to the fair value curve.

In the fixed income world, each security has its own characteristics. Some bonds tend to stay consistently rich or cheap on multiple RV metrics. For example, the high-coupon U.S. Treasury bonds with a coupon of up to 8.75% consistently trade rich on different RV metrics. These original-issue 30-year bonds were auctioned in the 1990s during a time of high interest rates. This systematic issue highlights the problem of purely looking only at the spread to a fair value curve. Consequently, investors need to look at this spread as a function of historical levels: the Z-score.

2. Patrick S. Hagan and Graeme West, "Interpolation Methods for Curve Construction," *Applied Mathematical Finance*, 13(2), 2008, pp. 89–129.

Z-Score

The Z-score measures how far above or below the mean the live level is in standard deviations. This allows investors to quantify the relative value while taking historical levels and volatilities into account. The Z-score is calculated as follows:

$$\text{Z-score} = \frac{\text{Current value} - \text{Mean value}}{\text{Standard deviation}}$$

The larger the absolute Z-score, the further the current level is deviated from the historical mean and the higher statistical probability of mean reversion.

Mean Reversion and Expected Return

Mean reversion is the main assumption of relative value analysis. It assumes the current level of a trade will converge to its average level or the moving average level. Expected return is defined here as the value an investor would obtain if the strategy were to revert to the mean from current levels. Quantifying the expected return allows investors to easily compare trades side by side in basis points. Trading signals to enter into a trade are usually set by a certain level of deviation from the mean. For example, an investor can set an alert and threshold for the absolute value of the Z-score as a point to enter or exit a trade.

Mean Reversion Assumption

The mean reversion assumption assumes that the current level of a trade would converge to the mean, although this is not always the case. Changes in macroeconomic paradigms or structural curve moves will result in the violation of mean reversion. When there are structural market changes or extreme market shocks like the recent financial crisis, assuming mean reversion becomes much more dangerous and an investor might have to sit on a trade for a longer period of time before current levels return to the mean. This is why traders and portfolio managers like carry and roll down in addition to expected return.

Carry

Carry is broadly defined as the component of return obtained from the receipts and payments associated with holding an asset. In the fixed income space, this is the coupon payment an investor receives from being long the bond, and the funding charges paid to borrow the capital needed to purchase the bond. If we assume a bond is trading at par and the coupon is higher than the funding cost (repo rate), then the carry is positive because the investor is receiving more from the coupon than paying in funding to hold the position. If the cost to fund the position is higher than the coupon, then carry is negative, and the investor will be paying interest to hold onto the position.

Roll Down

The roll down in fixed income markets refers to the component of return that an investor would obtain when a bond's yield changes as it matures. Calculating roll down assumes that the yield curve's shape does not change over time and is dependent on the steepness of the yield curve. An upward-sloping yield curve would result in positive roll down, and vice versa. For example, suppose that the 10-year point is at 2.00% and the 7-year point is 1.7%. If an investor bought the 10-year bond and held on to it for 3 years, it will become a 7-year bond. Assuming the yield curve's shape does not change, the bond's price has risen 0.3% as the yield has fallen from 2.00% to 1.70%, allowing the investor to now sell it at a higher price. This roll down return is independent from the carry return described earlier.

Estimating roll down on the curve is also a bit of an art. There is no perfect way to do it. Calculating roll down involves constructing or picking a curve to estimate the yield change for a given change in maturity. Some traders believe in using the market curve that consists of all the bonds in that space, but this rarely gives rise to a consistent roll down across the curve due to kinks from rich or cheap bonds and sectors. One option is using the CMT curve to estimate roll down because it is smoother and gives rise to a more uniform roll down across the curve.

Total Return

Traders and portfolio managers look holistically at the total return of a trade. The best trades are those with a high expected return as well as positive carry and roll down. The assumptions of mean reversion and a stable yield curve must be considered as well to ensure all the relevant risks are properly understood.

The total return from a position is calculated as follows:

$$\text{Total return} = \text{Expected return} + \text{Carry} + \text{Roll down}$$

Expected return is usually the largest return component of a trade, although that is not always the case. An investor needs to take into consideration all components of the total return. Expected return may also not materialize. To compensate for this, investors generally like to get paid to sit on a trade, and this is possible by entering into trades with positive carry and roll down. With the total return metric to compare trades in mind, investors next need to pick an RV model.

MARKET-BASED VS. MODEL-BASED RELATIVE VALUE

RV models can broadly be classified into two distinct groups: model based and market based. Market-based RV models utilize current market levels to create the fair value baseline. The biggest advantage of the market-based model is that they are directly tradable. We list here several popular models, as well as their pros and cons.

Market-Based RV Models

There are three main market-based RV models: bond asset swap spread, true swap, and Z spread.

Bond Asset Swap (ASW) Spread

Interest rate swaps provide unrivaled flexibility in that an investor can construct a swap with any start and end date, notional amount, and benchmark fixed rate. This flexibility makes these swaps one of the most traded fixed income derivatives, which gives rise to a liquid market and accurate prices. Because of this, many traders like to use RV models that assume the swap curve is the fair value baseline curve for measuring a bond's richness and cheapness. The most common swap curve that traders look at as a fair baseline curve is the LIBOR curve, but as the industry slowly moves away from LIBOR, the OIS curve and SOFR curve have gained prominence.

There are several popular ASW spreads, including the Yield-to-Yield asset swap spread and True-Spread against the LIBOR, OIS, and SOFR curves. The Yield-to-Yield asset spread (YY) is popular as it is easily tradable and simple to calculate. It is calculated by the bond yield minus the matched maturity par swap rate. That is,

$$\text{YY spread} = \text{Bond yield} - \text{Matched maturity par swap rate}$$

To trade this spread, an investor would buy a bond and sell the equivalent amount of a matched maturity par swap that would make the position market neutral (based on the dollar value of a basis point, DV01). Looking at the YY spread lets the investor evaluate a bond's performance against the swap curve relative to each other.

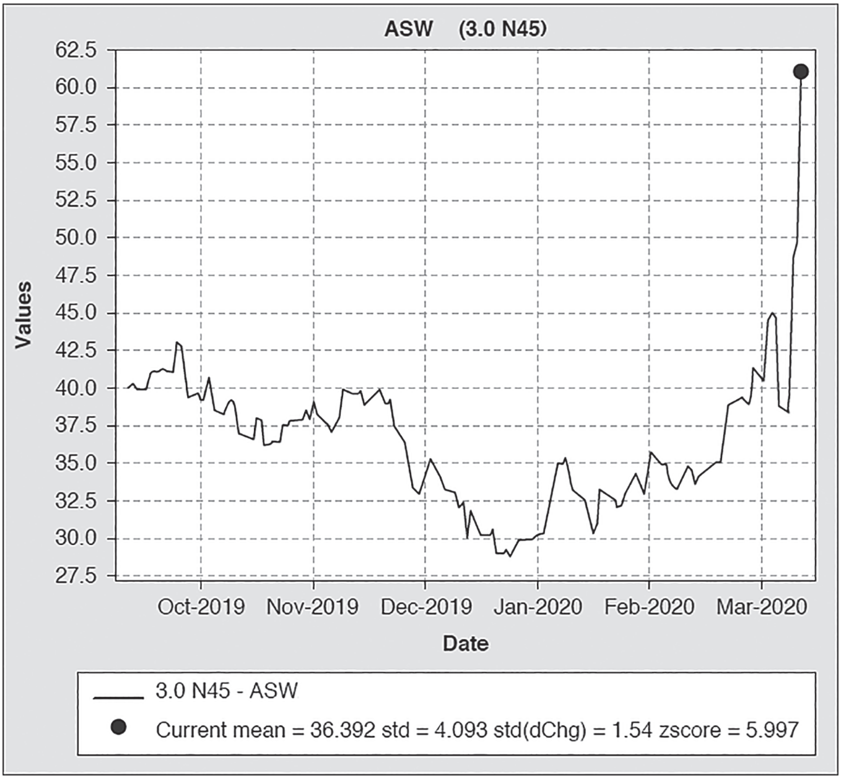
We can illustrate this with a specific case. The cheapest-to-deliver (CTD) bond for the WNM0 contract is the "Treasury 3% 11/15/2045." On 3/12/2020, the yield dropped 1.4 bps to 1.346%. At the same time, the match-maturity swap rate became 0.742%, giving a YY spread of 60.9 bps, as seen in Exhibit 35-1. Taking the last three-month history into account, the Z-score, which is the number of standard deviations the current level is from the mean, was around 6, as shown in Exhibit 35-1, which indicates a strong signal and attractive entry point. If we assume mean reversion and that there was not a good catalyst for this move, an investor should take the opportunity to enter into a short ASW or long bond position here. Assuming mean reversion and a mean of 36.4 as seen in Exhibit 35-1, this trade could produce 24.5 bps in value.

True Spread

To calculate the true asset swap spread, an investor should create a matched maturity interest rate swap, where the swap fixed cash flows are equivalent to the bond cash flows. The investor would then set the net present value (NPV) of the

EXHIBIT 35-1

Historical Yield-Yield Asset Swap Spread for 3.0% 11/15/2045



Source: RiskVal Financial Solutions, LLC

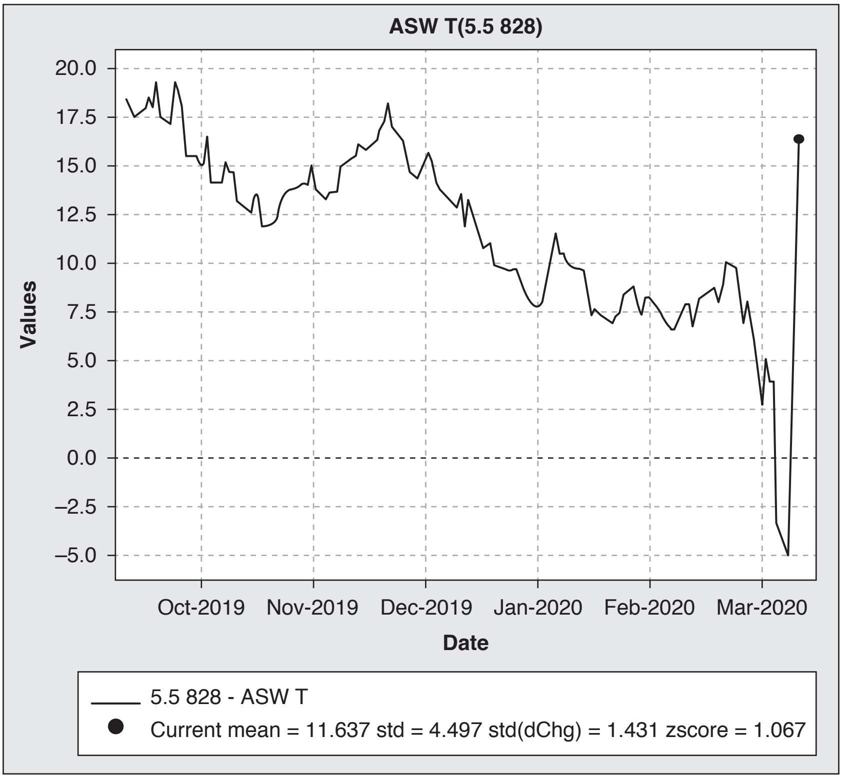
swap to match the bond's dirty price minus par value and solve for the spread to LIBOR. That is,

$$\text{Bond Dirty Price} - 100 = \sum_{i=1}^{n} \frac{\text{bond cash flow}_i}{(1+\text{discount rate})^i} - \sum_{i=1}^{n} \frac{\text{swap floating index}_i + \text{true spread}}{(1+\text{discount rate})^i}$$

As an example, for the 5.5% 8/15/2028 USD Treasury on 3/12/2020, the true spread on that day showed a strong bounce back from its historical low point in the three-month period. With a mean of 11.6 bps as seen in Exhibit 35-2, an investor could enter into a short at current levels of 16.4. However, looking at these levels, investors would have wished that they knew of this trade on 3/9/2020, where the level was (5.0) bps (as seen in Exhibit 35-2) and instead entered into a long position at that point. Assuming mean reversion and a current mean of 11.6 bps, a long position at (5.0) bps would give an investor 16.6 bps of return.

EXHIBIT 35-2

Historical True Asset Swap Spread for 5.5% 8/15/2028



Source: RiskVal Financial Solutions, LLC

As with any trading model, there are assumptions that need to be considered for asset swap spread models. These models assume that the swap curve used is liquid and that the rates derived from the curves are fair. This is not always the case, as the swap curve can also display systematic dislocations for various reasons, including large flows in the financial markets. However, given these assumptions, the Yield-to-Yield and True asset swap spreads are easily understandable and tradable, making them important metrics to look at when trading RV.

Z-Spread

The Z-spread, also called the static spread, is the constant spread to the yield curve is solved for that makes all the discounted cash flows of a bond (which are discounted at their respective yields plus the Z-spread) equivalent to the current dirty price of the bond. That is,

$$\text{Bond Dirty Price} = \sum_{i=1}^{n} \text{cashflow}_i \,/\left(1 + r_i + \text{Z spread}\right)^i, \text{where } i = 1, 2, 3, \ldots n$$

The Z-spread is not a tradable level, but looking at this metric allows an investor to evaluate a bond's performance against the current yield curve relative to other bonds.

The Z-spread can also be looked at in a similar way to the YY and true spread. Looking at the three-month Z-score (ASW Z ZS) of the Z-spread, traders can quickly identify the rich or cheap securities in each sector. As the Z-spread is not a tradable or market quoted level, traders utilize this information to trade these bonds outright or on a spread to each other. In Exhibit 35-3, this sector of bonds maturing from 2026 to 2029 looks rich on a Z-spread basis as seen in the ASW Z column, but it is more important to look at each security relative to other securities in the sector. Hence, it is a good trade to be short a rich bond like the 2.375% 5/15/2027, which is 3.8 standard deviations rich, and going long a cheaper bond like the 2.625% 2/15/2029, which is just 1.5 standard deviations rich.

EXHIBIT 35-3

Asset Swap Z-Spread, Daily Change, Heatmap and Z-Score

	Px	dPx	Yld	dYld	ASW Z	ASW dZ	ASW Z Rich↔Chp	ASW Z ZS
T 1.875 31-Jul-2026	107-181	1-175	0.661	(24.1)	(1.5)	(9.3)		(2.6)
T 1.500 15-Aug-2026	105-112	1-171	0.647	(24.0)	(3.2)	(9.1)		(3.4)
T 1.375 31-Aug-2026	104-157	1-181	0.662	(24.5)	(1.8)	(9.5)		(2.7)
T 1.625 30-Sep-2026	106-032	1-186	0.670	(24.3)	(1.1)	(9.1)		(2.6)
T 1.625 31-Oct-2026	106-046	1-206	0.674	(24.9)	(1.0)	(9.6)		(2.6)
T 2.000 15-Nov-2026	108-212	1-206	0.668	(24.4)	(1.5)	(9.1)		(2.8)
T 1.625 30-Nov-2026	106-066	1-202	0.676	(24.4)	(0.9)	(8.9)		(2.5)
TYM0	138-00+	1-23+	0.675	(23.0)				
T 1.750 31-Dec-2026-TYM0	107-096	1-182	0.648	(23.0)	(3.8)	(7.4)		(3.7)
T 1.500 31-Jan-2027	105-176	1-20+	0.672	(24.0)	(1.8)	(8.2)		(2.9)
T 2.250 15-Feb-2027	110-27	1-132	0.644	(20.0)	(4.5)	(4.2)		(3.0)
T 1.125 28-Feb-2027	103-04	1-196	0.664	(23.6)	(2.8)	(7.8)		(3.1)
UWI T 1.125 31-Mar-2027	103-06+	1-201	0.656	(23.6)	(3.7)	(7.5)		
TYU0	137-19	1-23+	0.665	(22.9)				
T 2.375 15-May-2027-TYU0	112-04	1-22	0.640	(22.9)	(5.5)	(7.0)		(3.8)
T 2.250 15-Aug-2027	111-166	1-246	0.655	(23.4)	(4.8)	(7.4)		(3.8)
T 2.250 15-Nov-2027	111-232	1-29+	0.677	(24.5)	(3.5)	(8.6)		(3.5)
T 2.750 15-Feb-2028	115-272	2-07	0.689	(26.9)	(2.8)	(11.1)		(3.3)
T 2.875 15-May-2028	117-072	2-12+	0.700	(28.0)	(2.2)	(12.2)		(3.1)
T 2.875 15-Aug-2028	117-16	2-102	0.727	(26.4)	0.1	(10.4)		(2.2)
T 3.125 15-Nov-2028	120-006	2-13+	0.735	(26.5)	0.5	(10.3)		(2.1)
T 2.625 15-Feb-2029	116-032	2-102	0.754	(25.1)	1.8	(8.7)		(1.5)
T 2.375 15-May-2029	114-10	2-10+	0.755	(24.8)	1.4	(8.0)		(1.7)
T 1.625 15-Aug-2029	107-296	2-07	0.751	(23.7)	0.1	(6.5)		(2.0)
UXYM0	155-20	2-30	0.734	(22.8)				
T 1.750 15-Nov-2029-UXYM0	109-15+	2-06+	0.731	(22.8)	(2.3)	(5.2)		(2.7)

Source: RiskVal Financial Solutions, LLC

The Z-spread model assumes that the bond yield curve is the fair value baseline model and hence that the yield curve rates are fair. As mentioned earlier in this chapter, this is not necessarily the case, especially with high-coupon bonds. It is also not a market tradable level. However, the benefit of just using the bond curve here is that this model only uses one type of instrument, Treasury bonds, and so isolates any idiosyncrasies in the valuations to be from one type of financial instrument and market only.

Model-Based RV Models

Model-based RV models usually require significantly fewer market observable inputs and puts them through a predefined model to construct a fair value baseline. The resulting RV spreads of the bond to the baseline curve are not directly tradable but are often used to determine the richness or cheapness of that bond. We list several models we have found effective, as well as their pros and cons.

Constant Maturity Treasury (CMT) Curve[3]

The traditional Constant Maturity Treasury (CMT) curve uses all the bonds in the U.S. government universe as fitting points to build the baseline fair value curve. This ensures that the curve incorporates all the information from the bond market, including the outright level, curvature, and liquidity profile of each point. To fit all 300 bonds from the U.S. Treasury universe, the Nelson-Siegel-Svensson (NSS) multifactor model and weighted least square method are usually combined as the fitting procedure.

The fitting points take the entire bond universe into account. Since the bond maturity distributions are very tight, excluding some bonds do not have a material effect on the overall curve construction. This allows more flexibility as the real-world liquidity of each bond is not identical, which reduces the effectiveness of the model in real-time analysis

One limitation of the NSS model often cited by investors suggests that the model's accuracy is sacrificed at either the long end or short end of the yield curve. This limitation is a result of model parameter assumptions, which are significantly different at each end of the yield curve. Therefore, selecting the best parameters is unique to each situation and should be reconsidered as interest rate regimes change.

To deal with this limitation, two NSS curves are used to fit the discount curve. One curve is used for the short-term fit, while the other is used for long-term fit. This results in a closed-form formula for the discounting factor, which is calculated from the negative natural log of the discount factor denoted as logDF as follows:

$$\text{DiscountFactor}_{\text{double}}(m) = \exp\left(-\log DF_{\text{double}}(m)\right)$$

3. Hana Hladíková and Jarmila Radová,H Hladíková, "Term Structure Modelling by Using Nelson-Siegel Model," *European Financial and Accounting Journal* 7(2), 2012, pp. 36–55, and Hana Hladíková, "Term Structure Modelling by Using Nelson-Siegel Model," *European Financial and Accounting Journal*, 7, 2012, pp. 36–55.

There is an overlapping period [T_{short}, T_{long}] between the short-term curve and long-term curve. For this period, a time-weighted method is introduced to join these two curves and derive the following double-curve model:

$$\log DF_{\text{double}}(m) = \begin{cases} \log DF_{\text{short}}(m)\, \mathit{if}\ m \le \mathrm{T}_{\text{short}} \\ w * \log DF_{\text{short}}(m) + (1-w)\log DF_{\text{long}}(m)\ \mathit{if}\ \mathrm{T}_{\text{short}} < m < \mathrm{T}_{\text{long}} \\ \log DF_{\text{long}}(m)\, \mathit{if}\ m >= \mathrm{T}_{\text{long}} \end{cases}$$

where

$$w = \frac{(m - T_{\text{short}})}{(T_{\text{long}} - T_{\text{short}})}.$$

Using an optimization method to minimize the model error, we get the CMT curve.

The CMT curve model uses all the bonds in their respective country's universe as the fitting pool. This ensures that the constructed curve indeed captures the characteristics of the bond market, from the short end to the long end. There are benefits to not introducing multiple products into the same model as this isolates any market nuances that arise.

The disadvantages of the CMT curve is its sensitivity to the quality of data. Most long-term bonds are not as frequently traded as short-term bonds. This does not apply to the U.S. Treasury market as it is the most liquid market in the world, but this liquidity issue is more prominent in the markets of other less liquid countries. Because of this, the last or mid prices used to fit these curves may be biased. Additionally, the double-curve method cannot guarantee all real-world nuances. For example, in a low interest rate environment, some governments may decide to lock in low borrowing costs and issue ultra-long-term bonds. Austria, for instance, issued 100-year bonds in 2017. These new bonds, being outside the original curve tenor and having lower sizes and liquidity, tend to deteriorate the quality of the constructed curve. This requires investors to customize the used bonds, which is less of a science and more of an art.

Looking at this particular sector of the CMT curve in Exhibit 35-4 and specifically at the three-month CMT standard deviation (CMT RVS ZS), investors could go long a cheap bond like the 1.875 7/15/2026, which is 0.9 standard deviations cheap, while shorting a rich bond like the 1.75 12/31/2026, which is 4.2 standard deviations rich, to create a profitable spread trade.

EXHIBIT 35-4

Spread Between Yield and CMT Yield, Heatmap and Z-Score

	Px	dPx	Yld	dYld	CMT Model Yld	CMT RVS	CMT dRVS	CMT RVS Rich↔Chp	CMT RVS ZS
T 1.875 31-Jul-2026	108-191	0-313	0.506	(15.0)	0.499	0.7	0.0		0.9
T 1.500 15-Aug-2026	106-086	0-312	0.508	(15.0)	0.501	0.6	0.1		0.2
T 6.750 15-Aug-2026	139-295	1-037	0.448	(14.8)	0.494	(4.6)	0.1		(1.4)
T 1.375 31-Aug-2026	105-162	1-001	0.509	(15.4)	0.502	0.7	(0.2)		1.2
T 1.625 30-Sep-2026	107-06	1-00+	0.509	(15.3)	0.504	0.6	0.0		(0.0)
T 1.625 31-Oct-2026	107-08+	1-012	0.511	(15.4)	0.506	0.5	(0.0)		0.2
T 2.000 15-Nov-2026	109-252	1-02	0.508	(15.5)	0.506	0.2	(0.1)		(0.6)
T 6.500 15-Nov-2026	139-246	1-066	0.450	(15.4)	0.499	(4.9)	(0.2)		(1.3)
T 1.625 30-Nov-2026	107-116	1-02+	0.509	(15.8)	0.507	0.2	(0.3)		(1.0)
T 1.750 31-Dec-2026	108-102	1-03+	0.505	(16.0)	0.509	(0.4)	(0.4)		(4.2)
T 1.500 31-Jan-2027	106-23+	1-03	0.505	(15.7)	0.511	(0.7)	0.0		(3.7)
TYM0	139-16	1-18+	0.458	(17.4)					
T 2.250 15-Feb-2027-TYM0	112-022	1-08	0.478	(17.4)	0.511	(3.3)	(1.7)		(8.2)
T 6.625 15-Feb-2027	142-08	1-116	0.433	(16.6)	0.504	(7.1)	(1.1)		(2.4)
T 1.125 28-Feb-2027	104-09+	1-052	0.497	(16.7)	0.513	(1.6)	(0.9)		(7.4)
UWI T 1.125 31-Mar-2027	104-123	1-05+	0.487	(16.7)	0.513	(2.6)	64.9		
TYU0	139-02+	1-18+	0.491	(17.1)					
T 2.375 15-May-2027-TYU0	113-08	1-09	0.495	(17.1)	0.515	(2.0)	(1.2)		(6.4)
T 2.250 15-Aug-2027	112-222	1-08	0.508	(16.2)	0.519	(1.1)	(0.1)		(3.8)
T 6.375 15-Aug-2027	143-06	1-112	0.459	(15.3)	0.512	(5.3)	0.6		(1.2)
T 2.250 15-Nov-2027	113-02+	1-106	0.512	(16.7)	0.522	(1.1)	(0.5)		(2.9)
T 6.125 15-Nov-2027	142-24+	1-14+	0.454	(15.9)	0.516	(6.2)	0.1		(1.9)
T 2.750 15-Feb-2028	117-102	1-126	0.519	(16.7)	0.524	(0.5)	(0.3)		(0.7)
T 2.875 15-May-2028	118-256	1-15	0.524	(16.9)	0.527	(0.3)	(0.4)		(0.9)
T 2.875 15-Aug-2028	119-10+	1-16	0.529	(16.7)	0.529	0.0	(0.1)		(0.8)
T 5.500 15-Aug-2028	141-09+	1-212	0.495	(16.8)	0.524	(2.9)	(0.4)		(1.8)
T 3.125 15-Nov-2028	121-312	1-19	0.531	(17.0)	0.530	0.1	(0.3)		(1.3)
T 5.250 15-Nov-2028	140-086	1-226	0.503	(16.8)	0.526	(2.3)	(0.3)		(1.5)
T 2.625 15-Feb-2029	118-07	1-186	0.534	(16.8)	0.532	0.2	0.1		(0.8)
T 5.250 15-Feb-2029	141-12	1-256	0.507	(17.2)	0.528	(2.0)	(0.5)		(1.8)
T 2.375 15-May-2029	116-152	1-226	0.534	(17.8)	0.533	0.0	(0.7)		(3.4)
T 1.625 15-Aug-2029	110-002	1-202	0.536	(17.0)	0.535	0.0	0.3		(1.2)
T 6.125 15-Aug-2029	151-20+	1-31	0.511	(17.0)	0.528	(1.7)	(0.1)		(0.4)

Source: RiskVal Financial Solutions, LLC

Some swap traders like to use the CMT curve to calculate the carry and roll down as CMT curves tend to be smoother. Additionally, the CMT curve can used in principal component analysis calculations and can applied this analysis to other instruments.

Hull-White Two-Factor Model

The traditional Hull-White two-factor model, also called the "2+ model," describes the short-rate dynamics of the Treasury yield curve. In this model, it is assumed that the short rates satisfy the following differential equations:

$$dZ(t) = k\left(X(t)+Y(t)-Z(t)\right)dt$$

$$dX(t) = \mu dt + \sigma_x dW_x$$

$$dY(t) = -\alpha Y(t)\,dt + \sigma_y dW_y$$

where

X is the risk-neutral process for the long-term rate factor

Y is the risk-neutral process of the short-term spread factor, such that the "equilibrium" instantaneous rate is *X*+

Z is the risk-neutral process for the actual instantaneous rate

How to use the 2+ model: Using the 2+ model, we construct a fair value Treasury curve. We then discount a specific bond's cash flow on this fair baseline curve to derive the theoretical fair price and yield of the bond. Comparing this fair yield with the current market yield of the bond shows investors the richness or cheapness of each specific issue as seen by the RV spread to the 2+ model curve (2+ RVS) and the resultant Z-score (2+ RVS ZS) in Exhibit 35-5.

EXHIBIT 35-5

Market Yield, 2+ Model Spread, Daily Change, Heatmap and Z-Score

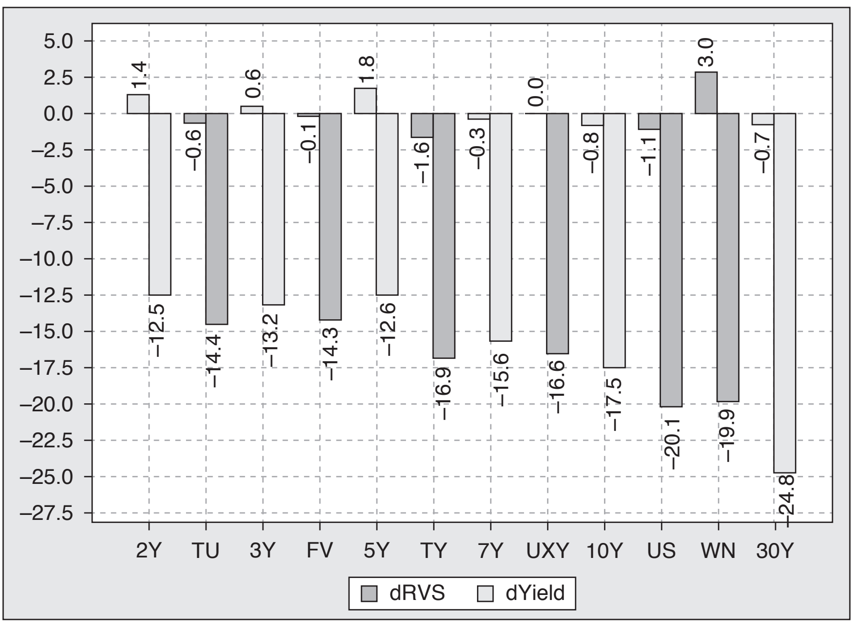
	Px	dPx	Yld	dYld	2+ RVS	2+ dRVS	2+ RVS Rich↔Chp	2+ RVS ZS
T 1.625 15-Feb-2026	106-185	0-27+	0.498	(14.3)	4.2	1.2		5.4
T 6.000 15-Feb-2026	132-195	0-317	0.428	(14.7)	(2.4)	0.7		0.8
T 2.500 28-Feb-2026	111-245	0-275	0.498	(13.9)	4.2	1.6		5.5
T 2.250 31-Mar-2026	110-146	0-291	0.495	(14.6)	3.7	1.0		5.0
T 2.375 30-Apr-2026	111-096	0-30	0.503	(14.8)	4.4	0.8		5.4
T 1.625 15-May-2026	106-266	0-296	0.500	(14.9)	3.9	0.8		5.1
T 2.125 31-May-2026	109-31	0-316	0.496	(15.5)	3.4	0.1		4.7
T 1.875 30-Jun-2026	108-17	1-002	0.499	(15.7)	3.5	0.0		4.5
T 1.875 31-Jul-2026	108-195	0-317	0.504	(15.3)	3.8	0.5		4.9
T 1.500 15-Aug-2026	106-087	0-313	0.507	(15.1)	3.9	0.7		5.6
T 6.750 15-Aug-2026	139-29+	1-036	0.448	(14.8)	(1.4)	0.8		1.2
T 1.375 31-Aug-2026	105-176	1-015	0.502	(16.2)	3.3	(0.3)		4.3
T 1.625 30-Sep-2026	107-066	1-012	0.506	(15.6)	3.5	0.2		4.6
T 1.625 31-Oct-2026	107-086	1-01+	0.510	(15.6)	3.6	0.3		5.0
T 2.000 15-Nov-2026	109-252	1-02	0.508	(15.5)	3.4	0.4		5.5
T 6.500 15-Nov-2026	139-25+	1-07+	0.447	(15.7)	(2.1)	0.0		1.3
T 1.625 30-Nov-2026	107-12+	1-032	0.506	(16.2)	3.1	(0.2)		4.4
T 1.750 31-Dec-2026	108-102	1-03+	0.505	(16.0)	2.8	(0.0)		4.1
T 1.500 31-Jan-2027	106-23	1-02+	0.507	(15.5)	2.7	0.5		4.8
TYM0	139-17+	1-20	0.452	(18.0)				
T 2.250 15-Feb-2027-TYM0	112-036	1-09+	0.472	(18.0)	(0.8)	(2.0)		(1.3)
T 6.625 15-Feb-2027	142-08	1-116	0.433	(16.6)	(4.1)	(0.7)		0.1
T 1.125 28-Feb-2027	104-09	1-046	0.499	(16.5)	1.7	(0.4)		3.0
UWI T 1.125 31-Mar-2027	104-117	1-05	0.489	(16.5)				
TYU0	139-04	1-20	0.486	(17.7)				
T 2.375 15-May-2027-TYU0	113-092	1-102	0.489	(17.7)	0.4	(1.5)		1.7

Source: RiskVal Financial Solutions, LLC

The 2+ model is particularly useful in looking at the benchmark points on the Treasury curve and especially so when there are significant moves. In the USD Treasury RVS shown in Exhibit 35-6, the second and larger bar chart of each benchmark point represents the change in yield for each benchmark and future point across the curve. The 2+ model quantifies how rich or cheap each point is based on the movement for that day. In Exhibit 35-6, as shown from the second bar chart of each benchmark point, the WN future, which is the ultra 30-year bond futures contract, has not rallied as much as the U.S. ultra 10-year bond futures or the 30-year benchmark point. The 2+ model is used to quantify how cheap the WN contract is, concluding it is 3 bps cheap given the move of the rest of the benchmark points. This graph gives investors a quick look at the daily yield changes of each point, as well as the resulting richness or cheapness of each point using the 2+_model. Investors could go long the WN contract, which looks to be 3 bps cheap, while short the US contract which looks to be 1.1 bps rich, as represented by the first bar charts for the respective benchmark points.

EXHIBIT 35-6

Treasury RVS Graph, Yield and 2+RVS Model



Source: RiskVal Financial Solutions, LLC

The Hull-White two-factor model assumes that the rate factors follow a random walk and that there is constant volatility in both the *X* and *Y* processes. The advantage of two-factor model is that it better captures the dynamics in both the short- and long-term rate regimes. It also allows two different volatilities instead of just one, which provides more flexibility.

In practice, a normal distribution and constant volatility are not particularly realistic. Additionally, fat tails are another topic heavily debated in the academic world.

Once the different RV models are understood, investors can then pick and choose how they want to construct their fair value model, how to look at rich and cheap, and how to start constructing trades.

Spread Trades

Trading a single bond outright carries much higher risk than trading two bonds as a spread. This is because when trading a single outright bond, an investor would have duration risk and would be exposed to a parallel shift in the yield curve. By entering into a spread trade and being long one bond and short the other, and if hedged correctly, an investor would be DV01 neutral. This removes the parallel curve move risk as the profits attained from one bond in a market rally would perfectly offset the losses on the other bond.

The remaining risk would be the spread risk, or relative risk between the two securities, which is what investors set out in the first place to gain exposure to. Additionally, constructing a butterfly trade where investors are long the middle issue while short both wings and vice versa would achieve similar relative risk exposure. Constructing these RV spread strategies can also boost an investor's returns by both being long a cheap issue with high expected total return and pairing this with being short a bond that is perceived to be rich.

Constructing a Trade—CMT Curve

Earlier we discussed using the CMT curve as a fair value baseline curve. We will now construct an example spread trade using the CMT curve.

Looking at the basket of bonds in Exhibit 35-7, the 2.375 15-May-2029 is 3.2 standard deviations cheap from the CMT RV Z-score (CMT RVS ZS) column. Investors can pair this with the 2.375 15-May-2027, which is 6.9 standard deviations rich. Again, it is not the actual spread to the fair value baseline curve (CMT RVS) that matters as much, but rather the standard deviation of the RV spread, which takes the past three-month level into account. We can also see that there is positive carry and roll down (3M C+ R) of 0.3 bps on the 2.375 15-May-2027 and negative carry and roll down of (0.4) bps on the 2.375 15-May-2029. Presented graphically in Exhibit 35-8, the yield spread level for the last three months further confirms that there has been a dislocation from previous trading levels.

EXHIBIT 35-7

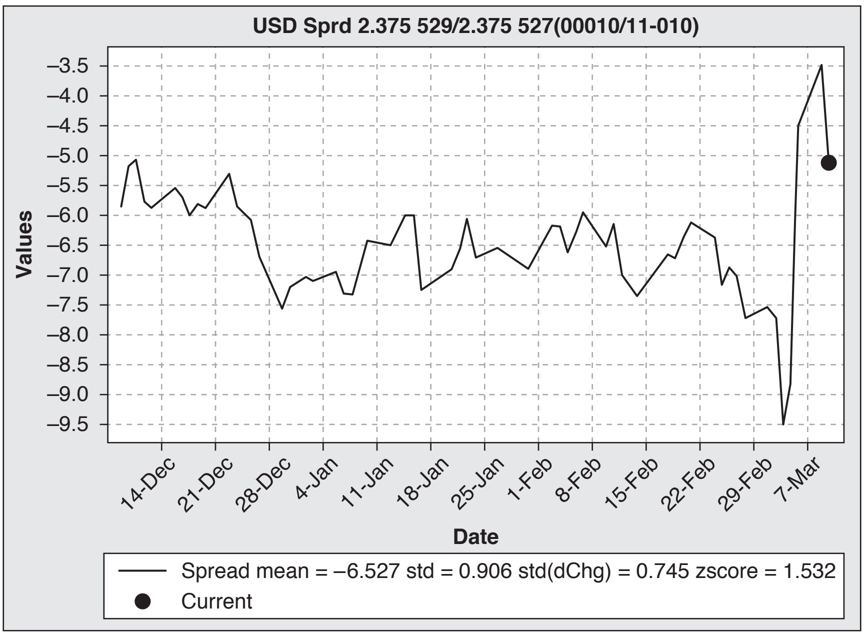
Carry, Roll, CMT Relative Value Spread Model, Daily Change, Heatmap and Z-Score

	Px	dPx	Yld	dYld	3M C	3M R CMT	3M C+R	CMT RVS	CMT dRVS	CMT RVS Rich↔Chp	CMT RVS ZS
T 2.375 15-May-2027-TYU0	112-082	(0-306)	0.626	12.7	(0.3)	0.6	0.3	(2.7)	(0.4)		(6.9)
T 2.250 15-Aug-2027	111-212	(1-002)	0.640	13.0	(0.2)	0.4	0.2	(1.8)	(0.3)		(6.5)
T 2.250 15-Nov-2027	111-316	(1-01)	0.647	12.8	(0.2)	0.3	0.2	(1.5)	(0.6)		(4.5)
T 2.750 15-Feb-2028	116-052	(1-022)	0.655	12.6	(0.1)	0.2	0.1	(0.7)	(0.9)		(1.2)
T 2.875 15-May-2028	117-196	(1-056)	0.659	13.4	(0.1)	0.1	(0.0)	(0.4)	(0.2)		(1.4)
T 2.875 15-Aug-2028	118-05	(1-06+)	0.658	13.2	(0.1)	0.0	(0.1)	(0.5)	(0.4)		(2.8)
T 3.125 15-Nov-2028	120-252	(1-08)	0.657	13.2	(0.1)	(0.1)	(0.2)	(0.6)	(0.4)		(4.1)
T 2.625 15-Feb-2029	116-30	(1-096)	0.668	13.7	(0.1)	(0.2)	(0.3)	0.7	0.1		1.9
T 2.375 15-May-2029	115-056	(1-09+)	0.667	13.4	(0.1)	(0.3)	(0.4)	0.8	(0.2)		3.2
T 1.625 15-Aug-2029	108-26+	(1-10)	0.658	13.6	(0.1)	(0.4)	(0.5)	0.2	0.1		(0.4)

Source: RiskVal Financial Solutions, LLC

EXHIBIT 35-8

Historical Spread Between 2.375% 5/15/2027 and 2.375 5/15/2029



Source: RiskVal Financial Solutions, LLC

EXHIBIT 35-9

Strategy Level Total Return, Expected Return, Carry and Rolldown

	Sprd Bfly	Sprd	dSprd	Sprd Rich↔Chp	Sprd ZS	Weight	Total Return	Expected Return	3M C	3M R CMT	3M C+R
1	2.375 529/2.375 527	(5.05)	(1.56)		1.6	-1/1	2.10	1.5	(0.2)	0.8	0.6

Source: RiskVal Financial Solutions, LLC

Putting the two trades together as a strategy as shown in Exhibit 35-9—being long the 2.375 15-May-2027 and short the 2.375 15-May-2029 produces a 1.6 standard deviation (Sprd Zs) cheap trade. This strategy also gives investors a total carry and roll down of 0.6 bps (3M C+R), expected return of 1.5 bps, and a total return of 2.1 bps. This means that an investor who puts this position on now will get paid 0.6 bps to sit on this trade for three months while waiting for the trade level to revert to the mean. Reversion to the mean would result in an additional 1.5 bps of return. All in all, a pretty good position to have.

SCENARIO AND HORIZONTAL ANALYSIS

Scenario Analysis

In the context of the assessment of an RV trade, scenario analysis involves estimating the new expected value of a portfolio after a given time period assuming specific market changes. It is commonly used to estimate changes to a portfolio's value in response to an unfavorable event and may be used to examine the theoretical worst-case scenario. For example, the 9/11 terrorist attacks and the 2008 global financial crisis are two commonly used scenarios today by investors to understand the potential impact of such events on their portfolios. Common scenario changes include parallel curve moves or curvature changes.

A parallel curve bump assumes that each point on the curve moves up or down in unison (i.e., by the same number of basis points). Any profit and loss generated from a parallel move would be due to duration risk. Thus, a DV01 neutral strategy can be used in such scenarios.

A curvature change reflects a change in convexity of the yield curve. As illustrated in Exhibit 35-10, there are four general cases: bull steepener, bull flattener, bear flattener, and bear steepener. A bull market refers to when the Treasury market richens, and a bear market refers to Treasuries cheapening and hence an opposite move in the yield curve.

Running different scenarios including those of extreme events allows an investor to better understand the risks of their portfolio and provides an event with information to make more informed investment decisions.

Horizontal Analysis

In fixed income analysis, horizontal analysis is an extension of scenario analysis, assessing the change in portfolio value in different scenarios and time periods. Horizontal analysis provides an understanding of how a portfolio will perform under multiple scenarios and time periods. It is useful for traders to compare their different portfolios against the same change in parameters to understand which portfolio might perform better in a rate environment they believe might occur. In Exhibit 35-11, the profit and loss for a given range in curve moves and time period are shown.

EXHIBIT 35-10

Different Types of Yield Curve Moves

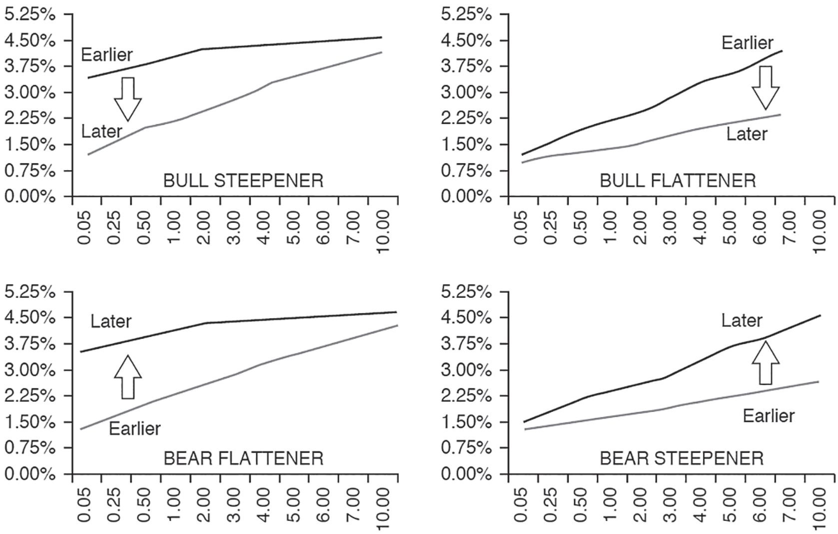
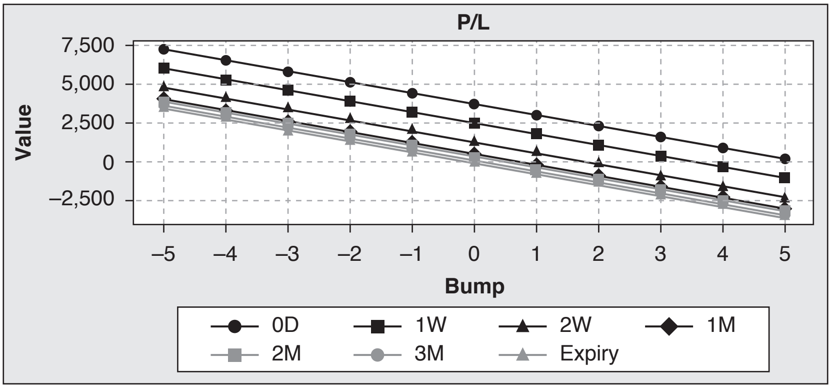


EXHIBIT 35-11

Horizontal Analysis



Source: RiskVal Financial Solutions, LLC

DATA AND THE FUTURE OF RELATIVE VALUE

The most important building block in constructing and using models is data, and having clean and reliable historical data is absolutely essential. Without it, it would be impossible to build and calibrate an effective model, much less use it. As a data provider and analytics company, we maintain massive databanks of historical data. This has allowed us the rare opportunity to explore automation in the data space.

RV Analysis

RV analysis, as seen in Exhibit 35-12, helps investors automatically generate trades with the highest total return based on the parameters that they define. Investors can choose the basket of instruments to run the analysis on. For instance, they can filter by sector or remove high-coupon bonds. They can also pick the RV model they want like in yield or true asset swap and generate the best long and short trades taking carry and roll down into consideration. Investors can also use this in the swap space, which reduces trade identification time by magnitudes due to the vast amount of combinations.

Automation

This was the first step in automation, but we do not believe in stopping here. We are always testing new ways to define and identify trades with the most risk–reward ratio and realized return. With the large swathes of available data being generated everyday, the industry has moved toward using machine learning and artificial intelligence to identify the best trades. Additionally, as computers become more powerful and sophisticated, our models can start using multiple dimensions in the analysis as well. We might be several years away, but quantum computing is also favored to completely reengineer how these financial models work.

From the rising importance of RV trading and how to build a fair value baseline curve model to creating RV trades with high expected value and building and testing these fixed income portfolios, we hope that this chapter has given you a foundational step in understanding fixed income RV. However, investors must keep in mind that no trade or investment is without risk, and model limitations and assumptions should be fully understood. Long-Term Capital Management (LTCM) was a good example of what could happen if investors blindly follow these models.

LTCM was a wildly successful hedge fund from 1994 to 1998 that ran arbitrage and RV strategies including the 2+ model. They had $5 billion in assets but had positions worth over $1 trillion by using leverage to increase returns. In 1998, their position in Russian government bonds plummeted as the Russian government defaulted on its debt. LTCM's models continued to recommend holding their positions and losses approached $4 billion. The U.S. government had to

EXHIBIT 35-12

RV Analysis

USD RV Analysis

Orig: ALL Sctr: >=2Y Mty Sctr: Cpn: To 4

Measure: Yld Generate

	Bond	Yld	dYld	Yld Rich↔Chp	Yld ZS	Yld Stdev	Yld Dev	Yld C+R	ASW YY C+R
1	T 1.125 28-Feb-2022	1.081	(6.65)		(3.62)	0.00	(42.95)	(7.87)	1.74
2	T 1.875 28-Feb-2022	1.101	(6.46)		(3.55)	12.02	(42.72)	(8.59)	1.03
3	T 1.750 28-Feb-2022	1.099	(6.36)		(3.54)	11.89	(42.06)	(8.60)	1.02
4	T 2.375 15-Mar-2022	1.081	(6.26)		(3.58)	12.04	(43.07)	(8.62)	0.89
5	T 1.875 31-Mar-2022	1.097	(6.48)		(3.51)	12.14	(42.66)	(8.09)	0.78
6	T 1.750 31-Mar-2022	1.088	(6.57)		(3.52)	12.09	(42.61)	(8.20)	0.68
7	T 2.250 15-Apr-2022	1.092	(6.38)		(3.49)	12.39	(43.24)	(7.97)	0.82
8	T 1.875 30-Apr-2022	1.090	(6.24)		(3.49)	12.37	(43.12)	(7.71)	0.78
9	T 1.750 30-Apr-2022	1.087	(6.05)		(3.50)	12.23	(42.80)	(7.74)	0.75
10	T 2.125 15-May-2022	1.089	(6.31)		(3.46)	12.58	(43.46)	(7.49)	0.94
11	T 1.750 15-May-2022	1.076	(6.29)		(3.45)	12.60	(43.53)	(7.63)	0.81
12	T 1.750 31-May-2022	1.081	(6.00)		(3.47)	12.46	(43.26)	(7.32)	0.80

Total Return | Expected Return

Generate RV Strategy Strategy Count 4 Sprd/Bfly Length 1M Tolerance 15D

☑ Same Direction C+R ☐ Same Direction Yld Exp Return

	Stgy	Total Return	Expected Return	Yld C+R	ASW YY C+R	Yld	ZS	MACD Sprd	RSI	Sprd OvrBt↔Sd
1	Long Sprd Strategy									
2	6.0 226/2.25 326	2.73	2.13	0.59	0.55	5.57	1.97	0.51	70.1	
3	6.875 825/2.75 825	2.23	1.67	0.56	0.78	4.56	1.70	0.28	64.4	
4	6.75 826/1.375 826	2.14	1.52	0.63	0.83	5.45	1.15	0.18	65.6	
5	7.5 N24/1.5 N24	1.98	1.44	0.54	0.52	1.22	1.18	0.26	60.7	
6										
7	Long Bfly Strategy									
8	1.375 O22/1.875 O22/7.625 N22	2.65	1.81	0.84	0.55	4.35	1.64	0.17	61.5	
9	1.75 922/1.875 O22/7.625 N22	2.57	1.54	1.03	0.54	4.76	1.51	0.03	58.8	
10	2.75 625/2.875 725/6.875 825	2.56	2.00	0.56	0.52	4.65	1.89	0.41	64.2	
11	2.625 D25/2.625 126/6.0 226	2.55	2.03	0.52	0.52	5.33	1.95	0.50	62.8	
12										
13	Short Sprd Strategy									
14	2.625 126/6.0 226	(2.47)	(2.01)	(0.45)	(0.51)	(4.80)	(2.01)	(0.48)	30.4	
15	2.875 725/6.875 825	(2.26)	(1.79)	(0.46)	(0.50)	(4.05)	(1.77)	(0.34)	32.3	
16	1.875 726/6.75 826	(2.02)	(1.47)	(0.55)	(0.60)	(4.94)	(1.21)	(0.21)	38.7	
17	1.875 O22/7.625 N22	(1.84)	(1.15)	(0.69)	(0.65)	(3.90)	(1.07)	(0.05)	42.5	
18										
19	Short Bfly Strategy									
20	2.625 126/6.0 226/2.25 326	(5.19)	(4.15)	(1.04)	(1.06)	(10.36)	(2.00)	(0.99)	28.2	
21	2.875 725/6.875 825/2.75 825	(4.48)	(3.47)	(1.02)	(1.28)	(8.61)	(1.75)	(0.62)	31.9	
22	1.875 726/6.75 826/1.375 826	(4.17)	(2.99)	(1.18)	(1.43)	(10.39)	(1.19)	(0.40)	34.3	
23	1.875 O22/7.625 N22/2.0 N22	(3.62)	(2.03)	(1.59)	(1.43)	(7.52)	(1.03)	(0.08)	43.8	

Source: RiskVal Financial Solutions, LLC

organize a bailout as they deemed LTCM's disorderly collapse a systematic risk. At that time, their positions totaled about 5% of the global fixed income market.

LTCM's downfall was in their inability to fully understand the limitations of their models. The models performed exactly as expected but did not account for fat tail risks, which LTCM did not fully take into consideration. In order to prevent this type of recurrence, model users need to both fully understand the models' limitations and also have proper risk controls in place.

The RV path is littered with many dangers, but hopefully this chapter provides you with a better understanding of how to navigate it, because with no risk, there is no reward.

KEY POINTS

- Relative value trading has grown in importance in the current low rate and low volatility environment.
- There are numerous market-based and model-based relative value models, each with its own assumptions, advantages, and disadvantages.
- Understanding the Z-score, mean reversion assumption, and total return is essential in constructing relative value trades.
- Scenario and horizontal analysis can be used to better understand the rate and time sensitivities of a strategy or portfolio.
- Relative value trading concepts can be applied to many other financial securities.
- Big data and machine learning pave the way for automation of relative value trading.

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CHAPTER
THIRTY-SIX

VALUATION OF BONDS WITH EMBEDDED OPTIONS

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The complication in building a model to value bonds with embedded options and option-type derivatives is that cash flows will depend on interest rates in the future. Academicians and practitioners have attempted to capture this interest rate uncertainty through various models, often designed as single or multi-factor models. These models attempt to capture the stochastic behavior of rates.

In practice, these elegant mathematical models must be converted to numeric applications. Here we focus on one such model—a single-factor model that assumes a stationary variance or, as it is more often called, volatility. We demonstrate how to move from the yield curve to a valuation lattice. Effectively, the lattice is a representation of the model, capturing the distribution of rates over time. In our illustration we will present the lattice as a binomial tree, the most simple lattice form.

The lattice holds all the information required to perform the valuation of certain option-like interest rate products. First, the lattice is used to generate cash flows over the life of the security. Next, the interest rates on the lattice are used to compute the present value of those cash flows.

There are several interest rate models that have been used in practice to construct an interest rate lattice. These are described in other chapters. In each case, interest rates can realize one of several possible rates when we move from one period to the next. A lattice model where it is assumed that only two rates are possible in the next period given the current rate is called a *binomial model*. A lattice model where it is assumed that interest rates can take on three possible rates in the next period is called a *trinomial model*. There are even more complex models that assume more than three possible rates in the next period can be realized.

Regardless of the underlying assumptions, each model shares a common restriction. The interest rate tree generated must produce a value for an on-the-run optionless issue that is consistent with the current par yield curve. In effect, the value estimated by the model must be equal to the observed market price for the optionless instrument. Under these conditions, the model is said to be "arbitrage free." A lattice that produces an arbitrage-free valuation is said to be "fair." The lattice is used for valuation only when it has been calibrated to be fair. More on calibration below.

In this chapter we show how to value bonds with embedded options using the lattice methodology. We begin by demonstrating how an interest rate lattice is constructed. Then we use the model to value bonds with an embedded option. The lattice methodology also can be used to value floating-rate securities with option-type derivatives, options on bonds, caps, floors, swaptions, and forward-start swaps.[1]

THE INTEREST RATE LATTICE

Exhibit 36-1 provides an example of a binomial interest rate tree, which consists of a number of "nodes" and "legs." Each leg represents a one-year interval over time. A simplifying assumption of one-year intervals is made to illustrate the key principles. The methodology is the same for smaller time periods. In fact, in practice, the selection of the length of the time period is critical, but we need not be concerned with this nuance here.

The distribution of future interest rates is represented on the tree by the nodes at each point in time. Each node is labeled as N and has a subscript, a combination of L's and H's. The subscripts indicate whether the node is lower or higher on the tree, respectively, relative to the other nodes. Thus node N_{HH} is reached when the one-year rate realized in the first year is the higher of the two rates for that period, then the highest of the rates in the second year.

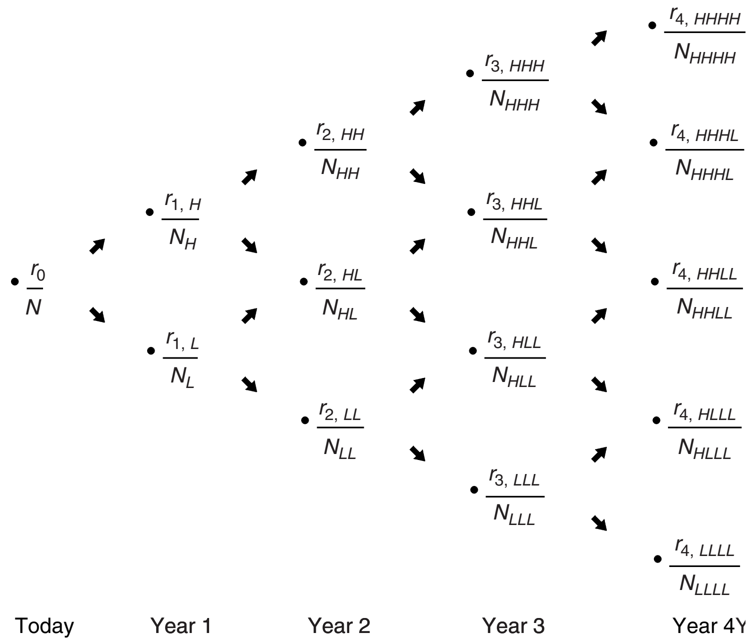
The root of the tree is N, the only point in time at which we know the interest rate with certainty. The one-year rate today (i.e., at N) is the current one-year spot rate, which we denote by r_0.

We must make an assumption concerning the probability of reaching one rate at a point in time. For ease of illustration, we have assumed that rates at any point in time have the same probability of occurring; in other words, the probability is 50% on each leg.

1. These applications of the lattice methodology are presented in Frank J. Fabozzi, Andrew Kalotay, and Michael Dorigan, "Yield Curves and Valuation Lattices" and "Using the Lattice Model to Value Bonds with Embedded Options, Floaters, Options, and Caps/Floors," Chapters 13 and 14 in Frank J. Fabozzi (ed.), *Interest Rate, Term Structure, and Valuation Modeling* (Hoboken, NJ: Wiley, 2002).

EXHIBIT 36-1

Four-Year Binomial Interest Rate Tree



The interest rate model we will use to construct the binomial tree assumes that the one-year rate evolves over time based on a log-normal random walk with a known (stationary) volatility. Technically, the tree represents a one-factor model. Under the distributional assumption, the relationship between any two adjacent rates at a point in time is calculated via the following equation:

$$r_{1,H} = r_{1,L}e^{2\sigma\sqrt{t}}$$

where σ is the assumed volatility of the one-year rate, t is time in years, and e is the base of the natural logarithm. Since we assume a one-year interval, that is, $t = 1$, we can disregard the calculation of the square root of t in the exponent.

For example, suppose that $r_{1,L}$ is 4.4448% and σ is 10% per year, then

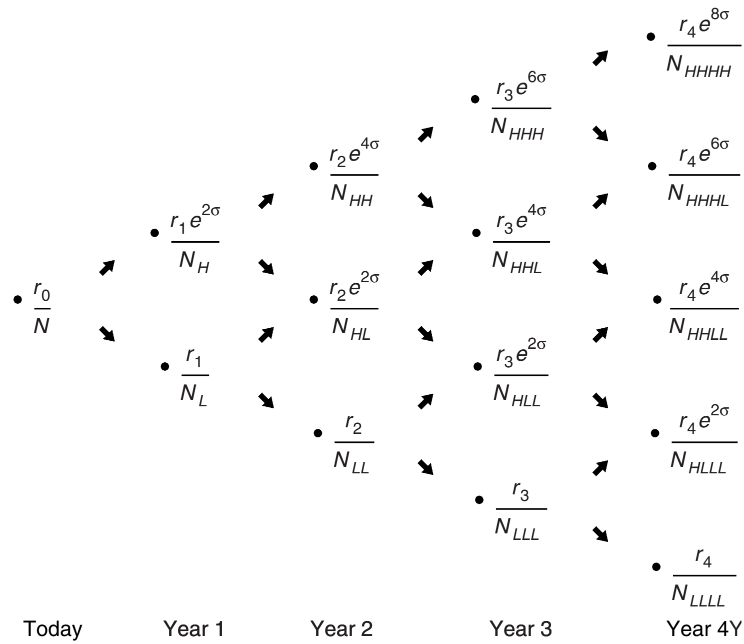
$$r_{1,H} = 4.4448\%(e^{2\times 0.10}) = 5.4289\%$$

In the second year, there are three possible values for the one-year rate. The relationship between $r_{2,LL}$ and the other two one-year rates is as follows:

$$r_{2,HH} = r_{2,LL}\,(e^{4\sigma}) \qquad \text{and} \qquad r_{2,HL} = r_{2,LL}(e^{2\sigma})$$

EXHIBIT 36-2

Four-Year Binomial Interest Rate Tree with One-Year Rates*



*r_t is the lowest one-year rate at each point in time.

Thus, for example, if $r_{2,LL}$ is 4.6958%, and assuming once again that σ is 10%, then

$$r_{2,HH} = 4.6958\%(e^{4\times0.10}) = 7.0053\%$$

and

$$r_{2,HL} = 4.6958\%(e^{2\times0.10}) = 5.7354\%$$

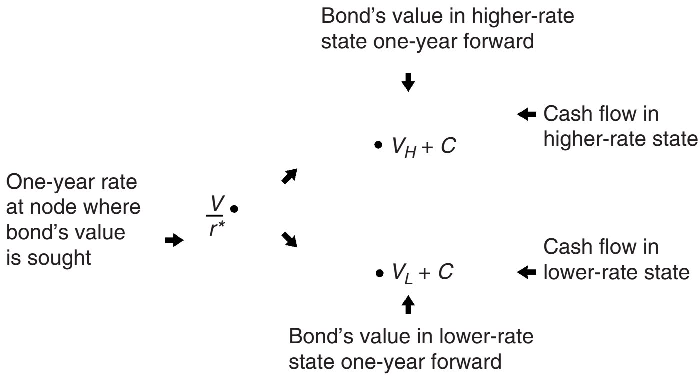
This relationship between rates holds for each point in time. Exhibit 36-2 shows the interest rate tree using this new notation.

Determining the Value at a Node

In general, to get a security's value at a node, we follow the fundamental rule for valuation: The value is the present value of the expected cash flows. The appropriate discount rate to use for cash flows one-year forward is the one-year rate at the node where we are computing the value. Now there are two present values in this case: the present value of the cash flows in the state where the one-year rate is the higher rate and one where it is the lower-rate state. We have assumed that the probability of

EXHIBIT 36-3

Calculating a Value at a Node



both outcomes is equal. Exhibit 36-3 provides an illustration for a node assuming that the one-year rate is r^* at the node where the valuation is sought and letting

V_H = the bond's value for the higher one-year rate state
V_L = the bond's value for the lower one-year rate state
C = coupon payment

From where do the future values come? Effectively, the value at any node depends on the future cash flows. The future cash flows include (1) the coupon payment one year from now and (2) the bond's value one year from now, both of which may be uncertain. Starting the process from the last year in the tree and working backward to get the final valuation resolves the uncertainty. At maturity, the instrument's value is known with certainty—par. The final coupon payment can be determined from the coupon rate or from prevailing rates to which it is indexed. Working back through the tree, we realize that the value at each node is calculated quickly. This process of working backward is often referred to as *recursive valuation*.

Using our notation, the cash flow at a node is either

$V_H + C$ for the higher one-year rate
$V_L + C$ for the lower one-year rate

The present value of these two cash flows using the one-year rate at the node, r^*, is

$$\frac{V_H + C}{(1 + r^*)} = \text{present value for the higher one-year rate}$$

$$\frac{V_L + C}{(1 + r^*)} = \text{present value for the lower one-year rate}$$

Then the value of the bond at the node is found as follows:

$$\text{Value at a node} = \frac{1}{2}\left[\frac{V_H + C}{(1+r^*)} + \frac{V_L + C}{(1+r^*)}\right]$$

CALIBRATING THE LATTICE

We noted earlier the importance of the no-arbitrage condition that governs the construction of the lattice. To ensure that this condition holds, the lattice must be calibrated to the current par yield curve, a process we demonstrate here. Ultimately, the lattice must price optionless par bonds at par.

Assume the on-the-run par yield curve for a hypothetical issuer as it appears in Exhibit 36-4. The current one-year rate is known, 3.50%. Hence the next step is to find the appropriate one-year rates one-year forward. As before, we assume that volatility σ is 10% and construct a two-year tree using the two-year bond with a coupon rate of 4.2%, the par rate for a two-year security.

Exhibit 36-5 shows a more detailed binomial tree with the cash flow shown at each node. The root rate for the tree r_0 is simply the current one-year rate, 3.5%. At the beginning of year 2, there are two possible one-year rates, the higher rate and the lower rate. We already know the relationship between the two. A rate of 4.75% at N_L has been chosen arbitrarily as a starting point. An iterative process determines the proper rate (i.e., trial-and-error). The steps are described and illustrated below. Again, the goal is a rate that, when applied in the tree, provides a value of par for the two-year 4.2% bond.

Step 1. Select a value for r_1. Recall that r_1 is the lower one-year rate. In this first trial, we arbitrarily selected a value of 4.75%.

Step 2. Determine the corresponding value for the higher one-year rate. As explained earlier, this rate is related to the lower one-year rate as follows: $r_1 e^{2\sigma}$. Since r_1 is 4.75%, the higher one-year rate is 5.8017% (= 4.75% $e^{2\times 0.10}$). This value is reported in Exhibit 36-5 at node N_H.

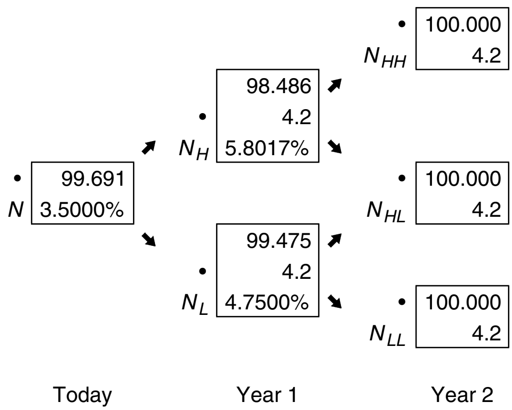
EXHIBIT 36-4

Issuer Par Yield Curve

Maturity	Par Rate	Market Price
1 year	3.50%	100
2 years	4.20%	100
3 years	4.70%	100
4 years	5.20%	100

EXHIBIT 36-5

The One-Year Rates for Year 1 Using the Two-Year 4.2% On-the-Run Issue: First Trial



Step 3. Compute the bond's value one year from now. This value is determined as follows:

a. Determine the bond's value two years from now. In our example, this is simple. Since we are using a two-year bond, the bond's value is its maturity value ($100) plus its final coupon payment ($4.2). Thus it is $104.2.

b. Calculate V_H. Cash flows are known. The appropriate discount rate is the higher one-year rate, 5.8017% in our example. The present value is $98.486 (= $104.2/1.058017).

c. Calculate V_L. Again, cash flows are known—the same as those in step 3b. The discount rate assumed for the lower one-year rate is 4.75%. The present value is $99.475 (= $104.2/1.0475).

Step 4. Calculate *V*.

a. Add the coupon to both V_H and V_L to get the cash flow at N_H and N_L, respectively. In our example we have $102.686 for the higher rate and $103.675 for the lower rate.

b. Calculate *V*. The one-year rate is 3.50%. (*Note:* At this point in the valuation, r^* is the root rate, 3.50%.) Therefore, $99.691 = 1/2($99.214 + $100.169)

Step 5. Compare the value in step 4 to the bond's market value. If the two values are the same, then the r_1 used in this trial is the one we seek. If, instead, the value found in step 4 is not equal to the market value of the bond, this means that the value r_1 in this trial is not the one-year rate that is consistent with the current yield curve. In this case, the five steps are repeated with a different value for r_1.

When r_1 is 4.75%, a value of \$99.691 results in step 4, which is less than the observed market price of \$100. Therefore, 4.75% is too large, and the five steps must be repeated trying a lower rate for r_1.

Let's jump right to the correct rate for r_1 in this example and rework steps 1 through 5. This occurs when r_1 is 4.4448%. The corresponding binomial tree is shown in Exhibit 36-6. The value at the root is equal to the market value of the two-year issue (par).

We can "grow" this tree for one more year by determining r_2. Now we will use the three-year on-the-run issue, the 4.7% coupon bond, to get r_2. The same five steps are used in an iterative process to find the one-year rates in the tree two years from now. Our objective is now to find the value of r_2 that will produce a bond value of \$100. Note that the two rates one year from now of 4.4448% (the lower rate) and 5.4289% (the higher rate) do not change. These are the fair rates for the tree one-year forward.

The problem is illustrated in Exhibit 36-7. The cash flows from the three-year 4.7% bond are in place. All we need to perform a valuation are the rates at the start of year 3. In effect, we need to find r_2 such that the bond prices at par. Again, an arbitrary starting point is selected, and an iterative process produces the correct rate.

The completed version of Exhibit 36-7 is found in Exhibit 36-8. The value of r_2, or equivalently $r_{2,LL}$, that will produce the desired result is 4.6958%. The corresponding rates $r_{2,HL}$ and $r_{2,HH}$ would be 5.7354% and 7.0053%, respectively.

EXHIBIT 36-6

The One-Year Rates for Year 1 Using the Two-Year 4.2% On-the-Run Issue

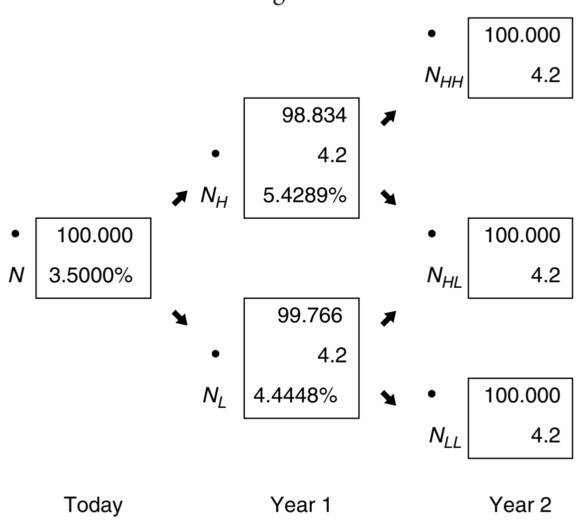


EXHIBIT 36-7

Information for Deriving the One-Year Rates for Year 2 Using the Three-Year 4.7% On-the-Run Issue

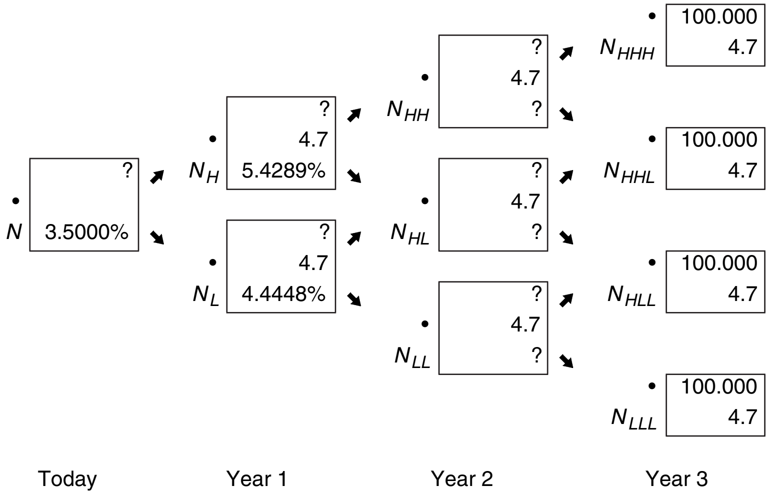
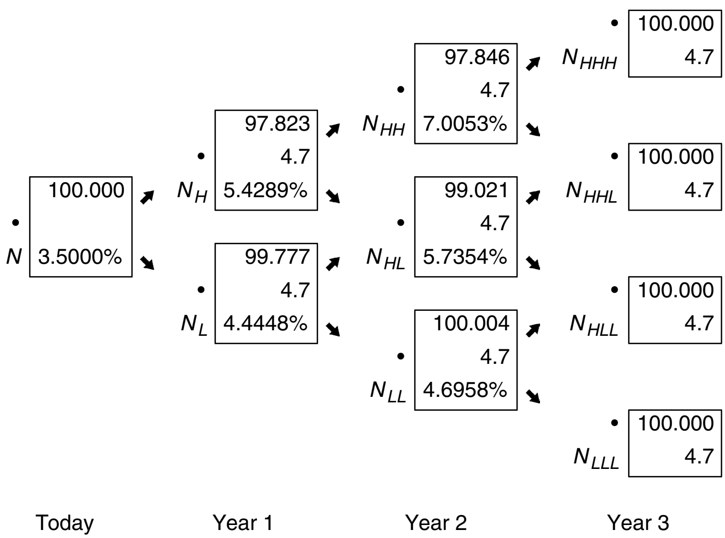


EXHIBIT 36-8

The One-Year Rates for Year 2 Using the Three-Year 4.7% On-the-Run Issue



To verify that these are the correct one-year rates two years from now, work backward from the four nodes at the right of the tree in Exhibit 36-8. For example, the value in the box at N_{HH} is found by taking the value of \$104.7 at the two nodes to its right and discounting at 7.0053%. The value is \$97.846. Similarly, the value in the box at N_{HL} is found by discounting \$104.70 by 5.7354% and at N_{LL} by discounting at 4.6958%.

USING THE LATTICE FOR VALUATION

To illustrate how to use the lattice for valuation purposes, consider a 6.5% option-free bond with four years remaining to maturity. Since this bond is option-free, it is not necessary to use the lattice model to value it. All that is necessary to obtain an arbitrage-free value for this bond is to discount the cash flows using the spot rates obtained from bootstrapping the yield curve shown in Exhibit 36-4. The spot rates are as follows:

1 year	3.5000%
2 years	4.2147%
3 years	4.7345%
4 years	5.2707%

Discounting the 6.5% four-year option-free bond with a par value of \$100 at the above spot rates would give a bond value of \$104.643.

Exhibit 36-9 contains the fair tree for a four-year valuation. Exhibit 36-10 shows the various values in the discounting process using the lattice in Exhibit 36-9. The root of the tree shows the bond value of \$104.643, the same value found by discounting at the spot rate. This demonstrates that the lattice model is consistent with the valuation of an option-free bond when using spot rates.

FIXED-COUPON BONDS WITH EMBEDDED OPTIONS

The valuation of bonds with embedded options proceeds in the same fashion as in the case of an option-free bond. However, the added complexity of an embedded option requires an adjustment to the cash flows on the tree depending on the structure of the option. A decision on whether to call or put must be made at nodes on the tree where the option is eligible for exercise. Examples for both callable and putable bonds follow.

Valuing a Callable Bond

In the case of a call option, the call will be made when the present value (PV) of the future cash flows is greater than the call price at the node where the decision to exercise is being made. Effectively, the following calculation is made:

$$V_t = \min[\text{call price, PV(future cash flows)}]$$

EXHIBIT 36-9

Binomial Interest Rate Tree for Valuing Up to a Four-Year Bond for Issuer (10% Volatility Assumed)

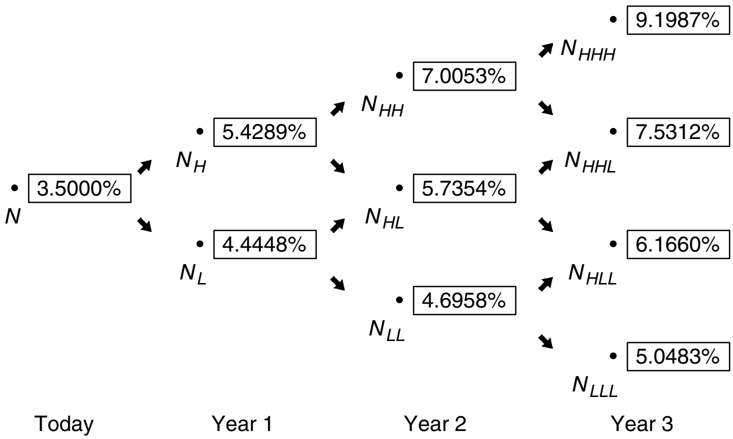
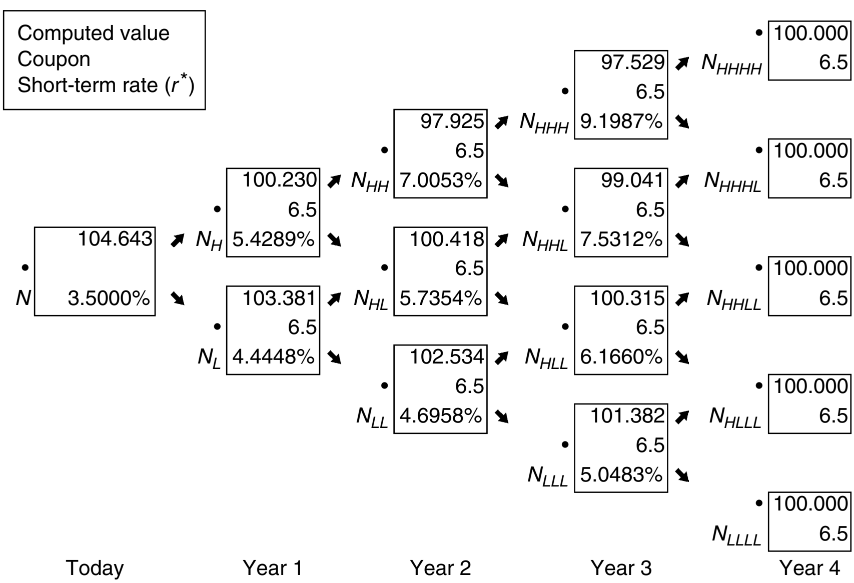


EXHIBIT 36-10

Valuing an Option-Free Bond with Four Years to Maturity and a Coupon Rate of 6.5% (10% Volatility Assumed)



where V_t represents the PV of future cash flows at the node. This operation is performed at each node where the bond is eligible for call.

For example, consider a 6.5% bond with four years remaining to maturity that is callable in one year at \$100. We will value this bond, as well as the other instruments in this chapter, using a binomial tree. Exhibit 36-9 is the binomial interest rate tree that was derived earlier in this chapter and then used to value an option-free bond. In constructing the binomial tree in Exhibit 36-9, it is assumed that interest rate volatility is 10%. This binomial tree will be used throughout this chapter.

Exhibit 36-11 shows that two values are now present at each node of the binomial tree. The discounting process explained earlier is used to calculate the first of the two values at each node. The second value is the value based on whether the issue will be called. Again, the issuer calls the issue if the PV of future cash flows exceeds the call price. This second value is incorporated into the subsequent calculations.

In Exhibits 36-12 and 36-13, certain nodes from Exhibit 36-11 are featured. Exhibit 36-12 shows nodes where the issue is not called (based on the simple call rule used in the illustration) in years 2 and 3.[2] The values reported in this case are the same as in the valuation of an option-free bond. Exhibit 36-13 shows some nodes where the issue is called in years 2 and 3. Notice how the methodology changes the cash flows. In year 3, for example, at node N_{HLL} the recursive valuation process produces a PV of 100.315. However, given the call rule, this issue would be called. Therefore, 100 is shown as the second value at the node, and it is this value that is then used as the valuation process continues. Taking the process to its end, the value for this callable bond is 102.899.

The value of the call option is computed as the difference between the value of an optionless bond and the value of a callable bond. In our illustration, the value of the option-free bond is 104.643 (calculated earlier in this chapter). The value of the callable bond is 102.899. Hence the value of the call option is 1.744 (=104.634 − 102.899).

Valuing a Putable Bond

A putable bond is one in which the bondholder has the right to force the issuer to pay off the bond prior to the maturity date. The analysis of the putable bond follows closely that of the callable bond. In the case of the putable, we must establish the rule by which the decision to put is made. The reasoning is similar to that for the callable bond. If the PV of the future cash flows is less than the put price (i.e., par), then the bond will be put. In equation form,

$$V_t = \max[\text{put price, PV(future cash flows)}]$$

Exhibit 36-14 is analogous to Exhibit 36-3. It shows the binomial tree with the values based on whether or not the investor exercises the put option at each node.

2. We assume cash flows occur at the end of the year.

EXHIBIT 36-11

Valuing a Callable Bond with Four Years to Maturity, a Coupon Rate of 6.5%, and Callable After the First Year at 100 (10% Volatility Assumed)

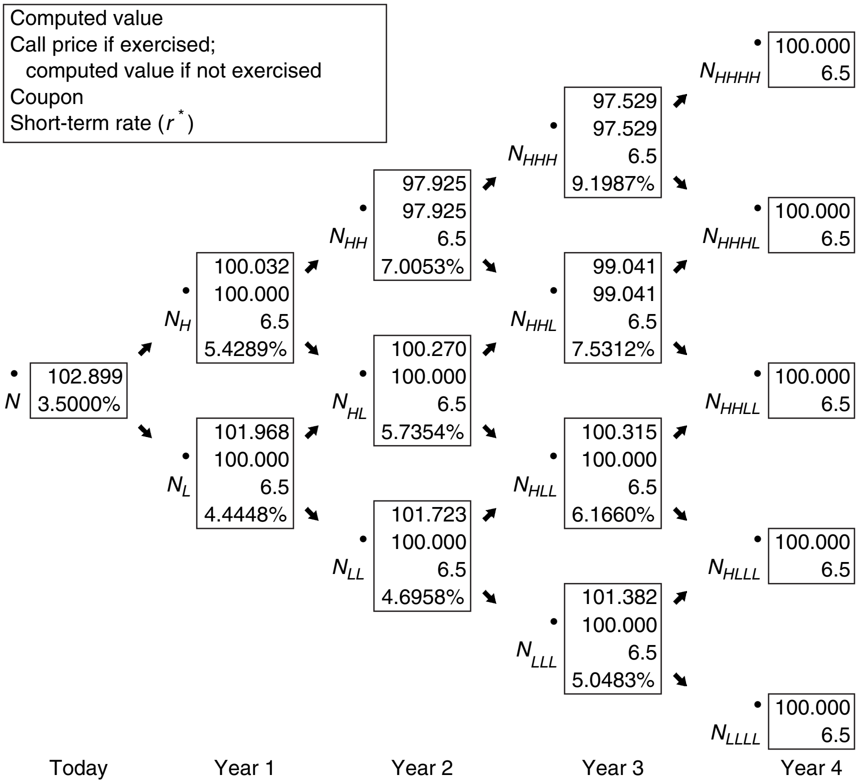


EXHIBIT 36-12

Featured Nodes in Years 2 and 3 for a Callable Bond: Nodes Where Call Option Is Not Exercised

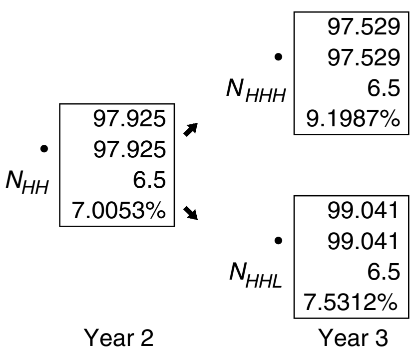


EXHIBIT 36-13

Featured Nodes in Years 2 and 3 for a Callable Bond: Selected Nodes Where the Call Option Is Exercised

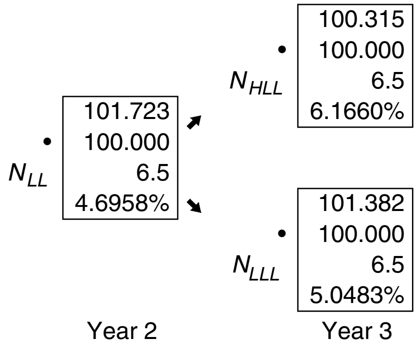
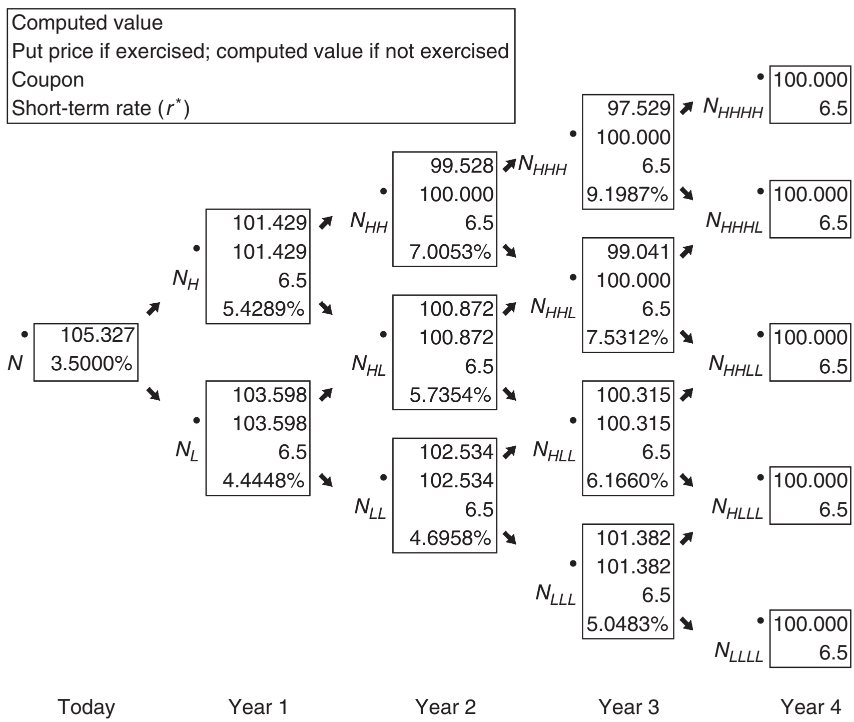


EXHIBIT 36-14

Valuing a Putable Bond with Four Years to Maturity, a Coupon Rate of 6.5%, and Putable after the First Year at 100 (10% Volatility Assumed)



The bond is putable any time after the first year at par. The value of the bond is 105.327. Note that the value is greater than the value of the corresponding option-free bond.

With the two values in hand, we can calculate the value of the put option. Since the value of the putable bond is 105.327 and the value of the corresponding option-free bond is 104.643, the value of the embedded put option purchased by the investor is effectively 0.684.

Suppose that a bond is both putable and callable. The procedure for valuing such a structure is to adjust the value at each node to reflect whether the issue would be put or called. Specifically, at each node there are two decisions about the exercising of an option that must be made. If it is called, the value at the node is replaced by the call price. The valuation procedure then continues using the call price at that node. If the call option is not exercised at a node, it must be determined whether or not the put option will be exercised. If it is exercised, then the put price is substituted at that node and is used in subsequent calculations.

VALUATION OF TWO MORE EXOTIC STRUCTURES

The lattice-based recursive valuation methodology is robust. To further support this claim, we address the valuation of two more exotic structures—the step-up callable note and the range floater.

Valuing a Step-Up Callable Note

Step-up callable notes are callable instruments whose coupon rate is increased (i.e., "stepped up") at designated times. When the coupon rate is increased only once over the security's life, it is said to be a *single step-up callable note*. A *multiple step-up callable note* is a step-up callable note whose coupon is increased more than one time over the life of the security. Valuation using the lattice model is similar to that for valuing a callable bond described earlier except that the cash flows are altered at each node to reflect the coupon characteristics of a step-up note.

Suppose that a four-year step-up callable note pays 4.25% for two years and then 7.5% for two more years. Assume that this note is callable at par at the end of year 2 and year 3. We will use the binomial tree given in Exhibit 36-9 to value this note.

Exhibit 36-15 shows the value of the note if it were not callable. The valuation procedure is the now familiar recursive valuation from Exhibits 36-12 and 36-13. The coupon in the box at each node reflects the step-up terms. The value is 102.082. Exhibit 36-16 shows that the value of the single step-up callable note is 100.031. The value of the embedded call option is equal to the difference in the optionless step-up note value and the step-up callable note value, 2.051.

EXHIBIT 36-15

Valuing a Single Step-Up Noncallable Note with Four Years to Maturity (10% Volatility Assumed)

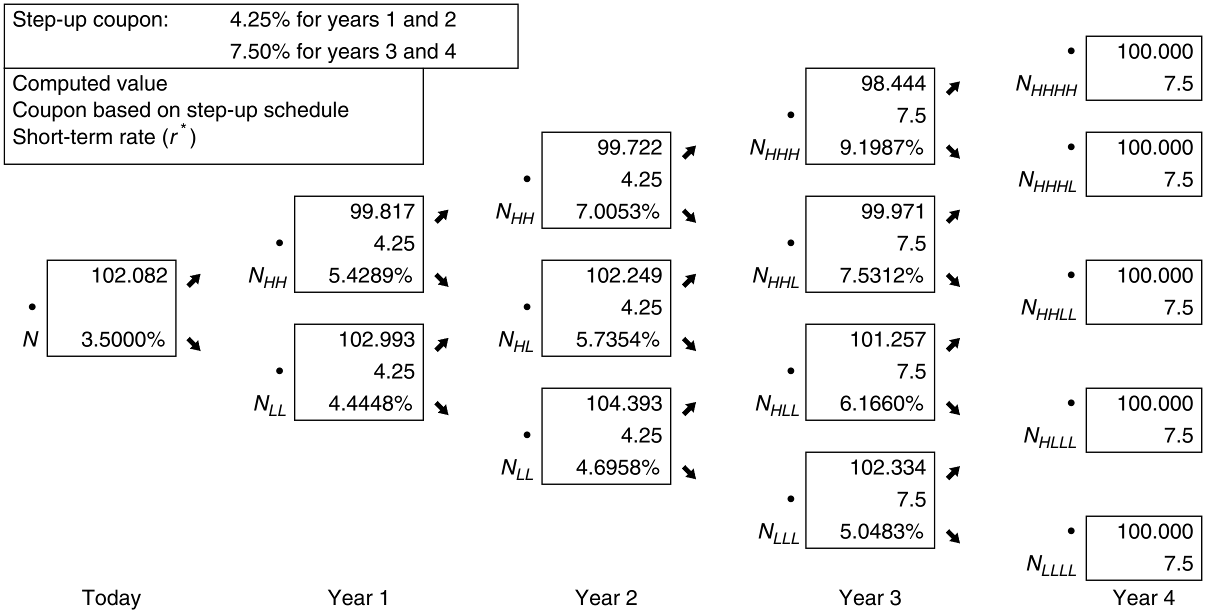


EXHIBIT 36-16

Valuing a Single Step-Up Callable Note with Four Years to Maturity, Callable in Two Years at 100 (10% Volatility Assumed)

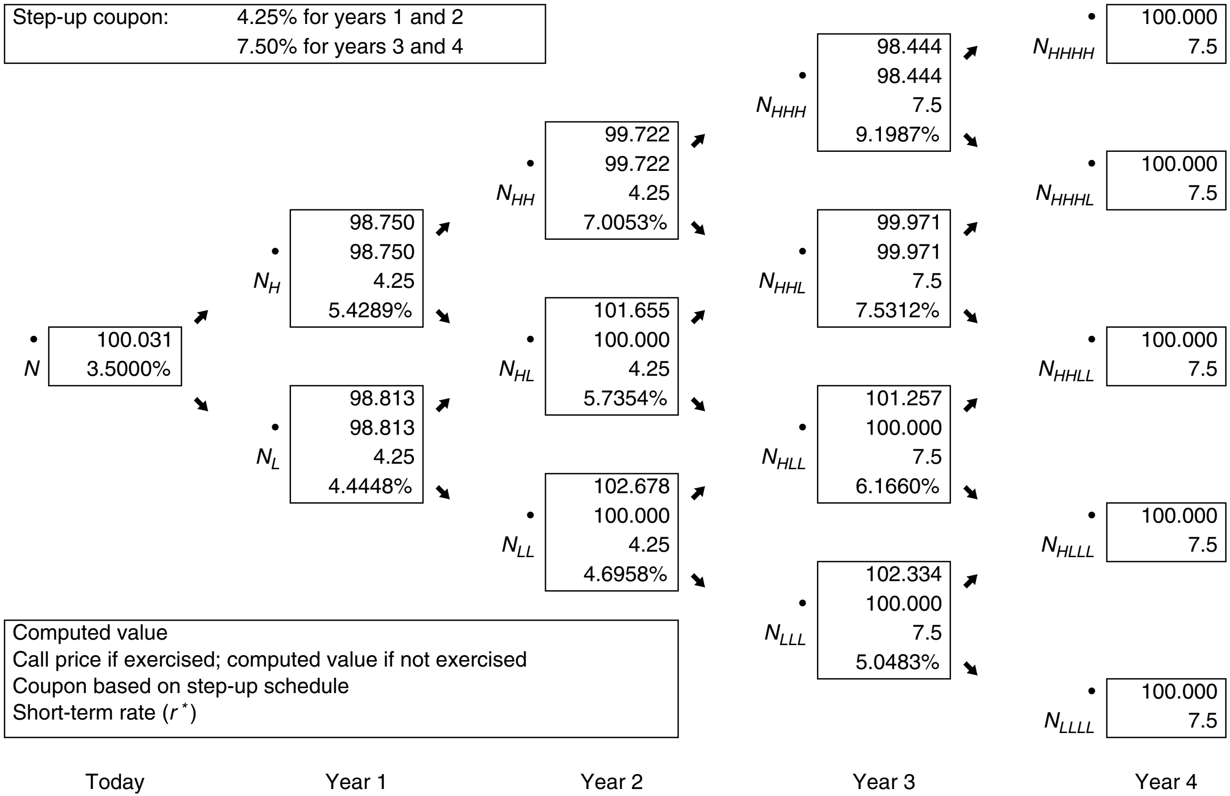


EXHIBIT 36-17

Coupon Schedule (Bands) for a Range Note

	Year 1	Year 2	Year 3
Lower limit	3.00%	4.00%	5.00%
Upper limit	5.00%	6.25%	8.00%

Now we move to another structure where the coupon floats with a reference rate but is restricted. In this next case, a range is set in which the bond pays the reference rate when the rate falls within a specified range, but outside the range no coupon is paid.

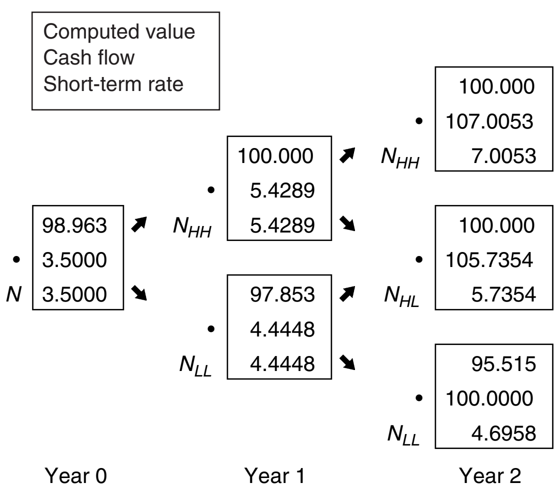
Valuing a Range Note

A *range note* is a security that pays the reference rate only if the rate falls within a band. If the reference rate falls outside the band, whether the lower or upper boundary, no coupon is paid. Typically, the band increases over time.

To illustrate, suppose that the reference rate is, again, the one-year rate and the note has three years to maturity. Suppose further that the band (or coupon schedule) is defined as in Exhibit 36-17. Exhibit 36-18 holds our tree and the cash

EXHIBIT 36-18

Valuation of a Two-Year Range Floater



flows expected at the end of each year. Either the one-year reference rate is paid, or nothing. In the case of this three-year note, there is only one state in which no coupon is paid. Using our recursive valuation method, we can work back through the tree to the current value, 98.963.

EXTENSIONS

We next demonstrate how to compute the option-adjusted spread, effective duration, and the convexity for a fixed income instrument with an embedded option.

Option-Adjusted Spread

We have concerned ourselves with valuation to this point. However, financial market transactions determine the actual price for a fixed income instrument, not a series of calculations on an interest rate lattice. If markets are able to provide a meaningful price (usually a function of the liquidity of the market in which the instrument trades), this price can be translated into an alternative measure of value, the option-adjusted spread (OAS).

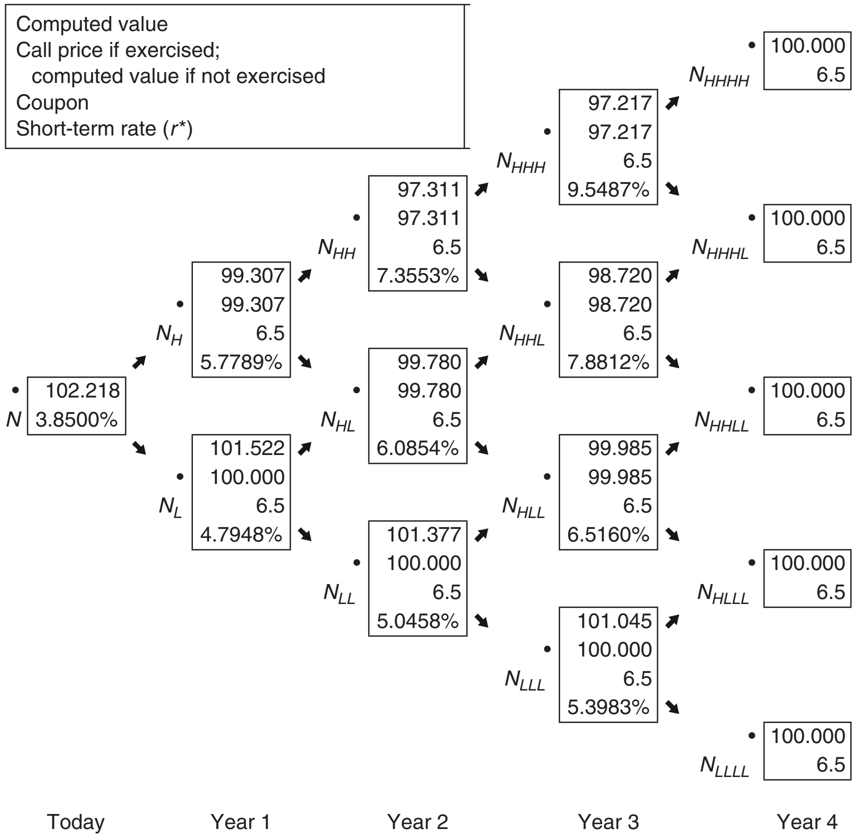
The OAS for a security is the fixed spread (usually measured in basis points) over the benchmark rates that equates the output from the valuation process with the actual market price of the security. For an optionless security, the calculation of OAS is a relatively simple, iterative process. The process is much more analytically challenging with the added complexity of optionality. And just as the value of the option is volatility-dependent, the OAS for a fixed income security with embedded options or an option-like interest-rate product is volatility-dependent.

Recall our illustration in Exhibit 36-11, where the value of a callable bond was calculated as 102.899. Suppose that we had information from the market that the price is actually 102.218. We need the OAS that equates the value from the lattice with the market price. Since the market price is lower than the valuation, the OAS is a positive spread to the rates in the exhibit, rates that we assume to be benchmark rates.

The solution in this case is 35 basis points, which is incorporated into Exhibit 36-19 that shows the value of the callable bond after adding 35 basis points to each rate. The simple binomial tree provides evidence of the complex calculation required to determine the OAS for a callable bond. In Exhibit 36-11, the bond is called at N_{HLL}. However, once the tree is shifted 35 basis points in Exhibit 36-19, the PV of future cash flows at N_{HLL} falls below the call price to 99.985, so the bond is not called at this node. Hence, as the lattice structure grows in size and complexity, the need for computer analytics becomes obvious.

EXHIBIT 36-19

Demonstration That the Option-Adjusted Spread Is 35 Basis Points for a 6.5% Callable Bond Selling at 102.218 (Assuming 10% Volatility)*



*Each one-year rate is 35 basis points greater than in Exhibit 36-11.

Effective Duration and Effective Convexity

Duration and convexity provide a measure of the interest rate risk inherent in a fixed income security. We rely on the lattice model to calculate the effective duration and effective convexity of a bond with an embedded option and other option-like securities. The formulas for these two risk measures are given below:

$$\text{Effective duration} = \frac{V_- - V_+}{2V_0(\Delta r)}$$

$$\text{Effective convexity} = \frac{V_+ + V_- - 2V_0}{2V_0(\Delta r)^2}$$

where V_- and V_+ are the values derived following a parallel shift in the yield curve down and up, respectively, by a fixed spread. The model adjusts for the changes in the value of the embedded call option that result from the shift in the curve in the calculation of V_- and V_+.

Note that the calculations must account for the OAS of the security. Below we provide the steps for the proper calculation of V_+. The calculation for V_- is analogous.

Step 1. Given the market price of the issue, calculate its OAS.

Step 2. Shift the on-the-run yield curve up by a small number of basis points (Δr).

Step 3. Construct a binomial interest-rate tree based on the new yield curve from step 2.

Step 4. Shift the binomial interest-rate tree by the OAS to obtain an "adjusted tree." That is, the calculation of the effective duration and convexity assumes a constant OAS.

Step 5. Use the adjusted tree in step 4 to determine the value of the bond, V_+.

We can perform this calculation for our four-year callable bond with a coupon rate of 6.5%, callable at par selling at 102.218. We computed the OAS for this issue as 35 basis points. Exhibit 36-20 holds the adjusted tree following a shift in the yield curve up by 25 basis points and then adding 35 basis points (the OAS) across the tree. The adjusted tree is then used to value the bond. The resulting value V_+ is 101.621.

To determine the value of V_-, the same five steps are followed except that in step 2, the on-the-run yield curve is shifted down by a small number of basis points (Δr). It can be demonstrated that for our callable bond, the value for V_- is 102.765.

The results are summarized below:

$$\Delta r = 0.0025$$
$$V_+ = 101.621$$
$$V_- = 102.765$$
$$V_0 = 102.218$$

Therefore,

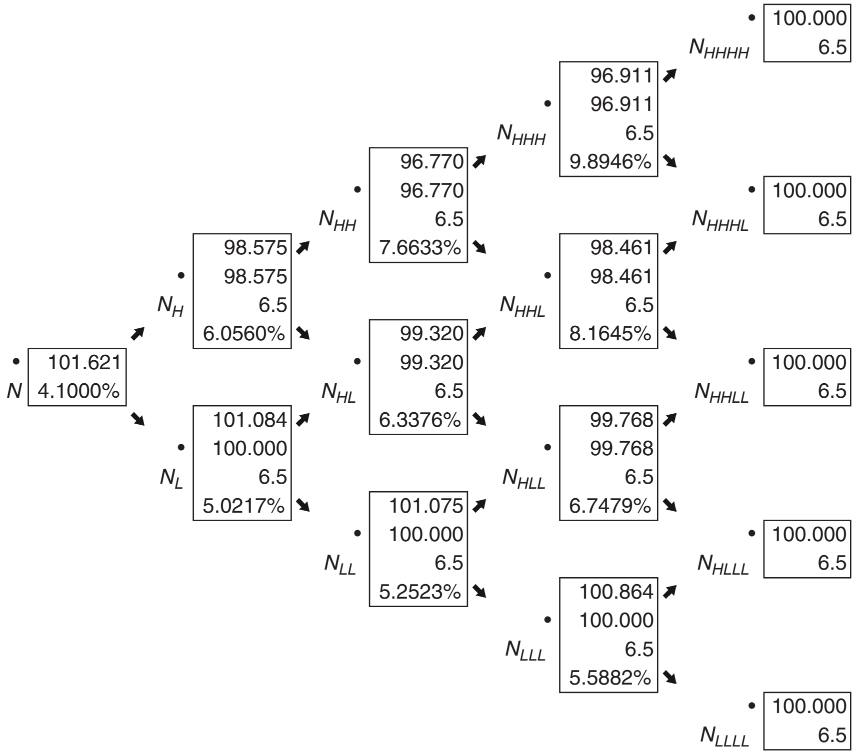
$$\text{Effective duration} = \frac{102.765 - 101.621}{2(102.218)(0.0025)} = 2.24$$

$$\text{Effective convexity} = \frac{101.621 + 102.765 - 2(102.218)}{2(102.218)(0.0025)^2} = -39.1321$$

Notice that this callable bond exhibits negative convexity.

EXHIBIT 36-20

Determination of V_+ for Calculating Effective Duration and Convexity*



*+25 basis point shift in on-the-run yield curve.

KEY POINTS

- For bonds with embedded options, the expected cash flow will depend on future interest-rate levels, which in turn depend on expected interest-rate volatility.
- An interest rate lattice provides a robust means for the valuation of a number of fixed income securities and derivatives.
- Given the market price of a bond, a lattice model can be used to obtain the option-adjusted spread to a benchmark yield curve based on an assumed interest rate volatility.

- A bond's OAS is the fixed spread (usually measured in basis points) over the benchmark rates that equates the output from the valuation process with the actual market price of the security.
- Effective duration and convexity can be computed for a bond by changing the yield-curve up and down by a given number of basis points and calculating what the new prices would be on the revised interest rate tree. These new prices are then used in the standard duration and convexity formula.

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CHAPTER

THIRTY-SEVEN

VALUATION OF MORTGAGE-BACKED SECURITIES

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The valuation of a mortgage-backed security (MBS) is a complex undertaking that requires a variety of inputs and models, including an interest rate process, a prepayment model for projecting speeds along a given interest rate path, and numerous assumptions on the various macro drivers that can influence MBS cash flows. In this chapter, we describe the elements of MBS valuation and the steps involved in pricing an MBS. We start the chapter by reviewing the traditional static valuation techniques that are used for analyzing fixed income securities and explain why they are of limited use when valuing bonds with embedded options, like MBS. We then introduce Monte Carlo simulation and describe several popular interest rate models used for valuing mortgage products. Next, we provide an overview of the overall mortgage modeling framework. This section includes a brief introduction to prepayment models and how they are used in conjunction with term structure models to project the cash flows on mortgage-backed securities. We then introduce option-adjusted spread (OAS) and related analytical measures. We conclude the chapter with an illustrative example.

STATIC VALUATION AND ITS LIMITATIONS

The value of a bond is the present value of its expected future interest and principal payments, that is, its total cash flows, as shown in Equation 37-1:

$$V=\sum_{n=1}^{N}\frac{CF_n}{\left(1+r_n\right)^n}, \tag{37-1}$$

where CF_n is the total cash flow in the nth period, r_n is the discount rate corresponding to a tenor of n periods, and N is the remaining term. Using Equation 37-1, we can back out the **yield to maturity** (YTM) given the market price P of the bond, as illustrated in Equation 37-2. YTM is the anticipated rate of return on a bond if the bond is held until maturity and all intermediate cash flows are reinvested at that same rate, which is unlikely to occur in practice:

$$P=\sum_{n=1}^{N}\frac{CF_n}{\left(1+YTM\right)^n}. \tag{37-2}$$

Yield to maturity has a few common variations to better handle bonds that have embedded options. *Yield to call* assumes that the bond will be called as soon as permitted, and it is therefore calculated using a shorter set of cash flows than is used in the calculation of yield to maturity. *Yield to worst* is used when a bond has multiple embedded options—it is the lowest yield based on all call dates listed in the prospectus.

It is also useful to measure the excess return that a bond offers over a selected benchmark in order to gauge relative value. The simplest such measure is *nominal spread*, which is simply the difference between the yield of the bond and the yield of a similar-maturity Treasury. Mortgage-backed securities return principal to investors throughout the life of the pool. So, the nominal spread on an MBS is typically computed as the difference between yield to maturity and interpolated Treasury yield at the mortgage bond *weighted average life* (WAL). The weighted average life is the average time to receipt of principal, as shown as in Equation 37-3:

$$WAL=\frac{1}{12}\frac{\sum_{n=1}^{N}n\times P_n}{\sum_{n=1}^{N}P_n} \tag{37-3}$$

where P_n is the principal received in month n. In other words, WAL is the time it takes for half of the face value to be returned to the investor. Prepayments (defined below) on mortgage-backed securities reduce the WAL and can hurt or help returns, depending on whether the bond was purchased at a premium or at a discount.

Nominal spread, though simple, has limited value because it is computed with reference to a single point on the benchmark yield curve and therefore does not account for the fact that MBS principal is returned to investors throughout the life of the pool. A better measure of incremental return versus a benchmark is z-spread, which can be found by solving Equation 37-4:

$$P=\sum_{n=1}^{N}\frac{CF_n}{\left(1+y_n+z\right)^n} \tag{37-4}$$

where y_n is the interpolated Treasury/swap yield corresponding to a tenor of n periods. Note that the z-spread may be computed off of the spot yield curve, as shown above, or off of the forward curve, as shown in Equation 37-5:

$$P = \sum_{n=1}^{N} \frac{CF_n}{\prod_{m=1}^{n} \left(1 + f_m + z\right)} \tag{37-5}$$

where f_m is the one-month forward rate for month m. The z-spread is sometimes referred to as the zero vol OAS.

Investors are also interested in gauging how much the value of their portfolio will change in response to a given change in yield. *Modified duration* measures the percentage change in the price of a bond in response to a change in interest rates, as shown in Equation 37-6:

$$ModD = -\frac{1}{P}\frac{dP}{dy} = \frac{\sum_{n=1}^{N} \frac{n \times CF_n}{(1+y)^{n+1}}}{\sum_{n=1}^{N} \frac{CF_n}{(1+y)^{n}}} = \frac{\frac{1}{(1+y)} \sum_{n=1}^{N} n \times PV(CF_n)}{\sum_{n=1}^{N} PV(CF_n)} \tag{37-6}$$

Two related measures are *dollar duration*, which measures the change in the value of a bond for a 100 bps change in rates and *DV01*, which measures the change in the value of a bond for a 1 bp change in rates. *Key rate durations* are extensions of bond duration—they measure the sensitivity of bond price to a change in yield at a specific maturity point on the curve. Collectively, the various measures of duration help fixed income investors design effective investment strategies and gauge risk when managing their portfolios.

Drawbacks of Static Valuation for MBS Analysis

The static valuation metrics described above are widely used in the industry for evaluating many types of bonds and assessing relative value. But a complexity arises in the valuation of mortgage-backed securities because the collateral cash flows are sensitive to the interest rate environment and its evolution. Mortgage loans are usually prepayable by the borrower at any time, so the total principal paid on an MBS pool in any month is the sum of scheduled principal and prepaid principal. In fact, prepayments typically constitute the dominant component of principal payments over the life of the pool.

Prepayment rates or speeds can be measured in terms of a *single monthly mortality* (SMM) rate, which is the ratio of unscheduled principal to the "prepayable" balance. More precisely, the SMM in month n is given by Equation 37-7:

$$SMM_n = \frac{P_n - SP_n}{Bal_{n-1} - SP_n} \tag{37-7}$$

where Bal_{n-1} is the actual balance at the *end* of month $n-1$ while P_n and SP_n are the total and scheduled principal payments occurring *during* month n. Prepayment speeds are usually reported as an annualized percentage rate called the "conditional prepayment rate" (CPR), as shown in Equation 37-8:

$$CPR = 100 \times \left(1 - \left(1 - SMM\right)^{12}\right) \tag{37-8}$$

Perhaps the most obvious limitation of the static approach for MBS analysis is that the prepayment projections, cash flows, and associated valuation metrics are contingent on the single assumed primary mortgage rate path being realized. Any deviation of realized primary mortgage rates from this projected path can dramatically alter the MBS cash flows and any assessments of relative value.

Another drawback of the static approach is that the static yield may significantly overstate the return that the investor will achieve. As mentioned above, yield equals return only if the bond is held to maturity and the reinvestment rate on all intermediate cash flows equals the yield itself. However, in the case of an MBS, this shortcoming is amplified by the impact of the embedded prepayment option. When rates rally, prepayment rates increase, and more principal is returned to the investor, which must be reinvested at a lower rate, resulting in a lower return than implied by the static yield. Conversely, when rates rise, prepayment rates decrease, and less principal is returned to the investor, which cannot be reinvested at a higher rate, again resulting in a lower return than implied by static yield.

An MBS usually offers a higher static yield than duration-matched Treasury securities or swaps. This makes sense, because an unhedged MBS investor is taking a view not only on interest rate levels but also on interest rate volatility. If rates do not move much over the holding period, an MBS position that is duration-hedged with an appropriately sized short position in Treasuries or swaps should provide a positive return, as predicted by the nominal yield spread. But if rates move significantly and prepayments vary, an MBS will likely underperform its duration hedge. Static yield fails to alert the investor to this dynamic behavior. Likewise, z-spread tends to overstate the excess return that an investor can achieve because the impact of the embedded prepayment option is ignored under a static rate assumption.

Yet another limitation of the static valuation approach is that modified duration (defined back in Equation 37-6) cannot be used to accurately gauge the sensitivity of MBS prices to interest rates. This simple method for calculating duration is unable to account for the sensitivity of the cash flows themselves to interest rates and the resulting "price compression" that occurs when yields fall. When rates rally, prepayment speeds increase, leading to a lower price than on an otherwise identical option-free bond.

To be sure, static valuation techniques can be useful for evaluating certain types of mortgage-backed securities with limited prepayment risk—for example, call-protected CMO classes, certain types of nonagency RMBS and CMBS, or

MBS pools backed by adjustable-rate mortgages. But the static metrics are of limited value in analyzing most other types of MBS, including fixed-rate mortgage pass-throughs, interest rate-sensitive CMO classes such as support tranches, and mortgage derivatives (such as IO and PO classes, floaters, and inverse floaters). Indeed, the static metrics are likely to lead to unreliable assessments of relative value across much of the MBS universe.

In contrast with the static valuation approach, the MBS valuation process is quite involved and computationally intensive because it requires the use of several complex models, numerous market inputs and assumptions, and a wide range of borrower and loan attributes. Prepayment models and the speed projections that they produce are at the center of mortgage security valuation and analysis. But mortgage valuation also calls for an option pricing model that can handle the unique characteristics of MBS cash flows, including interest rate sensitivity and path dependence (introduced later in this chapter). So, before we dive into the elements of prepayment modeling, we review several popular interest rate models and introduce Monte Carlo simulation for valuing mortgage-backed securities.

MONTE CARLO MODELS FOR VALUING MBS

MBS valuation calls for a methodology that accounts for the impact of interest rate volatility and fully adjusts for the value of the embedded option. So, how can we go about valuing the option? A closed-form solution, when available is ideal. But closed-form valuation formulas, like the one provided by the Black-Scholes option pricing model, only exist for the simplest types of options such as plain vanilla European-style options on stocks or swap rates. These closed-form formulas are based on arbitrage freedom and dynamic hedging and are certainly not available for valuing options as complex as the prepayment option that is embedded within mortgage-backed securities.

Monte Carlo is a statistical method wherein the set of financial observables required for pricing are simulated many times—each simulation is known as a "path." The security cash flows are then determined on each path and the price is determined as the average of the discounted cash flows over all paths.

Broadly speaking, there are four steps in the Monte Carlo process. First, a model of interest rates must be selected, where the choice of model is determined by characteristics of the security—a balance must be struck between sufficient realism to capture the dynamics that drive the variability in the security price and computational complexity. Second, the model must be calibrated, which amounts to selecting the parameters based on some predetermined criteria. At this point, if the model is too computationally expensive, factor reduction must be employed. Factor reduction is a method of reducing the model complexity such that the price of the security can be determined in a reasonable amount of time with limited resources. The final step is to generate the paths by using the calibrated model to evolve the financial observables and price the security.

We briefly describe each of these steps in the next sections. Our goal here is not to provide a full exposition on term structure modeling and Monte Carlo methods, but rather to give the reader a sense of the various types of term structure models, the considerations that go into selecting a model, and the elements of Monte Carlo simulation.

Choosing an Interest Rate Model

The 10-year swap rate is closely correlated with the primary mortgage rate that is a key driver of MBS cash flows and valuations. The swap rate is a weighted average of observable forward rates where the weightings are determined by the prices of zero-coupon bonds throughout the entire 10-year tenor of the swap. Therefore, as expected LIBOR rates rise, the swap rate correspondingly rises. However, as the shape of the yield curve changes to inverted or to hump-shaped, the corresponding swap rate changes are harder to intuit. It is clear that any model of the evolution of expected LIBOR rates must contain sufficient structure to model the covariances that exist between the LIBOR rates in a realistic way.[1]

Modeling the future evolution of interest rates can be done in a number of ways. The simplest class of models are econometric models, most notably the Nelson-Siegel parameterization, which uses economic motivation to parameterize the yield curve. The parameters are determined for each of a series of dates in the past, and the future values are predicted by using the historical covariances of the parameters. This type of evolution is known as the "real-world measure" approach and is widely used in risk modeling where the future evolution of the yield curve must closely reflect the past evolution, as well as economic forecasting by central banks. However, a drawback of this method is that it does not fit today's term structure exactly and therefore would not correctly price hedging instruments.

The preferred alternative is to use an arbitrage-free model of the term structure. Arbitrage freedom guarantees that the securities that are used to hedge MBS (such as Treasuries and swaps) are correctly priced on all future paths, making it less likely that the target security is mis-hedged. Arbitrage freedom is guaranteed by the Heath-Jarrow-Morton (HJM) condition, which is a relationship between the drift and volatility of the evolution of the forward curve. There are two general classes of HJM models: continuous-rate models and market models.

In continuous-rate models, the yield curve is represented by the instantaneous forward rate, that is, the rate at a specific time for lending over an infinitesimally short time horizon. The most well-known of the continuous-rate models are

1. Tier 1 banks will no longer be required to respond to the LIBOR poll after December 2021, implying that LIBOR may cease to be a valid index after that date. It is expected that the swap market will still be active and liquid but will be based on an alternative index: SOFR in the United States, SONIA in the United Kingdom, ESTR in the Eurozone, and SARON in Switzerland.

the short-rate models such as those due to Ho-Lee,[2] Black-Karasinski,[3] Vasicek,[4] and Hull-White.[5] These are models of the instantaneous short rate, and this one factor drives the dynamics of the entire forward rate curve. No single-factor model will perform adequately for applications to MBS, since their use will inevitably lead to high static correlations between forward rates. There also exist multifactor extensions to these single-factor models that can capture a more realistic structure of the correlations and covariances between the observable forward rates. However, a drawback of all continuous-rate models is that the short rate is not a true financial observable since there is no market security that transacts which depends on this hypothetical rate.

The other classes of HJM models are market models, where the underlying factors are the observable rates themselves. The most popular model in this class is the LIBOR market model,[6] where the set of forward LIBOR rates spanning a time horizon are the stochastic factors.

Exhibit 37-1 summarizes the benefits and drawbacks of several popular interest rate models. The continuous-rate models have the benefit of simplicity and, in the case of some models, admit closed-form solutions for the prices of certain types of securities. Closed-form solutions can greatly enhance the accuracy (as well as the speed) of the Monte Carlo simulations. However, the drawback of all one-factor models is that they cannot adequately simulate the covariance structure necessary to generate realistic dynamics for the swap rate.

The LIBOR Market Model: The preferred interest rate model for pricing mortgage-backed securities is the LIBOR market model (LMM), since it has many underlying factors and therefore can accurately capture the swap rate dynamics. Another benefit of the LMM is that the stochastic factors are financial observable quantities, rendering the calibration process and results much more intuitive. The underlying factors in the LMM are the forward LIBOR rates that span the time from today to the last required simulated date. Typically for mortgages, this is 30 years into the future, which means the LMM can have hundreds of stochastic factors. Therefore, after calibration is performed, a factor reduction step is necessary.

Each individual forward rate is assumed to be lognormally distributed, with a drift that is calculated via the HJM condition to ensure arbitrage freedom. Each

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2. Thomas Ho and Sang-Bin Lee, "Term Structure Movements and Pricing Interest Rate Contingent Claims," *Journal of Finance* (December 1986), pp. 1011–1029.
3. Fischer Black and Piotr Karasinski, "Bond and Option Pricing When Short Rates are Lognormal," *Financial Analysis Journal* (August 1991), pp. 52–59.
4. Oldrich Vasicek, "An Equilibrium Characterization of the Term Structure," *Journal of Financial Economics* (1977), pp. 177–188.
5. John Hull and Alan White, "Pricing Interest-Rate-Derivative Securities," *Review of Financial Studies* (1990), pp. 573–592.
6. Alan Brace, Dariusz Gatarek, and Marek Musiela, "The Market Model of Interest Rate Dynamics," *Mathematical Finance* (1997), pp. 127–155.

EXHIBIT 37-1

Benefits and Drawbacks of Popular Interest Rate Models

Model	*Benefits*	*Drawbacks*
Ho-Lee	Closed-form solutions for bond options, caps/floors, swaptions.	Unrealistic modeling of the interest rate, no mean reversion.
Hull-White	Closed-form solutions for bond options, caps/floors, swaptions. Mean reversion, implying a humped structure for the volatility term structure, something usually seen in market data.	Single-factor models lead to a much higher forward rate correlation than is seen in the market.
Black-Karasinski	Lognormal rates, meaning rates cannot go negative. Until recently, the nonnegative rates assumption was heralded as a benefit of interest rate models. However, in 2015 many non-U.S. rates were seen to go negative.	Leads to nonsensical results for Eurodollar futures, due to its lognormality of rates.
LIBOR Market Model	Driving factors are financial observables. Approximate closed form for swaptions.	High dimensionality of the model can lead to large computational runtime.

of the forward LIBOR rates has a volatility $\sigma_j(t)$, and every pair of forward LIBOR rates has a correlation ρ_{jk}. The dynamics of the forward LIBOR rates are described by the following stochastic differential equation:

$$dL_j(t) = \begin{cases} -L_j(t)\sum_{k=1}^{i-1}\frac{\tau L_k(t)}{1+\tau L_k(t)}\sigma_j(t)\sigma_k(t)\rho_{jk}dt + \sigma_j(t)L_j(t)dW_i & j < i \\ L_j(t)\sigma_j(t)dW_i & j = i \\ L_j(t)\sum_{k=i+1}^{N}\frac{\tau L_k(t)}{1+\tau L_k(t)}\sigma_j(t)\sigma_k(t)\rho_{jk}dt + \sigma_j(t)L_j(t)dW_i & j > i \end{cases} \tag{37-9}$$

Although as written, the LMM cannot handle negative rates, adding a shift parameter is straightforward,[7] and necessary in today's global low-rate environment. This parameter can be calibrated, but typically is set to a small negative level. Alternatively, the LMM can be written such that the forward LIBOR rates follow a normal distribution. There also exist other extensions of the LMM:

7. Eymen Errais, Gianvittorio Mauri, and Fabio Mercurio. "Capturing the Skew in Interest Rate Derivatives: A Shifted Lognormal LIBOR Model with Uncertain Parameters." *Banca IMI Internal Report* (2004).

constant elasticity of variance,[8] stochastic volatility,[9] and jump diffusion.[10] However, these extensions greatly increase the computational complexity of Monte Carlo simulation and are therefore not used as often as the parsimonious normal and shifted lognormal variations.

Calibrating the Model

The parameters required to calibrate the LMM are the initial term structure of interest rates and the covariance matrix containing the volatilities and pairwise correlations of all forward LIBOR rates. There are two approaches to determining the parameters of the model.

The first approach is based exclusively on the historical data. The entries in the covariance matrix are estimated by looking at the relevant historical time series. However, historical time series analysis typically produces covariance matrices that render the model internally inconsistent. Furthermore, if a purely historical approach is used, then the model is not guaranteed to reflect the information on the future evolution of interest rates implied by the current prices of securities.

The preferred approach is to calibrate the covariance and correlation to the current prices of market instruments. Market-implied calibration begins with the current prices of traded securities and the initial term structure of interest rates: short-term cash instruments, forward-rate agreements, swaps, caps/floors, and swaptions. As with all HJM models, the initial term structure of interest rates is an input and therefore the prices of zero-coupon bonds are guaranteed to be exactly reproduced on average by the Monte Carlo simulation. Collectively, caps and floors contain the information about the volatility of the set of forward rates. Swaptions are used to extract the correlations between the forward rates. The output of the calibration process is the covariance matrix that is implied by the market prices of currently traded securities. The entire calibration process can be tested by so-called round tripping, where the calibrated model is used to reproduce the prices of the instruments used in calibration, either exactly or in a least-squares sense.[11]

8. Leif Andersen and Jesper Andreasen, "Volatility Skews and Extension of the LIBOR Market Model," *Applied Mathematical Finance* (2000), pp. 1–32.

9. Riccardo Rebonato, Kenneth McKay, and Richard White, *The SABR/LIBOR Market Model* (John Wiley & Sons Ltd, 2009).

10. Paul Glasserman and S. G. Kou, "The Term Structure of Simple Forward Rates with Jump Risk," *Mathematical Finance* (2003), pp. 383–410.

11. In some parametric forms of the volatility term structure, the prices of market securities cannot all be exactly matched. In this case, the best fit is produced by minimizing the error between the market and model prices.

Factor Reduction

For LIBOR market models, there can be dozens to hundreds of underlying factors that need to be simulated. By choosing even a modest number of Monte Carlo paths, this could result in the need to generate millions of correlated random numbers, which is untenable in terms of computational time as well as storage requirements. Factor reduction techniques help to mitigate this issue.

The goal of factor reduction is to reduce the number of stochastic factors of the model in such a way that the covariance structure is preserved as much as possible. This is accomplished by performing a principal component analysis (PCA) on the calibrated covariance matrix. The calculation is iterative in nature and finds the linear combination of factors with the maximal variance; the first principal component explains the greatest fraction of covariance in the original model, the second explains the next greatest fraction, and so on. Typically, the first few principal components contribute a high fraction of the covariance, and therefore only a small number are retained. Increasing the number of principal components leads to a more faithful model, but at the expense of greater computational complexity.

For interest rate movements, the first three principal components are directly related to the three well-known movements of the yield curve: parallel shift, twist, and buckle. These three principal components will generally explain a large share of the entire covariance of the yield curve. Since the amount of covariance explained can be quantified, it can be used as the decision criterion to determine how many principal components to use in the Monte Carlo simulation. Usually the first three principal components suffice, as they typically account for over 70% of the total covariance.

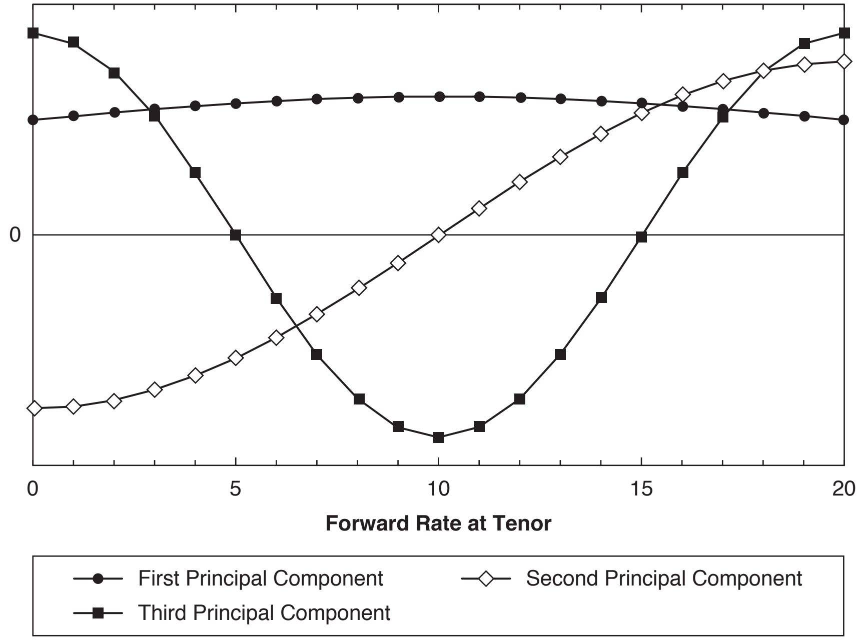
Exhibit 37-2 displays a typical principal component analysis showing the first three principal components of a covariance matrix describing forward rates. The largest contribution to the covariance of the forward curve comes from the first principal component, which is represented by a linear combination of LIBOR rates with all positive contribution—it therefore represents parallel shifts of the yield curve. The linear combination corresponding to the second largest contribution changes sign representing a twist effect. The third largest contribution is seen to change sign twice, and this contribution is known by various names such as "shape effect" or "buckle."

Path Generation

The final step is to generate correlated random numbers and construct the arbitrage free paths of the future observable rates. Exhibit 37-3 shows 200 possible interest rate paths from the shifted LIBOR Market Model. On each path, the prepayment model and the cash-flow engine (both of which are discussed in the next section) are used to generate the speeds and corresponding cash flows. Given the cash flows, the bond can be priced. The error in the Monte Carlo estimate decreases as the number of paths increases. Therefore, choosing a large number

EXHIBIT 37-2

Largest Principal Components of the Forward Curve—Shift, Twist, and Buckle

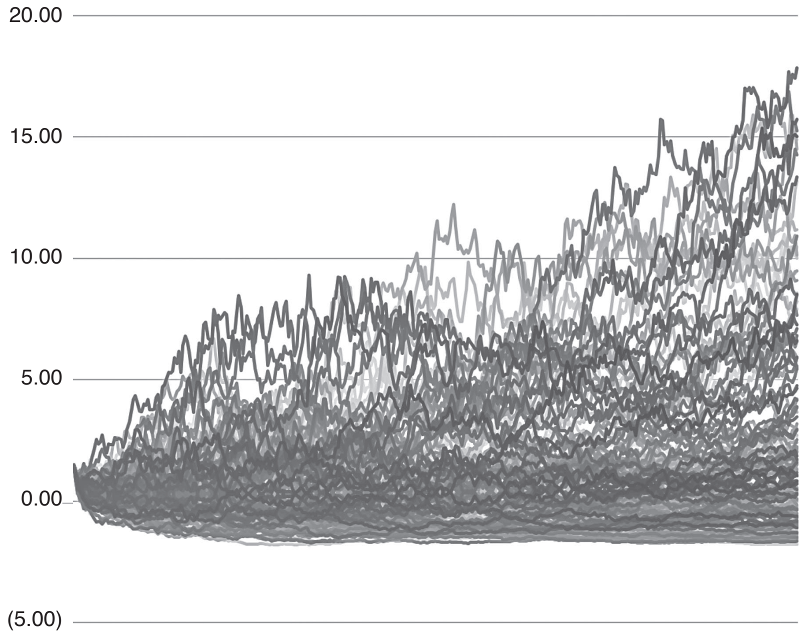


of paths is desirable, but this choice must be balanced against the constraint that the pricing calculation needs to complete in a reasonable time. This is of particular concern in the analysis of mortgage-backed securities since computing the cash flows on each individual path takes a relatively long time due to the complex relationship between interest rates and prepayments. Furthermore, in the case of CMOs, the cash-flow waterfall (which is itself path dependent) must be applied along each path.

Since Monte Carlo is a statistical technique, the resulting price has a distribution; each simulation (performed using a different set of random numbers) results in a different price. Therefore, the price has an associated variance that can be reduced in two ways. Increasing the number of paths will certainly reduce the variance. Alternatively, variance reduction techniques can be applied that can produce a more accurate result for a given number of paths. These techniques typically use knowledge of the specific problem under consideration. However, there is one variance reduction technique that can be applied to any Monte Carlo problem—for every vector of random numbers used to generate a Monte Carlo path, the complement of this path is also generated by using the negative of the original random numbers. This eliminates any bias in the paths that could be introduced by the random nature of the sampling process.

EXHIBIT 37-3

Monte Carlo Paths Generated Using the Shifted LIBOR Market Model (Shift = 200 Bps)



MBS MODELING FRAMEWORK

Next, we turn to the problem of projecting the future cash flows on a mortgage pool given a primary mortgage rate path. This requires a prepayment model as well as a mechanism for projecting the primary mortgage rate, a forecast for home price appreciation (HPA), and finally a cash-flow calculator. We describe each of these components next.

Projecting the Primary Mortgage Rate

Any forecast of MBS prepayments is contingent on a specified path of the primary mortgage rate. While primary mortgage rates are closely correlated with other market rates such as Treasury yields or swap rates, mortgage rates are also influenced by drivers unique to the mortgage market (such as pricing in the secondary mortgage market) as well as by certain non-market-driven factors. Because of this, a nontrivial methodology is required to translate the interest rate paths generated by Monte Carlo simulation into primary mortgage rate paths. A useful first step is to decompose the primary rate into the current coupon yield and the primary–secondary spread. The current coupon yield is the yield on a (likely hypothetical) par priced MBS and the primary–secondary spread is the difference between the prevailing primary mortgage rate and the current coupon yield. The goal here is to isolate the secondary market component that moves more tightly with swap or Treasury yields from the spread component that is less market driven.

There are two main approaches used in the market for estimating the current coupon yield: a regression-based approach and a risk-neutral approach. The regression-based method is simple and intuitive—the historical data is regressed on one or more market rates, say, for example, the 2-year and 10-year swap or Treasury yields. But this methodology ignores the fact that mortgage rates are driven by all tenors on the yield curve. An alternative is to utilize a risk neutral method like Citi's Mortgage Option-Adjusted Term Structure (MOATS) model methodology.[12] In this approach, the current coupon yield is calculated within the Monte Carlo generator itself via a backward-induction algorithm that accounts for the prepayment option. This approach results in a more dynamic and realistic model of the primary rate but is much more computationally intensive. Both methods are widely used in the market, but one model may be more suitable than the other depending on the prevailing market environment.

The other component of the primary rate, the primary–secondary spread, consists of two components: the guarantee fee (or "g-fee") that is charged by the agency and the servicing spread, which is compensation to the loan servicer. The guarantee fee itself consists of an upfront component and an ongoing component. Upfront fees are paid to the agency at origination and they are a function of a variety of loan attributes such as loan-to-value ratio, borrower attributes such as credit score, and several other factors. The ongoing component of the guarantee fee is built into the primary rate that is offered to potential borrowers. But lenders also will typically convert the upfront component of the g-fee to an ongoing basis and add it to the mortgage rate that the borrower pays.

Turning to the servicing spread, the government sponsored enterprises (GSEs), that is, Fannie Mae and Freddie Mac, usually require a minimum of 25 bps of retained servicing for 30-year fixed loans. The remainder of the servicing spread beyond the mandated minimum is known as excess servicing and lenders have some discretion in setting the level. Excess servicing can rise significantly in response to market conditions, especially during periods of housing market distress or when delinquency rates begin to rise.

The risk of loan putback can also lead to a widening in the level of excess servicing. The GSEs have the right to put back to lenders loans that violate any of the reps and warrants (R&W). Reps and warrants allow the GSEs to purchase and guarantee loans without having to perform a thorough credit evaluation on each loan—therefore, they help to support credit availability. But putback costs

12. Ranjit Bhattacharjee and Lakhbir S. Hayre, "The Term Structure of Mortgage Rates," *The Journal of Fixed Income* (Spring 2006), pp. 34–47.

skyrocketed during the financial crisis as defaults surged and the GSEs became more aggressive in terms of enforcing the reps and warrants. To mitigate the risk of putback, originators began applying credit overlays and expending more time and effort into underwriting, leading to higher underwriting costs. Putback risk has eased over the past few years as the GSEs have taken steps to provide rep and warrant relief, including the introduction of sunset provisions.

Finally, the level of excess servicing is also influenced by mortgage lending capacity vis-à-vis demand. When rates drop quickly, the demand for refinancing loans (as well as purchase loans) tends to spike and overwhelm the origination pipeline, leading to "capacity constraints" in the mortgage lending system. It takes time for the industry to add loan origination capacity to meet the increased demand. In the interim, lenders' pricing power increases, which can lead to a widening of the level of excess servicing. As the industry gradually staffs up and capacity constraints ease, excess servicing gradually reverts to more "normal" levels.

Modeling Mortgage Prepayments

Practitioners generally rely on econometric prepayment models, and associated auxiliary models, to generate speed forecasts. These models project speeds based on a selected set of explanatory variables and make many assumptions on the future evolution of the drivers of prepayments along with the interrelationships between the various sources of prepayments. A good model is based on intuitive relationships that are likely to persist over time. But a modeling framework must also be dynamic and flexible enough for the modeler to quickly react to regime shifts or changes in the macro backdrop. Given the amount of judgment and the wide range of assumptions that go into a model, any set of prepayment projections clearly contains an element of subjectivity. In short, MBS prepayment modeling and valuation is part science, part art.

Practitioners should take the time to fully understand the model assumptions and the implications on valuations. A practitioner should also be aware of the scope of the model in use, recent market changes that the model may not be capturing, and any other limitations. The practitioner should ask questions such as the following:

- Are there important prepayment drivers that the model excludes?
- Is the model capturing the impact of recent regulatory initiatives?
- Is the projected primary mortgage rate path reasonable?
- Is the model assumption on home price growth realistic?
- Are baseline speeds appropriate, given the economic environment and housing fundamentals?

Most prepayment models expose certain dials that the practitioner can adjust in order to express a difference of opinion versus the model assumptions or to extend the model to handle out-of-scope collateral types. Common user-facing dials include refi and turnover multipliers, refi S curve steepener/flattener and elbow shift, length of the turnover seasoning ramp, and overrides on external economic drivers such as home price growth.

With these considerations in mind, we examine the sources of prepayments in MBS pools and their key drivers.

Rate-driven refinancings: Refinancings are the most volatile component of prepayments, with speeds surging when rates decline and falling sharply when rates increase. From this perspective, an MBS pool can be likened to a callable corporate bond. However, rate-driven refis are much harder to predict than corporate bond redemptions for several reasons:

- Mortgage-backed securities have embedded within them hundreds or thousands of individual prepayment options—the investor has in effect sold a call option to each underlying borrower. So, it is necessary to project the collective responsiveness of numerous borrowers versus a single entity (typically the chief financial officer of the issuing corporation).
- The economics of refinancing differs across borrowers because of factors such as variation in the note rate, expected home tenure, and credit profile.
- Redemption efficiency also varies across borrowers as the most financially savvy borrowers tend to refinance relatively promptly, while less savvy or more credit-impaired borrowers are more likely to delay exercise.

The refi response function is modeled as an S curve representing the relationship between refi speeds and interest rate incentive. A pool's aggregate S curve is not static—it represents the rate sensitivity of prepayment speeds at a particular point in time, based on the composition of the pool at that time and prevailing market conditions. The shape of the S curve (slope, amplitude, and elbow) gradually changes over time as the pool composition evolves, in part because of the difference in realized speeds across the fast and slow populations within the pool. The economic environment, underwriting standards, and policy initiatives also drive the overall shape of the S curve. Seasoning also plays a role—pools backed by newly originated loans tend to be less responsive to interest rates, as borrowers who have just refinanced or recently purchased a home are less likely to immediately move or refinance again, regardless of rate levels. Reactivity gradually increases, or equivalently, the S curve becomes steeper, as the pool seasons. But responsiveness tends to be lower on very seasoned pools, as the most reactive borrowers have already exited the pool.

Cashout refis: Borrowers who have accumulated significant equity since loan origination (via amortization or an increase in home value) may refinance the existing loan to extract some of that equity—this is known as a cashout refi. The borrower may be facing financial hardship or may wish to use the cash for home improvements or to pay down non-tax-deductible consumer debt. As the name implies, cashouts are primarily motivated by a desire for cash rather than a lower rate. Cashouts do usually result in a lower mortgage rate, but under certain circumstances, a borrower may choose to extract built-up equity even if it does not lead to a lower mortgage rate.

Home price growth, housing market sentiment, and easing lending standards are key determinants of cashout refi speeds, which can be very significant under favorable market conditions. Cashouts were popular in the years leading up to the financial crisis, but almost disappeared during the crisis as home prices plummeted and underwriting standards tightened. In recent years, the share of cashout refis has picked up again fueled by an improving macro backdrop, strong home price growth, and gradually easing underwriting standards.

Credit-driven refis: Borrowers whose credit profile has measurably improved since loan origination may be able to qualify for cheaper financing, even if overall interest rates have not declined—this is known a credit-driven refi. In theory, credit-driven refi rates should be negligible for several months after loan origination and tend to gradually rise as the pool seasons and the underlying borrowers continue to make on-time payments on their mortgages and other financial obligations.

Housing turnover: Housing turnover is the second most significant source of prepayments in agency MBS pools and generally becomes the dominant component of total speeds when a pool is out of the money. Conventional mortgage loans typically contain a "due on sale" clause, so a property sale leads to a prepayment of the outstanding loan balance. Turnover speeds tend to be very slow early in the life of a mortgage pool, especially in the case of purchase loans, as borrowers who have recently moved are unlikely to do so again for a while. Turnover speeds typically rise to their fully seasoned level over the course of two to three years. Turnover speeds also show a strong seasonal pattern with speeds peaking during the summer months and dropping off in winter.

Turnover does show mild dependence on interest rates—mortgage rates influence affordability, so higher rates can make it harder for borrowers to trade up. Furthermore, a borrower with a below-market note rate may be reluctant to relinquish that rate and may delay moving. This phenomenon is known as "lock-in." However, home sales are much less dependent on interest rates than refinancings because they are often motivated by necessity (e.g., marriage, divorce, growing family, and job change), placing a floor on turnover speeds as well as total prepayment speeds.

Curtailments: Debt aversion or the desire to build equity faster may lead some borrowers to accelerate loan paydown by remitting more than the scheduled monthly payment. This is known as a curtailment and is passed through to investors as a partial prepayment of the outstanding balance. Curtailments, as well as full payoffs, tend to be very low early in the life of a pool, but become significant late in the life of a pool as borrowers grow older and wish to eliminate mortgage debt prior to retirement. Older borrowers may also be more financially stable than their younger counterparts and are more likely to have spare cash available that can be used to reduce mortgage debt.

Involuntary prepayments: When a borrower stops making timely mortgage payments, the owner of the mortgage note has the right to foreclose on the property, leading to a prepayment, principal write-down, or some combination of the two. Regardless of whether the defaulted loan backs an agency or nonagency pool, it flows through the same process of moving from foreclosure to real estate–owned (REO) or other form of liquidation. But there is a difference in how losses are recognized on defaulted loans within agency versus nonagency mortgage pools. In agency pools, a loan default is passed through to investors as a full prepayment of the principal balance. In nonagency pools, a default isn't recognized until loan liquidation and it may result in a partial or full write-down of the outstanding loan balance if the net sales proceeds are insufficient to pay off the loan.

Current LTV as well as the borrower's credit profile are the key determinants of default. In theory, default should not occur so long as the current LTV is under 100%, because the borrower can simply sell the property to avoid default. But in practice, financial hardship also plays a role—therefore, the borrower's credit profile and external macro factors are also important default drivers.

Path Dependence and Its Implications

This discussion on the sources and drivers of prepayments brings to light a critical difference between mortgage-backed securities and callable corporates. While both types of investments have embedded optionality, MBS cash flows are path dependent. This means that the future cash flows on an MBS at any point in time are a function not just of prevailing interest rate levels but also of the path along which interest rates (and other driving variables) reached their current level. Path dependence largely dictates the appropriate valuation methodology for mortgage-backed securities. To correctly price an MBS and fully account for the embedded prepayment option, we must generally look beyond closed-form solutions and lattice-based methods that can be used in the valuation of less complex financial instruments.

Burnout is a well-known example of how path dependence manifests itself in MBS prepayment behavior. The responsiveness of a mortgage pool at any point in time is a function of the degree of past exposure to refi opportunities. When a pool moves into the money, the most reactive borrowers refinance and exit the pool, leaving behind the less reactive borrowers. Therefore, all else equal, a pool that has been deep in the money for an extended period in the past is likely to be much less reactive than an otherwise similar pool that moves into the money for the first time since origination.

The interaction between voluntary and involuntary prepayments is another manifestation of path dependence—fast early refis in a mortgage pool are likely to reduce lifetime cumulative defaults, since fewer loans remain outstanding that can default in the future.

Housing Market Outlook

Mortgage valuation requires practitioners to take a view on housing market fundamentals. An MBS cash flow forecast is contingent on an assumed path of home price appreciation (HPA), the pace of future home sales, the availability of mortgage credit, and other housing-related drivers. Cumulative HPA is a key determinant of current LTV, which is the main driver of mortgage defaults. HPA is also a determinant of loss severity and the recovery lag on nonagency loans. Likewise, the frequency of cashout refis is also directly tied to HPA, as it determines the pace at which borrowers build extractable equity.

Housing fundamentals are also a key driver of turnover speeds. Turnover can be estimated as the ratio of existing home sales to the total single-family housing stock. The correlation between the two metrics is not perfect, as the existing home sales/housing stock ratio is based on the entire housing market, consisting of properties backing agency loans, nonagency loans, and whole loans, as well as foreclosed properties and homes without a mortgage. However, this ratio still provides a good sense of aggregate turnover trends.

Moreover, HPA encourages trade-ups, leading to a shorter turnover seasoning ramp and faster aggregate speeds. Strong home price growth can also encourage lenders to loosen underwriting standards, which can help to support home sales, especially for first-time buyers. But the availability of housing and the pace of building can also influence turnover. The inventory of homes for sale currently stands near record low levels—limited availability can make it harder for borrowers to trade up or to relocate for other purposes.

Cash-Flow Engine

The projected voluntary and involuntary prepayment speeds and other required assumptions described above are passed to a cash-flow model to generate the principal and interest payments on the mortgage-backed security. The projected cash flows can then be used for further analysis and for computing a variety of valuation and sensitivity measures. Cash-flow modeling involves two main steps: (1) projecting the cash flows on the underlying asset pool and (2) modeling the waterfall, that is, the collection of rules that determine the order in which principal and interest payments are distributed to the various tranches in the deal. The deal structure can be as simple as a pass-through, in which all the principal and interest payments are remitted to investors on a pro rata basis. The structure can also be much more complex with a variety of tranche types and variable principal and interest waterfalls.

OPTION-ADJUSTED VALUATION METRICS

Armed with a methodology for producing the Monte Carlo interest rate paths, as well as a prepayment model as described above, we are now ready to produce MBS analytics that account for the dynamic evolution of interest rates and the optionality embedded within mortgage-backed securities.

Option-Adjusted Spread

Option-adjusted spread (OAS) is defined as the unique spread over the forward rates on each Monte Carlo path that is required for the option pricing model to reproduce the market observable price, as shown in Equation 37-10. Unlike z-spread, which is calculated over a single path of forward rates, OAS takes into account the potential for the cash flows to change in differing interest rate environments. OAS is computed iteratively by starting with an initial guess and adjusting it until the resulting price matches the market price to within some tolerance.

$$P = E\left[\sum_{n=1}^{N} \frac{CF_n}{\prod_{m=1}^{n}\left(1+f_m+OAS\right)}\right] \tag{37-10}$$

The value of the embedded option is calculated as the difference between z-spread to forward rates and OAS, as shown in Equation 37-11:

$$\text{Option Cost} = z - OAS. \tag{37-11}$$

A positive option cost implies that the investor is short the option whereas a negative option cost implies that the investor is long the option. Mortgage-backed securities always have nonnegative option cost, since the investor is short the prepayment option.

OAS is a useful indicator of relative value and excess returns over Treasuries or swaps and is a key tool that is widely used by investors for deciding whether a mortgage-backed security is rich or cheap versus historical levels or versus other bonds. It is a significant improvement over the static valuation metrics described earlier. Nevertheless, investors should keep in mind that OAS is an extremely model-dependent valuation metric. This should be clear from the large number of assumptions and steps that go into its calculation. The strong model dependency means that the excess return implied by the OAS will not be precisely realized in practice unless all of the model assumptions are realized, which is of course, extremely unlikely. Model dependency also implies that option-adjusted spreads produced by different models are extremely unlikely to match each other. Therefore, OAS comparisons should be only be made *within* a specified modeling framework, never across different modeling frameworks.

Effective Duration and Effective Convexity

As mentioned earlier in this chapter, the traditional measures of interest rate sensitivity, such as modified duration, assume that the cash flows remain unchanged when yields change—these metrics are therefore unsuitable for the analysis of mortgage-backed securities. Effective duration (also known as option-adjusted duration) is computed using simulated Monte Carlo paths and therefore accounts for the change in the cash flows (based on the prepayment model) under the shocked rate scenarios.

Effective and modified duration are generally close on securities whose cash flows do not change with interest rates, such as noncallable fixed-rate bonds, and when the interest rate curve is relatively flat. However, for securities with optionality, rational issuers (or borrowers, in the case of MBS) will alter their decisions based on interest rates and exercise the option when it is beneficial. The deviation between effective and modified duration on mortgage-backed securities is driven by the interest-rate-sensitive nature of the cash flows.

The procedure for computing effective duration is as follows. The OAS is first computed based on the market price of the bond. The interest rate curve is then shocked up by adding a fixed number of basis points, Δr, to the entire term structure of interest rates. The shifted interest rate curve is then used with the arbitrage-free term structure model to generate a new set of Monte Carlo paths and the bond is repriced, holding OAS constant. Subsequently, the interest rate curve is shocked downward by the same number of basis points, a new set of Monte Carlo paths is generated, and the bond is priced again. Effective duration is defined as follows:

$$\text{Effective duration} = \frac{P_- - P_+}{2P_0 \Delta r} \tag{37-12}$$

where P_0 is the price of the bond based on the prevailing yield curve and P_- and P_+ are the values of the bond when yields are shifted down and up, respectively, by Δr.

Duration is a linear measure and therefore the predicted price change is a good approximation to the true price change for small shifts in interest rates but starts to diverge when the rate shift grows. For larger interest rate shifts, the linear approximation breaks down and one needs to introduce a second-order, or parabolic, correction. This second-order correction is known as convexity. For securities with positive convexity, the linear approximation underestimates the true price increase when rates fall and overestimates the true price decrease when rates rise. Conversely, for securities with negative convexity, the linear approximation overestimates the true price increase when rates fall and underestimates the price decrease when rates rise.

Effective convexity is calculated by an identical process to the one that is used to calculate effective duration, that is, the interest rate curve is shifted up and down by a fixed number of basis points and the full recalculation of the security price is performed using the option pricing model. Effective convexity is defined as follows:

$$\text{Effective convexity} = \frac{P_{+} - 2P_{0} + P_{-}}{P_{0}\Delta r^{2}}. \tag{37-13}$$

In contrast with noncallable bonds, convexity on many types of mortgage-backed securities is negative over a wide range of interest rates because the investor is short the embedded prepayment option. The price compression mentioned earlier in this chapter is a direct result of the negative convexity of MBS.

Extensions to Effective Duration

Effective duration has embedded within it a number of implicit assumptions that can limit its utility. It represents the sensitivity to a parallel shift of the yield curve and also assumes that volatilities and OAS remain fixed when rates change. In practice, the yield curve may change in much more unpredictable ways and may be accompanied by changes in volatility, spreads, and other drivers of MBS valuations.

The option-adjusted valuation approach described above can be used to compute many different kinds of price sensitivities beyond a parallel curve shift. Collectively, these sensitivities are known as "partial effective durations." Each such measure describes the sensitivity of bond price to a specific driver of value. The methodology is similar to the one that is used to compute effective duration, given in Equation 37-12. That is, a particular factor is shocked up and down, new Monte Carlo paths are generated, and the bond is repriced, holding OAS constant. The effective partial duration with respect to a factor F is given by the following:

$$\text{Effective partial duration} = \frac{P_{-}^{F} - P_{+}^{F}}{2P_{0}\Delta F}, \tag{37-14}$$

where P_{-}^{F} and P_{+}^{F} are the values of the security when the factor F is shifted down and up, respectively, by ΔF units.

Equation 37-14 can be used to compute key rate effective durations (KRD) by shocking individual tenors or sections of the yield curve while the rest of the curve is held constant. Exposure to other types of yield-curve movements such as twist and buckle can also be computed using this methodology. Moreover, price sensitivities to factors beyond interest rate levels can also be calculated. For instance, vol duration is the sensitivity of bond price to changes in the interest rate volatility assumptions that are used in the generation of the simulated Monte Carlo paths. Likewise, spread duration can be computed by perturbing only the bond's option-adjusted spread, holding all else constant.

AN ILLUSTRATIVE EXAMPLE

In this section, we review a set of analytical results on Fannie Mae 30-year 3.0s of 2019 using static analysis and using two different term structure models. The purpose of this example is to illustrate the steps involved in computing selected static and option-adjusted analytics, compare the analytics under different approaches, and understand how the analytics change as the underlying assumptions shift.

The process to produce selected static and option-adjusted valuation metrics is summarized below:

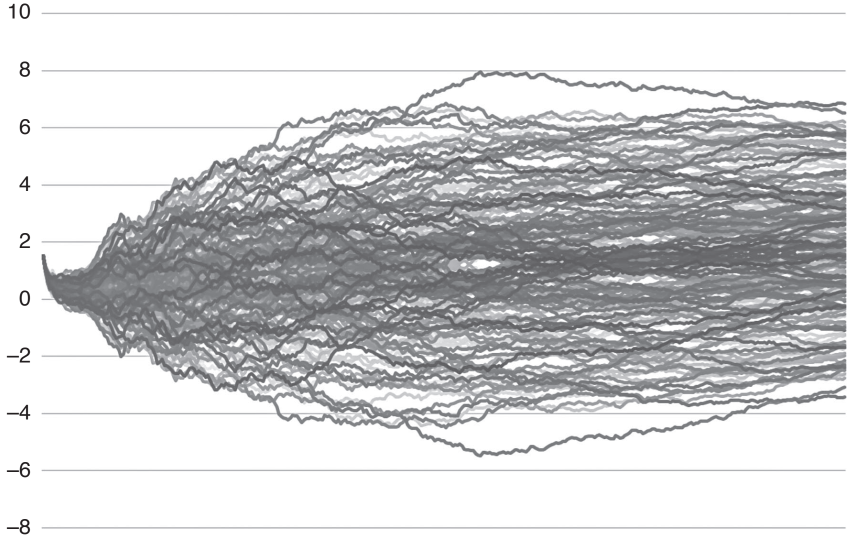
1. Select a term structure model and generate a set of interest rate paths (as illustrated in Exhibit 37-4)
2. For each path,
   - **a.** Determine the cash flows along this path (see Exhibit 37-5).
     1. Compute the sequence of prepayment speeds.
     2. Compute scheduled and unscheduled principal payments and interest payments on the collateral and on the bond.
   - **b.** Discount the cash flows using an initial guess for OAS to obtain the price on this path.
3. Compute the yield, WAL, and z-spread based on the cash flows along the forward path of interest rates (see Exhibit 37-6)
4. Find the OAS that makes the computed average price across all Monte Carlo paths equal to the market price of the security (see Exhibit 37-6)

Regarding the selection of a term structure model, the normal LLM (illustrated in Exhibit 37-4) may be preferable when market interest rates are approaching zero and negative rate paths become more plausible. Of course, a shifted lognormal process (illustrated in Exhibit 37-3) can generate negative rates—but the value of the shift, 200 bps in our example, limits how far below zero rate paths can go.

Along each Monte Carlo path, the prepayment model is used to produce a sequence of single monthly mortality rates. Likewise, the prepayment model also projects speeds along the forward curve. The cash-flow engine then computes along each path the principal, interest, and total cash flows on the underlying collateral and on the mortgage bond. Exhibit 37-5 shows the projected bond cash flows for the next 18 months along the forward curve. Readers may notice that prepayment speeds ramp up rapidly over the next few months, in part due to seasoning and turnover seasonality, but mostly due to a sharply lower primary mortgage rate. The table illustrates how a decline in interest rates can lead to a significant rise in prepayment speeds especially in the case of recent-vintage collateral that sits near the "cusp" of the refi S curve.

EXHIBIT 37-4

Monte Carlo Paths Generated Using the Normal LIBOR Market Model



Once the cash flows have been generated, the various valuation metrics can be calculated, as described in this chapter. Exhibit 37-6 shows the results of our analysis—WAL and z-spread along the forward curve and option-adjusted analytics based on the shifted lognormal LMM and the normal LLM.

The table illustrates the large difference between the z-spread and the option-adjusted spread (computed using either of the two term structure models). As mentioned above, z-spread typically overstates MBS return as it ignores the impact of the embedded option that the investor has sold. Nevertheless, z-spread and the other static valuation metrics can be useful for certain applications because of their relative simplicity.

All of the metrics, especially OAS and related measures like effective duration, are highly dependent on the underlying models and assumptions. In our example, changing only the term structure model while using the same prepayment model leads to big movements in OAS and effective duration. These results highlight the importance of utilizing a consistent analytical framework when evaluating mortgage-backed securities or gauging relative value. For investors who want to measure relative performance or compute tracking errors, it is important to assess both the benchmark and the portfolio within the same modeling framework. Otherwise, any measures of relative performance are likely to be distorted and the tracking errors are likely to be overstated.

EXHIBIT 37-5

Projected Cash Flows (First 18 Months) on Fannie Mae 30-Yr 3.0s of 2019 Along the Forward Curve

Month	Balance	Scheduled Principal	Prepaid Principal	Total Principal	Interest	Total Payment	CPR
25-Apr-20	$949,030	$1,461	$8,279	$9,740	$2,397	$12,137	9.9
25-May-20	$936,215	$1,453	$11,362	$12,815	$2,373	$15,188	13.5
25-Jun-20	$907,684	$1,441	$27,091	$28,531	$2,341	$30,872	29.7
25-Jul-20	$870,678	$1,403	$35,602	$37,006	$2,269	$39,275	38.2
25-Aug-20	$832,629	$1,353	$36,697	$38,049	$2,177	$40,226	40.4
25-Sep-20	$797,962	$1,300	$33,367	$34,667	$2,082	$36,748	38.8
25-Oct-20	$767,587	$1,252	$29,124	$30,375	$1,995	$32,370	36.0
25-Nov-20	$738,720	$1,210	$27,657	$28,867	$1,919	$30,786	35.7
25-Dec-20	$713,097	$1,170	$24,453	$25,623	$1,847	$27,470	33.3
25-Jan-21	$688,611	$1,135	$23,351	$24,486	$1,783	$26,269	33.0
25-Feb-21	$666,379	$1,101	$21,131	$22,232	$1,722	$23,953	31.2
25-Mar-21	$647,189	$1,071	$18,119	$19,190	$1,666	$20,856	28.2
25-Apr-21	$626,951	$1,045	$19,193	$20,238	$1,618	$21,856	30.4
25-May-21	$608,123	$1,017	$17,811	$18,828	$1,567	$20,395	29.3
25-Jun-21	$589,671	$991	$17,461	$18,453	$1,520	$19,973	29.5
25-Jul-21	$572,475	$966	$16,229	$17,195	$1,474	$18,670	28.5
25-Aug-21	$555,860	$943	$15,673	$16,615	$1,431	$18,046	28.4
25-Sep-21	$539,871	$920	$15,070	$15,990	$1,390	$17,379	28.1
. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

EXHIBIT 37-6

Analytical Results (as of March 27, 2020)

	Forward Curve	Shifted Lognormal LMM	Normal LMM
WAL/Effective Duration	3.83	2.14	1.71
Z-spread/OAS (bps)	82	16	31
Option Cost (bps)	NA	66	51
Effective Convexity	NA	–1.35	–0.76

KEY POINTS

- A complete mortgage valuation framework includes a prepayment model, a cash-flow engine, a methodology for forecasting house prices, a term structure model, and a mechanism for translating Monte Carlo interest rate paths into a primary mortgage rate projection.
- Econometric prepayment models are at the center of mortgage security valuation and analysis. These models predict the collective response of borrowers using a wide range of borrower and loan attributes and macroeconomic drivers. A good model is based on intuitive relationships that are likely to persist over time. But every model needs to be reassessed from time to time to determine if the methodology needs to be updated based on prevailing market conditions.
- Monte Carlo simulation is generally used to price mortgage-backed securities due to the path-dependent nature of their cash flows; variance reduction techniques must also be utilized, since the entire valuation process, which may include modeling a cash-flow waterfall, can be computationally intensive.
- The preferred interest rate model for pricing mortgage-backed securities is the LIBOR market model (LMM), since it is calibrated based on observable market instruments and has a sufficient number of underlying factors to accurately capture the swap rate dynamics. Although the standard LMM is a lognormal model of forward LIBOR rates, other variants exist that can handle negative rates, such as the shifted lognormal LMM and the normal LMM.
- The traditional static valuation metrics, such as yield and z-spread, have the benefit of simplicity and can be useful for certain applications. However, the option-adjusted analytics, including OAS, effective duration, and effective convexity, offer a significant improvement over the static measures as they account for the embedded optionality and sensitivity of MBS cash flows to interest rates.

- Given the wide range of assumptions and the amount of subjectivity involved in mortgage valuation, investors should take care to utilize a consistent analytical framework when evaluating bonds or gauging relative value. It is also important for investors to understand the strengths and weaknesses of the different valuation metrics, while keeping in mind that there is no single best measure of value. A variety of analysis techniques, taken together as part of a consistent framework, help the savvy investor build an intuition as to the drivers of return and associated risks of the target security.

CHAPTER

THIRTY-EIGHT

CONVERTIBLE SECURITIES

Mihir Bhattacharya, Ph.D.

Convertible notes or debentures are hybrid equity-linked securities that span the space from common stock on the one hand to nonconvertible (straight) debt on the other, and analogously for convertibles in their preferred share forms. The popularity of their structural variations wax and wane, largely driven by macro factors and market conditions under which issuer needs are balanced against investor participation and preferences, most often through intermediary investment banks. Specifically, during periods of attractive arbitrage opportunities, typically associated with moderate to high volatility in equities, interest rates, and credit spreads (and currencies, if applicable) concurrent with accompanying liquidity, participation by hedge funds tends to dominate. Under these conditions, convertible structures have emerged with several embedded options, path dependencies, and hence complexities. On the other hand, absent these conditions, to wit, during periods of low interest rates, low volatility, and low liquidity, *long-only investors*, also known as *outright investors*, who do not short the underlying stock and/or undertake other hedging trades, tend to be the principal investors with preference for relatively simpler or traditional structures.[1]

In any event, the balancing of issuer needs against preferences of the holders is achieved through varying the levels of the available structural descriptors of this hybrid asset class. The volume and structure selection of convertible issuance each year, therefore, depend on the aforementioned macro factors. In the current context, they have coalesced around relatively short-dated convertible obligations, notes in particular—the so-called *plain vanilla convertible note*—and *mandatorily convertible preferred shares*, with the former in preponderance.

Perpetual convertible preferred shares, that is, with no maturity date and hence no obligation to pay back par, were also considered a "traditional" structure with banks being the principal issuers but were also issued by nonbanks. As a result of their perpetual nature, they used to be considered equity substitutes to some degree with their preferred dividends distributions deferrable though usually not tax deductible. However, updated capital adequacy standards per

1. While exact estimates are difficult, it is believed that prior to the financial crisis of 2008, hedge funds accounted for approximately 80% of convertible asset class. Currently, in the low-volatility and low-rate environments as of this writing, the role of long-only holders is estimated to be a touch above 50%.

Basle III—aimed at member banks' ability to deal with financial stress—now excludes preferred shares in the computation of Core Equity Tier 1, a primary metric of banks' financial stability. Consequently, the issuance of perpetual preferred shares, including of the convertible variety, is now rare.[2]

This chapter will focus on prototypes of the plain vanilla convertible note[3] and a traditional mandatorily convertible. The discussion will address the descriptors and variables—the knobs, so to speak—that provide the flexibility and together define the underpinnings for their theoretical valuation. Post-issuance structural adjustments to reflect corporate actions, the most notable of which, the *Make Whole Conversion Ratio Adjustment Matrix,* is elaborated upon.

CONVERTIBLE NOTE

As a prototype, consider the "Tesla 2's of 24"as it is referenced in common trader language; its formal name is "Tesla Inc. 2.00% Convertible Senior Notes due May 15, 2024," CUSIP: 88160RAG6. It was priced at the close of trading day on Tuesday May 2, 2019, with settlement date of Thursday May 7, 2019, designated at T+2 (i.e., trade date plus 2 days).

The May 2, 2019, closing price for the TSLA common stock, which trades on the NASDAQ Exchange, was $244.10 per share. However, simultaneously with the convertible note issuance, Tesla also sold $862.5 million of common stock at a price of $243 per share. This $243 per share price is the base price or *reference price* for the convertible off of which the conversion price and the initial conversion ratio for the convertible are calculated.

Convertible Note Descriptors

Each of these *descriptors*, or simply, *terms*—in conjunction with the applicable variables—helps determine the value of a convertible. Comments on the terms and their *ceteris paribus* impacts follow:

- *Aggregate amount (also known as the principal amount, par amount*, *or deal size*): $1.6 billion, subject to an additional 15% if the underwriters' option to sell additional notes is exercised within a stipulated period, usually 30 days. This option was exercised, and the total issue size increased to $1.84 billion.

2. Issuance of notes at the prevailing low level of interest rates, along with their tax deductibility feature, has further contributed to the decline in the issuance of perpetual convertible preferred. Hence although not discussed in this chapter, the valuation principles for convertible bonds also apply to convertible preferred shares.

3. Despite the maturity differences between debt notes and bonds, since their valuation logic is identical, this chapter uses the two terms—notes and bonds—interchangeably. Also, using common parlance, a convertible security is called a "convertible" or, simply, a "convert."

Typically, large issue size, which usually occurs for large, attractive issuers with strong research and investor following, is usually accompanied by greater trading liquidity in the secondary market.[4,5]

- *Issue Price*: 100% of principal amount, at $1,000 per note.

  While issuance at par is most common, in countries with very low or negative nominal interest rates, convertible notes may be issued at a premium to par, say, 102% of par, with redemption at par at maturity, if not converted.[6]
- *Coupon rate*: 2.0% per annum, payable semi-annually, on May 15 and November 15, beginning on November 15, 2019. Note that the first coupon payable on November 15, 2019, is longer than six months by a few days from the settlement date of May 7, 2019, and is called a *long coupon date*.

  The higher the coupon rate, the higher the value of the note. Tesla common share pays zero dividends. So, the *yield advantage* at issue, defined as the coupon rate divided by purchase price of the convert minus dividend yield of the stock; at the time of issue, the yield advantage of the TSLA note was 2%. The higher the yield advantage, the more attractive the convert.[7]
- *Maturity date*: With its Maturity Date of May 15, 2024, its time to maturity is five years plus a few days from the date of issue, this convertible is still deemed as a "five-year note."

  While the five-year maturity notes are most common, seven-year notes are also issued. The longer the time to maturity, the lower the present value of par when interest rates are positive, and hence the higher the note's duration and, consequently, its interest-rate risk. Credit spread also features in to adversely impact value if, as expected under normal conditions, credit spread for the note widens with longer time

4. According to Kynex, Inc., convertible issues of less than $100 million aggregate amount, while present, are not very liquid. In calendar year 2019, of the 106 U.S. convertible debt issues larger than $50 million, of the total U.S. raise of $53 billion, the median issue was in the $200 million to $300 million range.
5. As an aside, according to Bank of America Merrill Lynch Global research, an estimated $44 billion of U.S. convertible issues were retired, thereby bringing about the net new issuance at $9 billion.
6. A variant seldom used now is a *discount convertible bond* issued at below par value that, in lieu of paying a cash coupon, accreted to par at maturity at the prespecified deemed coupon rate; taxable holders had to consider the accretion amount as deemed income. This structure resulted in a conversion price rising continuously to maturity date at the accretion rate. Some Asian issues were a modified version of this structure, issued at par but accreting to beyond par at maturity, the so-called *premium redemption convertible bonds*.
7. Notable exceptions being convertibles issues by real estate investment trusts (REITs) with their already high common share dividend yield. Dedicated convertible funds seeking high-yielding securities tend to buy these despite the negative yield advantage as their fund structure usually prohibits them from holding common shares. Other justifications are that they are senior to the common in bankruptcy proceedings and for dividend distribution. Further, that as a convertible, per the *Put–Call Parity theorem*, they may also be viewed equivalently as a stock with a put option.

to maturity. Offsetting this latter negative impact to some degree is the conversion option, which is commensurately longer, particularly in the absence of diminution of value due to earlier redemption or "*provisional redemption*" of the note (see below).

- *Seniority*: Senior Unsecured.

  This seniority level is now the most frequent for newly issued convertible notes, while others have been issued as Senior Subordinated Unsecured, and less frequently as Subordinated Unsecured. When issued at the holding company level, they are also most commonly subordinated to debt issued at the subsidiary level, and also to trade debt.

  Unlike straight debt, convertible debt is generally issued without typical financial covenants or tests pertaining to minimum net worth, maximum leverage, coverage of fixed obligations, or working capital.
- *Issue Rating*: Unrated by Moody's; B– by S&P.

  The overwhelming majority of convertibles issued are either noninvestment-grade-rated or are unrated. In calendar year 2019, of the 105 convertible notes issued in the United States with issue size of at least $50 million, only four were rated as investment grade.
- *SEC Registration*: Yes, off of a prior "shelf registration," with registration supplement. This was to be expected considering the concurrent secondary equity offering.

  SEC-registered securities can be purchased by all potential investors, whereas those issued under Rule 144A can only be purchased or transferred between Qualified Institutional Buyers ("QIBs"). Nearly two-thirds of the 106 convertible notes issued in the United States in 2019 were under Rule 144A.
- *Underlying common stock*: TSLA.

  Although not relevant in the current TSLA note context, convertible notes can also be in an *exchangeable* structure wherein the underlying share for the conversion option is not that of the issuer but into another stock in which, usually, the issuer has a holding and the convertible being used to potentially divest this holding at a premium to its current price. Another variation is a *structured convert* such as the one issued by JP Morgan, cash-settled conversion option linked to the share price of the Chinese company, Tencent Holdings. This exchangeable followed a familiar pattern of issuance motivated by investor interest in convertible structure exposure to specific equities otherwise not available to the convertible asset class investors.[8]
- *Conversion premium*: 27.5%.

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8. JP Morgan/Tencent Holdings 0% of August 2022, issue size $400 million. Also, JP Morgan/Alibaba Group Holdings 0,125% of January 2023, issue size $500 million.

Conversion premium, along with the coupon rate and the issue size, is one of the three items that issuers and the underwriters focus on most when pricing a convertible new issue. Initial conversion premium in the range of 15% to 30% is most common, though some issues with investment grade rating and/or high volatility, and/or popularity of the underlying stock may price at higher premiums. The higher (lower) the conversion premium, the closer the convert is to a straight bond (equity).

- *Conversion price*: This is calculated as the price of the underlying stock at issue, that is, the reference price of $243 per share in this case, multiplied by (1 plus the conversion premium) = 243.00 × 1.275 = $309.83 per share.
- *Initial conversion ratio*: Issue price of par per note divided by the conversion price = $1000 / 309.63 = 3.2276 shares per note.

  As will be discussed below, this is an important number to which formulaic increments are conditionally made with a view to remedy corporate actions that may adversely impact the time value of the conversion option of the convertible.
- *Conversion option*: Freely convertible at the holder's option only commencing a calendar quarter prior to the maturity date of the note, that is, from February 15, 2024. However, it is *conditionally convertible* prior to the business day immediately preceding February 15, 2024, only if any of the following conditions apply: (a) Following the first full calendar quarter since issue, that is, September 30, 2019, if during any such following calendar quarter the last reported sale price of TSLA equals or is in excess of 130% of the applicable conversion price, for any 20 out of 30 consecutive trading days. This is called the *provisional conversion clause*. (b) The convertible note trades at greater than 2% discount to its then conversion value for an observation period, as defined. (c) Offer to sell the underlying stock at a discount of 10% or greater to substantially all holders of TSLA common shares, rights, warrants, or options. (d) Upon a fundamental change of ownership due to corporate events.

  While the above nonconversion period and conditional or contingent conversions[9] are particular to this issuer, it is not uncommon to find conversion restrictions and contingencies in other convertible notes too. They are driven by the issuer desire to avoid immediate share dilution recognition pertaining to the underlying number of shares of the note.

9. The term *contingent convertible*, or *CoCo,* in the context of an equity-linked security is not to be confused with identically named "CoCo" bonds issued by a bank as an Enhanced Capital Note. The latter is issued toward achieving conformance per banking regulatory requirements with respect to capital adequacy to address potential adverse financial conditions. Structurally, while issued as a debt obligation of the issuing bank, they may be converted at the option of the issuer or directed to do so by the regulatory body, into equity capital of the issuer bank and the debt obligation eliminated, most often with no compensation in any form to holders, when the bank has breached, or is close to breaching, the required minimum capitalization ratio.

Additionally, such conversions may adversely affect hedging transactions undertaken by the issuer in conjunction with the issue (discussed below). However, while these may be viewed as an abrogation of the holder's traditional right to freely convert, the nonconversion period and the conditional conversion rights, when inside of a no-call period, and taken together, do not adversely affect the value of the convertible since absent the above conditional conversion triggering events, it is suboptimal for the holder to truncate the time value of the conversion option.

- *Settlement upon conversion*: TSLA has the option to settle its obligation through delivery of shares—called *physical settle*—or cash, or a combination thereof. Further, cash payment, if any, shall be computed based on the 20-day *observation period* preceding the conversion effective date as the average daily computed conversion value that results from the multiplication of the then effective conversion ratio and the corresponding daily volume-weighted average price (VWAP) for that trading day.

  Identical, or closely approximate, terms feature in almost all convert note issues. A common method in this context is *Net Share Settlement* wherein an issuer satisfies its obligation to pay the conversion value by paying par in cash plus the overage in a number of shares calculated by dividing the overage amount due by the share price on payment date; the definition of the share price in this context is also specified.
- *Redemption*: The TSLA 2's of 24 is nonredeemable, that is, noncallable for life unless under a *fundamental corporate change* event, as defined, occurs. In that event, the incremental make-whole share additions matrix stated in the prospectus supplement is applied to the then applicable conversion ratio.

  If callable prior to maturity, all converts have a noncall period, usually three years, followed by a *provisional call* or *soft call* until maturity, conditioned on the underlying stock price exceeding a pre-stated threshold price, usually set at 130–160% above the initial conversion price. Typically, this threshold would need to be met or exceeded for a prespecified period, commonly for 20 out of 30 trading days, not necessarily continuous. To effect redemption, the issuer will need to provide written notification to holders with details of the prespecified notice period, usually 15 to 30 days, and note delivery instructions to effect conversion. Redemption notice is generally delayed by the issuer until confident that during the notice period the underlying stock price will not drop to an extent as to fail the redemption trigger test.[10]

10. The so-called freely redeemable bond with unconditional issuer redemption rights commencing following expiry of a "hard noncall period" and/or a "soft-call period," with its prespecified call price schedule, is increasingly rare.

Note that redemption option(s) benefit the issuer and would, therefore, need to be compensated for via the convertible's initial pricing terms through a lower conversion premium and/or a higher coupon rate and/or even a reduced offering size in some cases. As an alternate, a *make-whole adjustment matrix* to the conversion ratio is also used by some issuers.

- *Conversion rate adjustments*: Present. This conversion ratio adjustment feature is now standard for all newly issued convertibles. Although popularly known as *dilution protection adjustments,* they also include, in addition, *value conservation adjustments*. Together, through their respective conversion rate adjustment formulae, they are intended to mitigate conversion value erosion that would be expected to result from specified future corporate actions, should they transpire. As detailed in Appendix 38A at the end of the chapter, while the adjustment triggers generally result in upward revisions in the conversion ratio, a share consolidation through a reverse stock split would decrease it.
- *Fundamental change make-whole*: Present. This usually takes the form of a conversion ratio adjustment matrix with scenarios of underlying stock price on the horizontal axis and calendar dates pertaining to early conversion on the vertical axis. The cells populating the matrix represent incremental conversion ratio additions per note to the then current conversion ratio.

  This make-whole matrix feature is now a standard in all new convert issues and seeks to protect the interests of holders in the event of the corporate fundamental changes, as defined, that might otherwise adversely affect, or even truncate, the value of the convert. These are further detailed in Appendix 38B.
- *Conditional poison put*: Present. This clause is triggered when (using nonlegal language here) an external entity, not related to the issuer, files notice per regulatory requirements of its having directly acquired beneficiary ownership of greater than 50% of the issuer's underlying common stock or by acquiring a combination of assets and securities that lead to the same outcome. Upon exercise by the holder per instructions detailed in the prospectus, this requires the issuer to pay holders the principal amount of the note, plus accrued interest, as applicable, on the stipulated date per calculations specified.

  The poison put feature is yet another attribute that is increasingly found in new convert issues.[11]

11. A poison put feature is controversial from corporate governance perspective in that it is (potentially) additive to existing barriers to change of corporate control that favor entrenchment of current management. However, from a convertible security holder perspective, it could be of positive value when taken together with the fundamental make-whole clause. For example, if the acquiring entity is highly leveraged or is through a going-private transaction, in both cases due to the higher implied credit spread of the resulting convertible and the associated probability of default, the value of the convertible may decline and/or its conversion option truncated.

- *Concurrent hedging and warrant transaction by the issuer*: Present. Increasingly a common feature, this concurrent hedging—colloquially known as a *happy meal*—is aimed at reducing, if not eliminating, the potential dilution of common shares through trades with the underwriter(s) of the issue. The additional warrant transaction is aimed at effectively increasing the conversion price beyond that defined in the issue. This is elaborated in Appendix 38C.

  The immediate impact of these transactions is that the price of the underlying stock rises upon announcement of the convertible with these concurrent transactions, whereas absent these there would tend to be an immediate downward pressure on the underlying stock due to dilution effect further compounded by shorting by hedge funds.

CONVERTIBLE NOTE AS A CONTINGENT CLAIM

In its most general definition, a contingent claim is a security or contract whose future payoff is contingent on the occurrence, or not, of a prespecified state of an underlying asset. Payoff of convertibles fit the definition, with the state of the underlying common stock determining its payoff.

Consider a portfolio consisting of a long position in a European call option, C_t at time t, a short position in a European put option, P_t, with identical maturity date, T, and exercise price for both options, K, on the same underlying stock, S, and the present value of the exercise price, $Ke^{-r(T-t)}$ to the exercise date with $T > t$, where r is the discounting rate and assuming continuous compounding. That is,

$$\text{Portfolio}_t = \mathrm{C}_t - \mathrm{P}_t + Ke^{-r(T-t)}$$

At the maturity of the options, $t = T$, the present value grows to K. Denoting the stock price at maturity as S_T, if $S_T > K$, the put option expires worthless, and the call option is in-the-money and worth $(S_T - K)$ upon exercising it. Replacing this for the value of C_T in the above equation, the portfolio value at maturity of the options equates to S_T. Analogously, if $S_T < K$, then the call option expires worthless, and the put is in-the-money and worth $(K - S_T)$ and will exercised with K received as the exercise proceeds. Replacing the value of P_T in the above equation, the portfolio is once again worth = S_T. So also, the case when $S_T = K$.

Assuming the absence of arbitrage and market frictions, the above Equation for the case of European options can be stated as

$$S_t = C_t - P_t + Ke^{-r(T-t)} \tag{38-1}$$

Or, equivalently as

$$S_t + P_t = Ke^{-r(T-t)} + C_t \tag{38-2}$$

This is the *Put–Call Parity theorem* for European options for a stock that pays no dividends.[12] In the case of the underlying common stock paying dividends at a continuously compounded dividend yield rate, d, Equation 38-2 can be modified as

$$S_t + P_t = Ke^{-(r-d)(T-t)} + C_t \tag{38-3}$$

Viewed through this lens, from the right-hand side of Equation 38-3, which is a fixed income investor's perspective, a convertible note may be viewed as a combination of a straight bond of the same tenor and a call option to convert into the underlying common share. From equity investors' perspective, which is the left-hand side of Equation 38-3, it may be viewed as a long position in the underlying share with a put option to exchange the share for a straight bond with a swap to receive the bond coupons for the common share's dividends. Hence, another frequently cited manner of describing a convertible note is that it provides exposure to equity upside with downside protection.

Despite the complexities introduced through additional features, including conditional call and put, into even the plain vanilla convertible note—as seen in the prototype Tesla 2's of 24—the above viewpoints are still conceptually valid.

The value diagram in Exhibit 38-1 depicts changes in the character of the convertible note in relation to changing underlying stock price. The x-axis represents the *conversion value* or *parity value,* or, simply, *parity,* which is the conversion ratio times the price of the underlying common. This is also represented by the ODQ (which is a line 45% to the x-axis as both axes represent parity). ACVS represents the theoretical valuation curve for the convertible note, while ACDB, the bond value representing the present value of the debt obligation of the convertible note with respect to its obligation to pay the stipulated coupons and par in the event the convertible is not converted into equity.

The value difference between any point on the convertible note valuation curve, ACVS, and its projection on the parity value line, represented by ODQ, is the *conversion premium* expressed in percent over parity value, or equivalently, in bond points over parity value, called the *points premium*. Analogously, the value difference between the same point on the convertible valuation curve and bond floor, ACDB, expressed in percentage terms, is the *investment premium.*

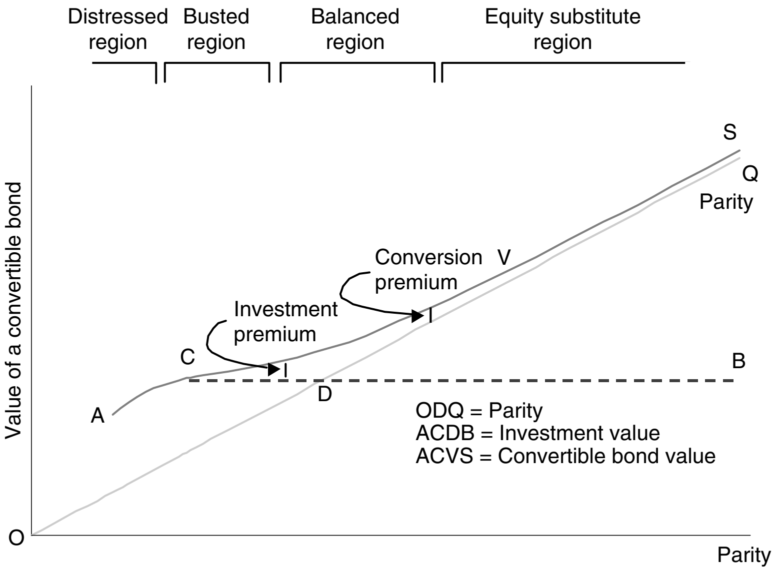
The convertible value curve is above the parity line. The value difference between their corresponding points represents the time value of the embedded long call option in the convertible that benefits the holder. The conversion premium, the investment premium, and *delta,* also called the *neutral hedge ratio* of the convertible, help characterize the changes in the value of a convertible in response to changing value of the underlying common share.

For illustration, consider a convertible note with par at \$1000 issued at 100% of par, with the underlying stock price at issue = \$20 per share, conversion

12. See J. Cox and M. Rubinstein, *Option Markets* (Englewood Cliffs, NJ: Prentice Hall, 1985), pp. 41–43.

EXHIBIT 38-1

Convertible Value Diagram



premium = 25%, and therefore conversion price = 20 × 1.25 = $25, a conversion ratio = 1,000 / 25 = 40 shares per note. If, in response to the share price increasing by 15% to $23, the convert price moves to $1100, with the bond floor, say, at $865, then

$$\text{Conversion premium} = [(\text{Convert price} / \text{Parity}) - 1] \times 100 \quad (38\text{-}4)$$
$$= [(1{,}100 / (23 \times 40)) - 1] \times 100 = 19.57\%$$

$$\text{Points premium} = (\text{Convert price} - \text{Parity}) / 10 \quad (38\text{-}5)$$
$$= [1{,}100 - (23 \times 40)] / 10 = 18.00 \text{ bond points}$$

$$\text{Investment premium} = [(\text{Covert price} / \text{Investment value}) - 1] \quad (38\text{-}6)$$
$$\times 100 = [(1{,}100 / 865.00) - 1] \times 100 = 27.17\%$$

In this numerical illustration, in response to the common stock experiencing a 15% gain (from $20 to $23), the convert note price increases only by 11% (from $1,000 to $1,100), reflecting a decline in the conversion premium from 25% to 19.57%. If, on the other hand, the stock price were to decline by 15%, the convert price would decline by less than 15%, and the conversion premium would expand to be higher than 25%. This is due to the positive convexity of the embedded long conversion option of the convert.

Note, therefore, that the valuation curve, ACVS, is convex in the segment CVS and concave in segment CA, with C being the point of inflection. Under distress conditions, with parity trending to (precipitously) lower levels beyond point C, the bond value of the convert declines in an accelerated manner and does not continue along the dotted line to the *y*-axis. In fact, even at some stock price levels not far from zero, there exists the distinct possibility of default by the issuer. Hence the valuation curve for the convertible in this region is not easily determined, or at least not a continuous curve as it then depends on multiple default-related factors including seniority of the convertible in the capital structure defining its claim priority and the recovery rate in the event of default. The value diagram schematic in Exhibit 38-1 shows an extreme, though unlikely, case of the convert value being only equal to its bond value beyond point C, with no remaining time value.[13]

The delta or neutral hedge ratio applicable to a convert is analogous to that of an equity call option and is the ratio of the change in the price of the convert to an infinitesimal change in its parity, and ranges from 0 to 1. At zero delta the convertible behaves like straight debt, and as equity when the delta is 1.0. At a delta of, say, 46.65%, for a conversion ratio of 40 shares per bond, to achieve a delta neutral position would need a short position of

$$\text{Conversion ratio} \times \text{delta} = 40 \times 0.4665 = 18.66 \text{ shares per bond}$$

The neutral hedge ratio is the tangent to, and the slope of, the convertible bond valuation curve at a given stock price level. For infinitesimal moves up or down in the stock price from this initial level, a hedged portfolio consisting of long the convert and short the appropriate number of shares, as illustrated above, will experience neither a loss nor gain as a result. For noninfinitesimal stock price change upward, the gain arising from the long position in the convert will be lesser than the loss incurred due to the short position in the shares as the conversion premium declines, as seen in the illustrative numerical example. In the event of a large move up, the ex ante neutral hedged position turns out to be ex post underhedged, and hence the long convert leg does not gain as much as the parity gain. The reverse is true in a large down move in share price. In this case, the ex ante neutral hedge position turns out to be overhedged and, therefore, the decline in the convert price, all else being the same, will be lower than the gain on the short position in parity, resulting in the conversion premium increasing. These scenarios exhibit the positive convexity, also called the positive gamma,[14] property of a long equity call option position with respect to the underlying stock, and hence with respect to parity for a long position in the convertible. On the other hand, if the convertible

13. The value of a convertible in a two-factor valuation model would be represented by a three-dimensional surface with the third dimension representing the interest rate plus credit spread on the *z*-axis. The simpler two-dimensional representation above is, therefore, a section of the pricing surface parallel to the *x*,*y*-plane, at a given level of interest rate plus credit spread, assuming a constant volatility level. On the other hand, the volatility surface of a convertible can be graphically represented if the interest rate plus credit spread were to be held constant, while volatility, represented on the *z*-axis, is assumed to change with changing stock price levels.

14. Gamma, as in equity options, is second derivative of the price change in the derivative with respect to the price change in the underlying. It measures the rate of change of the delta with respect to the underlying.

is callable prior to maturity, like all callable fixed income instruments, it also will have negatively convex attributes with respect to interest rates.[15]

The stages of a convertible and their attributes are discussed next as impacted by changes in two of its principal variables, namely, the price of the underlying equity and interest rates.[16]

STAGES OF A CONVERTIBLE NOTE

There are four stages of a convertible note approximately depicted in the value diagram in Exhibit 38-1. We describe each below.

Balanced Converts

Convertibles with conversion premium of 15–40%, and investment premium of 15–25%, respond materially to changes in both the underlying equity and interest rate. The deltas of such convertibles range from roughly 55–75%. Hence converts with these attributes, either upon issuance or as a result of subsequent stock price movements, are called *balanced convertibles*. Their upside/downside participation and risk/return trade-off characteristics appeal to outright convertible funds and equity funds seeking a lower risk alternative or add-on position to common stock from an issuer with attractive equity fundamentals.

Equity Substitute Converts

When the conversion premium is about 15% or less, its investment premium is usually higher than 40%, and equity delta is above 80–85%, it is viewed as being equity-like or as an *equity substitute.* At this stage, the investor put option to exchange the convert for its redemption price is deep-out-of-the-money. While share price is the prime determinant of the value of a convert in this stage, it cannot be emphasized enough that other factors, such as remaining call protection and stock price volatility, also materially affect its value. The shorter (longer) the remaining call protection, the lower (higher) the conversion premium an investor would be willing to pay reflecting the remaining time value of the security. Outright convert funds tend to sell the security at this stage in favor of other balanced converts, while equity income funds tend to buy in this stage. With the positive convexity feature of the convertible being very prominent at this stage, portfolio leverage and small net capital requirement due to the shorting at the high delta level, this stage of the convertible constitutes a potentially lucrative trading opportunity for hedge funds.

15. If a bond features an early redemption, or callability, the bond value will be negatively convex to interest-rate changes as the early redemption feature is in effect an embedded short put position from the holder's perspective. And all short option positions are negatively convex.

16. Interest rate as discussion here includes the applicable benchmark interest rate as well the credit spread.

Busted Converts

When the underlying share price declines to where the conversion option is deep out-of-the-money, the conversion premium increases while parity is still in the convex region, CVS, in the diagram. Conversion premium in this stage is usually greater than 50%, and sometimes significantly higher. The investment premium in this stage may be 15%, or lower, as the note's value approaches the bond floor due to the holder option to put the note to the issuer at par on settlement date and its value approximates as determined by its yield to maturity, which unless otherwise, is the settlement date.[17] Outright buyers tend to exit busted converts and are replaced by fixed income funds seeking equity exposure while receiving bond-like yields. Credit analysis expertise, understandably, is of importance. Hedging at this stage against further decline in the underlying shares can be achieved via overhedge through shorting more shares than suggested by the neutral hedge, However, the overhedge strategy bears the risk of substantial loss should the stock happen to bounce back. Instead, a long position in equity put or credit hedge, if available at reasonable prices, would be better alternatives.[18]

Distressed Converts

Convertible notes in this stage may be considered a subset of busted converts with the distinction that with the underlying share price so low as to materially increase the probability of default. Implied here is that credit spread widens out rapidly with declining levels of the underlying stock, very unlike in the other stages where the bond floor holds up reasonably well. In this stage, both the conversion premium and investment premium are quite small. This is the concave region of the valuation curve. This is where *distress funds* with expertise in bankruptcy proceedings, asset recovery in default, and post-bankruptcy reorganization tend to be the principal holders. Interestingly, the equity gamma is even higher than in the busted phase, and small changes in the underlying stock may change the delta significantly.

Before leaving this section, it is useful to point out that while conversion premium is commonly used to label the stage in which a convertible note belongs, a more reliable measure is the investment premium. For example, an in-the-money convertible note with an extended remaining period of call protection, on a high volatility stock that pays low or no dividend, can trade at a very substantial

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17. Unlike straight bonds, convertibles generally do not have any significant operating or financial covenants. Currently, they rarely include an unconditional investor put option but may have an event-triggered put such as a poison put triggered by an acquisition of the underlying stock. In such a case, the convert note will be valued as the higher of the conversion value or the note's bond value based on the yield to maturity or yield to put.

18. Some funds, though, may choose to retain the exposure in the busted convertible note if they deem it worthwhile if the risk/return trade-off is compelling based on their credit analysis and valuation models. The yield forgone in exchange for the deep out-of-the-money call may be relatively minor or even negative, the latter due to possible pricing inefficiencies in this region.

conversion premium. However, the higher (lower) the investment premium, the unambiguously more (less) in-the-money is the convertible note.

INVESTING IN CONVERTIBLE SECURITIES

A common and oversimplified categorization of investors in convertibles as an asset class is that some are long-term holders and, by inference, the others are not. The former category includes dedicated convertible funds and others with asset allocations to convertibles such as equity income funds, insurance companies, many fixed income funds, and in-house managed pension funds as well as family offices. An aspect of the charter of dedicated convertible funds as well as of fixed income funds and others may not allow them to hold common shares, effect hedging by shorting securities, nor engage in option transactions, but convertibles with their embedded derivatives are permitted. The common investment objective of the outright investors is to obtain equity exposure with portfolio volatility lower than that of common stocks. To that end, inclusion of convertible securities, with their lower risk and equity upside potential of convertibles, as an asset class is attractive for active money managers as they are often measured by holding period returns compared to benchmark indices—such as the S&P 500 Index or the Russell 2000 Index of small stocks—on a risk-adjusted basis. In that context, the Sharpe ratio is an often-used measure of risk efficiency to evaluate a portfolio manager's performance.[19]

The second category of investors in convertibles are hedge funds. Security shorting and option trades to effect hedges for arbitrage purposes are their distinguishing characteristics. Hedge funds engaging in convertible arbitrage include those dedicated exclusively to the asset class, as well as multi-strategy hedge funds. The latter may participate selectively, from time to time and allocating capital accordingly, based on their assessment of the attractiveness of a specific convertible security or the asset class as a whole. A third group consists of the convertible and/or equity trading desks of investment banks engaged in underwriting and market-making of the securities. However, there has been a substantial reduction in their role as market-makers and liquidity providers due to the attendant capital requirements per banking regulations. Hedge funds are, therefore, viewed as liquidity providers—for a price—to some extent whose trades help toward price discovery

Outright investors will seldom buy a convert unless they like the fundamentals, or the *equity story,* of the underlying stock. Ideal attributes of an issuer, from the perspective of outright investors, include:

19. The Sharpe ratio is defined as the excess return of the portfolio divided by the risk of the portfolio as measured by the standard deviation of its returns. Portfolio excess return is the realized return of the portfolio minus the return from the riskless asset. It attempts to measure the excess return per unit of risk undertaken by the portfolio manager. The measure can be applied to portfolios or to asset classes. The higher the Sharpe ratio, the better the performance of the portfolio manager or the asset class.

- A strong management team with a well-articulated business model
- Presence in a growing sector of the economy
- The firm being in the growth phase of its business cycle
- Strong or improving credit with the ability to undertake the fixed liability without jeopardizing its credit rating
- An attractive yield advantage of the convertible over that of the underlying common share
- High volatility and hence the propensity of the underlying stock to exceed the conversion price threshold

Hedge funds, essentially being relative value traders, are more concerned with the relative cheapness of a convertible and hence arbitrage possibilities. Therefore, additional valuation inputs considered include:

- Liquidity of the convertible and that of its underlying stock
- Cost of stock borrow
- Credit spread for an otherwise identical straight debt, or a credit default swap for the issuer, if it exists, or an estimate thereof
- Hedging instruments available, their efficacy, and remaining basis risk[20]

Since a convertible note spans the space from straight debt at one extreme and pure equity on the other, it affords the investor spectrum to choose among these and the intervening stages that suit their investment objectives and mandates. A convertible note with low conversion premium will have higher delta with respect to the underlying equity and hence tend toward a common stock as the conversion premium decreases and the delta increases along with corresponding increase in the investment premium. In such situations, the convertible's sensitivity to downward moves in the stock is high because at the then high equity levels, the downside protection afforded by the bond floor more is distant. At low investment premium levels, conversely, the conversion premium is high and the delta with respect to the underlying equity is low. Hence the convert, now tending toward a bond, will be more sensitive to interest-rate changes.

Given the changing attributes of the convertible notes, successful investing in them requires a combination of tools in the areas of equity fundamentals, fixed income valuation, and valuing derivatives. The next section discusses the variables that, in conjunction with the descriptors, help determine their theoretical values and provides an overview of valuation modeling.

20. For example, given the thin, or in some cases nonexistent, market for credit default swaps on individual issuers, index swaps may be used as proxy. The offsetting effect of the latter not being the same introduces a correlation element and a residual risk, called the basis risk.

CONVERTIBLE NOTE VALUATION FRAMEWORK

If, in addition to the usual terms of the coupon rate, conversion ratio, and maturity date, the convertible note specifically neither permitted early conversion by the holder nor redemption by the issuer, then its value at any time would equal the present value of the scheduled and contingent cash flows from the valuation date forward until the maturity date, provided that the terminal stock price and the discount rate to calculate the present value were known. The above statement implicitly ignores the possibility of default by the issuer.

An earlier-generation measure to assess the relative attractiveness of a convertible note relied on this simplicity in calculating the *payback period.* Essentially, it is the time required, in years, over which the holder would recover the price of the convertible note, as opposed to acquiring the number of the underlying shares, and being compensated through the positive differential between the coupon payment of the note and the expected dividend payment from the underlying shares.[21] The shorter the payback period, the more attractive the convertible note, and particularly so if the payback period is inside the call protection period. Note that this metric also ignores the present value concept.

All current valuation models for convertible securities follow the arbitrage-free framework for contingent claims pioneered by Black and Scholes[22] and Merton[23] and are based on participants optimally acting in their best interest. That is, at all times, given the several interacting embedded options then available, the convertible note holder would choose the most likely value-maximizing choices whereas the issuer would correspondingly pursue optimal value-minimizing actions for the note, with the aim of preserving the residual value benefit for issuer's current common shareholders. Thus, there are game-theoretic aspects of the actions taken by the two parties. As a result, even for the so-called traditional convertible note, a closed-form solution to value it is not possible.

Further complexities are introduced when the conversion right, conversion ratio, call price, and put price features, if present, vary over time and could be specified as European, Bermudan, or American options, thereby requiring appropriate valuation boundary conditions. Other variations include mandatory conversion and whether accrued coupon is to be paid or not upon redemption, conversion, or put exercise.[24] Also to be considered are the cash payments, in part

21. Defined in years, at time = t, it is the ratio of (a) \$ price of the convertible note less its parity value, and (b) the annual cash flow from the convertible note coupon payments minus (the conversion ratio multiplied by annual dollar dividend of the underlying common stock).

22. F. Black and M. Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, May–June 1973, pp. 637–659.

23. R. Merton, "Theory of Rational Option Pricing," *Bell Journal of Economics and Management Science*, Spring 1973, pp. 141–183.

24. A convert note offering specifying that holders would not be eligible to receive the accrued interest pursuant to a redemption or call or put exercise is not looked upon favorably by holders. Therefore, they require cheaper terms at issue for convertible notes with such a clause—derogatively called *screw clause*—except where otherwise would involve "double dipping" payment to the holder. Use of the screw clause is not common now.

or whole, to satisfy the conversion option, changes in dividend payment, as well as whether there is a repo spread for the short equity position in the underlying stock by a hedge fund.[25]

Exercising the Embedded Options

The discussion that follows assumes the most general case, wherein the convertible note has a freely redeemable period and/or a conditional redeemable period, American-style conversion option, and also a put schedule of the Bermudan[26] type. Note that the prototype TSLA 2's of 24 is more restrictive and does not have these embedded options.

Issuer's Options

- *Conversion forcing redemption*: For a freely redeemable note, the benefits to shareholders from forcing conversion include saving the interest expense, lower leverage, and increased debt capacity value due to the additional equity in the balance sheet. However, the issuer may choose to defer redeeming the note if the after-tax cost of the coupon is lower than that of the dividend yield, or in the case of accreting converts, if the after-tax cash flows are positive to the issuer. While theoretically the issuer should redeem the freely callable note as soon as the parity value equal the redemption price, holders need to be provided a written notice of redemption of usually 15 to 30 days. However, with a view toward a higher probability of conversion, the issuer may delay issuing the redemption notice until the parity value exceeds the redemption level by a margin that reduces the likelihood of parity falling below the redemption price and, consequently, the holder opting to receive redemption price in cash instead. This *call delay*[27] becomes moot if the issuer is indifferent between issuance of shares upon conversion or cash. And particularly so if the issuer has already hedged the equity exposure at

25. The repo spread depends on how easily the underlying stock can be borrowed. The more difficult to borrow, the lower is the rebate for the cash collateral credited to the borrower while the lender uses the cash collateral to invest in (usually short-term) Treasury securities.
26. As opposed to a European option exercisable by the holder only at maturity, or an American option that is exercisable by the holder at any time during the life of the option, a Bermudan option can only be exercised on distinctly specified intermediate days prior to expiration.
27. It is equal to $\sigma\sqrt{t}$, where σ is the stock's volatility estimate for the period and t is the length in years of the redemption notice period. As a numerical illustration, if t is one month, the short-term volatility estimate is 0.30 per annum, and, absent any jumps, the stock is expected to move $0.30 \times \sqrt{(1/12)} = 0.866$, that is, ±8.66% in one month with a probability of 68%. The two-standard deviation, or equivalently, a 95% confidence interval, implies a call delay of $2 \times 8.66 = 17.32\%$ above the effective conversion price, assuming a log-normal return distribution for the stock price.

the time of issue through a derivative transaction, as has been done by the issuer pertaining to the TSLA 2's of 24.[28]

- *Debt refinancing redemption:* If the issuer does not want conversion to occur, then during a free-redemption period, the logic of call delay also applies here, except now the parity value needs to be below the redemption price so as to provide the desired cushion. The issuer's reasons for calling the debt may include elimination of the potential equity dilution, refinancing at a lower rate and/or extending maturity. The cost of debt of matching seniority and maturity is the appropriate benchmark from a cost of capital perspective.
- *Put extension sweetener*: If the convertible note feature includes a put or multiple puts scheduled prior to maturity, and in situations where it is optimal for the holder to exercise the immediately next put while the issuer does not wish that the put be exercised, put extension sweeteners may be used by inserting an additional put at a next suitable proximate date and/or a knock-in payment to the holder may be used as enticements to the holder to defer exercise of the put.

Holder's Options

- *Conversion option*: American options have an intrinsic value component plus a nonnegative time value component, the latter for the possibility of the underlying to go further in the direction that increases the value of the option. Voluntary exercise eliminates the time value and is the right decision only when the benefits of early exercise outweigh the time value component. In the context of the embedded long call option, unless forced to do so as a result of a redemption notice, voluntarily conversion by the holder is optimal only when the present value of parity plus the related dividend stream to the maturity date plus any other benefits of owning the common shares exceeds the present value of the price of the convertible note and its coupon stream. This is rarely ever the case in normal conditions and even redeemed convertibles are therefore optimally tendered for conversion on the last possible date prior to the expiration of the conversion option. With features such as dividend protection, dilution, and value preservation adjustments (described in Appendix 38A), as well as conversion ratio changes in the event of corporate actions (described in Appendix 38B), premature conversion is even less likely. Despite this, valuation models need to feature premature exercise option as an investor choice.
- *Put option*: If the convertible note features a put option, its exercise is rational if the estimated value of the note immediately following the

28. B. Grundy and P. Verwijmeren, "Disappearing Call Delay and Dividend-Protected Convertible Bonds," *Journal of Finance*, 2016, pp. 195–224.

earliest next put date is lower than the put price. Hence, the aforementioned put sweetener if enacted by the issuer to prevent early exercise will need to be similarly assessed. The same logic applies to the conditional poison put taking into consideration the make whole clause that would also likely be triggered.

For the most general case of currently redeemable by the issuer, and convertible by the holder, the above leads to the boundary condition for convertible bond value at any grid point in time and underlying stock price combination level, as

$$\max(\min(CB_1, CB_2), CB_3)$$

where CB_1 is the note price if the note is neither redeemed nor converted at that point in time, CB_2 is the note's redemption price, and CB_3 is its conversion value. If not redeemable, then $CB_2 = \infty$; and if not convertible, then $CB_3 = 0$; for conditionally redeemable and conditionally convertible, those respective levels apply.

Analytical Valuation Models and Factor Choices[29]

Convertible bond valuation models differ from each other in the number of *stochastic variables* or *factors* used in their construction.[30] The simpler one-factor model assumes the stock return as the underlying stochastic variable. All other items that impact the value of a convertible are descriptors and nonstochastic (i.e., deterministic) variables. A more complex multifactor models may, in addition, include interest rates, credit spreads, and exchange rates, the latter in the case of multicurrency securities. Based on the stochastic process assumed to generate the return process for the underlying asset, a partial differential Equation (PDE) that applies to corporate securities is developed. Boundary conditions relevant to the particular corporate security being valued, in this case, the convertible, are applied when solving the PDE using numerical methods.

Candidate stochastic variables used to model the value of a convert include:

- *Stock returns:* Single-factor model assumes stock returns to be the sole stochastic variable and posits a Weiner process for the evolution of stock return distribution, with specification for its first two moments. Simpler versions use a flat volatility as an input for all time and stock price levels. The more sophisticated ones may specify a time-dependent

29. Space limitations do not permit a thorough development of the valuation analytics. Hence only an overview is presented here.

30. A variable whose value changes over time in a nondeterministic manner is said to follow a stochastic process. Simply stated, a stochastic process describes the probabilistic evolution or behavior of a variable whose future value is uncertain and leads to different outputs even when provided the same input parameters and initial conditions. Or more formally, a stochastic process is a system that evolves in time while undergoing chance fluctuations. See R. Coleman, "What is a Stochastic Process," in *Stochastic Process, Problem Solvers,* vol. 14 (Dordrecht: Springer, 1974).

volatility structure, and yet others may also incorporate *option volatility skew,* wherein the volatility estimate depends on the extent the option is away from the at-the-money strike price.

Estimating the volatility of the underlying stock likely to be realized over the life of the convertible is of primary importance as it, in conjunction with the risk-free interest rate, most prominently affects the equity optionalities embedded in the convertible security. Implied volatilities from short-dated liquid options on the stock are used for near-term volatility estimates, while realized historical volatilities estimates for the stock return are inferred for longer maturities. Estimates of very high volatility stocks are generally priced at lower volatilities in the market due to the expectation of some degree of mean reversion of volatility over time. Additionally, the ex ante implied volatilities generally tend to be higher than the ex post realized volatility, except when the reverse occurs with uncertain frequency and duration. Thus, although statistical methods are available to estimate the evolution of volatility and its terms structure, it is still considered an art rather than a science in trading circles.

- *Interest rates:* The benchmark interest rate, usually the applicable U.S. Treasury rate, together with the credit spread applicable to the issue, helps estimate the value of the bond floor of a convert by discounting the convert's cash flows. An increase (decrease) in the interest rate increases (decreases) the value of the conversion option, and the reverse for the option to put the convert, if there exists an investor prematurity put feature.[31]

  Valuation models for bonds and bond options have interest rates as the main stochastic variable. Since the price dynamics of a convertible are also influenced to a considerable degree by the straight bond component and its convexities, it stands to reason that two-factor convertible models include interest rates as the second factor. However, fixed income valuation models themselves can be posited as multifactor models. Examples include the two-factor model of Longstaff and Schwartz with the factors being the short-term interest rate and the yield volatility.[32] In addition, a third factor, the long-term interest rate has also been posited for modeling the term structure. Based on their empirical research on U.S. Treasury bond returns, Litterman and Scheinkman label the three explanatory factors as representing the general interest

31. The issuer's interest being exactly contrary to that of the holder, the effect of changes in the interest rates are also exactly offsetting with respect to the issuer's propensity to redeem the convertible security. However, the issue becomes moot if the issuer has already entered into dilution-hedging contracts with underwriters and/or other derivative third parties, assuming nondefault by these counterparties.

32. F. Longstaff and E. Schwartz, "Interest Rate Volatility and the Term Structure of Interest Rates: A Two-Factor General Equilibrium Model," *Journal of Finance*, 1992, pp. 1259–1282.

rate, its slope, and its curvature.[33] However, opting for simplicity, Barone-Adesi, Bermudez, and Hatgioannides posit a two-factor model to value convertibles wherein the second factor is the a modification of the Hull and White dynamic for the stochastic interest rate.[34,35]

Under the latter version of the two-factor model, the term structure of interest rates is inferred from Eurodollar futures for short tenors and from swap rates for longer maturities, both of which sources are liquid. In addition, the correlation between the stock return process and the interest-rate process has to be estimated as also the market price of risk as interest rate is not a traded security.

- *Credit spread:* The higher the assessed probability of default by the issuer, the lower the credit rating of the issue and correspondingly the higher the credit spread. Credit risk is increasingly viewed as a stochastic variable in its own right due to the volatility of the credit-spread of non-investment-grade or unrated issues, which constitute the majority of the securities in this asset class. So, while stock returns, interest rates, and credit risk are three natural factors to drive their valuation, there is general disfavor for three-factor models. Additionally, Grimwood and Hodges suggest that the impact of interest rates is of the second order importance when valuing convertible securities.[36] An example of a two-factor model with the more important credit risk as the second factor is per Xiao.[37]

  Estimating the credit curve for a convert requires inferring the option-adjusted spread from currently traded straight bonds of similar seniority and tenor from the issuer or obtaining the credit default spread (CDS) estimate applicable for the issuer. However, due to market illiquidity in these products, such estimates are rarely available. The closest liquidly traded proxies are the CDS Indices for investment grade (CDX.NA.IG) and non-investment grade issues (CDX.NA.HY), and for some industry sub-sectors thereof. Using these estimates for a given convertible introduces the aforementioned basis risk. In addition, the correlation between the equity return factor and the credit risk factor needs to be posited.

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33. R. Litterman and J. Scheinkman, "Common Factors Affecting Bond Returns," *Journal of Fixed Income*, 1991, pp. 54–61.
34. G. Barone-Adesi, A. Bermudez, and J. Hatgioannides, "Two-factor Convertible Bonds Valuation Using the Method of Characteristic Finite Elements," *Journal of Economic Dynamics and Control*, 2003, pp. 1801–1831.
35. J. Hull and A. White, "Pricing Interest Rate Derivatives," *Review of Financial Studies* 3 (1990), pp. 573–592.
36. R. Grimwood and S. Hodges, "The Valuation of Convertible Bonds: A Study Of Alternative Pricing Models," 2002, Working Paper, University of Warwick.
37. T. Xiao, "A Simple and Precise Method for Pricing Convertible Bond with Credit Risk," *Journal of Derivative Hedge Funds* 19 (2013), pp. 259–277.

- *Exchange rates:* Consider a U.S. dollar-denominated bond—both par and coupon are US$ denominated—exchangeable into shares of a UK pound (GBP) denominated underlying stock. In addition to the equity risk associated with the investor's conversion option into the underlying ordinary shares, a U.S.-based investor is also exposed to exchange rate risk. Since exchange rates are stochastic, they could potentially be an additional factor in the valuation of such converts. Volatilities for the underlying equity in GBP and the GBP/USD exchange rate evolution processes would have to be estimated as well as the correlation between them to value this composite option.

To summarize, the more the number of factors, the higher the modeling complexity in the number of partial differential equations to describe the process and also the cross-correlation between the stochastic processes. These, in turn, imply more parameter estimation as inputs and longer computation time. In each case, traders need to periodically calibrate the model to market prices.

Continuous time *partial differential equations* (PDE) are developed corresponding to the specific factor or factors selected to model the price evolution of the convertible. The system of PDEs is then solved by employing numerical methods that approximate them by *discrete difference equations*. These equations are then solved iteratively subject to applicable boundary conditions. The most frequently employed are (a) Explicit Finite Difference method, which is a forward difference approximation; (b) Implicit Finite Difference method, which is a backward difference method; and (c) Crank-Nicholson method, which is an average of the Implicit and Explicit Finite Difference methods. The explicit finite difference method, commonly used in the Binomial tree approach to value equity options, has the advantage of being computationally fast in convergence while the computationally slower implicit method has better convergence and stability properties. The Crank-Nicholson has the advantage of faster convergence than either of the other two.

Since no model perfectly describes the market valuation curve and model outputs depend on the estimated input parameters and variables, it is common practice to opt for the simpler models and making trading adjustments based on the historical observed bias of the model used. Furthermore, all models take the stand-alone security valuation approach and not the value of the security in the context of totality of all securities of the firm. They also take an atomistic approach and do not account for liquidity or size of the proposed trade, nor of the incremental risk approach of the particular trade on the desk's portfolio. It is commonly argued that most often, these trading judgment-based pricing adjustments and parameter estimation errors swamp the accuracy that might be derived from a theoretically more consistent and robust multi-factor model.

Along this line of logic is the Tsiveriotis-Fernandes single-factor model that employs a flat interest rate and solves the PDE solved using the explicit finite difference method.[38] It discounts the convert cash flows at the risky rate of

38. K. Tsiveriotis and C. Fernades, "Valuing Convertible Bonds with Credit Risk," *Journal of Fixed Income* 8(2), 2008, pp. 95–102.

the interest rate plus the credit spread, and the equity option at the risk-free rate. The logic being that should the holder opt for conversion, the issuer's liability can be defrayed by issuance of common shares and thus involves no credit risk. The model has been critiqued for inconsistency as it does not take into account theof probability of default by the issuer as the stock price declines to the concave region of the value diagram in Exhibit 38-1. Others have addressed this—while retaining the simplicity of a single-factor model by positing a heuristic or deterministic structure of the credit spread, specifically ever-widening as the stock level falls in the concave region even before the stock price reaches zero. In addition, some models may also provide estimates of recovery value in the event of default. One such is the off-the-shelf model, along with the applicable descriptor database and market prices of relevant securities, is from KYNEX, Inc,. and its front page is displayed in Exhibit 38-2.[39]

MODEL OUTPUTS: IMPLIEDS AND GREEKS

Given the requisite inputs, the most common application of the valuation models is to estimate the theoretical value of a convertible security on a stand-alone basis. If the theoretical value is, say, 102.5, and the security is trading at par, it is said to be 2.5% cheap theoretically. In addition, the models provide risk sensitivity attributes of the security, that is, the *greeks,* that help toward deeper evaluation of the security's risk/reward aspects. They are the partial derivatives of the security's change in value in response to an incremental change in the value of an underlying variable when viewed *ceteris paribus*.

Market-Implied Metrics

Equivalent to calculating the theoretical cheapness instead, with the market price of the convertible as an input, these models can be used to iteratively solve for the value of the selected variable that equates the model value to the market price, once again with all other inputs being the same. These are called the *market-implied partial* derivative metrics and include:

- *Implied volatility*: The higher (lower) the implied volatility, the richer (cheaper) the security.
- *Implied credit spread*: The higher (lower) the credit spread, the higher (lower) the market's assessment of the default probability of the security and hence lower (higher) the price of the security.

39. Note that there are several other commercial "off-the-shelf" models available in the market, and others available as a subscription service, such as from Bloomberg, and still others available free from investment banks and brokerage firms with the expectation of trade executions through them. Not surprisingly, therefore, most trading desks subscribe to one or more of these models and focus their attention on estimating the inputs to these models. There is the unstated assumption that the construction technology among the various vendors of the models results in valuation outcomes within acceptable bounds of each other, given the same set of inputs.

EXHIBIT 38-2

A Convertible Analytics Model: Sample Page

Tesla Inc (TSLA)

2.000% Convertible Bonds due May 15, 2024

COMPANY DESCRIPTION

Tesla Motors goal is to accelerate the world's transition to electric mobility with a full range of increasingly affordable electric cars. California-based Tesla designs and manufactures EVs, as well as EV powertrain components for partners such as Toyota and Daimler. Tesla has delivered almost 10,000 electric vehicles to customers in 31 countries. www.teslamotors.com

Trades:18 Mar 142.499 vs 386.118; 17 Mar 159.11 vs 427.965; 154.989 vs 430.716; 158.934 vs 440.196; 159.711 vs 440.725

PRICES

	Nuke	Price ▼
Convertible Price Mar 17, 2020		156.950
Accrued Interest		0.694
Stk Price(US$:1) Mar 17, 2020		430.200

VALUATION

Current Yield		1.27%
Conversion Premium		13.03%
Break Even Hedge/Outright		NM / NM
Hard Call Protection		4.15Y
Eff. Strike/Median Exp Life		309.828/4.16Y
Yield to Maturity (4.16Y)		-9.00%
Stock Yield		0.00%
Parity / Pt. Premium	138.85	18.10
Fair Value / %Cheap	155.36	-1.02
Invest Value / %Prem	76.63	104.81
Delta: Hedge/Outright	91.22	81.16
Gamma 1% / Rho(100bps)	0.15	-1.23
Vega 1pt / 1%	0.466	0.210
Credit Spread(100bps)/Div Yld(1%)	-1.23	-0.08
Borrow Cost (100bps)		-4.46
Implied Spread / Vol	801	48.4
Implied Delta	88.5	91.0
Assumed Spread (bps) / Vol	816	45.0
Call Adjustment	None ▼	0 %
Borrow Cost / IAD(USD)	0.000 %	0.0000
Valuation Date	Trade ▼	3/18/2020

Recalc Reset US$ Tsy ▼

Show

ADVANCED MODEL INPUTS

Model	Stock Spread	Bkptcy Y/N	Decay Factor	Floor %
Risky ▼	816	✓	0	? 30

Inv. Screwed: Default ▼ Call Effective: Div Prot: ✓

Div Type: Continuous ▼ Discr Yrs: CashCallParity: 0.29

TKO Date: Price: USD Cash%:

Mtx:

Vol Surface

Net Share Settlement : None ▼ 0 ?

ParityEvent 0

ISSUE TERMS

Date/ Amount	May 02, 2019	1,840m
Price Convert / Stock	100.000	243.00
Yield / Premium	2.00	27.50
144a @ Issue / Current	Regd	Regd

INDICATIVE

Amount Outstanding	1,840m
Symbol / FIGI	BBG00P2DPCT8
Moodys / S&P	NR/B-
Pay Frequency	Semi-Annual
Trades Net/Gross	Net
Redemption Value	100%
Conversion Price (USD)	309.828
Conversion Ratio '000	3.2276
Co-Co/Co-Pa/Net-Shrs	Y/N/?
Div/Takeout Protection	Y/Y
Debt Ranking	Senior
Debt Backing	Unsecured

Schedules Choose a Schedule ▼

FUNDAMENTALS

Year	EPS	P/E	PEGY
FY1	7.98	53.9x	0.4
FY2	14.52	29.6x	0.2
Long Term Growth Rate			130%
Volatility 90d / 250d		86.8%	66.3%
From 52-Wk Hi/Lo		-55.6%	143.1%
Market Capitalization			79.3b
KYNEX Industry			Automobiles
KYNEX Eco Sector			Consumer Discretionary

CUSTOM NOTES

Insert Indication

While the implied metrics are useful in assessing the user's *a priori* estimates and possibly generate trade ideas, caution is in order regarding their interpretations. First, the estimated "implieds" are conditioned on the estimation accuracies pertaining to all the other inputs into the model as well as the market price replication accuracy of model itself. Second, it is well known that the value of a convertible is most sensitive to volatility when the convert is near-the-money, and to credit-spread when deep out-of-the-money; it is less sensitive to either when deep-in-the-money. Misleading implications may be drawn if unmindful of the context, the skews, and maturities of the embedded options.

Partial Derivatives

The greeks commonly used in monitoring equity and bond derivative risk/reward profiles are also applicable in convertible portfolio management. The principal ones, in addition to the neutral hedge ratio or delta, include:

- *Gamma:* This measure of convexity, the rate of change of delta, is a very closely monitored second derivative and constitutes a prominent trading strategy by hedge funds. A long position in the convertible in the nondistressed stage—segment CS in the Exhibit 38-1—is positively convex due the holder being long the call and put options embedded in the convert. Shorting the underlying common stock against a long position in the convertible, usually in a delta-neutral position, unless deliberately retaining directionality exposure, increases the leverage in the portfolio not available to outright investors. In the concave segment of the convertible value diagram—segment CA in Exhibit 38-1—downside hedging by holders through buying equity put and/or credit protection, if available, is advisable. A negative gamma position resulting from short option positions such as writing a put or writing a call, or shorting a convertible with a view to harvest high implied volatility of the individual convertible or the portfolio, can quickly cause significant losses in the event of large up moves in the underlying. Typically, though, hedge funds buy additional convexity exposure by *"paying theta."* This gamma trading also affects the other greek metrics of the portfolio and, therefore, will need to be adjusted to obtain the desired levels of exposures to them.
- *Rho:* As in the case of straight bonds, this measures the change in the value of the convertible bond to a small change in the interest rate and is the bond's *duration*. The higher the volatility of interest rates or *yield volatility*, the higher the risk in the convertible due to its sensitivity to duration risk and the negative convexity embedded in the convertible. Common hedging trades for interest-rate risk are through shorting Eurodollar and/or U.S. Treasury futures and/or options on them.
- *Credit-spread delta,* or simply*, credit delta,* is used to monitor and separate the interest-rate risk from the credit risk of the position. A long convertible bond, unless credit hedged, is short credit convexity as the investor is also exposed to the credit risk of the bond. A credit default swap with a bond of the issuer of the convertible as the reference security, if available and liquid, would be the ideal credit hedge instrument. However, these being rarely available for the typically noninvestment-grade-rated or unrated issuers of convertibles, a short position in the appropriate CDX index is generally used as a proxy, at a portfolio level with the attendant credit basis risk introduced. For a portfolio with credit hedge instituted, increase (decrease) in the credit spread leads to higher (lower) portfolio P&L level due to the credit move. Further, as interest

rates and credit spread are generally correlated, hedging one also affects the measure of the other. Hence traders also use judgment in apportioning resources between hedging interest-rate and credit-spread risks. Asset swap for a convertible, if available, would hedge both interest-rate and credit-spread risks. The asset swap counterparty, in such a transaction, assumes both these risks and being compensated by cash flows from the convertible while the convertible holder retains the equity exposure.

- *Theta:* Measures the rate of time decay in the value of the options embedded in the convertible, with its decay rate increasing with declining time to maturity or the stipulated or conditional terminal date of the option. As in all options, the decay rate is highest closest to maturity or alternate early-termination events; the latter include mandatory conversion date and the convertible note *redemption notice period.* As theta is a drag on the portfolio's performance, its cost/benefit is intensely monitored.
- *Vega:* Measures the change in value of the convertible to a small change in volatility of the underlying stock. High volatility underlying shares, such as those in the Internet, media, technology, and telecommunication sectors, carry the risk of volatility collapse, more specifically, collapse of the implied volatility. Illiquidity-driven implied volatility collapse devastates the value of convertibles. This has occurred episodically in the past and includes the global recession that started in 2007–2008.[40] Note that volatility can have a perverse impact in close to event dates such as maturity date or redemption date with little or no remaining call protection remaining for the convert. In such situations, increase (decrease) in the volatility level can lower (increase) the value of the convertible though mitigated to some extent if the terminal price of the stock is an average price on the event date is computed over a stipulated averaging period. The role of vega, in addition to in the gamma trading context, is also crucial in variance and volatility swaps trades that aim to hedge or profit from the estimated volatility of the portfolio.
- *Second derivatives:* The most important of these are the gamma for equity options and its analog for interest rates, convexity. Another is *volga*, the rate of change in vega for a small change in volatility.
- *Cross partials:* These are second-order, although important, risk elements. Examples include the evolution of credit spread with the change in the price of the underlying stock and, similarly, for change in volatility with change in the underlying stock price.

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40. Note that equity volatility may continue to be high for highly volatile stocks during periods of high stress in the market, as happened in the 2008 recession. However, investor withdrawals from the markets resulted in "fire sale" liquidation of securities in most asset classes and even more so in lower-rated securities. The convertible bond pricing curve experienced a significant dislocation, further accentuated by illiquidity. Therefore, although vega and illiquidity are distinctly different, holders are mindful of high-vega stocks in this context.

Collectively, these metrics help guide the investor toward a desired risk exposure and corresponding expected return from the perspective of a single security holding perspective. Additionally, the specific relative attractiveness compared with other available opportunities, its risk/expected return profile, and its contribution to the portfolio as a whole also need to be considered. The trading task is made easier when the model also provides scenario analyses—for varying input parameters of holding period horizon, rates, spread, volatility, changing richness/cheapness from current situations—and also built-in portfolio management, risk analytics, and trade execution systems. Most analytical trading models provide for these features.

Second in issuance only to convertible notes, though a distant second, is the structure colloquially called "mandatories," discussed next.

MANDATORILY CONVERTIBLE SECURITIES

In its earliest iteration, in the early 1990s, the current version of the mandatorily convertible security, or simply known as a *mandatory,* started out as a convertible preferred share maturing in three years, with an out-of-the-money conversion option benefiting the holder, as in a standard convertible debt security, but without the holder's option to receive par in the event of the parity value being less than par at maturity and instead was replaced with the holder mandatorily obligated to receive parity value delivered in shares at settlement. Thus, holders have no downside protection other than the higher preferred dividend yield of the mandatory that exceeded the dividend yield on the underlying common stock.

Therefore, it can be viewed as share-settled convertible, into the underlying shares, with the additional feature of an at-the-money put that the issuer is long and the holder is short, compensated for by the issuer paying a higher preferred dividend rate.[41] Equivalently, a mandatory with the underlying asset being one share of the common, can be viewed as a combination of (a) long one share of the underlying common stock at the reference price, plus (b) a *ratio call spread* comprising (i) a long position in less than one unit of a call at a higher strike price and lower conversion ratio, and (ii) a short position in one unit of an at-the-money call at the lower strike price and higher conversion ratio.

To illustrate, if the mandatory is sold at a 20% premium over the reference price of \$40, its conversion price—$40 \times 1.20 = \$48$—is the *higher strike price*. Its corresponding initial conversion ratio—$\$40 / \$48 = 0.8333$ shares—is also known as the *lower conversion ratio*, or the *upside conversion ratio*. The at-the-money short call position has a strike price of \$40 and a conversion ratio of 1 share. They are known, respectively, as the *lower strike price* and the *higher conversion ratio*.[42] In this context, the higher yield of a mandatory when compared to an

41. Or a higher coupon rate, if structured as a mandatory note.

42. If the mandatory is issued with a redemption value equal to \$50 or \$100, as is now commonly done, the underlying shares and strike prices are scaled accordingly. For example, in the case illustrated above, if the mandatory issue price were \$50 for a \$50 redemption price each, the upside conversion ratio would be $= \$50 / \$48 = 1.0417$.

otherwise identical traditional convertible security is to compensate for the short at-the-money leg in the ratio call spread. Its payoff diagram approximates that of a *prepaid forward share agreement*.[43]

The convertible mandatory product was developed in response to issuers' intent to lower the debt-to-equity ratio on their balance sheets, a factor considered by rating agencies in assessing the issuing corporate's credit worthiness and assigning debt rating accordingly. Its popularity with issuers stems from the possibility of selling common equity at a premium, thereby effecting a lower dilution rather than selling common shares at the then spot price. As it results in issuance of additional shares under any outcome, issuance of a mandatory receives the same 100% equity credit from the rating agency, S&P, as if the issuer had issued common shares.

In the equity-linked terminal payoff diagram in Exhibit 38-3, the 45-degree line GAE represents the common stock, and OABC the traditional convertible debt security; GABC represents the mandatory security.[44]

This basic structure has evolved, such as into mandatory convertible notes structure in Europe, and changes in the U.S. mandatories to address accounting and tax concerns of issuer and holders.[45,46] However, despite the structural differences, the descriptors and underlying variables applicable to the valuation of a mandatory are essentially the same as applicable to convertible notes. Additional features, analogous to convertible notes, now include conversion ratio adjustments (as in Appendix 38A), equity-dilution-reducing transactions by the issuer (as in Appendix 38C), as well as make-whole adjustments to conversion

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43. Not surprisingly, therefore, that a suggestive marketing name for this structure from an underwriter investment bank was "YES," the acronym for Yield Enhanced Stock.

44. As an aside, from the mandatory securities' evolutionary perspective, the earliest mandatorily convertible security was of the capped common variety represented by GADF in the schematic of Exhibit 38-3. Within six months of its design, in 1991, by the investment bank Morgan Stanley, and called Preferred Equity Redemption Cumulative Stock ("PERC"), it was used to raise $4 billion by several then-well-known and desirable issuers such as General Motors, K-Mart, and Texas Instruments. It attracted yield-oriented investors due to its higher yield than that of the underlying common share, which was to compensate the investor for the short out-of-the-money call in the structure that benefited the issuer. PERCS soon lost popularity with investors due to its upside cap on the gains of the underlying and so reflected in the financial press. See, for example, L. Light, "'PERCS' You May Be Better Without," *Bloomberg News*, April 19, 1992.

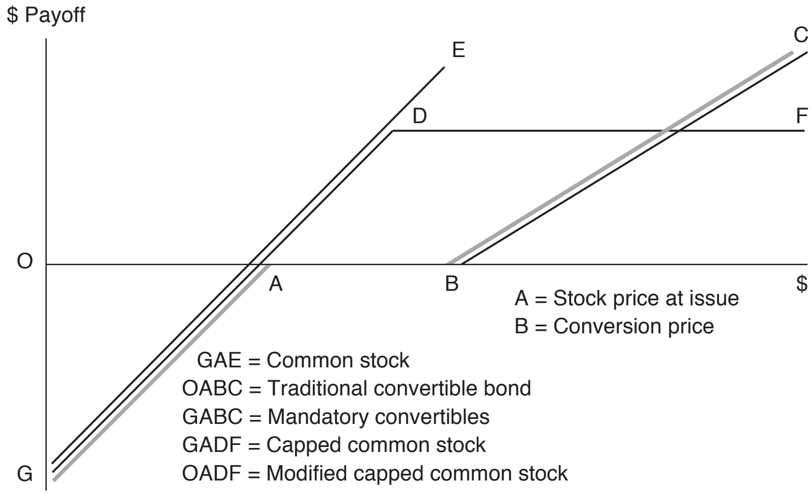
Another structure of the capped common—this one with downside protection of a bond—was issued by Microsoft Corp. in December 1996. Despite its payoff schematic as OADF, it was eagerly received by dedicated convertible investors as the only manner of obtaining exposure to a very popular growth stock whose common stock paid no dividends. These capped common structures are no longer issued in public markets.

45. The tax, accounting, and legal details are the realm of professionals in those fields and hence passing mention only here.

46. An overly simplified rationale for the current structure of U.S. mandatories is due to the earlier convertible preferred share structure resulting in dividend withholding from non-U.S. domiciled investors not otherwise subject to U.S. taxes. In addition, in the United States the structures have evolved to address the tax deductibility of the periodic distributions made to service the mandatory convertible security.

EXHIBIT 38-3

Equity-Linked Payoff Diagram



ratio upon fundamental change (as in Appendix 38B) and incrementally elaborated below.

Valuation

The most logical approach to valuing a mandatory in its current structural iteration is to value its constituent components, namely, the prepaid forward share agreement plus the ratio call spread, as proposed by Arzaq[47] and modified by Amman and Seiz.[48] The price of the mandatory at time t, P_t, is given by

P_t = Present value of the par amount discounted at the risk-free rate

+ Present value of the fixed coupon payment to maturity discounted at the credit curve for the issuer

+ Value of the long conversion option at the upper strike × the number of calls at the upper strike price

– Value of the short call at the lower strike × the number of calls at the lower strike price

47. E. Arzac, "PERCS, DECS, and Other Mandatory Convertibles," *Journal of Applied Corporate Finance*, Spring 1997, pp. 54–63.
48. J. Amman and R. Seiz, "Pricing and Hedging Mandatory Convertible Bonds," *Journal of Derivatives* 13(3), 2006, pp 30–46.

While the valuation of the options is straightforward using standard option valuation formulae, it is argued that because the par value can be settled in stock and hence the possibility of default is eliminated, its discounting should be at the risk-free rate. On the other hand, the cash coupons should be discounted at the risk-free rate plus the credit spread applicable to the payment date considering the possibility of default by the issuer. However, this differential discounting rate does not handle the case if, as seen in the Stanley Black & Decker mandatory (below), the periodic payments that proxy the coupons can be deferred without causing default and can also be paid in cash or shares or combination.

Sample Mandatory Convertible

A very recent mandatory issued in the United States exemplifies current evolution of the terms of the mandatory product.

Off of the closing price of the day for its common stock on November 7, 2019, Stanley Black & Decker raised a gross amount of $675 million through the sale of its "Equity Notes" via a group of underwriters. Effective for trade at the start of the next day, November 8, and trade settle date of November 13, 2019, and maturity date of November 15, 2022, this structure that was effectively a three-year mandatorily convertible security, convertible into its own stock (Ticker = "SWK") was priced at a 20% conversion premium, paying 5.25% per annum, to be paid quarterly, in arrears. Sold at 100% of its redemption value, also colloquially called par value, of $100, it is nonconvertible prior to maturity, other than in exceptional conditions specified. In addition, it includes standard features such as conversion ratio adjustments for corporate actions, make-whole upon fundamental change, and the issuer's choice to settle upon conversion by issuance of shares or cash or combination thereof. Further, SWK also has the option to pay the periodic payments, here termed as the "Contract Adjustment Payments," in cash, shares, or combination; these payments are deferrable but cumulative.[49]

Terms:	
Reference price:	Closing price on November 7, 2019 = $159.45
Initial conversion premium:	20%
Initial conversion price:	$159.45 × 1.20 = $191. 34
Initial upside conversion ratio:	$100.00 / $191.34 = 0.5226 common shares
Maximum settlement rate:	$100.00 / $159.45 = 0.6272 common shares

49. The preceding summary is abstracted from the detailed definition and language of the Offering Prospectus documents, and Supplements thereto, from the perspective of a holder of the security. It does not purport to be fully reflective of the tax, accounting, and legal aspects of the offering documents.

Further, if at settlement, the share price is lower than the conversion price but higher than the reference price, then conversion shall be into a variable number of the underlying common shares whose value equals \$100. For example, if the share price at settlement, as defined, were to be \$175, the number of shares due to the holder, assuming no prior conversion ratio adjustments, would be \$100.00 / \$175.00 = 0.5714 common shares.

The terms describing the structural aspects from which the above summary is extracted bears some mention. Labeled as Stanley Black & Decker "Equity Units," the security is issued as a "Corporate Unit" and offered at a price of 100% of each Equity Unit's "stated amount" of \$100, together with a contractual obligation for the holder to purchase and the issuer to sell a 10% interest in the issuer's 0% Perpetual Convertible Preferred Stock with a liquidation preference of \$1,000. The "Contract Adjustment Payments" shall be at the annual rate of 5.25% (payable as elaborated above). Only the 0% Perpetual Convertible Preferred has the conversion option and separated from it, the equity units do not. Further, if the event that the remarketing of the 0% Perpetual Convertible Preferred, which shall occur in 2022, a new, presumably higher, preferred dividend rate may apply to this remarketed convertible preferred and the conversion option continues with it. Typically, such remarketing efforts being rarely successful, the equity units shall obligatorily acquire the proportionate interest in the 0% perpetual convertible preferred and immediate conversion thereupon into the number of shares per the terms established.[50]

The make-whole matrix for fundamental change for a mandatory, while based on the same principles as that for a convertible note, reflects its aforementioned embedded ratio call spread and the present value of the projected cash flows to the maturity date.

For the Stanley Black & Decker 5.25% mandatory, in the make-whole matrix (see Exhibit 38-4), all cells under the column \$159.45 are set to zero, and holders will receive the Maximum Conversion Rate since that equates the holder's \$100 investment. Also, the last row representing the settlement or maturity date, has all cells at zero since at maturity both options in the embedded call spread have zero time value remaining. For all other cells, the adjustment reflects the time value of the call spread for each share price level and effective date. As usual, share adjustments shall be per linear interpolation for share price levels and effective dates not represented in the matrix, with the caveat that in no event shall the number of shares at settlement exceed twice the Maximum Settlement Rate of 0.6272.

Note that compared to the make-whole matrix for the Tesla 2's of 24, where with the exception of the zero filler cells and left-most column of the common share price at issue, all other cell entries are monotonically decreasing from left to right columns and from top to bottom rows. Not so in the case of the make-whole for the mandatory due to the two present value components and the two parts of the ratio call spread that define a mandatory.

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50. From a holder perspective, abstracted from the above legal language is message that the periodic payments are tax deductible for the issuer with applicable resulting impact for the holder.

EXHIBIT 38-4

Make-Whole Matrix

	Stock Price																
Effective Date	**$30.00**	**$60.00**	**$80.00**	**$100.00**	**$120.00**	**$159.45**	**$170.00**	**$180.00**	**$191.34**	**$200.00**	**$220.00**	**$240.00**	**$260.00**	**$280.00**	**$300.00**	**$350.00**	**$400.00**
November 13, 2019	0.4746	0.2165	0.1440	0.0933	0.0544	0.0000	0.0281	0.0518	0.0756	0.0694	0.0574	0.0477	0.0399	0.0336	0.0284	0.0189	0.0124
November 15, 2020	0.3196	0.1478	0.0998	0.0637	0.0327	0.0000	0.0125	0.0366	0.0609	0.0551	0.0440	0.0354	0.0288	0.0237	0.0197	0.0127	0.0083
November 15, 2021	0.1617	0.0754	0.0530	0.0355	0.0158	0.0000	0.0000	0.0217	0.0452	0.0391	0.0280	0.0204	0.0154	0.0120	0.0096	0.0061	0.0040
November 15, 2022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TRADING CONVERTIBLE PORTFOLIOS

The convertible asset class has evolved in response to changes in macro factors in the global economy. Prominent among the latter are the extended period of low interest rates, and low volatility levels accompanied by inexorably rising equity prices, though with some periodic correction blips. Both the supply side as well as the demand side for convertibles have significantly impacted their issuance volumes, structure, and portfolio trading.

On the supply side, trends include:

- Lower net issuance, defined as new issuance dollar amounts less matured, redeemed, or converted amounts. The upsurge in straight debt issuance at attractively low rates has reduced the need for issuance of convertibles with its attendant potential equity dilution.
- Issuer recognition that equity volatility, which is a by-product of its inherent business operations, is an asset that can also be monetized. This is manifested in ever tightening competitive terms offered to the issuer by competing investment banks in selling to the convertible asset class investors.
- Structural rationalizations, such as the dilution protection and value conservation clauses, contribute toward reducing pricing inefficiencies in the asset class.
- Reduced liquidity provision by investment banks in response to increased regulatory capital requirements has negatively affected secondary market trading.

The corresponding demand side trends include:

- Surge in passive trading and indexation and the proliferation of exchange-traded funds (ETF) has created considerable fee pressures for both the convertible long-only funds as well as the convertible arbitrage funds.[51]
- Reduced demand for downside protection, as offered by convertibles, in a generally rising equity unhedged exposure.

As a result, convertible portfolio management requires deliberate decisions on retained risk exposures. The tools available to the outright manager in that context are:

- Security selection: participating or not in any individual convertible security available based on the fundamental analysis of the underlying equity, its expected volatility, the issuer credit, and potential liquidity.
- Concentration and diversification aspects from issuer, industry sector, ratings, maturity tenor, and geographical/political risks.

51. Only a few dedicated convertible ETFs exist currently.

- Allocation of exposure to the asset class: specifically, this implies cash retention level in the case for dedicated convertible funds, despite the cash drag involved. For nondedicated, opportunistic long-investment investors into the asset class, it implies how much and when to invest. Thus, exposure timing is an important risk retention decision.

  While the principal sources of portfolio gains for outright funds are through valuation gains on the underlying stocks, and yield advantage of the convertibles, availability of analytical valuation models help inform their portfolio buy/sell/hold decisions, despite their not being permitted to engage in hedging trades. In addition to the fundamental research on equities and credit as done by the outright funds, convertible arbitrage incorporate the hedging analysis provided by the analytical valuation models in expressing their trades. Several dedicated convertible hedge funds have, as an upshot, evolved into trading in relative value credit arbitrage and capital structure arbitrage. That said, delta and gamma trading still remain a dominant focus area for convertible arbitrage funds and are operated with a leverage. While in the pre-2008 period portfolio leverage of 6× or higher was not uncommon, the current level is estimated to be in the 2–2.5× range.

  It is interesting, therefore, to study the P&L realization of a single convertible note through delta trading during what has been termed a "once-in-a-lifetime" period of rapid volatility evolution. This follows next.

DELTA TRADING P&L: A HIGH VOLATILITY SCENARIO EXAMPLE

Due to the exogenous event of the Coronavirus occurrence in the United States, security markets globally experienced valuation shocks. This has been intense in severity in the short period of time involved. In the United States, for example, the S&P 500 Index dropped 29.18% in one month, from February 19, 2020, to March 18, 2020. The TSLA common stock underlying the TSLA 2% of 24 convertible note, chosen by happenstance as the prototype security for this chapter, dropped from \$917.42 to \$361.22, a drop of 60.53%.[52]

Appendix 38D shows the daily changes in the convertible's value, its delta, gamma, and daily P&L for eight consecutive trading days, ending on March 18, 2020. It also shows the corresponding daily changes in the S&P Index, TSLA stock price, VIX Index levels, and the yield on Treasury five-year notes. The P&L reported is on an unlevered basis.

52. As of this writing, the S&P Index and TSLA stock have both recovered to reach new record levels. TSLA stock, in addition, has split 5:1 as of August 31, 2020. With the conversion ratio thus changed taken into consideration, the rest of the convertible valuation analytics remains unaffected.

KEY POINTS

- Structural evolutions in the convertible asset class products, in response to market macro factors and greater analytical sophisticated, on the part of issuers and investors, have contributed further toward convertibles being viewed as a fair and viable asset class for both issuers and investors.
- Convertible securities continue to be a small, though meaningful, source of investor capital for corporate issuers who, largely due to rating pressures, are generally unable or unwilling to access loan or senior unsubordinated debt markets.
- However, with dilution-neutralizing hedging being available to issuers, with TSLA 2% of 24 as an example, the average issuer profile is evolving toward larger size transactions and more liquidity.
- While yield advantage and positive convexity continue to be the principal return drivers, fundamental research, analytics, and risk measures are of ever-increasing importance as convertibles are now far evolved from when they were perceived—in some circles—as a small and hence inefficiently priced asset class.
- This trend toward pricing efficiency will be further enhanced when additional tools, such as single-name credit default swaps, become liquidly available to refine risk exposure types and levels that a holder chooses to retain in a convertible portfolio.

APPENDIX 38A

Conversion Ratio Adjustments to Corporate Actions

Objective: To preserve the conversion value of the conversion option embedded in the convertible security that might otherwise be adversely impacted by corporate actions or transactions while the convertible security is still outstanding.

Caveat: The adjustments, usually an increase in the applicable conversion ratio, will not be made if the convertible already participates concurrently with the common shares in proportion to the applicable conversion ratio as a result of the corporate actions described below. Exceptions to this caveat pertain to stock splits or reverse splits of the underlying common share, which will occur simultaneously.

Adjustment formulae for the typical cases, subject to a deferral option (see below) are:

1. *Anti-dilution adjustment*: For common share issuance pursuant to stock dividend, distribution of shares, stock split, or reverse split, the formula is

$$CR_{post} = CR_{pre} \times OS_{post} / OS_{pre} \tag{A38-1}$$

where CR = applicable conversion ratio, OS = shares outstanding, and the subscripts "pre" and "post" dates as defined for the above corporate event event.

2. *Discounted share sale adjustment*: This pertains to the case where through an offer of rights, warrants, or options, the underlying shares are offered for sale at a discounted price from the then-current stock price defined, say, as the average of the closing price of 10 consecutive days immediately preceding the offer announcement date. Such offers have an ex-date for the warrant or option exercise, and the formula is

$$CR_{post} = CR_{pre} \times (OS_{pre} + N_{addl}) / (OS_{pre} + N_{disc}) \tag{A38-2}$$

where N_{addl} = additional shares issued and N_{disc} = aggregate realized proceeds from the sale of the additional shares divided by the undiscounted average closing price, as defined.

Numerical example: OS_{pre} = 1,000,000 shares; distribution = one warrant per share outstanding; number of warrants to acquire an additional share = 2; average price of the share over the 10-day prior to the announcement date = \$40 per share; discounted price = 80% of the average price of \$40 = \$32 per share.

a. If all the warrants are exercised, then total issuable new shares = 500,000, then

$$CR_{post} = CR_{pre} \times (1{,}000{,}000 + 500{,}000) / (1{,}000{,}000 + (500{,}000 \times \$32 / \$40)) = CR_{pre} \times (1{,}500{,}000 / 1{,}400{,}000) = 1.0714$$

b. If only 700,000 warrants are exercised, total issuable new shares = 350,000, then

$$CR_{post} = CR_{pre} \times (1{,}000{,}000 + 350{,}000\ ) / (1{,}000{,}000 + (350{,}000 \times \$32 / \$40)) = CR_{pre} \times (1{,}350{,}000 / 1{,}280{,}000) = 1.0547$$

In the event that consideration for purchase of these warrants, rights, or options involves noncash consideration to any extent, the fair market value of such assets shall be determined by the board of directors of the issuer.

3. *Cash distributions and increase or decrease in dividends*: For the event date being the ex-dividend date, S as the stock price on the date immediately preceding the ex-dividend date, T as the threshold for the regular dividend then in effect preceding the ex-dividend date, and D as the distribution, the most frequently used formula is

$$CR_{post} = CR_{pre} \times S / (S - (D - T)) \tag{A38-3}$$

Note that the threshold dividend level is $T = 0$ in the case where the underlying stock did not pay regular periodic dividends at the time of issuance of the convertible, as in the case of the prototype Tesla convertible discussed. The logic for this adjustment is that in the case of the distribution D, the ex-dividend price of the underlying is expected to decline by an incremental amount over the usual decline to the extent that D exceeds T.

T = 0 also if this current distribution is a special or nonregularly scheduled distribution.

A less frequent alternate adjustment in the above cases is

$$CR_{post} = CR_{pre} \times (S - T) / (S - D) \tag{A38-4}$$

The adjustment in Equation A38-4 takes into consideration the ratio of the expected decline in the stock price, S, due to the regularly scheduled dividend threshold, T, to that expected to result from the increased or special dividend, D. This is perhaps a less defensible argument than that resulting in Equation A38-3.

Further, for every $D > T$, Equation A38-3 results in a larger conversion ratio adjustment. The opposite is the case where $D < T$, that is, in the event a cut in regular dividend should it occur.

In all events, T is adjusted in inverse proportion to the conversion ratio adjustment.

4. *In-kind distribution*: This case involves distribution in proportion to the underlying shareholding, and hence also proportional to the then-effective conversion ratio of the convertible. Further, in the usual non-readily-available traded prices of such assets—that may include debt assets, property, rights, warrants, options, unlisted shares—a fair market value estimate, F, is established by the board of directors, or their designees. A valuation period preceding the effective ex-distribution date and corresponding valuation methodology for pricing data available is also usually specified.

Conversion ratio adjustment in this case is identical to Equation A38-3, with $T = 0$ and F in place of D.

$$CR_{post} = CR_{pre} \times S / (S - F) \tag{A38-5}$$

5. *Spin-off of listed asset:* This case occurs when the common stock underlying the convertible effects a distribution of an exchange-listed equity or units in which it holds an interest. The event date is the spin-off effective date, the spin-off period is usually 10 days immediately preceding the spin-off date. The calculated fair market value, F, is the to-be-distributed equity's share price average of the reported closing prices for the spin-off period multiplied by the number of shares of the spin-off equity to be distributed per share of the underlying stock. S is the reported closing price of the underlying stock immediately preceding the ex-dividend date. In this case, the conversion ratio adjustment is

$$CR_{post} = CR_{pre} \times (P + F) / P \qquad \text{(A38-6)}$$

6. *Self-tender offer*: With a view to reducing the number of shares outstanding, if the issuer of the convertible security engages in share buybacks in the open market, there shall be no change in the conversion ratio of the convertible as the share price itself will reflect the effect of the share buyback, thereby benefiting all remaining equity interests, including the convertible holder. On the other hand, if effected through a self-tender or exchange offer to substantially all equity interests and not to the convertible holder, the convertible ratio will be adjusted upward to reflect the consideration paid out in the self-tender that results in the value of the underlying stock. The event date here is the expiration date of the tender offer and the conversion ratio adjustment is

$$CR_{post} = CR_{pre} \times (C_{tender} + (S_{tender} \times OS_{post})) / (S_{tender} \times OS_{pre}) \qquad \text{(A38-6)}$$

where

C_{tender} = the aggregate consideration received in cash and/or kind whose fair market value is established by the issuer's board of directors or their nominees

S_{tender} = usually the average of the reported closing price of the immediately 10 days starting with, and including, the trading day immediately following the tender offer expiration date

Note that OS_{post} excludes all shares accepted for purchase through this tender or exchange offer, while OS_{pre} does include such shares.

Deferral of conversion ratio adjustments: The above adjustments are made on the ex-date of the corporate event unless the change results in less than a typical threshold of 1% of the conversion ratio then in effect. In such cases, the ratio change is instituted at the earlier of when they cumulatively exceed the threshold level change or upon conversion.

APPENDIX 38B

Fundamental Change Make-Whole Adjustment to Conversion Ratio at Conversion

Motivation: Consider the case of an acquisition transaction where the common stock underlying the convertible is acquired in exchange for consideration comprising of a combination of:

- **a.** 0% to 100% of the acquiror's common shares
- **b.** 0% to 100% in cash
- **c.** Some illiquid or difficult to value in-kind asset(s)

Case (a): If 90%, or greater, of the consideration value is in the form of the acquiror's common shares, as agreed to by the acquiree's board of directors and so communicated to the Trustees for the issue, the time value of conversion option will be deemed to be unaltered. Consequently, there shall be no make-whole adjustment to the conversion ratio of the convertible. Going forward, post the effective date of the acquisition, the convertible security will continue into shares of the acquiror as determined in the acquisition share exchange ratio. Further, while the coupon rate and the maturity date remain unchanged, all other parameters including the dividend threshold, the value retention adjustments to the conversion ratio, will be correspondingly adjusted to conform to the terms of the convertible specified at issue. Despite these adjustments, the conversion value option may differ from before the event date due to the variables of the new underlying stock being different, particularly its volatility; its borrow cost, which, in turn, is a function of its liquidity; and the credit spread of the acquiror.

Case (b): An entirely cash takeout of the underlying common would retain zero residual time value of the holders' conversion option and would cause the holder to exercise conversion. The value erosion due to an in-kind component would be total.

Case (c): Subject to the conversion ratio adjustment, discussed in Appendix 38A, being in effect, some value erosion is likely, though not a total loss of value.

The *make-whole fundamental change matrix* specifies the temporary adjustment to the conversion ratio upon conversion, in the event of a fundamental corporate change. This matrix, left blank in a preliminary ("red") offering prospectus, is set forth in a supplement to the offering prospectus following the pricing of the convertible and prior to the commencement of its public trading on the relevant exchange on the next trading day.

The intent for this make whole fundamental change matrix is to mitigate the impact of value erosion through cases b and c above and also if redeemed by the issuer during a nonredemption period In effect for reasons permitted as described in the prospectus. Further, as an offset to provisional redemption terms or a freely redemption period, which would normally “cost” the issuer in a lower initial conversion premium or higher coupon, this make-whole may also be included in the defining terms of the convertible at issue.

As can be seen in Exhibit 38B-1, the matrix for the prototype Tesla 2’s of 24 share price scenarios for the underlying common are on the X-axis and Effective Dates for redemption or conversion on the Y-axis

The cells specify the number of additional shares, if any, to be added to the then effective conversion ratio to compensate for the erosion of the time value of the conversion option.

Typically, the *x*-axis scenarios extend to triple or even 5× times the price of the underlying at issue; going beyond 10×, as in the situation below, is highly unusual. For intermediate dates and stock price levels not represented in the matrix, a linear interpolation between the two adjustment ratios will be made for time difference based on a 365-day year. The matrix also specifies the maximum and minimum adjustment ratios. For example, for TSLA price at or above $2500 per share there shall be no additional share adjustment.

Calculation of the make-whole matrix cells: Recall the initial terms of the issue. They were as follows:

Issue pricing date:	Close of trading on May 2, 2019
Trade settle date:	May 7, 2019
Maturity date:	May 15, 2024
Par value of note:	$1,000.00
Price of note at issue:	$1,000.00
Reference price of the underlying:	$243.00 per share
Initial conversion premium:	27.5%
Initial conversion price:	$243 × 1.275 = $309.83
Initial conversion ratio:	$1,000 / $309.83 = 3.2276 shares per note
Redemption:	Nonredeemable for life

EXHIBIT 38B-1

Make-Whole Matrix

Effective Date	$243.00	$260.00	$280.00	$309.83	$350.00	$400.00	$500.00	$750.00	$1,000.00	$1,500.00	$2,000.00	$2,500.00
May 7, 2019	0.8876	0.7790	0.6738	0.5508	0.4306	0.3279	0.2080	0.0926	0.0520	0.0199	0.0066	0.0000
May 15, 2020	0.8876	0.7738	0.6591	0.5270	0.4006	0.2958	0.1790	0.0759	0.0425	0.0165	0.0055	0.0000
May 15, 2021	0.8876	0.7565	0.6306	0.4883	0.3560	0.2509	0.1418	0.0570	0.0322	0.0129	0.0043	0.0000
May 15, 2022	0.8876	0.7248	0.5836	0.4284	0.2909	0.1894	0.0961	0.0371	0.0217	0.0090	0.0030	0.0000
May 15, 2023	0.8876	0.6708	0.5034	0.3284	0.1893	0.1032	0.0438	0.0179	0.0111	0.0047	0.0016	0.0000
May 15, 2024	0.8876	0.6185	0.3438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Computation methodology for the cells in the matrix: Let S denote the stock price scenario under consideration, CRA denote the conversion ratio adjustment, ICR = 3.2276, as the initial conversion ratio. Then:

- For all rows under the column under S = \$243—which is the stock price on date of issue—and the last row pertaining to the maturity date, May 24, 2024, with the increasing stock price scenarios pertaining to that row, the CRA is calculated as follows:

  a. For $S \times \text{ICR} \geq \text{Par}$, CRA = 0;

  b. For $S \times \text{ICR} < \text{Par}$, CRA = $((\text{Par} - (S \times \text{ICR})) / S) - \text{ICR}$

  Numerical examples:

  1. For $S = 243$, $S \times \text{ICR} = 243 \times 3.2276 = 784.31$. Therefore, condition b applies. Hence,

  $$((1000 - 784.31) / 243) - 3.2276 = 0.8876$$

  Comment: 3.2276 + 0.8876 = 4.1152 shares is the upper limit and 3.2276 is the minimum number of shares specified for the Tesla convertible note. Similar limits pertaining to the make-whole adjustment matrix are common for new issue convertibles.

  2. For S = \$280 at maturity date, $S \times \text{ICR} = 280 \times 3.2276 = \$962.72$; condition b applies. Hence,

  $$((1{,}000 - 962.72) / 280) - 3.2276 = 0.3438$$

  3. For S = \$309.83, the initial conversion price, $S \times \text{ICR} = 309.83 \times 3.2276 = \$1{,}000$, and condition b applies. Hence adjustment ratio is zero. And so also for all other higher share price scenarios in that row.

- For S = \$2,500 or higher, there is zero conversion ratio adjustment specified regardless of the date of the option value erosion occurrence consequent to the fundamental corporate change event.
- For all other cells, a theoretical value— based on the then spot stock price, and the remaining time to maturity commencing from the event date—is computed with input variables as obtaining on the date of pricing the note. The adjustment ratio is then calculated as

  $$\text{Conversion ratio adjustment} = (\text{Theoretical value} - \text{ICR} \times S) / S$$

  Numerical example: For S = \$400, for date May 15, 2021, since the exact convertible valuation model is proprietary to the underwriter and hence not publicly available, the computed theoretical model value can be solved for and works out to be

  $$0.2509 = (1391.40 - 1{,}291.04) / 400$$

Note that here 1,291.40 is the conversion value at S= 400 and \$100.36 is the remaining time value computed using the convertible valuation model employed with values of variables—such as volatility, yield curve, credit spreads, stock borrow—as obtaining on the date of issue of the note. Hence the incremental adjustment of 0.2509 shares valued at S = 400 equals the remaining time value.

While the make-whole matrix does go a substantial way toward compensating the holder for the erosion of the time value of the conversion option, it is not perfect. The shortfall may come from the values of the estimated variables employed in the valuation model being different than those as of the event date, setting aside the idiosyncrasies of the valuation model and its sophistication.

- In the hypothetical case that the Tesla 2 of 24 had a provisional call at 130% after year 3—which it does not—the provisional conversion price would have been = \$309.83×1.30 = \$402.78. Then subject to the test that this provisional call price threshold was equaled or exceeded by TSLA closing price on 20 out of 30 trading days, the conversion ratio adjustment cells—for the column for \$402.78 or higher stock prices, for rows May 15, 2022, and May 15, 2023—would have been zeros.

APPENDIX 38C

Equity Dilution-Reducing Transactions by the Issuer

Equity dilution concern: Any financing undertaken by a corporate issuer is always analyzed for its eventual impacts on the cash flows and earnings per share that affect all holders of the issuer's securities. In the case of equity and equity-linked issues, this attention is further accentuated since equities, as the junior-most in the payoff hierarchy, are viewed as residual claimants to the assets of the firm. Black and Scholes, following their derivations to price options on an underlying stock, have also shown how a common share may be priced as call option based on the value of the underlying firm. Taking this concept a step further, Geske shows how an option on the underlying stock is thus a compound option on the value of the firm, and thus is even more sensitive with respect to the underlying firm value.[53]

53. Robert Geske, "The Valuation of Compound Options," *Journal of Financial Economics,* 1979, pp 63–81.

It is no surprise, therefore, that an issuer of a convertible security, with its embedded equity-linked options, be concerned with the dilution impact on the underlying shares should the conversion option be exercised thereby necessitating settlement by issuance of the stipulated shares or their cash value or in a combination thereof.[54,55] The direct effect of dilution is due to the reporting requirement that the issuer declare financial results, periodically, based on current shares outstanding as well as in the fully diluted form. The latter takes into account the potential incremental share issuances due to all then still outstanding equity-linked liabilities.

Additionally, the issuer is usually concerned by the signaling inferred by the market to the issuer's specific choice of the instrument, its size, pricing, use of proceeds, efficacy, and its eventual impact to equity valuation metrics. Finally, as it pertains to any equity-linked security, and particularly here applicable to convertible securities, is the impact of shorting of the underlying stock that is employed by hedge fund participants to hedge the convertible's embedded equity exposure to desired levels.[56]

Dilution reduction approaches: There are several methods available to either reduce or eliminate the dilution impact. In addition to open-market purchase of the underlying shares by the issuer, they include repurchase through a *forward contract*, a *pre-paid forward,* or a *collar contract* pertaining to the underlying common transacted, most commonly, with the derivatives desk of an investment bank as the counterparty, or even a *self-tender offer*. Each of these have their own advantages/drawbacks relating to the certainty of execution and net cost.

The most frequently used methods employed, as executed concurrently by TSLA at the time of issuance of the prototype "Tesla 2's of 24" convertible note, are:

- *"Happy meal" repurchase of shares*: Under this method of share buyback, the issuer enters into a derivative contract with the underwriter(s), or their affiliate(s), as counterparty, to offload the liability of the shares expected to be delivered, or their cash equivalent, or combination, upon conversion should it occur. This transaction is for the notional number of shares, underlying the aggregate note issue, occurs at an agreed upon delta hedge ratio, with the derivative contract maturity mirroring that of the convertible note. In turn, now with short equity exposure,

54. Ignoring the accounting and tax aspects, the in-cash settlement, in lieu of the physical settlement in shares, may be viewed as the issuer acquiring the applicable number of shares in the market and delivering equivalent value for them to the holder.
55. *A Roadmap to the Issuer's Accounting for Convertible Debt*, Deloitte, 2019, pp 1–260, provides details.
56. Holdings by hedge fund participants cannot be avoided even if the convertible new issue is initially fully subscribed for by, and fully allocated to, outright investors and zero allocations to hedge funds. Even in this case, hedge fund participants will establish positions via secondary market purchases.

the counterparty reduces some of it by buying back shares from hedge funds to whom a subset of the new notes is allocated. This benefits the hedge funds too as they seek to establish a short position against their newly acquired convertible note position. The price per share of the short exactly equals the reference price of the convertible. Because it provides the definitive price and assured short sale, with the exact settlement date as the new convertible note being allocated to them, the hedge funds are relived of the market exposure that they would have faced otherwise in sourcing and selling shares short in the open market to establish the hedge position at just the right starting neutral hedge ratio. This "packaged" bond allocation along with the requisite short equity trade in the underlying is, therefore, called a "happy meal" in the convertible vernacular.[57]

Numerical example: Consider a hypothetical convertible note of issue size \$100 million, issued at par = \$1000, priced off of a reference price of \$40 per share as of the close of trading on the date of issue, conversion premium = 25%. Hence conversion price = \$50 per share, and initially convertible into 20 shares per note, with aggregate number of underlying shares = 2 million, and suppose that the initial delta is 42% and allocation to hedge funds = \$35 million of notes, with the balance \$65 million to outright investors.

> Equity component of the short position with hedge funds in a happy meal transaction = 35,000 note × 20 shares per note × 0.42 hedge ratio = 294,000 shares
>
> Short sale proceeds = 294,000 shares at the reference price of \$40 per share = 294,000 × 40 = \$11.76 million
>
> Hedge funds net outlay = \$35 million allocation less \$ 11.76 short sale proceeds = \$23.24 million

To address the remaining initial short in the counterparty's position—to the tune of 546,000 shares, in this example—the counterparty will engage in actual or synthetically equivalent share purchases to start, and dynamically hedge the exposure to the expiration date.

- *Bond hedge overlay*: The purpose here is to synthetically raise the effective conversion price for some, or all, of the shares as stipulated in the overlay transaction. This bond hedge overlay consists of two parts, both subject to holders exercising conversion of the convertible security. The first involves the purchase of the hedge by the issuer from the counterparty, as described above, for the latter to deliver to the issuer the number of underlying shares agreed to, or their value in cash, or

57. The cost the happy meal is defrayed by the issuer from the proceeds of the note issue and usually ranges around 15% of the net fund raise.

combination thereof. The second is a warrant sold by the issuer to the counterparty at a higher conversion price—commonly 30% above the initial conversion price in the case of convertible notes, and 10–15% higher in the case of mandatorily convertible preferred shares—for the same number of underlying common shares as agreed to in the first part, or their cash value, or combination. For tax reasons, the warrant is issued separately and expires a few days beyond the maturity of the convertible.[58]

Equivalently, in lieu of the warrant, the same result can be attained by the issuer selling to the counterparty calls capped at the higher exercise price for the same number of shares as stipulated and with maturity date as in the convertible note. In this version, the two legs of the transaction are included in the same document.

ADDITIONAL COMMENTS

- Note that the conversion ratio adjustments made for the note per dilution protection and value preservation, described in Appendix 38A also carry through for the derivative contracts described here.
- Incremental to the direct upward pressure on the underlying stock caused by share purchases by the hedge counterparty as it sets up its own off-setting position, the inferred message of these dilution-reducing transactions is also beneficial to the underlying stock price.

58. For details, see the Deloitte note cited in footnote 55.

APPENDIX 38D

Delta Trading Illustration for the TSLA 2% of 24 Convertible Note

	1	2	3	4	5	6	7	8	9	10	11	12	13
Date	S&P 500 Index Close Level	S&P 500 Index % Change	5-year Treasury Yield in %	5-year Treasury Yield Change	VIX Index Close Level	VIX Index Points Change	Tesla Stock Price in $	Tesla Stock % Change	Tesla Note Price % of Par	Tesla Note Conversion Premium in %	Tesla Note Neutral Delta	Tesla Note Gamma	Tesla Note Delta Trade Profit/Loss
Friday 2020.03.06	2,972.37		0.58		41.94		703.48		240.60	5.97	0.9621	0.08	
Monday 2020.03.09	2,746.56	–7.60	0.46	–0.12	54.46	12.52	608.00	–13.57	212.28	8.17	0.9464	0.11	13.29
Tuesday 2020.03.10	2,882.23	4.94	0.63	0.17	47.30	–7.16	645.33	6.14	223.24	7.18	0.9537	0.10	–4.43
Wednesday 2020.03.11	2,741.38	–4.89	0.66	0.03	53.90	6.60	634.23	–1.72	219.85	7.40	0.9573	0.09	0.27
Thursday 2020.03.12	2,480.64	–9.51	0.66	0.00	75.47	21.57	560.55	–11.62	197.24	9.02	0.9442	0.11	1.56
Friday 2020.03.13	2,711.02	9.29	0.70	0.04	57.83	–17.64	546.62	–2.49	193.26	9.54	0.9457	0.11	2.65
Monday 2020.03.16	2,386.13	–11.98	0.49	–0.21	82.69	24.86	445.07	–18.58	162.54	13.15	0.9171	0.15	2.77
Tuesday 2020.03.17	2,529.19	6.00	0.66	0.17	75.91	–6.78	430.20	–3.34	156.95	13.03	0.9120	0.15	–11.88
Wednesday 2020.03.18	2,398.10	–5.18	0.79	0.13	76.45	0.54	361.22	–16.03	136.22	16.84	0.8793	0.19	–4.25
Wednesday 2020.02.19	3,386.15		1.41		14.38		917.42						

Source: US Treasury.gov; Yahoo! Finance; Kynex, Inc.

Issue Descriptors: Coupon Rate: 2.00%, Maturity Date: 5/15/2024; Par: $1,000; Underlying Common: TSLA; Reference Price: $243.00 as of 5/2/2020; Initial Conversion Premium: 27.5%; Conversion Price: $309.83; Conversion Ratio: 3.2276 shares per note; Non-redeemable.

Assumptions: Ignoring transaction costs and bid/ask spread; delta hedges and stock trades assumed executed at the levels indicated. Ignoring any inherent model error for the single-factor convertible bond model from KYNEX INC.; Default inputs used for equity volatility, interest rates, credit spreads per the model vendor.

Sample calculation: Portfolio profit/loss =gain (or loss) from the stock short position minus loss (or gain) in the note price
i.e. = ((703.48 – 608.00) × 0.9621 × 3.2276) – ((240.60 – 212.28) × 10) = $13.29 per bond

Comments:

1. The specific week chosen represents what has been termed "once in a generation" volatility in the markets with the S&P 500 Index dropping 29.18% in a month from its high on 2020.02.19 to 2020.03.18, and the VIX Volatility Index jumping from a modest 14.38 to its highest ever level of 82.69 points. Columns 1 through 8 indicate the level of market turbulence.
2. During the same period, TSLA declined by 36.73%. As expected, the convertible note starting so deep-in-the-money, with a high delta and low gamma, portrayed equity-like behavior as expected.
3. Delta trade P&L profile, in (column 13, demonstrates the inherent attributes of the convertible product of "upside participation with downside protection".
4. On 2020.03.17, while the S&P 500 Index gained 6%, TSLA stock declined by 3.34% yet the conversion premium also declined. This suggests a downward shift of the valuation curve due to the widening of its credit spread and/or the bid-offer.
5. The continuing high delta is due to the still remaining long non-call period and TSLA stock's high volatility.

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CHAPTER
THIRTY-NINE

RISK NEUTRAL PRICING OF CONVERTIBLE BONDS

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The aim of any convertible bond (CB) model should be to capture the price action present in both the equity and fixed income markets. Early approaches by Goldman Sachs[1] employed a binomial lattice to this end. An often-cited model is that of Tsiveriotis and Fernandes,[2] which split the CB into cash and equity components with only the former being subject to credit risk. The inability of the equity to default is the common criticism of all these early models. Takahashi, Kobayashi, and Nakagawa[3] made progress in addressing this by introducing a reduced form model for a default adjusted discount rate. The model linked the credit to the equity through the functional choice of the intensity. Ayache, Forsyth, and Vetzal[4] extended the approach of Takahashi, Kobayashi, and Nakagawa by assuming a fractional loss of the predefault value of the equity. Andersen and Buffum[5] went a step further—they model the possibility of default as the first hitting time of a Cox process, where the default intensity links the credit to the equity movements.

1. Goldman Sachs, "Valuing Convertible Bonds as Derivatives," *Quantitative Strategies Research Notes*, (1994).
2. Kostas Tsiveriotis and Chris Fernandes, "Valuing Convertible Bonds with Credit Risk," *Journal of Fixed Income* (1998), pp. 95–102.
3. Akihiko Takahashi, Takao Kobayashi, and Naruhisa Nakagawa "Pricing Convertible Bonds with Default Risk: A Duffie-Singleton Approach," *Journal of Fixed Income* (2001), pp. 20–29.
4. Elie Ayache, Peter A. Forsyth, Kenneth R. Vetzal, "Valuation of Convertible Bonds with Credit Risk", *Journal of Derivatives*, (2003), pp. 9–29.
5. Leif Andersen and Dan Buffum "Calibration and Implementation of Convertible Bond Models", *Journal of Computational Finance* (2004), pp. 1–34.

In all studies, the models are calibrated to traded nonconvertible (vanilla) bonds and equity options. Recently, Xiao[6] was able to obtain theoretical prices using this approach that only differed from observed CB prices by 1–2 points. Arguably, the prices are in close agreement, albeit still in error. The fact that the theoretical prices don't agree with observed prices shouldn't be surprising—even though corporate debt and CDS will trade to maturities of similar tenor to CBs, vanilla equity volatility markets rarely trade out beyond one to two years. With no meaningful volatility market, the ability to calibrate to the term of a convertible bond is limited—hence the inaccuracy.

As of mid-2019, there are more than 1800 daily closing CB prices from 1135 individual issuers as detailed in Exhibit 39-1. Across a five-year time horizon, that number of bonds with observable prices grows to more than 4000 individual securities.[7] Likewise, almost half the CB issuers have either an explicitly traded CDS or some other vanilla bonds in the market with observable prices. Rather than derive a theoretical price, the credit risk can be marked to term and the volatility can be implied from the market, thereby providing a full risk-neutral calibration. In this chapter, a model is outlined that explicitly captures default risk, based on the model by Andersen and Buffum, where the necessary modifications to calibrate to market prices, and the implied volatility, are detailed. The default characteristics of the model are also discussed by investigating five specific securities that represent a broad cross section of the CB universe by both tenor and credit spread. This leads to a specification of the intensity process that explicitly links the performance of the equity and credit by matching the model parameters to defaulted bond prices. Furthermore, a methodology for marking the credit risk for both traded and nontraded credits is presented, which is shown to capture the expected price action across the various asset classes.

The chapter concludes with a study of the implied volatility and sensitivities of the five CBs, where the links between the CB volatility and the equity volatility are investigated. The volatilities broadly agree across both markets with the longer-dated CB volatilities consistently trading at lower levels than the shorter-dated vanilla equity volatilities. This finding confirms the premise that marking to exchange-traded volatilities cannot provide an accurate valuation. Finally, links to convertible bond arbitrage are discussed before a summary of key points is given.

THE MODEL

The accepted theory for the valuation of convertible bonds is due to the early research notes published by Goldman Sachs and Tsiveriotis and Fernandes at Morgan Stanley. However, as previously noted, while these models contain the credit of the issuer, the credit is static and does not alter the bond characteristics

6. Tim Xiao, "A Simple and Precise Method for Pricing Convertible Bond with Credit Risk," *Journal of Derivatives & Hedge Funds* (2014), pp. 259–277.
7. Data maintained by FactSet Research Systems Inc.

EXHIBIT 39-1

Convertible Bond Price Universe

	5/16/2019	From 1/1/2019	From 1/1/2018	2-Year Window	5-Year Window
CB Issuers with Prices	1,135	1,222	1,434	1,571	2,155
CB ISIN with Prices	1,871	2,090	2,556	2,842	4,266
CB Parent with CDS (Issuer)	121 (132)	144 (155)	167 (181)	186 (204)	281 (329)
CB with CDS	327	384	464	520	560
Parent with Vanilla Bonds	526	538	571	589	636

Source: FactSet

if the issuer is distressed. Therefore, Andersen and Buffum introduced credit dynamics by modelling default with a Cox process[8] (sometimes referred to as a doubly stochastic Poisson process). The process models the issuers' credit dynamics via an intensity process, which is linked to the equity price. As the equity price decreases, the "first hitting time" of the Cox process—representing the default of the CB issuer—becomes more likely. The addition of this jump-to-default process requires a modification of the drift of the equity to maintain arbitrage freedom—that is, all forward contracts are correctly priced. Since $E\left[dN\right]=\lambda\left(S,t\right)dt$ (where $\lambda\left(S,t\right)$ is the default intensity, S is the stock price, and E denotes risk-neutral expectation) the resulting stochastic differential equation has the risk-neutral drift of the equity modified by the default intensity

$$\frac{dS_t}{S_{t-}}=\left(r_t-q+\lambda\left(S,t\right)\right)dt+\sigma dW_t-dN_t \tag{39-1}$$

where r_t is the risk-free interest rate, q is the instantaneous dividend yield, σ is the equity volatility, and W_t is a Brownian motion. That the first hitting time represents a default is guaranteed by the last term in Equation (39-1): the change in the underlying equity is the entire value and the equity price is driven to zero (assuming that equity holders do not recover any value in default).

The addition of this jump to default process gives rise to a modified Black-Scholes partial differential equation,

$$\frac{\partial V}{\partial t}+\left(r_t-q+\lambda\left(S,t\right)\right)S\frac{\partial V}{\partial S}+\frac{1}{2}\sigma_{t,S}^2S^2\frac{\partial^2 V}{\partial S^2}+f\left(V,S,t\right)=\left(r_t+\lambda\left(S,t\right)\right)V-\lambda\left(S,t\right)R \tag{39-2}$$

where V is the value of the convertible bond with recovery rate R and the function $f\left(V,S,t\right)$ represents external cashflows such as coupon payments. Standard finite difference techniques can be used to solve this equation numerically[9] with the appropriate boundary conditions, including call and put features.

The bond coupons c can be represented as an additional term that needs to be inserted on the correct node of the finite difference grid when solving Equation (39-2),

$$f\left(V,S,t\right)=\sum_i c_i\delta\left(t-t_i\right) \tag{39-3}$$

On dates where the holder can convert the bond to shares, the boundary condition is

$$V_t\geq L_tS_t \tag{39-4}$$

for a conversion ratio L_t, which can be implemented in the finite difference grid as

$$V_{t-}=\max\left(V_{t+},L_tS_t\right) \tag{39-5}$$

8. David Lando, "On Cox Processes and Credit Risky Derivatives," *Review of Derivatives Research* (1998), pp. 99–120.

9. Leif Andersen and Vladmir Piterbarg, *Interest Rate Modeling*, Volumes 1–3. (Atlantic Financial Press, 2010).

In addition to provisions that freely allow the holder to convert on certain dates, many convertible bonds also contain provisions that allow the holder to convert only if certain conditions are met, i.e., triggered conversion. Triggered conversion provisions that depend on S_t and V_t can often be included when solving Equation (39-2) via finite difference techniques. If the issuer can call the bond at some price H_t, then

$$V_t \leq \max\left(H_t, L_t S_t\right) \tag{39-6}$$

assuming the holder has the option to convert rather than to receive the call price H_t. Alternatively, the bondholder may own a put. This produces the free boundary condition

$$V_t \geq P_t \tag{39-7}$$

for a prespecified amount P_t. Other nonnumerical triggers do exist as there can be an announced redemption, a fundamental change to the company structure may occur that requires the bond to be redeemed, a distribution of entitlements or a rating condition may be attached to the bond. Mergers, asset transfers, corporate splits, or a change in the holding company may also be specified as redemption events. From a modelling perspective, these triggers are ignored.

The default intensity $\lambda\left(S,t\right)$ should be downward sloping (i.e., $\frac{\partial \lambda}{\partial S} < 0$) since as equity prices increase, credit generally tightens. Likewise, a distressed company corresponds to lower market capitalization and wider credit spreads. Several functional forms have been suggested in the literature; however, the particular functional form does not have a large impact on the results. The most popular and intuitive form is a power law, first introduced by Muromachi when studying Japanese convertible bonds[10]:

$$\lambda\left(S,t\right) = a\left(t\right)\left(\frac{S\left(0\right)}{S\left(t\right)}\right)^p \tag{39-8}$$

for an initial stock price, S(0). The determination of the function $a\left(t\right)$ and parameter p will be addressed by looking at the vanilla bond issuance and CDS quotes for the issuer.

THE DEFAULT INTENSITY

Given the parameterization in Equation (39-8), the exponent p must be determined. When fitting to Japanese corporate bonds, Muromachi found that $1.0 < p < 2.0$. This choice of p is illustrated in panel a of Exhibit 39-2, where equity price versus five-year CDS is plotted for Dish Network Corporation (DISH-US) from 2014 to 2019. This is known as a "hockey stick" graph, due to the shape of the scatter

10. Yukio Muromachi, "The Growing Recognition of Credit Risk in the Corporate and Financial Bond Markets," *NLI Research Institute* (January 1999), pp. 3–11.

plot. Following Muromachi, a log-log regression produces a parameter value of 1.0, and there is good overall agreement between the realized price movement and the calibrated intensity. However, the bounds defined by Muromachi do not persist in all markets over long time spans. As shown in panel b of Exhibit 39-2, the same calibration for Total SA (FP-FR) produces a best-fit of $p = 5.0$ to capture the desired price action. Olsen, Decker, Rustau, and Ho[11] find that calibrating the intensity to realized data is most effective for high yield credits, since such issuers generally display a comprehensive range of equity and CDS price action leading to superior statistical analyses of Equation (39-8). Nevertheless, calibration can still prove difficult for high yield credits. For instance, panel c of Exhibit 39-2 shows extreme CDS movements corresponding large decreases in the equity price of Chesapeake Energy Corp. (CHK-US) that cannot be captured.

Finally, for high-grade credits such as Commonwealth Bank of Australia (CBA-AU), shown in panel d of Exhibit 39-2, there is no history of distressed equity pricing, thereby making it impossible to calibrate to realized data. That same high-grade argument can also be applied to Dish and Total, since the range of realized equity price movement in panels a and b of Exhibit 39-2 do not decrease below USD 25 and EUR 35, respectively—there is no stressed market scenario present in the historic data. In contrast, the equity time series for Chesapeake covers USD 2–25.

In short, calibrating to realized price action is effective for specific issuers, but it is not applicable across the asset class, in fact credits that appear to calibrate well may not capture the desired stock–credit spread relationship if the history does not cover distressed regimes.

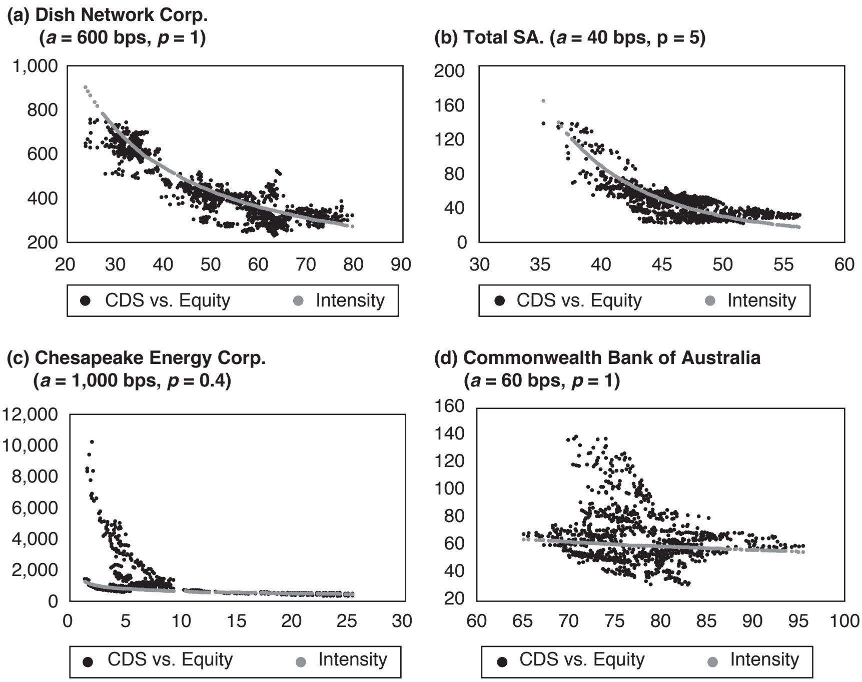
Now consider the effect of p on the valuation of convertible bonds[12]—accomplished by solving Equation (39-2). Exhibit 39-3 represents CB price versus stock price for a range of p values. These securities represent a broad spectrum of maturities from one to seven years. Likewise, they capture tight credit spreads (BioMarin), typical high-yield credit risk (Dish and Tesla), and distressed credit spreads (Chesapeake). When $p = 0$ (which amounts to ignoring the relationship between equity and credit) and the equity price tends to zero, the limiting value of the CB reduces to the bond floor, defined as the price of a hypothetical bond with identical terms and conditions as the convertible but ignoring the embedded equity option. The limitations of the models proposed by Goldman Sachs, Tsiveriotis and Fernandes, and Xiao are now evident. As there is no relationship between the credit risk and equity performance, the bond floor is fixed in those models regardless of the market perceived default probability. When $p > 0$, a "soft" bond floor is introduced in that the bond floor decreases when the stock price falls, signaling a distressed equity. As p is progressively increased, the value

11. Luke Olsen, Douglas Decker, Haidje Rustau, and Judy Ho, "Convertible Bonds: A Technical Introduction," *Barclays Capital Research Notes* (January 2002).

12. The CBs in question are BioMarin Pharmaceutical Inc. 1.5% 2020 (US09061GAF81), Tesla Inc 2.375% 2022 (US88160RAD35), Dish Network Corp. 1.5% 2024 (US25470MAD11), and Chesapeake Energy Corp 5.5% 2026 (US165167CY16).

EXHIBIT 39-2

Five-Year CDS vs. Equity and Calibrated Intensity



of the bond floor decreases to reflect the increased credit risk. Furthermore, as the tenor of the CB increases, the impact of p is magnified as credit risk typically increases with tenor. The soft bond floor was first reported by Takahashi et al.

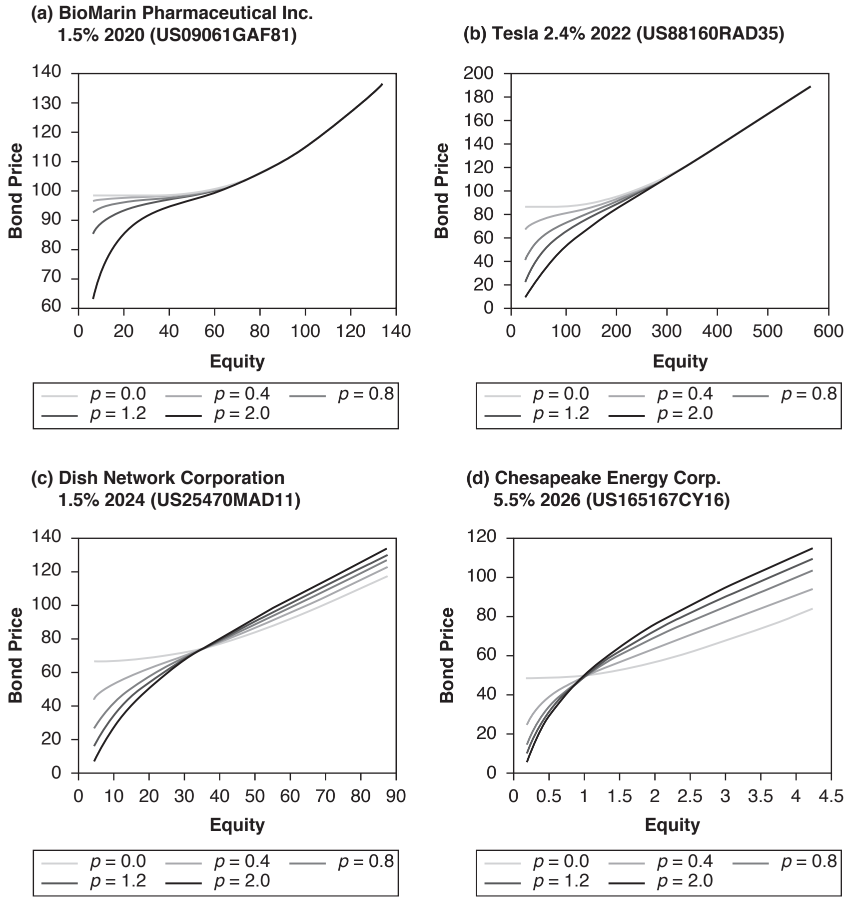
The static bond floor is certainly not borne out in financial data. In Exhibit 39-4, the closing bond prices for companies seeking bankruptcy protection are plotted for the day that the company filed for that protection. This is a snapshot of prices taken on that day and does not represent final recovery values, however, it does represent exactly the type of risk that Equation (39-8) aims to capture. There are 1134 distinct defaulted bonds[13] in Exhibit 39-4. There are several immediate takeaways:

- The average bond price was 37.
- Two-thirds of defaulted bonds had prices of 40 or less at default.

13. Data maintained by FactSet Research Systems Inc.

EXHIBIT 39-3

Bond Price vs. Equity



Note: From (1), $R = 0$ in this exhibit.

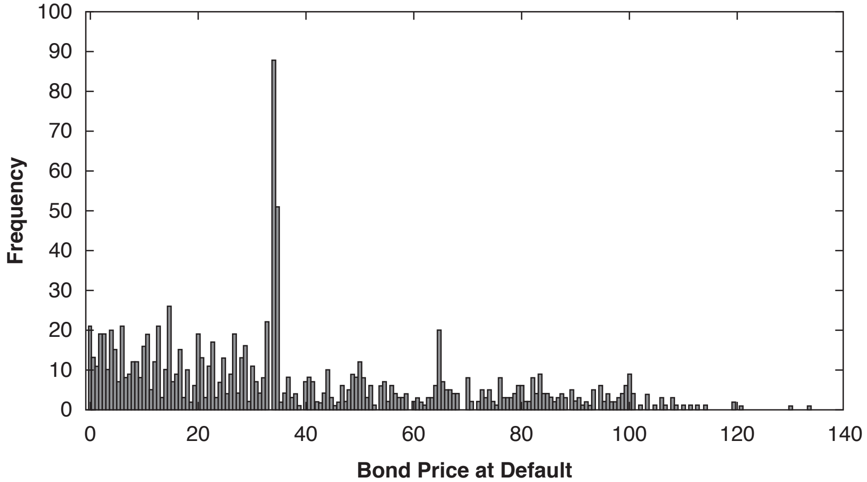
- The remaining third defaulted with higher prices–including a small fraction above par.
- The average price agrees closely with the standard ISDA CDS assumption that loss given default, LGD, is 60% for senior unsecured securities.

The choice of the Andersen and Buffum model is further motivated by the price action of the issuers of the bonds trading above par. Exhibit 39-5 represents the equity time series of four of these issuers.[14] A jump-to-default event

14. They are Residual Debt Services Ltd. (AXL-ZA), Lehman Brothers Holdings Inc. (LEHMQ-US), OFCB Capital PLC (OFCB-RU), and Transasia Airways Corporation (6702-TW).

EXHIBIT 39-4

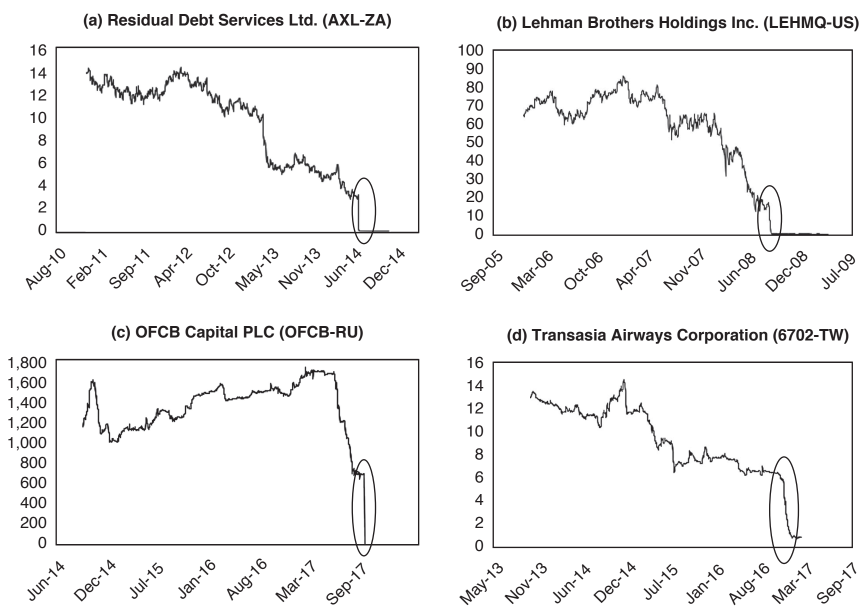
Corporate Bond Prices at Default vs. an Issue Price of 100



Source: FactSet

EXHIBIT 39-5

Equity Time Series Leading Up to Default



is observed for each company as the bankruptcy is announced. The addition of the Cox process, $N(t)$ in Equation (39-1), is therefore a necessary mechanism to capture this price movement.

Within the defaulted bond universe, 136 bonds were convertible. In Exhibit 39-6, the realized bond price versus equity performance of eight bonds is plotted. The bonds are chosen to be representative of results seen for issues with deeper data. In all cases, the realized performance agrees with Exhibit 39-3: as the equity drops significantly, the bond sells off markedly toward default, with a variety of recoveries observed from zero to 20% to 40%. Likewise, this is in line with the cross section observed in Exhibit 39-3. Furthermore, the selloff accelerates as the equity becomes distressed. We also note that prior to entering the distressed state, the bond price varies quite linearly versus the equity price. Hence convertible bonds display little positive gamma, but significant negative gamma, when the equity decreases sufficiently.

Translating this to Equation (39-8), bond prices where default typically occurs are not easily reachable unless p is sufficiently large. Rather than calibrating p at an issuer level to historic data, we can instead seek a value for p that is applicable across the asset class. Taking $p = 2$ produces model outcomes that match the default price distribution, as well as produces defaulted bond prices that are consistent with the distribution of defaulted bonds across all maturities. It also allows the debt–equity price action to be standardized across all issuers. Further refinement by tenor is also possible; likewise, calibrating to specific default values, such as LGD = 60%. On average, higher values of p increase credit risk, lower the bond floor, and translate to higher implied volatilities. For this chapter, $p = 2$ is applied across all issuers.

SPECIFYING THE CREDIT SPREAD

Following Andersen and Buffum, the function $a(t)$ in the default intensity from Equation (39-8) can be determined by a calibration to risky zero-coupon bond prices by solving for the equity price density, which satisfies the forward Kolmogorov Equation (the adjoint of Equation (39-2)), thereby incorporating the credit spread of each issuer. There are three possible situations one needs to account for in order to specify the credit spread.

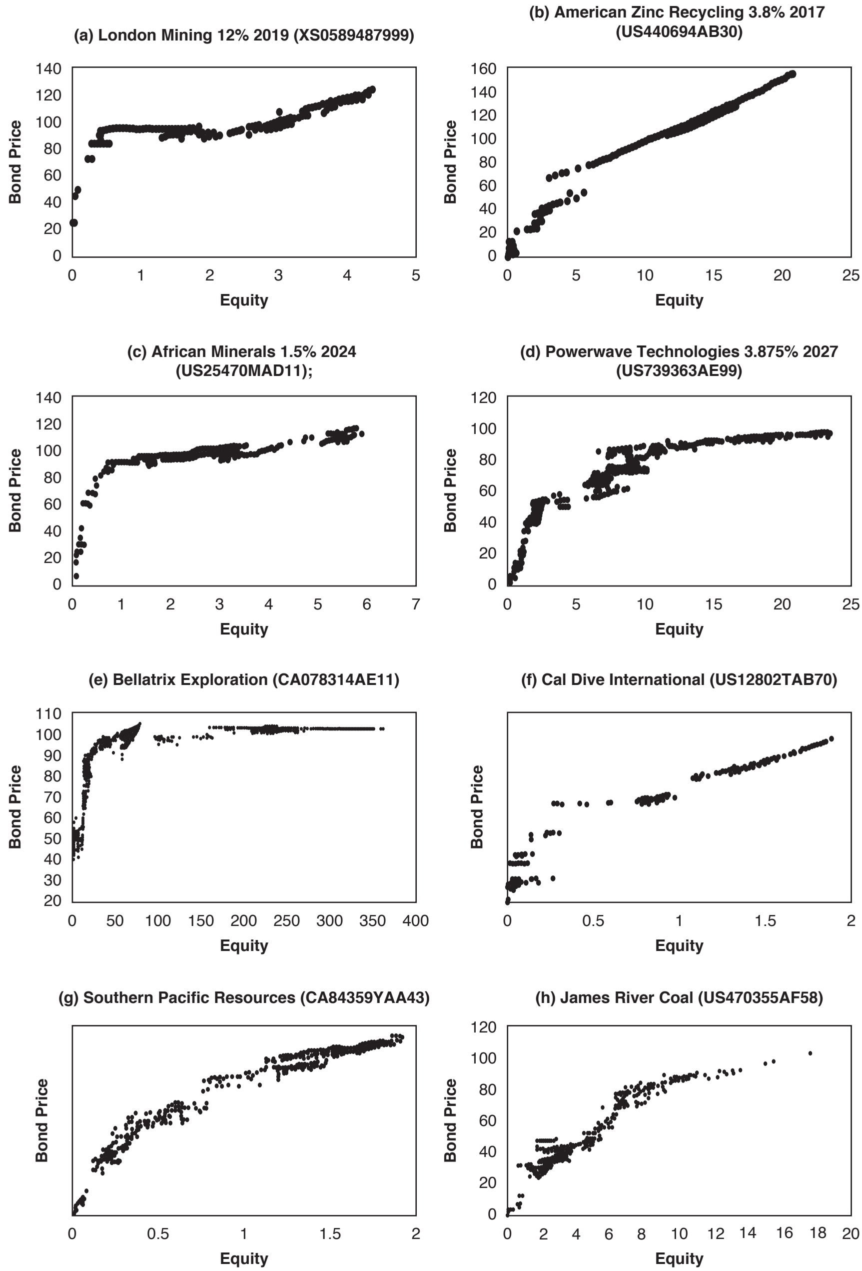
1. Traded CDS exists on the issuer

   The CDS represents the spot price of the credit risk. From Exhibit 39-1, the CDS is explicitly observed in the market for 327 CBs. For those bonds, the CDS should be used directly in Equation (39-8), after adjusting for seniority.
2. Issuer has traded vanilla bonds

   Across the 1135 CB issuers, 526 have vanilla bonds with closing prices in the market. For these counterparties, the asset swap spread from the bonds is adjusted for synthetic versus physical basis and seniority to mark the CDS.

EXHIBIT 39-6

Realized Bond Price vs. Equity for the Defaulted Convertible Bonds



Source: FactSet

3. Issuer has no vanilla bonds
   The remaining CBs are then mapped to either a traded index proxy, or by industry geography and rating to specific traded issuers.

With the credit risk marked to term, the volatility, σ, is implied from Equation (39-2) to match the market price,

$$V(S,t,\sigma) = B_t \tag{39-9}$$

where B_t, is the closing bond price for day t. To illustrate the methodology, return to the four bonds from Exhibit 39-3, with the addition of one further security, namely, the Oasis Petroleum Inc 2.625% 2023 bond (US674215AJ77).

In terms of the credit mark-to-market, we then have:

- Traded CDS: Dish Network Corp., Chesapeake Energy Corp. (DISH-US, CHK-US)
- Outstanding vanilla bonds: Oasis Petroleum Inc. (OAS-US)
- Index map: BioMarin Pharmaceutical Inc. (BMRN-US)
- Hybrid index map and traded CDS: Tesla Inc (TSLA-US)

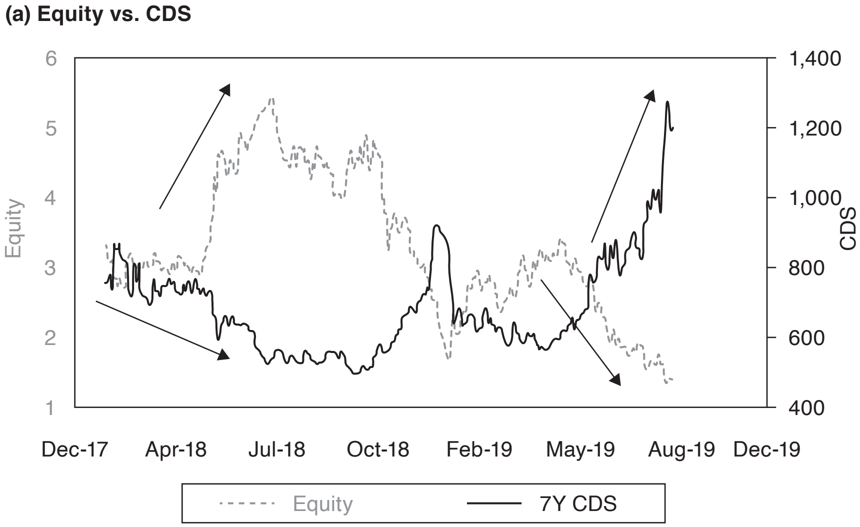
These five bonds will form the remainder of this chapter. The results for CHK-US are represented in Exhibit 39-7, where several observations are apparent. Firstly, the bond price tracks the performance of the equity closely. Secondly, the volatility and the bond price are negatively correlated; that is, on average, the volatility decreases (increases) when the forward increases (decreases). This is the price action contained in the SABR model by Hagan et al.[15] More formally, Hagan et al. propose a stochastic volatility model where asset prices are correlated to volatilities that correctly reproduces the dynamics of the volatility skew. The correlation, borne out by calibration to a specific market, is typically negative. For our purposes, we shall term the negative correlation between volatility and bond prices as "SABR-like."

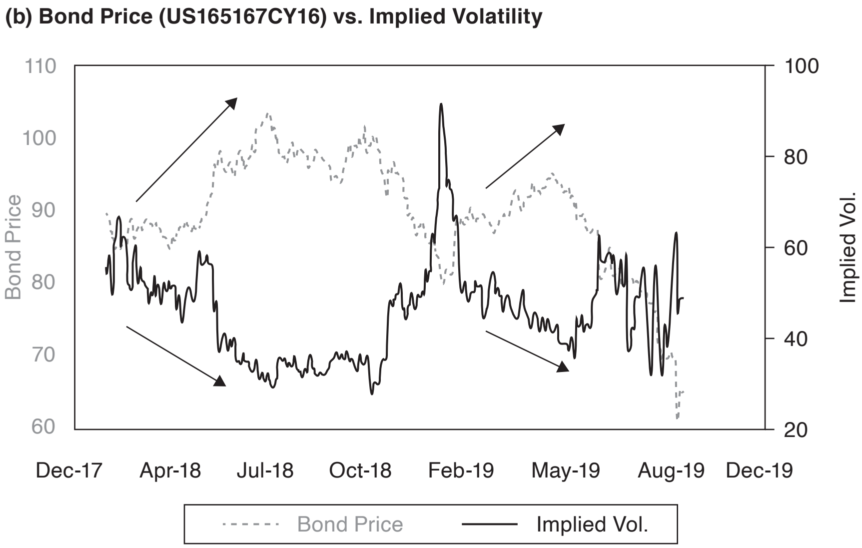
As the equity increases, the equity volatility decreases and the CDS tightens, leading to an overall risk reduction. Likewise, decreases in the equity price correspond to CDS widening and equity volatility increasing. A quick calculation shows that $\rho = -0.77$ between the stock and CDS, where ρ is the Pearson correlation coefficient. These observations further motivate the functional choice of the intensity process Equation (39-8) since the power law induces CDS spread widening as the equity price decreases, and vice versa. Running the same calculation on the implied volatility and the bond price produces $\rho = -0.58$. As desired, the price action is SABR-like.

15. Pat Hagan, Deep Kumar, Andrew Lesniewski, and Diane Woodward, "Managing Smile Risk," *Wilmott Magazine*, (September 2002), pp. 249–296.

EXHIBIT 39-7

CHK-US





Note: The axis matches the time series.

Similar price action is observed in Exhibit 39-8 for DISH-US. Again, the bond price tracks the performance of the underlying equity and the implied volatility is negatively correlated to the performance of the security itself, with $\rho = -0.73$. As required, spread tightening corresponds, on average, to increases in market capitalization. Weakening credit quality equates to CDS widening and $\rho = -0.94$ between the CDS and stock price; the price action is again SABR-like.

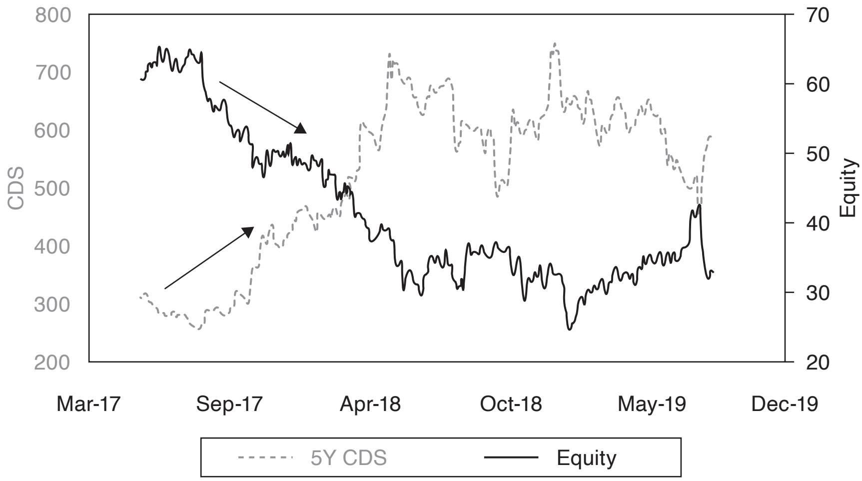
No traded CDS exists for OAS-US. However, nonconvertible bonds have been issued by this company. With the CB time series available from late 2016, there are four separate vanilla bonds with daily closing prices. The available bonds are the Oasis 7.25% February 2019 issue (US674215AD08), the Oasis 6.5% November 2021 security (US674215AD08), and the Oasis 6.875% January 2023 issue (US674215AE80). Furthermore, in mid-2018 the Oasis 6.25% May 2026 bond (USU65204AC06) was issued. From the 2016 snapshot, these securities translate to tenors from three to eight years. Although the CDS is absent, the bonds' z-spreads can be employed to infer a synthetic CDS; in this case with term structure.

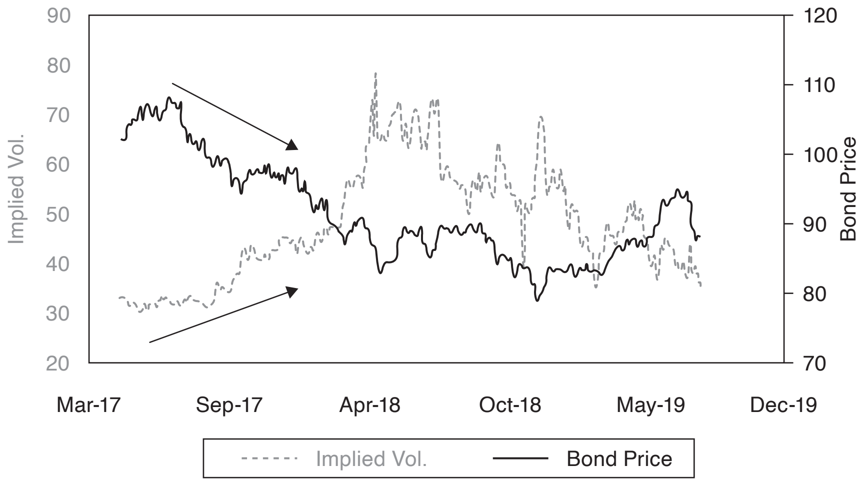
Theoretically, the credit risk from a bond and the CDS are equivalent—for a given maturity, the z-spread from a bond should equal the spread payable on a CDS contract of the same tenor. In practice, the markets trade separately and a bond-CDS basis exists. Tracking that basis allows a bond z-spread to be adjusted to produce a synthetic CDS. Returning to Exhibit 39-1, across the 1135 CB issuers, 526 have vanilla bonds with closing prices in the market. For these counterparties, if the CDS does not trade explicitly, the credit spread from the bonds can be adjusted for the synthetic versus physical basis and seniority to mark a "synthetic CDS." In panel a in Exhibit 39-9, the convertible bond credit spread, interpolated to a five-year tenor, for the 526 issuers is plotted versus the traded index CDX.NA.HY.5Y. The basis itself is represented in panel b in Exhibit 39-9. Although the basis varies significantly, it has been almost universally positive through time. Moreover, the outright spread levels of the CB issuers are commensurate with CDX.NA.HY, thereby indicating that CB issues can typically be regarded as high-yield bonds. On average, any synthetic CDS should therefore be marked wider if inferred from vanilla bonds. Typically, post-2008, CDS trades wider than bonds due to protection buying pressure, in contrast to pre-2008 when CDS traded tighter due to the structured credit bid.

The z-spread for three of the Oasis nonconvertible bonds are plotted in Exhibit 39-10. Initially, from September 2016 to early 2018, two bonds traded. Their maturities translate to tenors of approximately five and eight years. During this period, the term structure between those points is flat, which is not unexpected, since beyond five years, credit risk premiums generically only increase marginally. From April 2018, the credit spread for the November 2021 bond tightens. In effect, it is rolling down the curve toward a three-year tenor and subsequently to even more short-dated maturities. At the same time, the May 2026 bond was issued. This provided a new eight-year point. Combining and interpolating the z-spreads to fixed tenor produces an initial estimate for the five-year

EXHIBIT 39-8

DISH-US

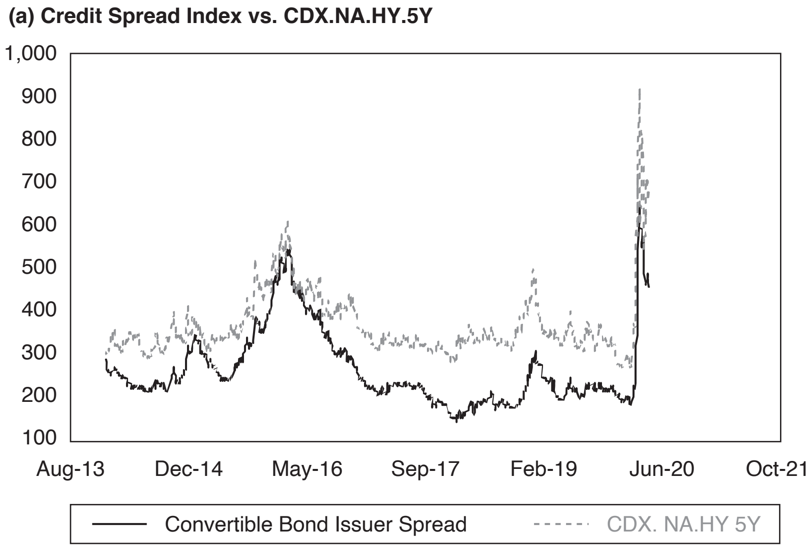




Note: Axis colors matches the time series.

EXHIBIT 39-9

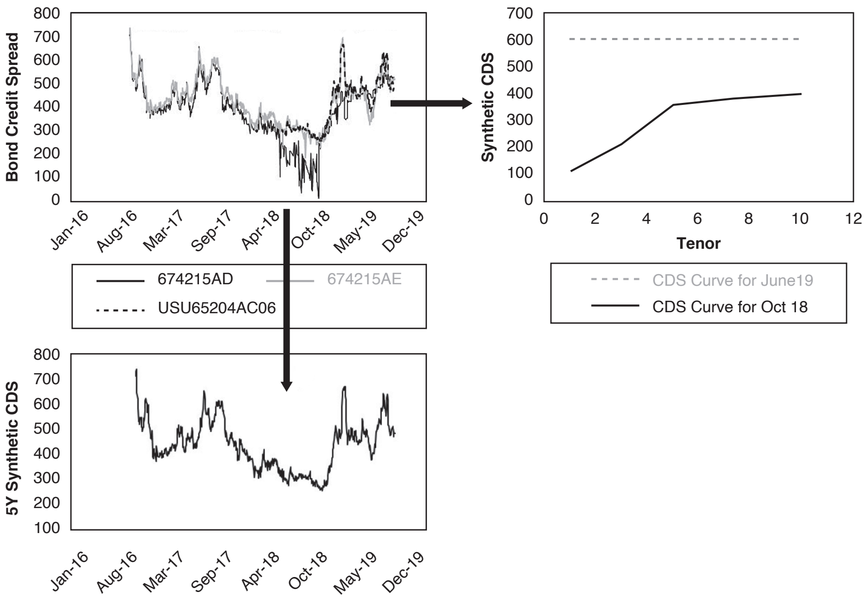
Convertible Bond Five-Year Index



Source: FactSet

EXHIBIT 39-10

OAS-US Nonconvertible Bond Z-Spread Mapped to the Five-Year Synthetic CDS and CDS Term Structure



synthetic CDS. Here, set the bond-CDS basis at 50 bps, which aligns with panel b in Exhibit 39-9 for mid-2016. Adjusting the spread wider for the bond-CDS basis produces the final synthetic CDS plotted in Exhibit 39-10.

One further observation is that the spread tightening for the bond maturing in November 2021 fails to hold after October 2018. Essentially the credit spread widens out to comparable levels to the five- to eight-year tenor bonds. This is a curve flattening effect—a bearish indicator, as it corresponds to a market perception of immediate corporate headwinds. The result is protection buying in the front end of the curve; that is, if default is imminent, then long-dated protection is not warranted. In Exhibit 39-10, the curve flattening is shown in the shape of the CDS curves that are plotted for October 2018 and then for June 2019. The one-year point widens from 100 bps to 600 bps, equivalent to the five-year spread.

The equity and synthetic CDS for Oasis Petroleum are plotted in panel a in Exhibit 39-11. A quick calculation between the synthetic CDS and the stock price produces $\rho = -0.39$, a weaker correlation, but still exhibiting the relationship contained in Equation (39-8). Once the synthetic CDS time series is constructed, Equation (39-9) can be solved, leading to the observation that the bond price again tracks the equity. The resulting implied volatility time series is represented in panel b in Exhibit 39-11, where it is plotted against the CB price. The SABR-like price action continues with the implied volatility showing high negative correlation to the bond price, with $\rho = -0.72$. Although qualitative, the high correlation indicates that the synthetic CDS is capturing the idiosyncratic risk associated with OAS-US. Looking across both panels a and b in Exhibit 39-11, the CB price continues to track the underlying equity.

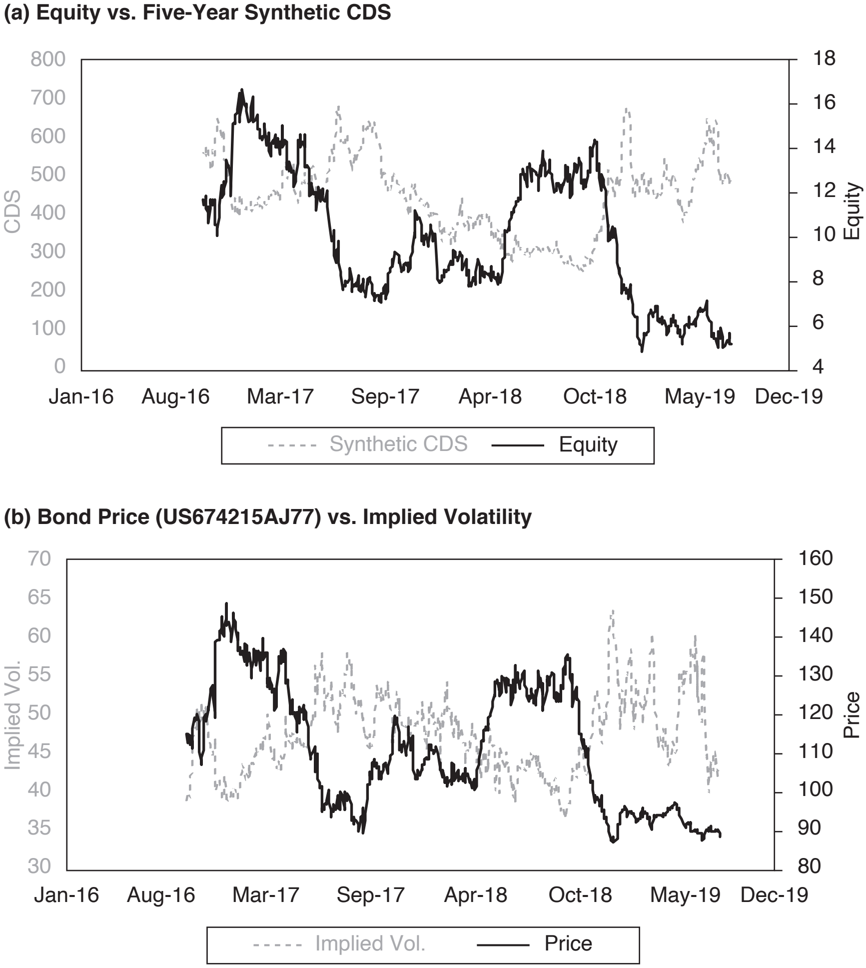
Marking BMRN-US is more problematic, since there are neither traded CDS nor any outstanding vanilla bonds. Instead, an index proxy can be sought. The advantage of this approach is that systemic risk is automatically captured, as any macro event that moves the market will be represented through the mark-to-market of the index. The knock-on effect is that any equivalent price movement in the CB will mirror the index proxy. Conversely, the limitation is that any idiosyncratic spread risk cannot be represented. Generically, CB issuers are cash-poor, low-credit-quality counterparties. On that basis, the obvious candidate for marking BMRN-US is the high-yield index CDX.NA.HY. The geographies match: the index represents a broad cross section of North American high-yield issuers. CDX.NA.HY is also liquid, with daily trading volumes exceeding USD 10 BN.[16] CDX.NA.HY trades as a bond price that can then be converted to a CDS spread. There are maturities from three to seven years, with five years representing the main tenor for on-the-run trading. This forms the starting point for building a synthetic CDS. An individual credit is then marked as a spread to that curve, either tighter or wider. In Exhibit 39-12, that mark for BMRN-US is shown.[17] The maturity on the bond is October 2020. CB data exists from July 2014. Hence, by 2018, the tenor has migrated from six years to two years. Initially, as the tenor was six years, the synthetic CDS was marked 100 bps wider than CDX.NA.HY. This agrees with the bond-CDS basis from panel b in Exhibit 39-9. BMRN-US is not rated by any agency.

An alternative to an index adjusted mark is to map BMRN-US to a spread representative of the industry. As a biotechnology firm, that industry is broadly "Health Technology." A comparison to other convertible bond issuers in that industry from mid-2014 places that mark in the high-yield single-B to CCC rating band, as shown in panel b in Exhibit 39-12. The 100bp differential varies through time. However, as the bond matures, the synthetic CDS in panel a of Exhibit 39-12 has been interpolated to roll down the curve and reflect the shortening maturity. As desired, the synthetic CDS captures the spread widening in late 2015 and early 2019, thereby capturing systemic risk.

16. See the DTCC data repository http://www.dtcc.com/repository-otc-data. Accessed June 2019.
17. The relevant CB is US09061GAF81.

EXHIBIT 39-11

OAS-US

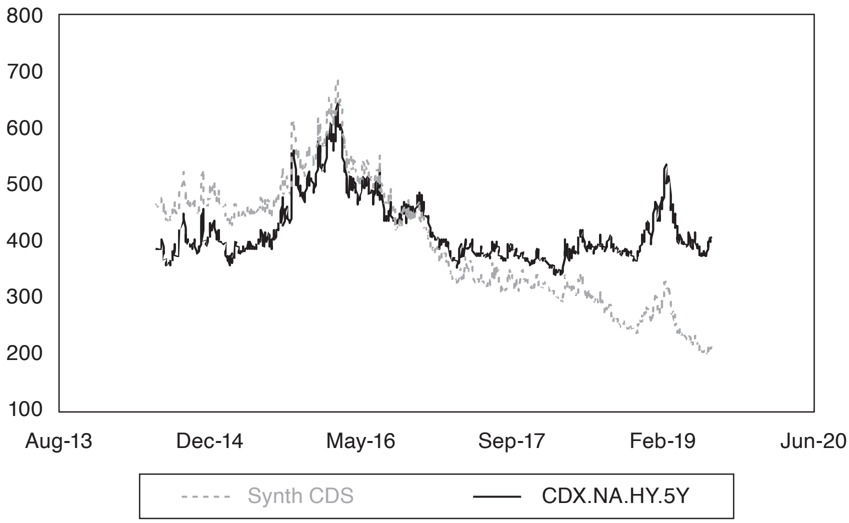


Note: the axis color corresponds to the time series.

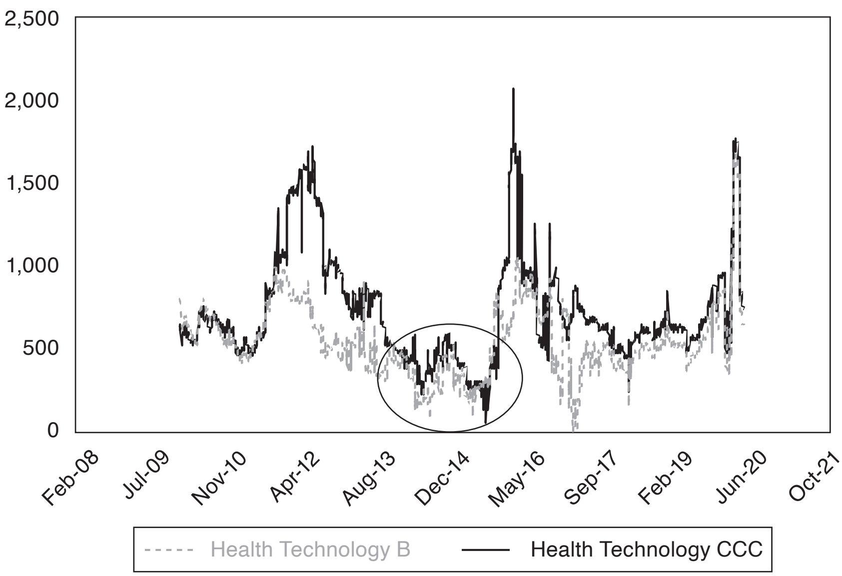
EXHIBIT 39-12

BMRN-US Synthetic CDS

(a) Marked to Maturity from CDX.NA.HY



(b) Compared to Convertible Bond Issuer CCC and B Health Technology Sector Indices



Source: FactSet

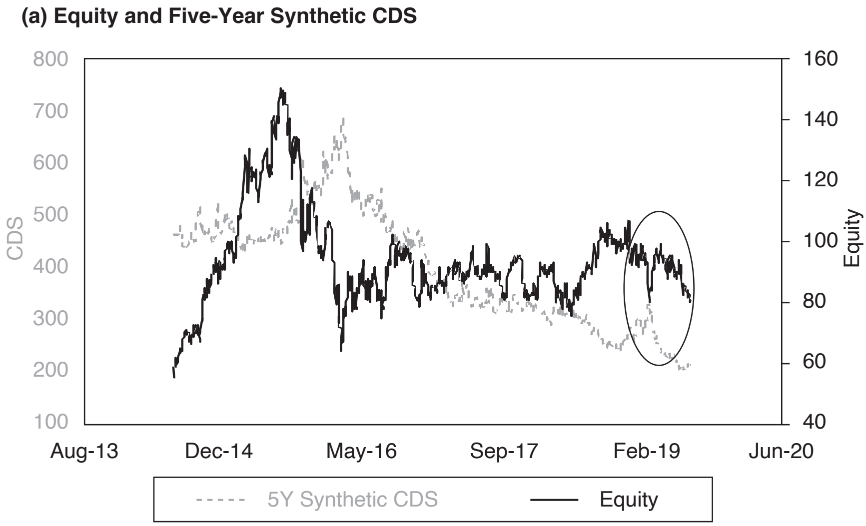
In Exhibit 39-13a, the stock price is plotted against the five-year synthetic CDS for BMRN-US. A quick calculation produces $\rho = -0.05$. The CB price is plotted against the implied volatility in panel b in Exhibit 39-13. Again, the correlation is lower with $\rho = -0.24$. This is not surprising as idiosyncratic risk cannot be captured from the index map. However, both panels a and b in Exhibit 39-13 continue to display SABR-like price movement. On average, CDS widening corresponds to decreases in market capitalization and spread tightening equates to increases in the equity price. Furthermore, the market shock from February 2019 is captured. Likewise, large market moves/trends in the CB price and the implied volatilities continue to follow the expected market movement.

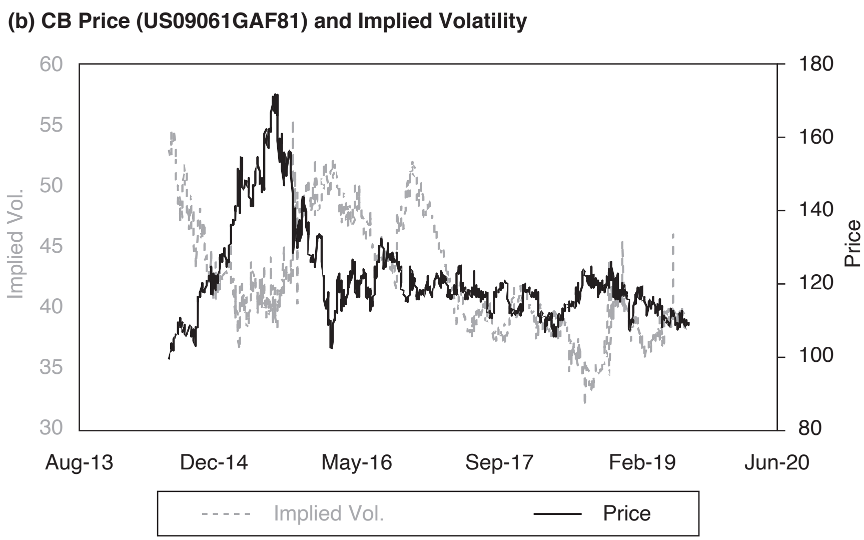
The final bond under consideration is the Tesla Corp. 2.2% 2022 bond. Approximately 18 months after issuance, Tesla CDS began trading in the market, therefore the effectiveness of the synthetic CDS can be tested, as this bond requires marking the synthetic CDS before transferring to the traded contract. Analogously to BMRN-US, the synthetic CDS is derived as a spread to CDX.NA.HY as the same credit quality arguments hold. Tesla is involved in a cycle of research and development on several fronts. This equates to a cash-intensive phase of the business with limited income. The long-term viability of the resulting products is also uncertain. Tesla is a high-yield issuer with an immature business model versus the majority of issuers in CDX.NA.HY. As such, Tesla should be marked wider than the index. Bond price data are available from March 2017. At that time CDX.NA.HY.5Y closed at 354 bps. Therefore, mark the five-year CDS for Tesla at 600 bps. Maintaining that spread to the index across tenors produces a CDS term structure. The actual Tesla CDS began trading in June 2018. The initial closing price was 515 bps. The corresponding synthetic mark was 600 bps. As shown in panel a of Exhibit 39-14, Tesla CDS immediately underwent spread widening. Intuitively this makes sense. Investors are, on average, long the credit. The market appetite will be for credit risk mitigation, that is, buying protection. After a wide close at 717bp, the CDS stabilized at 560bp in late July—in line with the last synthetic CDS close. Tesla CDS has subsequently traded as tight as 450 bps and as wide as 710 bps. This reflects the uncertainty in the market surrounding this credit.

The time series produced from calculating the implied volatility is graphed in panel b in Exhibit 39-14. Tesla Inc. is a credit subject to significant idiosyncratic risk. Hence, the efficacy of the index mark is diluted. From March 2017, the synthetic CDS tightens from 600 bps to 550 bps whereas the stock and CB price oscillates across a \$200 range. The CB price varies from 100 to 130 in the same period. Nevertheless, the Tesla bond is included to show that despite the idiosyncratic limitations, the CB can still be successfully marked. The level of uncertainty in this credit results in little meaningful SABR-like market movement. Just taking the region where the CDS trades, a quick calculation between the price and the implied volatility yields $\rho = -0.001$, whereas for the equity and the CDS, $\rho = -0.22$. There are areas where the price action matches expectations—for example, September 2017 and August 2018. But in general, there is

EXHIBIT 39-13

BMRN-US

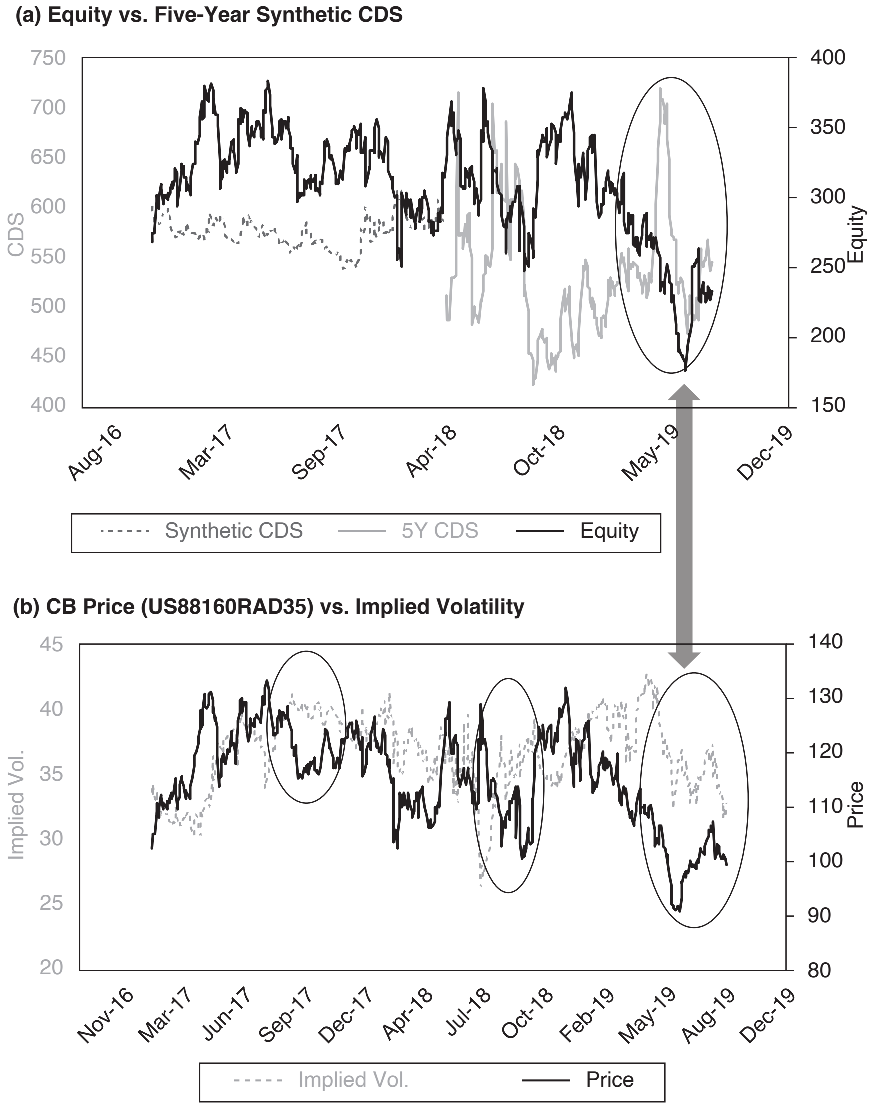




Note: Axis color corresponds to the color of the time series.

EXHIBIT 39-14

TSLA-US



Note: Axis color corresponds to the respective time series.

significant market uncertainty. Consider the time series from April to June 2019. Despite the CDS widening from 500 bps to 725 bps, the decrease in bond price equates to a decrease in implied volatility. This is counterintuitive and does not agree with the SABR price action expected from Hagan et al. What it suggests is that the CDS is too tight; that is, a wider CDS would have lowered the bond floor. If the CDS is sufficiently wide, marking the bond would require an increase in the implied volatility—not a decrease. The fact that falling prices and decreasing volatilities occur for extended periods suggests sustained mispricing.

SENSITIVITIES

The impact of the dynamic credit component from Equation (39-8) is not limited to the soft bond floor. The impact is also apparent in the sensitivities of the CBs. Define the unscaled delta as

$$\Delta = \frac{\partial V}{\partial S} \tag{39-10}$$

where V is the present value of the bond. Note that the unscaled delta can be greater than 1 because the bond represents more than one share of the underlying equity; that is, the unscaled delta is a function of the conversion ratio. If the conversion ratio is greater than 1, the delta can also exceed 1.

Similarly, the sensitivity to the volatility is

$$\nu = \frac{\partial V}{\partial \sigma} \tag{39-11}$$

and the sensitivity to interest rates is

$$\rho = \frac{\partial V}{\partial r} \tag{39-12}$$

where ∂r is a parallel perturbation to the infinitesimal short rate, which translates into a parallel shift of the yield curve. Following the notation of Calamos,[18] the credit delta, or sensitivity to the credit curve (omicron), is defined as

$$o = \frac{\partial V}{\partial CDS} \tag{39-13}$$

and ∂CDS represents a shock to the traded, or synthetic, CDS. Time decay is defined as

$$\theta = \frac{\partial V}{\partial t} \tag{39-14}$$

where θ is estimated using a one-calendar-day shift.

18. Nick P. Calamos, *Convertible Arbitrage* (New Jersey: Wiley, 2003).

The effect of the intensity process leads to seemingly counterintuitive analytics. The credit spread dynamics can produce deltas greater than the conversion ratio for sufficiently low stock prices. The vega can also be negative, given the downward concavity of bond value in the region where stock prices are low. The rho is typically negligible, demonstrating the validity of the statement in Andersen and Buffum that using deterministic rates is justified. This point is also made more compellingly by Grimwood and Hodges[19] who investigate convertible bonds using a stochastic interest rate. Their conclusion is that "the stochastic modeling of the spot interest rate appears the least important model feature."

To illustrate this, the deltas from Equation (39-10) of the four bonds from Exhibit 39-3 are plotted in Exhibit 39-15. When the credit dynamics are ignored ($p = 0$) the delta versus stock chart looks intuitive, being bounded between zero and the conversion ratio (mimicking a vanilla equity option). However, when the dynamics are included, delta can exceed the conversion ratio. The higher delta is capturing default risk—when the company is stressed, small increases in the equity price equate to a significant reduction in credit risk and a corresponding increase to the soft bond floor. Likewise, a decrease in the stock price under this scenario significantly decreases the bond floor. This is the main limitation of the early models from Goldman Sachs, Tsiveriotis and Fernandes, and Xiao: the downside value of the CB is limited to the bond floor, greatly underestimating the risk to the bondholder.

The four bonds in Exhibit 39-15 represent a cross section of maturities from one to seven years. For all maturities, the delta shows the behavior described above, with higher p values increasing delta. For CBs that are strongly in-the-money, the delta becomes independent of p. Hence, the choice $p = 2$ captures the downside risk and produces consistent price action across maturities. This behavior of delta was first reported by Olsen et al. and Ayache et al. Define the gamma as

$$\Gamma = \frac{\partial \Delta}{\partial S} \tag{39-15}$$

All four cases shown in Exhibit 39-15 show negative gamma with an inflection point where gamma becomes weakly positive, with longer-date securities showing a more pronounced effect. Significant positive gamma is only observed for short-dated bonds issued by well-capitalized issuers. The only exception is when $p = 0$, which consistently yields positive gamma. Xiao[6] found that positive gamma is a nontrivial contributor to the value of a CB, but this is only true when $p = 0$ and the credit risk is independent of equity movements.

CB prices are only monotonically increasing with volatility when $p = 0$, as shown in Exhibit 39-16. As the bond's maturity is increased, the bond price can actually decrease with volatility for nonzero p, with the effect being magnified as

19. Russell Grimwood and Stewart Hodges, "The Valuation of Convertible Bonds: A Study of Alternative Pricing Models," Working Paper, *University of Warwick* (2002).

p increases. Note, this is an added subtlety from our earlier assertion of SABR-like price action. In isolation, the implied volatility increases the value of the equity option. However, along with the equity upside comes heightened jump-to-default risk as a higher volatility translates to uncertainty and therefore credit deterioration. In certain circumstances, there is an upper limit to the CB price. For example, in panel b in Exhibit 39-16, the valuation of the TSLA CB cannot exceed 130 when $p = 2$. Furthermore, a volatility higher than 60% will reduce the valuation of the bond, which contradicts the classical hedging strategy that seeks to profit from higher volatility through delta hedging. That is only the case when $p = 0$, when the credit spreads are dynamically linked to credit there are scenarios where investors benefit from falling volatilities.

EXHIBIT 39-15

Unscaled Equity Delta

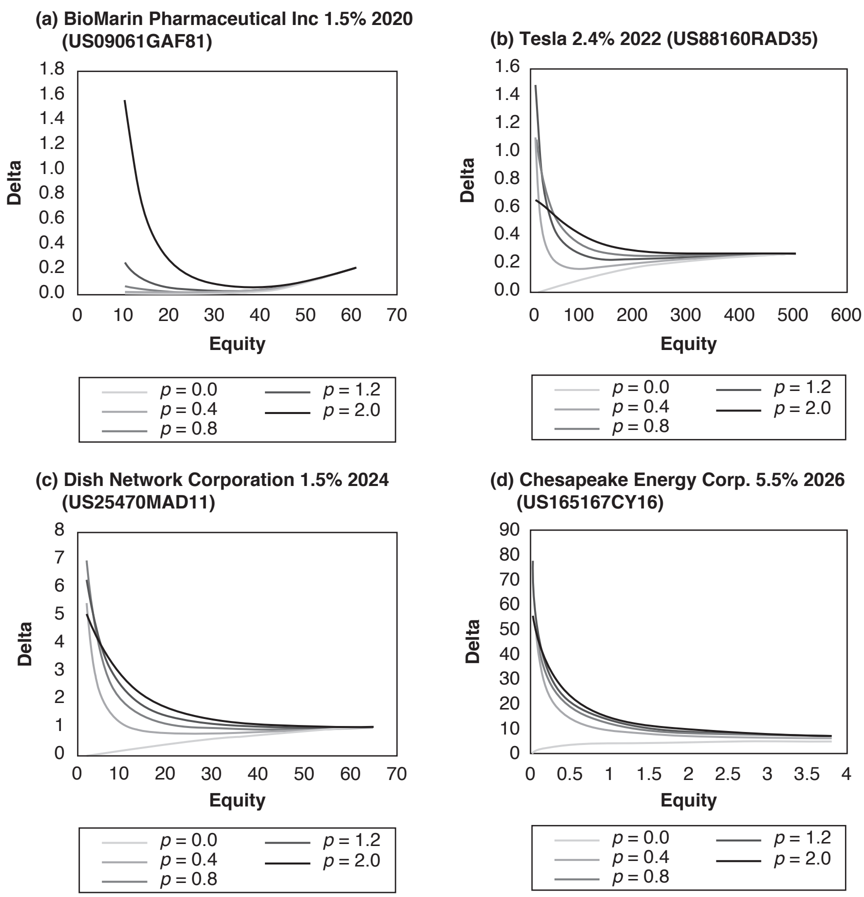
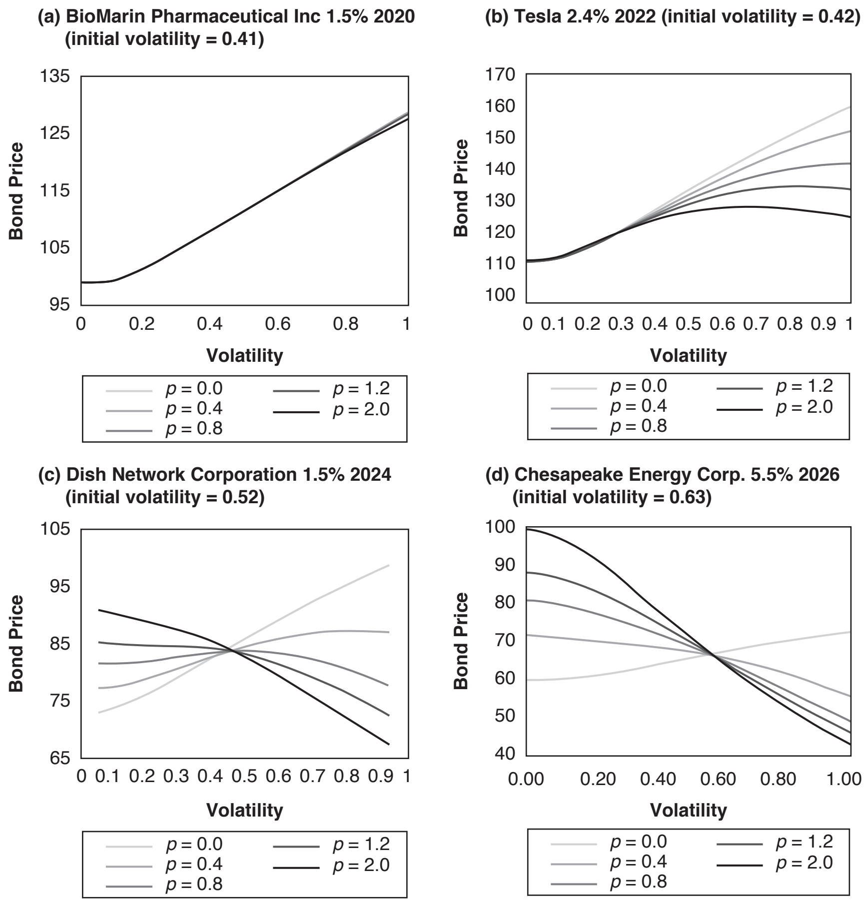


EXHIBIT 39-16

Bond Price vs. Volatility



The volatilities implied from CBs are typically long dated. Here, four of the five bonds under consideration have maturities greater than three years, which are well in excess of exchange-traded equity option markets. Typically, implied volatilities decrease with tenor, as per Hagan et al. The results from Exhibit 39-16 suggest that there may in fact be an upper limit to CB volatilities. At the very least, the valuation of CBs penalizes high-volatility stocks thereby moving volatilities naturally lower. This begs the question whether these two market implied volatilities are consistent.

Implied Volatilities

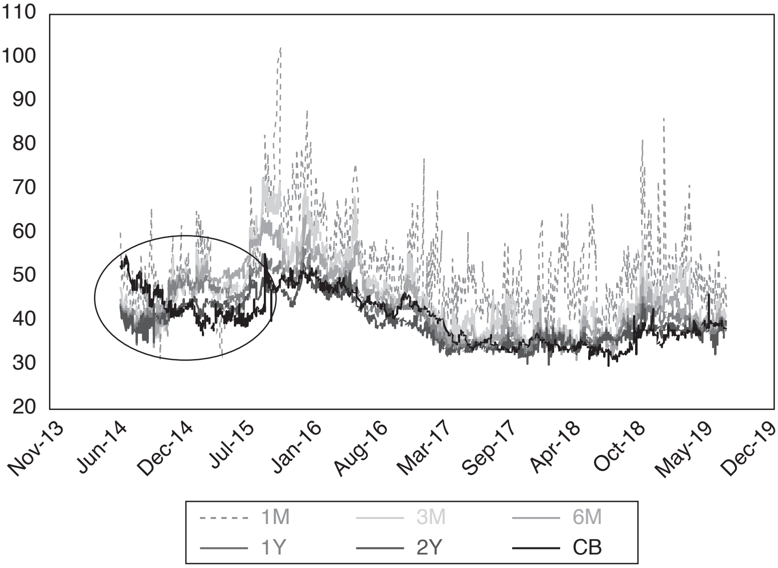
To connect the CB and exchange-traded option markets, the 80% moneyness implied volatilities for one-month to two-year equity options are plotted in Exhibit 39-17, along with the volatilities implied from the CB prices. The choice of 80% moneyness is designed to match the initial low-delta CB prices. Subsequent adjustments for moneyness to more accurately map the volatilities could be undertaken, but that is beyond the scope here. Across all five securities, the CB implied volatilities trade consistently lower than the exchange-traded volatilities. For BMRN-US, OAS-US, and CHK-US, the CB time series tracks the exchange traded data closely. DISH-US displays similar correlation in panel d of Exhibit 39-17, but with periods where the relationship breaks down. For example, in mid-2018, the CB volatilities are consistently higher than their equity-implied counterparts. The CB volatilities do subsequently trade back down. This is an indication of mispricing or an arbitrage opportunity. The CB volatilities for TSLA-US in panel b in Exhibit 39-17 are consistent from the synthetic CDS to the actual traded CDS contract. The Tesla CB volatilities trade consistently lower than equity option implied volatilities. Recall from earlier arguments that marking to exchange traded volatilities cannot match CB prices. These results confirm the premise from the introduction. Attempting to mark CBs from exchange-traded options will always result in error. With long-dated CB volatilities trading consistently at lower levels than short-dated exchange-traded volatilities, marking to the exchange-traded volatilities will either overvalue the option or undervalue the bond due to negative vega. Failing to mark to term will result in mismarking the bond.

The relationship between the exchange-traded volatilities and the CB-implied volatilities suggests a methodology to mark nontraded credit spreads. As shown previously for BMRN-US, marking to a traded index is useful in capturing systemic risk. However, there is a subjective element of where the specific credit should be marked versus the index—that is, wider or tighter. To examine this, fix the CB price and assume positive vega as shown for Biomarin in panel a in Exhibit 39-16. As credit spreads widen (tighten), the bond floor decreases (increases). The CB implied volatility must therefore increase (decrease) to match the CB price. It is now possible to adjust the index mark to solve for an implied volatility that is lower than, or at least in line with the longer maturity, equity-option-implied volatilities. Returning to BMRN-US, the choice of marking the credit wider than CDX.NA.HY was in part due to a view on the maturity of the business, the bond–CDS basis, but also to ensure the relationship between the CB and equity volatilities held. Nevertheless, the initial CB vol marks for BioMarin in panel a in Exhibit 39-17 were higher than the shorter-dated exchange-traded volatilities. This suggests that the CDS mark may be too wide. However, the general agreement of the volatility term structure across the time series points to an alternative explanation. The initial high-implied-volatility marks indicate that the bond initially traded at a premium. This may have been a supply issue with open interest in the bond forcing prices higher. Over time that demand–supply

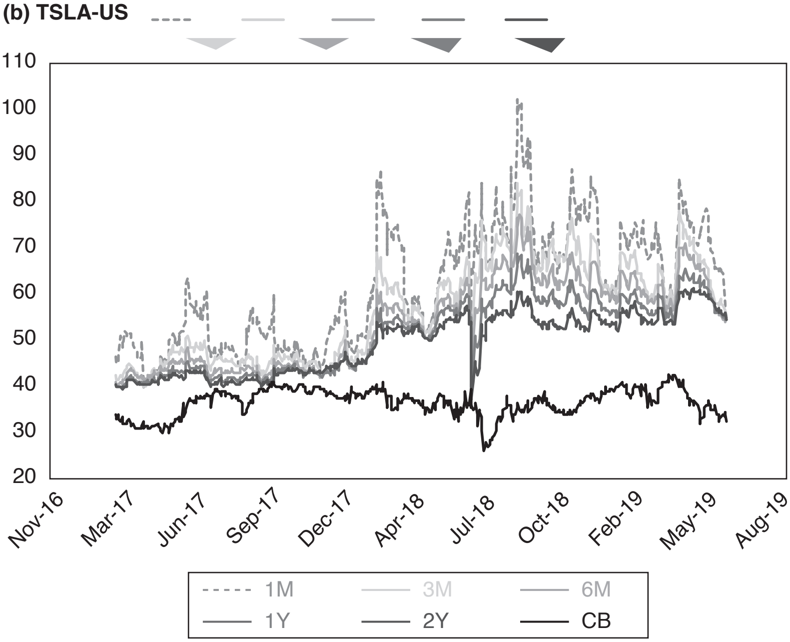
EXHIBIT 39-17

80% Moneyness Implied Volatilities for Exchange-Traded Options from One Month to Two Years (Gray) vs. Those Implied from the CB (Black).

(a) BMRN-US



(b) TSLA-US

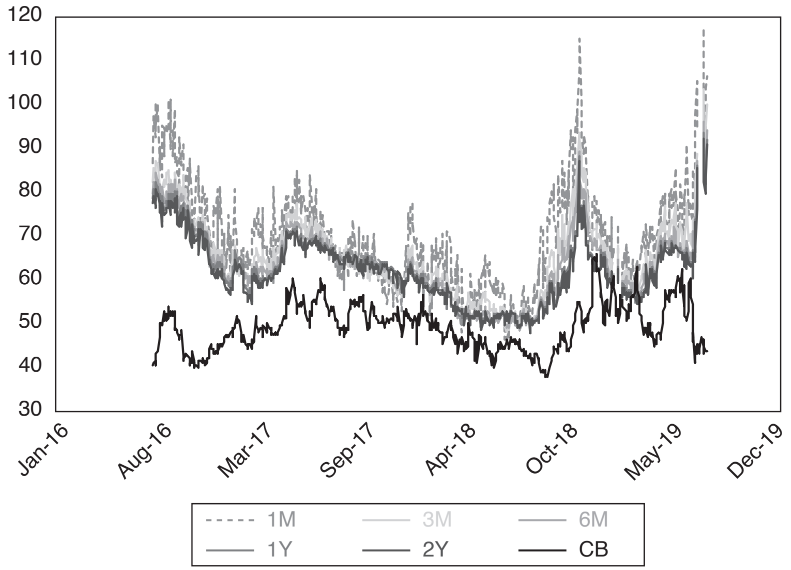


(Continued)

EXHIBIT 39-17

80% Moneyness Implied Volatilities for Exchange-Traded Options from One Month to Two Years (Gray) vs. Those Implied from the CB (Black) *(Continued)*

(c) OAS-US



(d) DISH-US

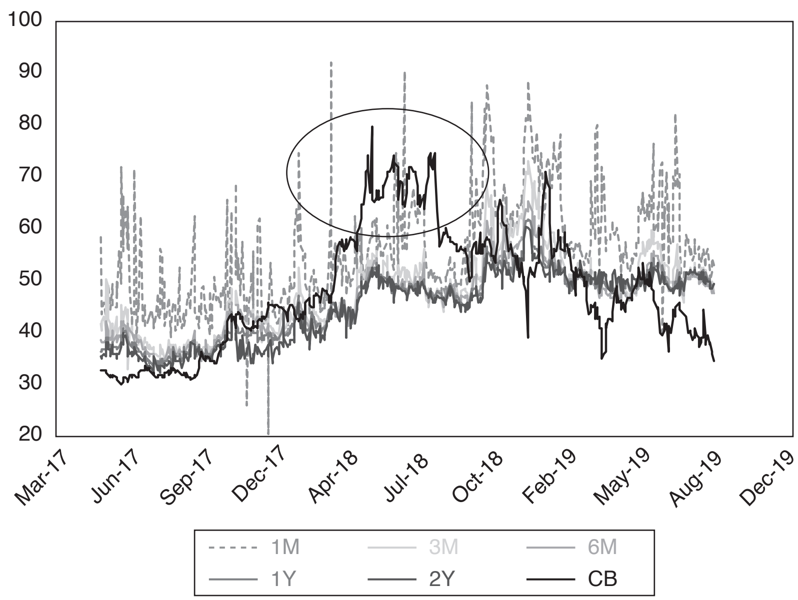
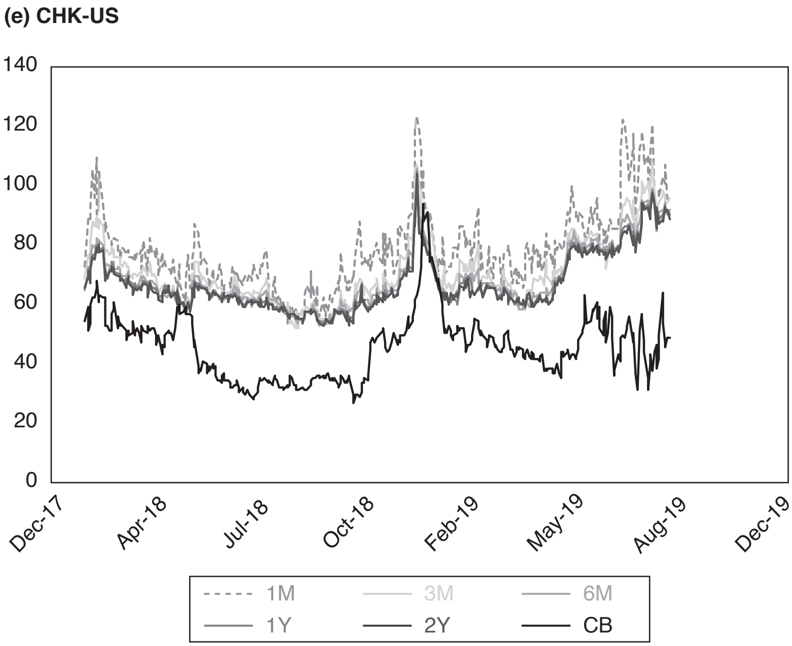


EXHIBIT 39-17

80% Moneyness Implied Volatilities for Exchange-Traded Options from One Month to Two Years (Gray) vs. Those Implied from the CB (Black) *(Continued)*



imbalance then corrected itself as the bond seasoned, as demonstrated by the decrease in CB-implied volatility versus the listed options.

Marking Tesla wider than CDX.NA.HY was related to the ongoing research-dependent nature of the enterprise and the associated cash burn. The overall viability of the business model is uncertain. The resulting agreement of the term structure of the implied volatilities confirms the choice. The outright magnitudes of the volatilities also support the view that the Tesla CDS trades too tightly. From panel b in Exhibit 39-16, Tesla displays positive vega for volatilities under 60%. The CB-implied volatilities have consistently traded between 25% and 40% with the exchange-traded volatilities at similar magnitudes only in mid-2017. Exchange-traded volatilities have increased in magnitude since early 2018, with prints more than 20 volatility points higher than those seen in 2017. However, the CB volatilities remain range bound despite the tenors between the asset classes progressively converging. The capital structure appears misaligned and the CB volatility is too cheap. This view is most easily expressed by buying Tesla protection; that is, the portfolio manager is expecting the CDS to widen thereby lowering the bond floor and increasing the volatilities.

Going a step further, the implied volatility term structure is also consistent across the CBs themselves. In addition to the Dish 2.375% 2024 bond, there is another security: Dish 3.375% 2026 (US25470MAB54). Likewise, Tesla has issued a second CB: Tesla 1.25% 2021 (US88160RAG65). The implied volatilities for these four bonds are shown in Exhibit 39-18. The implied volatilities for Dish are consistent, with the longer maturities trading at lower levels than the shorter-dated bond across the entire time series, as shown in panel a in Exhibit 39-18. Furthermore, the elevated volatilities observed in mid-2018 in panel d in Exhibit 39-17 are consistent across both bonds. The implied volatilities are also highly correlated with $\rho = 0.93$. This suggests that there was an asset class–wide misalignment across the capital structure of DISH-US. The Tesla bonds displayed the same price action across tenors from June 2018 to June 2019 ($\rho = 0.83$). Again, as the maturity increases the implied volatilities decrease. However, from May to early September 2019, the 2021 volatilities traded down below the 2022 volatilities. Recall from panel b in Exhibit 39-14 that there were price dislocations for the Tesla 2022 bond, with decreasing prices corresponding to decreasing implied volatilities during this same period. The short-dated volatilities trading at lower levels to the 2022 maturity indicate that the 2021 bond is oversold and reinforces the view that the Tesla CDS is trading too tightly. That misalignment was corrected in late September with the 2021 volatilities returning to higher outright magnitudes versus the 2022 implied volatilities.

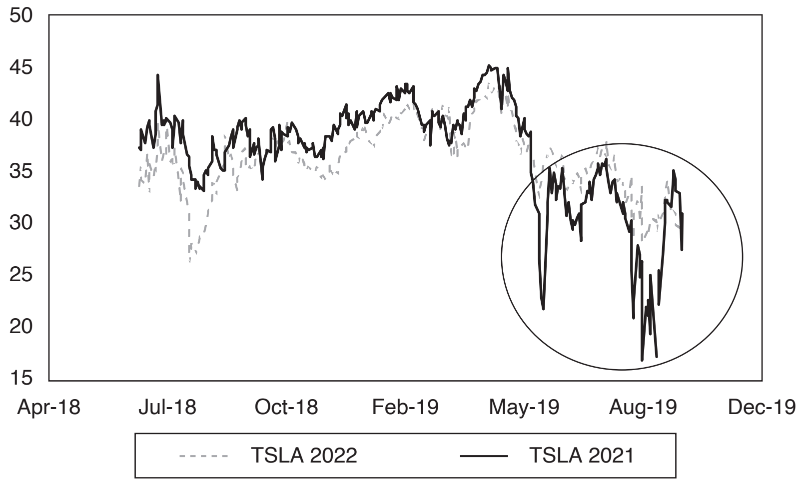
Linking exchange-traded and CB-implied volatilities is new. Likewise, the agreement between the term structure of the implied volatilities of the different asset classes has not previously been reported. The internal consistency of the term structure within the convertible bonds themselves is also new. In effect, combining the asset classes provides a consistent view of implied volatility for a given stock out to maturities that are not accessible from exchange-traded markets.

EXHIBIT 39-18

CB Implied Volatilities

(a) DISH 2.375% 2024 (US25470MAD11) and DISH 3.375% 2026 (US25470MAB54)

(b) CB Implied Volatilities for Tesla 1.25% 2021 (US88160RAG65) and Tesla 2.375% 2022 (US88160RAD35)



Sensitivity Time Series

Recall that the value of $p = 2$ was chosen to ensure agreement between the realized distribution of defaulted bond prices and the soft bond floor. This can result in negative vega and outsized delta, as seen in Exhibit 39-15 and Exhibit 39-16. In Exhibit 39-19 the time series for delta, vega, and rho are represented for all five bonds. In all cases, rho is negligible, as generally credit derivatives do not display large exposures to interest rates, giving further evidence for the conclusion above that the interest rate is the least important aspect of a convertible bond model.

Tesla displays a consistently positive vega, whereas the vega for the other four bonds moves between positive and negative values based on the equity performance, as outlined in Exhibit 39-16. The most notable delta is that for Chesapeake. In late 2018, the delta spiked as the equity decreased from USD 5 to USD 1. For sufficiently low equity prices, the delta increases markedly in response to the default risk that a low market capitalization represents (shown in Exhibit 39-15). For all five bonds, the sensitivities are stable, thereby producing meaningful risk. The difficulty for any portfolio manager hedging these securities arises from the inflection points in the risk—for example, where vega switches from positive to negative for $S \gg 0$, or the delta spikes as $S \rightarrow 0$.

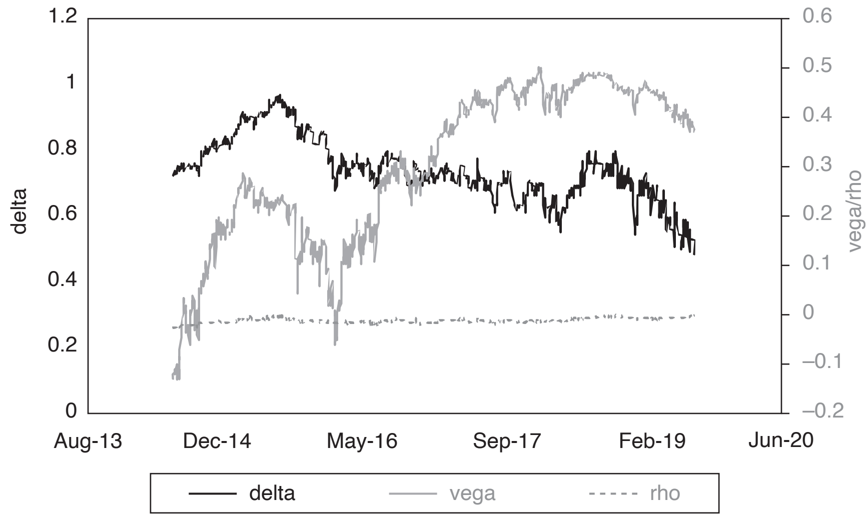
In Exhibit 39-20, the gamma theta and omicron are plotted for the five bonds studied. Most noteworthy is the Chesapeake 5.5% bond, where not only is the gamma consistently negative but it decreases from values close negligible to values with a magnitude of nearly 12 times the stock price. Recall from Exhibit 39-15 that for sufficiently low values of S, $\Delta \gg 1$. Alternatively, from a low stock valuation, small increases in the stock price correspond to dramatic decreases in the value of the bond, which was certainly the case in 2019 with the uncertainty surrounding Chesapeake's viability.[20] For the other bonds, the key takeaway is that the gamma has negligible magnitude. It can oscillate from weakly positive to weakly negative, as for Dish in panel d in Exhibit 39-20, but its overall importance to the bond valuation is less than omicron. The time series agree with Exhibit 39-6. CBs display weak positive gamma when $S \gg 0$ and outsized negative gamma as $S \rightarrow 0$. Another observation is that $|\theta| \approx \Gamma$ when Γ is positive. Also note that from comparing Exhibit 39-19 to Exhibit 39-20, $|o| \approx |\rho|$.

20. Chesapeake filed for bankruptcy in June of 2020.

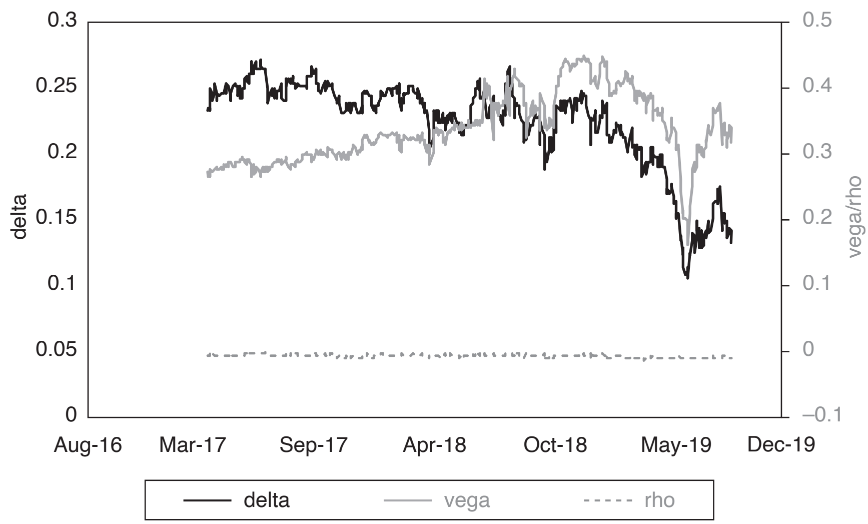
EXHIBIT 39-19

Delta, Vega, and Rho Time Series

(a) BioMarin Pharmaceutical Inc 1.5% 2020 (US09061GAF81)



(b) Tesla 2.4% 2022 (US88160RAD35)

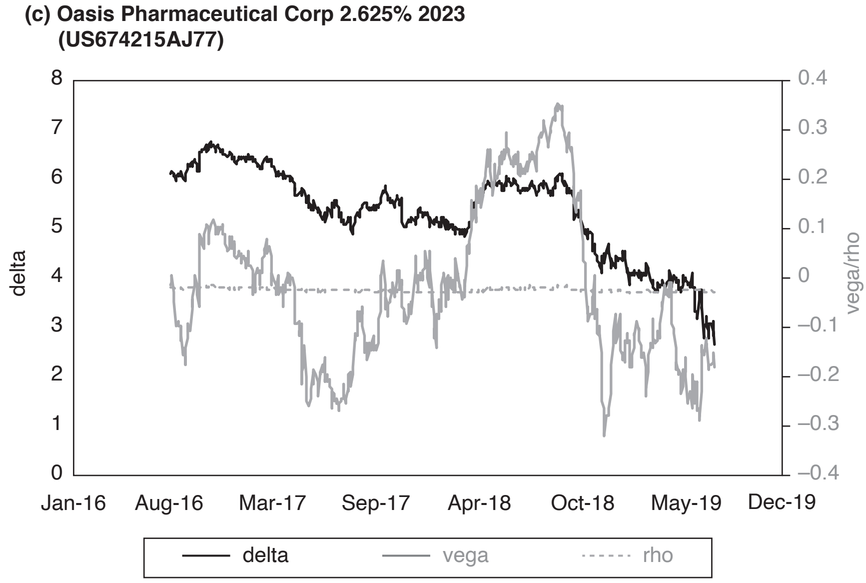


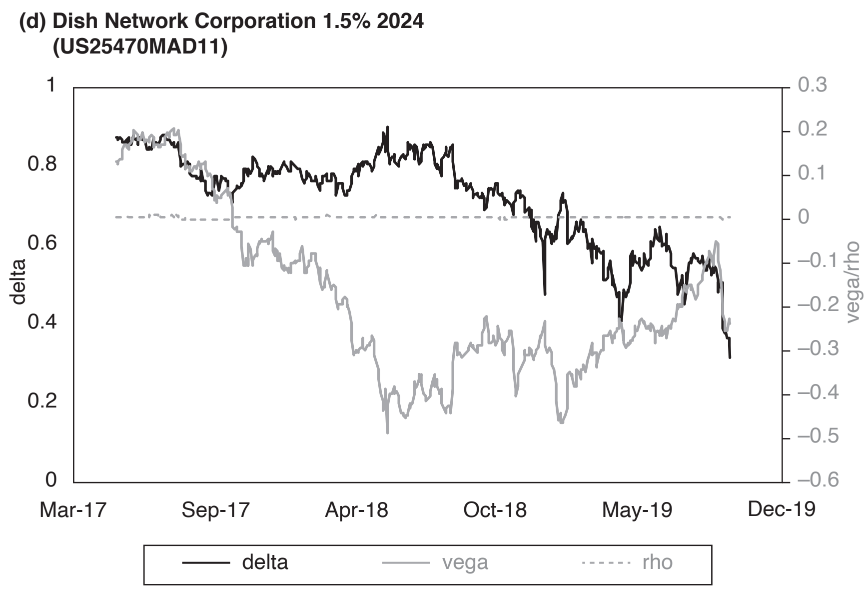
Note: Axis colors correspond to the time series and rho should be read from the same axis as vega.

(Continued)

EXHIBIT 39-19

Delta, Vega, and Rho Time Series *(Continued)*

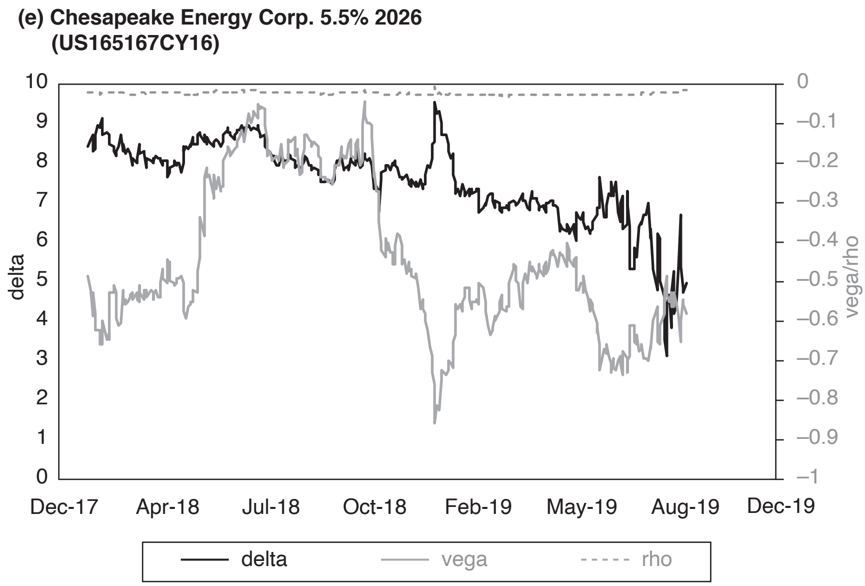




Note: Axis colors correspond to the time series and rho should be read from the same axis as vega.

EXHIBIT 39-19

Delta, Vega, and Rho Time Series *(Continued)*

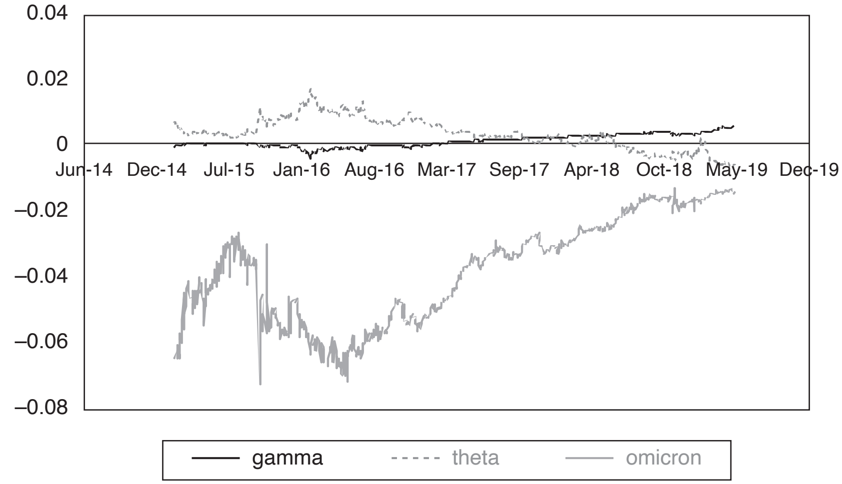


Note: Axis colors correspond to the time series and rho should be read from the same axis as vega.

EXHIBIT 39-20

Gamma, Theta, and Omicron Time Series

(a) BioMarin Pharmaceutical Inc 1.5% 2020 (US09061GAF81)



(b) Tesla 2.4% 2022 (US88160RAD35)

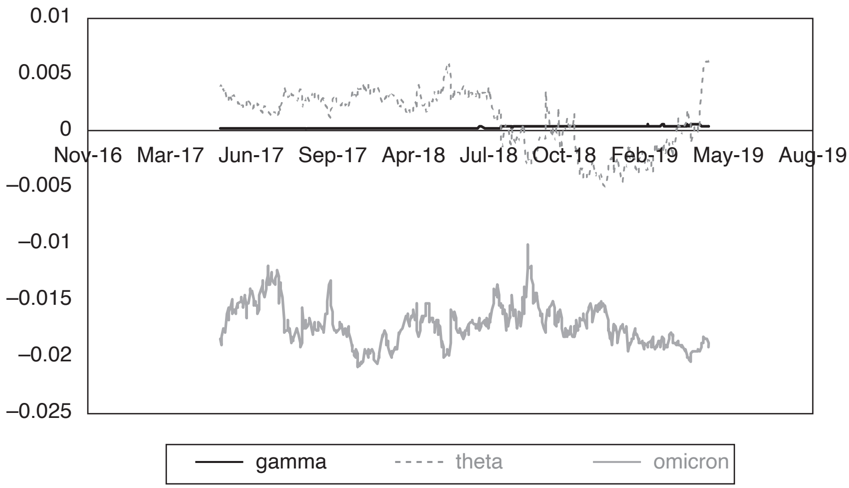
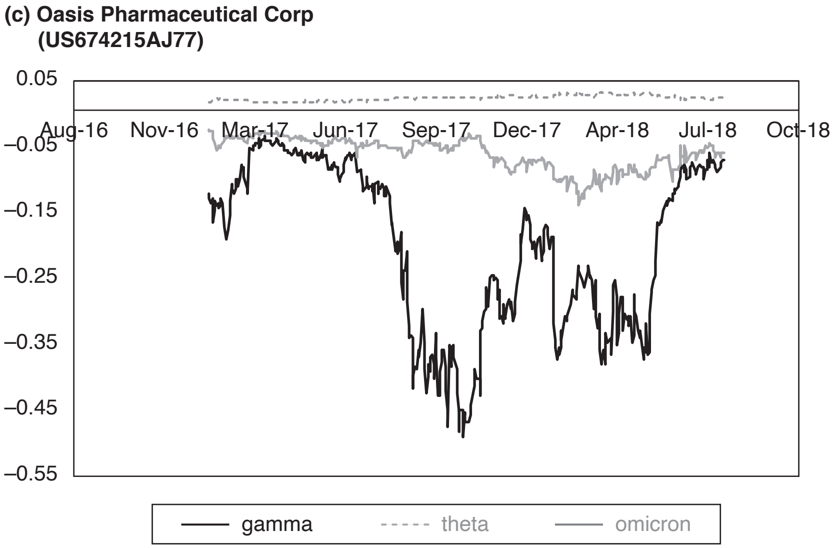
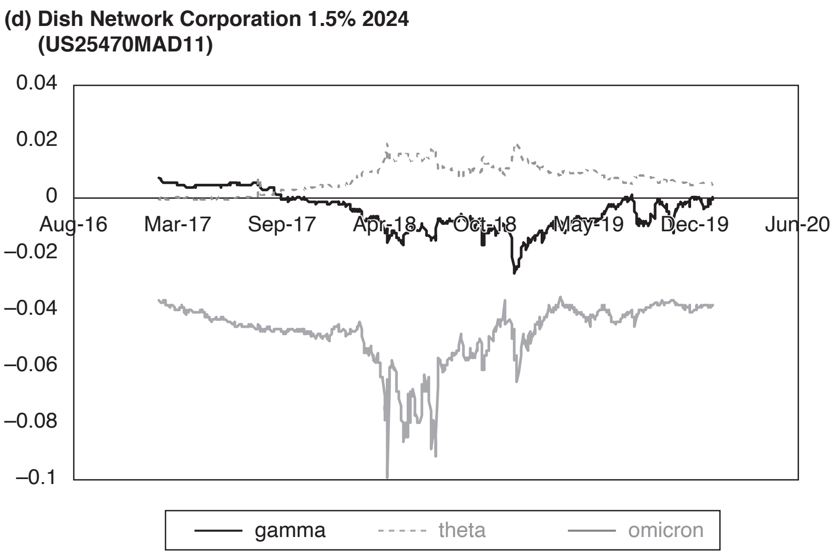


EXHIBIT 39-20

Gamma, Theta, and Omicron Time Series *(Continued)*



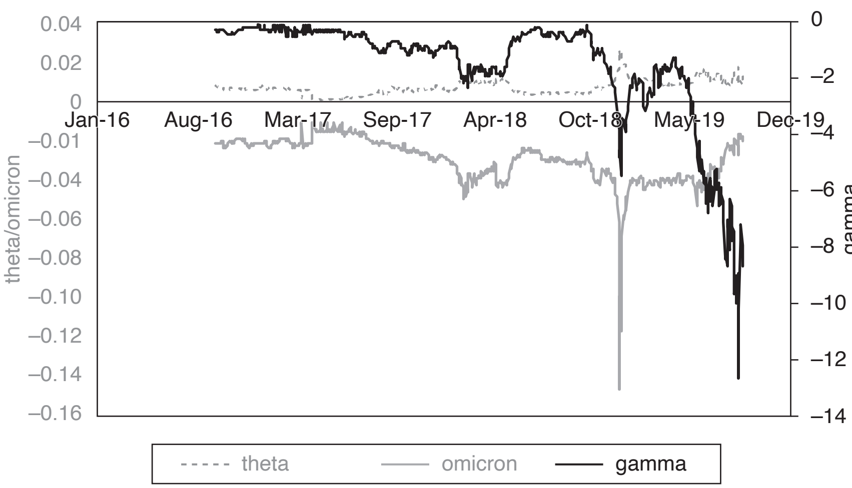


(Continued)

EXHIBIT 39-20

Gamma, Theta, and Omicron Time Series *(Continued)*

(e) Chesapeake Energy Corp. 5.5% 2026 (US165167CY16)



CONVERTIBLE BOND ARBITRAGE

The most commonly known trading strategy, associated with the idea of "arbitraging" a convertible bond, is where the bondholder shorts the underlying equity against the bond itself; essentially this is a pairs trade. The exact size of the short position is usually defined by Δ, but other ratios have been studied. This is in fact a relative value trade, not a true arbitrage, in the econometric sense. Following the literature,[21] what the arbitrageur seeks are "undervalued" or "mispriced" bonds at

21. Manuel Ammann, Axel Kind, and Christian Wilde, "Are Convertible Bonds Underpriced? An Analysis of the French Market," *Journal of Banking & Finance* (2003), pp. 635–653; Peter Carayannopoulos and Madhu Kalimipalli, "Convertible Bond Prices and Inherent Biases," *Journal of Fixed Income* (2003), pp. 64–73. Axel W. H. Chan and Nai-fu Chen, "Convertible Bond Underpricing: Renegotiable Covenants, Seasoning, and Convergence," *Management Science* (September 2007), pp. 1793–1814; Igor Loncai, Jenke Ter Host, and Chris H. Veld, "The Rise and Demise of the Convertible Arbitrage Strategy," *Financial Analysts Journal* (2009), pp. 35-50. Darwin Choi, Mila Getmansky, Brian Henderson, and Heather Tookes, "Convertible Bond Arbitrageurs as Suppliers of Capital," *Review of Financial Studies* (June 2010), pp. 2492–2522; Mark Hutchinson and Liam Gallagher, "Convertible Bond Arbitrage: Risk and Return," *Journal of Business Finance & Accounting* (2010), pp. 206_241. Abe De Jong, Marie Dutordoir, and Patrick Verwijmeren, "Why do Convertible Bond Issuers Simultaneously Repurchase Stock? An Arbitrage-Based Explanation," *Journal of Financial Economics* (2011), pp. 113–124; Brian J. Henderson and Heather Tookes, "Do Investment Banks' Relationships with Investors Impact Pricing? The Case of Convertible Bond Issues," *Management Science* (2012), pp. 2272–2291; Jonathan A. Batten, Karren Lee-Hwei Khaw, and Martin R. Young, "Convertible Bond Pricing Models," *Journal of Economic Surveys* (2013), pp. 775–780; and. Stephen J. Brown, Bruce D. Grundy, Craig M. Lewis, and Patrick Verwijmeren,"Convertibles and Hedge Funds as Distributors of Equity Exposure," *Review of Financial Studies* (2012), pp. 3077–3112.

issuance. When an appropriate initial offer is identified, the arbitrageur places the order and shorts the stock into the street. The pricing function employed in these studies is Tsiveriotis and Fernandes, without exception. The model is calibrated to historic equity volatilities calculated from 150 to 250 trading days of closing prices, prior to valuation. Where the model price is higher than the traded price, the bond is deemed to be undervalued.

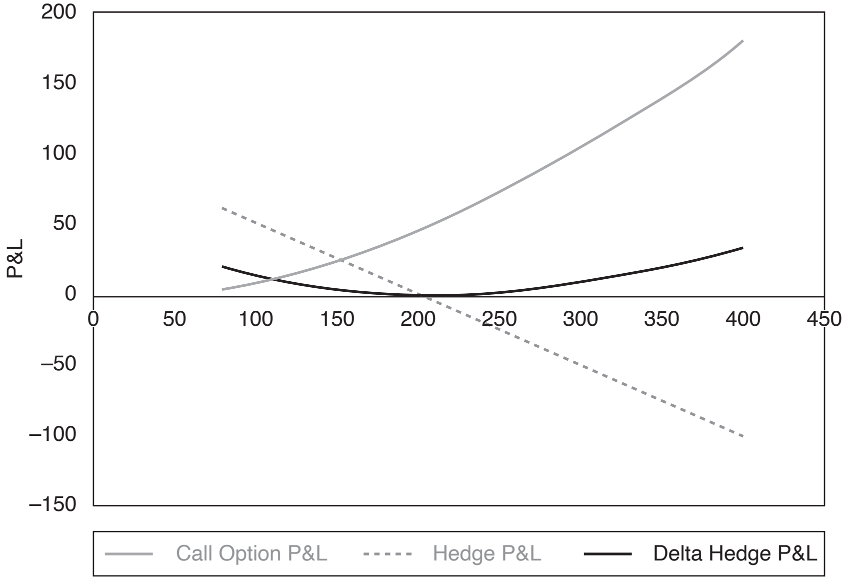
The profitability of this position has been associated with gamma trading the delta hedged bond.[22] As the stock price fluctuates, the arbitrageur adjusts the delta hedge and takes profit, thereby monetizing the position. This type of trading requires positive gamma. Holding rates and credit constant, a delta-hedged positive gamma position is shown in Exhibit 39-21, where the profit and loss (P&L) profile for a long-dated, at-the-money, delta-hedged TSLA-US option is represented. The option strike is the conversion price of the Tesla 2.4% 2022 bond, that is, \$327. The option is marked at 40% volatility, which is comparable to panel b in Exhibit 39-17. Essentially, this is equivalent to assuming $p = 0$ in Equation (39-2), coupled with a short equity position. From the shape of the resulting profit and loss (P&L) profile, this is also known as positive convexity; that is, as the stock price fluctuates, the arbitrageur always takes profit. The more volatile the stock, the more re-hedging of the stock position and the more profitable the position. Hence, if the bond is mispriced, it is trading at a lower volatility than the arbitrageur's anticipated market volatility, and the position may be profitable.

It is difficult to support the gamma trading theory based on the results presented in this chapter. Firstly, the gamma, when positive, is too weak to monetize for long dated positions. In Exhibit 39-20 gamma is of similar magnitude to theta. Even if the gamma is fully monetized, it will struggle to outperform the time decay. It would require extreme moves in the stock price to return even modest P&L. Calamos[23] does state that the trader must identify a "convertible with high gamma." However, Calamos does not explain how to make that identification. Moreover, the gamma switches from positive to negative. Under this scenario, the arbitrageur is under hedged and rebalancing the short position from movement in the underlying equity locks in a loss. Secondly, applying any model without dynamic credit (equivalent to $p = 0$ in Equation (39-8)) will misspecify the risk profile as there is no negative gamma, nor will the model display negative vega. As the stock price falls sufficiently, the expected P&L gains will not be realized and the anticipated P&L gains from a $p = 0$ model will not result.

22. Darwin Choi, Mila Getmansky, and Heather Tookes, "Convertible Bond Arbitrage, Liquidity, Externalities, and Stock Prices," *Journal of Financial Economics* (2009), pp. 227–251; Mats van Marle and Patrick Verwijmerem, "The Long and the Short of Convertible Arbitrage: An Empirical Examination of Arbitrageurs' Holding Periods," *Journal of Empirical Finance* (2017), pp. 237–249; and Frank J. Fabozzi, Jinlin Liu, and Lorne N. Switzer, "Market Efficiency and Returns from Convertible Bond Hedging and Arbitrage Strategies," *Journal of Alternative Investments* (October 2009), pp. 37–64.
23. Nick Calamos, *Convertible Arbitrage*, (New Jersey: Wiley, 2003); see p. 137.

EXHIBIT 39-21

At-the-Money TSLA-US Delta-Hedged Option Position (Strike = 327) for a Five-Year Maturity



The limitations of historic volatility are well documented. Implied volatilities are forward looking whereas historic volatilities can only offer a measure of realized volatility—if a convertible bond is undervalued, it must be quantified in terms of expected, not realized market performance. Convertible bonds may be priced attractively at issuance, as the low credit quality and size of many CB issuers will restrict the pool of eligible investors. Couple that with thinner liquidity and higher bid-offer spreads and the appetite from investors will be even lower. However, it is not mispriced, nor underpriced—it is the market price subject to these frictions.

There are other reasons to execute the delta-hedged convertible bond position.[24] If the yield on the bond is higher than the borrowing/funding cost, the arbitrageur has a positive carry. If the underlying credit is distressed and the equity has sold off, the bond is deemed to be busted. The option is essentially worthless, but an underlying credit position remains. Delta hedging the bond will isolate the credit risk. If the arbitrageur anticipates that the credit spread will tighten, the soft bond floor will increase, and the arbitrageur will book a profit.

24. See for example, John Crosby, "Convertible Bond Arbitrage," *Grizzly Bear Capital,* http://www.john-crosby.co.uk/pdfs/ConvBondArb_PDF.pdf.

One key differentiator from the gamma position is that despite a small sensitivity to credit, the potential spread moves may be several hundred to several thousand basis points. The arbitrageur may seek to exploit the outright volatility position. Holding interest rate and credit spread constant, the delta-hedged position is now long vega. If the bond has positive vega and volatilities rise, the arbitrageur will see mark-to-market gains. Similarly, these strategies can be combined. For example, the equity and the credit could be hedged together. The delta hedge then acts as downside protection. Finally, as the bond seasons, and the embedded option loses value, the gamma trading strategy can be effective. Calamos outlines several gamma capture strategies, namely, with Bull and Bear hedges. These approaches either under hedge versus the model delta, or they are over weight versus the delta, based on the directional view of the market. The ability to realize P&L through re-hedging can then outperform the cost of holding the option itself. However, this is only effective for short-dated positions where the gamma can outperform the theta.

KEY POINTS

- Calibrating to bond price produced meaningful implied CB volatilities. Across a variety of maturities and credit spreads, extended time series were obtained, not just for volatilities, but for sensitivities as well.
- The observed price action replicates the negative correlation observed in the market, that is, as bond prices decline, implied volatilities increase, and vice versa. High correlations between these risk factors were also observed.
- The term structure of the CB-implied volatilities agreed with exchange traded implied volatilities for each issuer. As maturities increased, the outright volatility levels declined with the CB-implied volatilities lower than shorter dated exchanged traded volatilities. Furthermore, the CB volatilities were consistent within the asset class; that is, longer-dated volatilities trade at lower outright levels than shorter-dated contracts.
- The choice of the intensity to capture the process between credit and equity allowed calibration to defaulted bond prices via a "soft bond floor." This also translated to increased deltas for sufficiently low equity prices. Likewise, negative vega was observed for higher market capitalizations.
- Negative gamma was also observed for low stock prices. This result questions the established understanding of convertible bond arbitrage as a gamma trading strategy.

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PART
SEVEN

CREDIT ANALYSIS

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CHAPTER
FORTY

CREDIT ANALYSIS FOR CORPORATE BONDS

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Professor of Finance
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Adam B. Cohen, J.D.

The purpose of this chapter is to provide a framework for the credit analysis of corporate bonds. Although there are numerous types of corporate bonds outstanding, three major issuing segments can be differentiated: industrials, utilities, and finance companies. This chapter will deal primarily with industrials in its general description of bond analysis and then discuss utility and finance issues. Special factors that must be considered in the credit analysis of high-yield corporate issues are addressed. At the end of this chapter, credit scoring models for identifying potential issuers that may default are described.

APPROACHES TO CREDIT ANALYSIS

Traditionally, credit analysis for corporate bonds has focused almost exclusively on the default risk of the bond—the chance that the bondholder will not receive the scheduled interest payments or principal at maturity. This one-dimensional analysis concerned itself primarily with the calculation of a series of ratios historically associated with fixed income investment. These ratios typically would include fixed charge coverage, leverage, and funds flow/total debt. Such an approach was deemed appropriate when interest rates were stable and investors purchased bonds with the purpose of holding them to maturity. Under those conditions, fluctuations in the market value of the bonds owing to interest rate changes were minimal, and fluctuations owing to credit changes of the bond issuer were mitigated by the fact that the investor had no intention of selling the

Parts of this chapter are based on the chapter by Jane Tripp Howe that appeared in previous editions of this handbook.

bond before maturity. During the past four decades, however, the purpose of buying bonds has changed dramatically. Investors still purchase bonds for security and thereby forgo the higher expected return of other assets such as common stock. Increasingly, however, investors buy bonds to trade them actively with the purpose of making a profit on changes in interest rates or in absolute or relative credit quality. The second dimension of corporate bond credit analysis addresses the latter purpose of buying a bond. What is the likelihood of a change in credit quality that will affect the price of the bond? This second dimension deals primarily with ratios and profitability trends, such as return on equity, operating margins, and asset turnover, generally associated with common stock analysis. Both dimensions should be applied in corporate bond analysis because they address the same issue—default or credit risk—from complementary perspectives. Only by using both dimensions of credit analysis will the analyst address the dual purpose of bondholding: security of interest and principal payments and stability or reduction in credit risk during the life of the bond.

Another outgrowth of the shift from buy-and-hold strategies to active bond management is a premium on prompt responses to news that affects a company's ability to generate cash flow to cover its interest charges. A sudden leap or plunge in stock price may reflect significant new information about a company's future profitability that the bond market does not yet reflect. By taking a clue from the equity market, an astute investor may get a jump on competitors in catching an upswing or avoiding a downswing in the issuer's bonds.

Beyond this sort of reactive approach, bond investors can use equity-based information to conduct systematic and potentially profitable analysis. The idea that stock analysis and bond analysis are intertwined has been advanced by the development of options analysis.[1] Underlying this line of reasoning is the basic insight that all of a company's liabilities derive their value from the same set of cash flows. This suggests that the intrinsic value of the equity must be consistent with the intrinsic value of the debt. (Note that the equity value referred to here is economic value, rather than the accounting value represented on the balance sheet by shareholders' equity.)

The ability to derive analytical benefits from these insights springs from the expectation that the company's owners will cease paying interest, that is, default on their debt, if the value of their equity drops to zero. This rational response is analogous to homeowners whose mortgages exceed the value of their houses "mailing the keys to the bank" instead of continuing to make interest payments. It follows that the bigger the equity cushion beneath bondholders, the more remote is the probability of default.

More generally, the probability of default is a function not only of the equity cushion's size, but also its volatility. A company with a comparatively small

1. Credit risk models, discussed in Chapter 42, are referred to as "structural models," "asset-value models," and "firm-value models."

equity cushion may receive a fairly high rating if its stock price is exceptionally stable. An extremely steady share price makes the company's equity value very unlikely to fall to zero and trigger a default.

A final caveat on the interpretation of equity valuations in the context of credit analysis is that under certain circumstances an increase in the equity cushion can indicate *increased* risk of default. The ultimate effect of a leveraged buyout (LBO) is that a substantial portion of the equity in the company's capital structure is replaced by debt, resulting in substantially heightened credit risk. To effect the transaction, however, the LBO sponsor must pay a premium to prevailing market value to acquire the stock from the existing shareholders. Sometimes, word of the pending LBO leaks into the market before the deal is announced, pushing the share price higher. That results in a short-run increase in the equity cushion, but analysts who leap to the conclusion that credit risk is declining will receive a rude surprise when the true cause of the price appreciation comes to light.

INDUSTRY CONSIDERATIONS

The first step in analyzing a bond is to gain some familiarity with the industry. Only within the context of an industry is a company analysis valid. For example, a company growing at 15% annually may appear attractive. However, if the industry is growing at 50% annually, the company is competitively weak. Industry considerations can be numerous. An understanding of the nine variables discussed in this section, however, should give the general fixed income analyst a sufficient framework for properly interpreting a company's prospects:

- Economic cyclicality
- Growth prospects
- Research and development expenses
- Competition
- Sources of supply
- Degree of regulation
- Labor
- Accounting
- Event risk

In some industries, for instance, an analysis of labor costs must consider technological advances that have made it feasible to outsource certain functions to lower-wage countries. Examples include handling of customer inquiries, analysis of diagnostic results, and financial statement analysis. Also, cross-border differences in accounting standards complicate credit quality comparisons of industry peers domiciled in different countries.

Economic Cyclicality

Does the industry closely follow gross domestic product (GDP) growth, as does the retailing industry, or is it recession-resistant but slow-growing, like the regulated electric utility industry? The growth in earnings per share (EPS) of a company should be measured against the growth trend of its industry. Major deviations from the industry trend should be the focus of further analysis. Some industries may be somewhat dependent on general economic growth but be more sensitive to demographic changes. For example, the aging of the U.S. population should cause demand for health care to grow faster than the economy as a whole. Analysts must bear in mind, however, that efforts by government and employers to control health care costs may limit revenue growth. Other industries, such as banking, are sensitive to interest rates. When interest rates are rising, the earnings of banks with a high federal funds exposure underperform the market because their loan rates lag behind increases in the cost of money. Conversely, as interest rates fall, banking earnings outperform the market because the lag in interest change works in the banks' favor.

In general, however, the earnings of few industries correlate perfectly with one economic statistic. Not only are industries sensitive to many economic variables, but often various segments within a company or an industry move countercyclically or at least with different lags in relation to the general economy. For example, the housing industry can be divided between new construction and remodeling and repair. New construction historically has led GDP growth, but repair and remodeling have exhibited less sensitivity to general trends. Therefore, in analyzing a company in the construction industry, the performance of each of its segments must be compared with the performance of the subindustry.

Growth Prospects

A second industry variable related to economic cyclicality is the growth prospects for an industry. Is the growth of the industry projected to increase and be maintained at a high level, such as in the nursing home industry, or is growth expected to decline, as in the defense industry? Each growth scenario has implications for a company. In the case of a fast-growth industry, how much capacity is needed to meet demand, and how will this capacity be financed? In the case of slow-growth industries, is there a movement toward diversification or a consolidation within the industry, such as in the railroad industry? A company operating within a fast-growing industry often has a better potential for credit improvement than does a company whose industry's growth prospects are below average. However, barriers to entry and the sustainability of growth must be considered along with growth prospects for an industry. If an industry is growing rapidly, many new participants may enter the business, causing oversupply of product, declining margins, and possible bankruptcies.

The growth prospects of an industry also should be considered in a global context, particularly if a company has international exposure. Frequently, the growth prospects of an industry vary by country. For example, the soft drinks industry is declining in the United States but continues to achieve high growth in many emerging market countries.

Research and Development Expenses

The broad assessment of growth prospects is tempered by the third variable—the research and development (R&D) expenditures required to maintain or expand market position. Products with high-tech components can become dated and obsolete quickly. Therefore, although a company may be well situated in an industry, if it does not have the financial resources to maintain a technological lead or at least expend a sufficient amount of money to keep technologically current, its position is likely to deteriorate in the long run. In the short run, however, a company with R&D expenditures consistently below industry averages may produce above-average results because of expanded margins.

Evaluation of research and development is further complicated by the direction of technology. Successful companies not only must spend an adequate amount of resources on development, but they also must be correct in their assessment of the direction of the industry. Deployment of significant amounts of capital may not prevent a decline in credit quality if the capital is misdirected. For example, computer companies that persisted in devoting a high percentage of their capital expenditures to the mainframe component of their business suffered declines in credit quality as the mainframe business declined. In industries such as software and telecommunications, new technologies emerge frequently, and not all achieve market viability. A company that ties its product plans to the wrong technology loses competitive ground in addition to being unable to recover a substantial investment in R&D.

Competition

Competition is based on a variety of factors, with their relative importance varying by industry. Price is almost always a major competitive consideration, but product quality also affects the customers' decisions. For many consumer products it is difficult to measure product quality by objective standards. Brand name recognition and celebrity endorsements consequently shape perceptions of product quality. Companies also compete by striving to achieve advantages in distribution and by cultivating long-term relationships with customers.

Some companies are able to maintain strong competitive positions over extended periods through patents and trademarks. The flip side is that the expiration of a patent can lead to a major revenue loss. This is particularly pertinent for a pharmaceutical maker that will have to begin competing with generic drug producers once patent protection expires on a highly successful product. Another danger signal is heavy concentration of revenues at a small number of customers. In such a situation, a decision by a major customer to switch to another provider could deal a severe blow.

Increasingly, all forms of competition are waged on an international basis and are affected by fluctuations in relative currency values. Companies that fare well are those that compete successfully on a global basis and concentrate on the regions with the highest potential for growth. Consumers are largely indifferent to the country of origin of a product as long as the product is of high quality and reasonably priced. This fact is exemplified by the significant increase in the manufacture of automobiles and automobile parts in Mexico that are shipped to the United States.

Competition within an industry relates directly to the market structure of an industry and has implications for pricing flexibility. An unregulated monopoly is in an enviable position in that it can price its goods at a level that will maximize profits. Most industries encounter some free-market forces and must price their goods in relation to supply and demand, as well as the price charged for similar goods. In an oligopoly, a pricing leader is not uncommon. A concern arises when a small company is in an industry that is moving toward oligopoly. In this environment, the small company's costs of production may be higher than those of the industry leaders, and yet it may have to conform to the pricing of the industry leaders. In the extreme, a price war could force the smaller companies out of business. This situation has occurred in the automobile industry over many decades, first on a national and later on a global basis. Many U.S. producers either failed or merged with larger competitors as the field narrowed to the Big Three—General Motors, Ford Motor Company, and Chrysler. In addition to getting squeezed on costs and pricing, smaller automakers faced a disadvantage in producing fewer models, making them more sensitive to changes in consumer tastes than the industry leaders. Similarly, concentration in one region of the world became a handicap as the industry globalized. Recessions usually vary in severity from country to country, so global producers could reduce their vulnerability to economic downturns by spreading their sales across continents.

A concern also arises when there is overcapacity in the industry. Often overcapacity is accompanied by price wars. Generally, price wars result in an industry-wide financial deterioration as battles for market share are accompanied by declining profits or losses.

Sources of Supply

The market structure of an industry and its competitive forces have a direct impact on the fifth industry variable—sources of supply of major production components. A company that is not self-sufficient in its factors of production but is sufficiently powerful in its industry to pass along increased costs is in an enviable position.

Degree of Regulation

In a regulated monopoly such as electric power generation, pricing is determined by a government body. The intention is to prevent companies from extracting excess profits, yet to provide a fair rate of return on capital. That policy tends to promote stable earnings regardless of economic conditions. State regulatory commissions vary, however, in their responsiveness to requests for rate relief to offset increased costs.

Non-monopoly industries face regulation in such areas as labor practices, financial reporting, product safety, and environmental impact. The costs of complying with these regulations are often substantial and the ability to pass the costs on to customers varies by industry. Compliance with regulations that are stricter than in other countries may disadvantage companies relative to foreign-based competitors. Violating regulations can result in costly fines as well as reputational damage that may result in lost business.

Labor

The seventh industry factor requiring analysis is the labor situation. Is the industry heavily unionized? If so, what has been the historical incidence of strikes? What level of flexibility does management have to reduce the labor force? When do the current contracts expire, and what is the likelihood of timely settlements? The labor situation is also important in nonunionized companies, particularly those whose labor situation is tight. What has been the turnover of professionals and management in the firm? What is the probability of a firm's employees, such as highly skilled engineers, being hired by competing firms? What is the likelihood of union activity in nonunionized companies? Are the states in which unionization is a possibility right-to-work states and therefore more difficult to unionize? How much of a cost advantage do the nonunionized companies have over the unionized companies?

The more labor-intensive an industry, the more significance the labor situation assumes. This fact is evidenced by the domestic automobile industry, in which overcapacity and high unionization have contributed to high fixed costs and cyclic record operating losses.

Occasionally, analysts concentrate on the per-hour wages of the labor force. Such an emphasis is misleading. An evaluation of the labor force should concentrate on work rules because work rules are more important in the overall efficiency of an organization than the wage rates. This is an important factor in the profitability of some automobile supply companies.

Accounting

One more industry factor to be considered is accounting. Does the industry have special accounting practices, such as those in the insurance industry or the electric utility industry? If so, an analyst should become familiar with industry practices before proceeding with a company analysis. Also important is whether a company is liberal or conservative in applying accounting rules. The norm of an industry should be ascertained and the analyst should analyze comparable figures.

Particular attention should be paid to companies that use an accounting system other than U.S. generally accepted accounting principles (GAAP). Reported results should be reconciled with those that would have been reported under U.S. GAAP. In addition, changes in GAAP should be scrutinized.

Care also should be taken when dealing with historical data. Frequently, companies adjust prior years' results to accommodate discontinued operations and changes in accounting. These adjustments can mask unfavorable trends. For example, companies that regularly dispose of underperforming segments and then highlight the more profitable continuing operations may be trying to hide poor management. To appreciate all trends fully, both the unadjusted and the adjusted results should be analyzed.

Accounting practices also demand attention when mergers and acquisitions occur. How much of pro forma synergies are attributable to savings that are not yet realized but are allowed in pro forma results? How much goodwill is generated by the combination? Are any contracts written up because the acquiring company believes that it can improve the historical performance of the company it acquired? A conscientious analyst will be aware of these accounting entries and determine whether they reflect a pro forma reality or a too-optimistic assessment of future performance.

Event Risk

The final industry factor to consider is event risk. This term refers to a major discontinuity in a company's financial performance. It includes transactions that radically alter a company's capital structure, such as leveraged buyouts and takeovers that are heavily financed with debt. Event risk also comprises shocks such as natural disasters, environmental catastrophes, nationalizations, terrorist attacks, and revelations of accounting fraud.

Shocks can have severe credit impact, up to and including bankruptcy. As an example, on April 6, 2020, Standard & Poor's downgraded Envision Healthcare all the way from B to CC in the wake of the COVID-19 pandemic. In just two weeks, business plunged by 65% to 75% at the ambulatory surgical center operator. In their determination to avoid contracting the new coronavirus, even people with mandatory care needs stayed away from doctors' offices. Shocks are unforeseeable by their nature, but in some instances it is possible to assess a company's risk of experiencing a shock such as an environmental calamity or a costly product liability problem.

FINANCIAL ANALYSIS

Having achieved an understanding of an industry, the analyst is ready to proceed with a financial analysis. The financial analysis should be conducted in three phases. The first phase consists of traditional ratio analysis for bonds. The second phase, generally associated with common stock research, consists of analyzing the components of a company's return on equity. The final phase considers such nonfinancial factors as management and foreign exposure and includes an analysis of the indenture.

Traditional Ratio Analysis

There are numerous ratios that can be calculated in applying traditional ratio analysis to bonds. Of these, the following eight will be discussed in this section:

- Pretax interest coverage
- Leverage
- Cash flow
- Net assets
- Intangibles
- Unfunded pension liabilities
- Age and condition of plant
- Working capital

These selected ratios are the ones with the widest degree of applicability. In analyzing a particular industry, however, other ratios assume significance and should be considered.

Pretax Interest Coverage

Generally, the first ratio calculated in credit analysis is pretax interest coverage. This ratio measures the number of times interest charges are covered on a pretax basis. Pretax interest coverage is calculated by dividing pretax income plus interest charges by total interest charges. The higher the coverage figure, the safer is the credit. If interest coverage is less than 1×, the company must borrow or use cash flow or proceeds from the sale of assets to meet its interest payments.

Generally, published coverage figures are pretax as opposed to after-tax because interest payments are a pretax expense. Although the pretax interest coverage ratio is useful, its utility is a function of the company's other fixed obligations. For example, if a company has other significant fixed obligations, such as rents or leases, a more appropriate coverage figure would include these other fixed obligations. An example of this is the retail industry, in which companies typically have significant lease obligations. A calculation of simple pretax interest coverage would be misleading in this case because fixed obligations other than interest are significant.

The analyst also should be aware of any contingent liabilities such as a company's guaranteeing another company's debt. Although the company being analyzed may never have to pay interest or principal on the guaranteed debt, the existence of the guarantee diminishes the quality of the pretax coverage. In addition, the quality of the guaranteed debt must be considered.

Once pretax interest coverage and fixed-charge coverage are calculated, it is necessary to analyze the ratios' absolute levels and the numbers relative to those of the industry. For example, pretax interest coverage for an electric utility of 3.0× is consistent with an A rating, whereas the same coverage for a drug company would indicate a lower rating.

Exhibit 40-1 shows the various key pretax interest coverage ratios reported by Standard & Poor's and how they are computed by that rating agency. The exhibit defines each measure used in a ratio and the formula.

Leverage

A second important ratio is leverage, which can be defined in several ways. The most common definition of *leverage* is long-term debt as a percent of total capitalization. The higher the level of debt, the higher is the percentage of operating income that must be used to meet fixed obligations. If a company is highly leveraged, the analyst also should look at its margin of safety. The *margin of safety* is defined as the percentage by which operating income could decline and still be sufficient to allow the company to meet its fixed obligations.

The traditional method of calculating leverage uses the company's capital structure as stated in the most recent balance sheet. A helpful supplement to the traditional ratio is the *market-adjusted debt ratio*. It uses debt as reported, but substitutes for stated shareholders' equity the market value of all outstanding shares.

One drawback to the traditional, book-value-based leverage ratio is that the accounting rules generally require physical assets to be recorded at historical cost. They may be written down to reflect impairment, but not written up to reflect increases in their economic value, unless they become involved in an acquisition. Furthermore, the accounting rules require immediate expensing, rather than capitalizing, of many outlays that create substantial long-run value. Examples include research and development, the creation of brand names, and the buildup of an effective sales organization. Consequently, the traditional ratio may overstate leverage by understating the economic value of the company's equity.

The market-adjusted version is a useful corrective, because under normal conditions, the stock market will reflect a disparity—whether positive or negative—between the book value and economic value of a company's assets. Analysts should bear in mind, however, that share prices can be highly volatile. As gauged by the company's stock market value, leverage may look considerably higher a month from now than today, with the change mainly reflecting a general drop in share prices rather than a fundamental decline in the company's earnings prospects.

EXHIBIT 40-1

S&P Glossary of Terms and Formulas for Key Ratios

Glossary

Pretax income from continuing operations: Net income from continuing operations before (1) special items, (2) minority interest, (3) gains or reacquisition of debt, plus income taxes.

Eight times rents: Gross rents paid multiplied by capitalization factor of eight.

Equity: Shareholders' equity (including preferred stock) plus minority interest.

Free operating cash flow: Funds from operations minus capital expenditures and minus (plus) the increase (decrease) in working capital (excluding changes in cash, marketable securities, and short-term debt).

Funds from operations (or funds flow): Net income from continuing operations plus depreciation, amortization, deferred income taxes, and other noncash items.

Gross interest: Gross interest incurred before subtracting (1) capitalized interest, (2) interest income.

Gross rents: Gross operating rents paid before sublease income.

Interest expense: Interest incurred minus capitalized interest.

Long-term debt: As reported, including capitalized lease obligations on the balance sheet.

Operating income: Sales minus cost of goods manufactured (before depreciation and amortization), selling, general and administrative, and research and development costs.

Total debt: Long-term debt plus current maturities, commercial paper, and other short-term borrowings.

Formulas for Key Ratios

Pretax interest coverage

$$= \frac{\text{Pretax income from continuing operations} + \text{Interest expense}}{\text{Gross interest (before subtracting capitalized interest and interest income)}}$$

Pretax interest coverage including rents

$$= \frac{\text{Pretax income from continuing operations} + \text{Interest expense} + \text{Gross rents}}{\text{Gross interest} + \text{Gross rents}}$$

EBITDA interest coverage

$$= \frac{\text{Pretax income from continuing operations} + \text{Interest expense} + \text{Depreciation and amortization}}{\text{Gross interest}}$$

Funds from operations (or funds flow) as a % of total debt

$$= \frac{\text{Funds from operations}}{\text{Total debt}} \times 100$$

$$\text{Free operating cash flow as a \% of total debt} = \frac{\text{Free operating cash flow}}{\text{Total debt}} \times 100$$

(Continued)

EXHIBIT 40-1

S&P Glossary of Terms and Formulas for Key Ratios (*Continued*)

Pretax return on permanent capital

$$= \frac{\text{Pretax income from continuing operations} + \text{Interest expense}}{\begin{array}{c}\text{Sum of (1) the average of the beginning of year and end of} \\ \text{year current maturities, long-term debt, noncurrent deferred} \\ \text{taxes, minority interest, and shareholders' equity and} \\ \text{(2) average short-term borrowings during year per footnotes} \\ \text{to financial statements}\end{array}} \times 100$$

$$\text{Operating income as a \% of sales} = \frac{\text{Operating income}}{\text{Sales}} \times 100$$

$$\text{Long-term debt as a \% of capitalization} = \frac{\text{Long-term debt}}{\text{Long-term debt} + \text{Equity}} \times 100$$

$$\text{Total debt as a \% of capitalization} + \text{short-term debt} = \frac{\text{Total debt}}{\text{Total debt} + \text{Equity}} \times 100$$

Total debt + 8 times rents as a % of capitalization + short-term debt + 8 times rents

$$= \frac{\text{Total debt} + 8 \text{ times gross rentals paid}}{\text{Total debt} + \text{Equity} + 8 \text{ times gross rentals paid}} \times 100$$

Source: "Adjusted Key U.S. Industrial Financial Ratios," *Standard & Poor's Credit Week*, September 20, 2000, pp. 39–44.

Finance companies traditionally have been among the most highly leveraged companies. Debt-to-equity ratios of 10:1 are not unusual for *captive finance companies* that finance the sales of, and have debt guarantees from, parent companies engaged in manufacturing or retailing. For noncaptive companies, ratios of 5:1 to 7:1 are typical nowadays. Investors tolerate finance companies' high leverage because of the generally liquid nature of their assets. Loans, receivables, and other financial instruments ordinarily can be sold without substantial loss of face value if necessary to repay maturing debt. In contrast, industrial companies typically include large amounts of plant and equipment that cannot be disposed of so quickly. Therefore, book-value-based leverage of 5:1 or more would cause an industrial company to be viewed as highly speculative.

In addition to considering the absolute and relative levels of leverage of a company, the analyst should evaluate the debt itself. How much of the debt has a fixed-rate, and how much has a floating rate? A company with a high component of debt tied to the prime rate may find its margins being squeezed as interest rates rise if there is no compensating increase in the price of the firm's goods. Such a debt structure may be beneficial during certain phases of the interest rate cycle, but it precludes a precise estimate of what interest charges for the year will be. In general, a company with a small percentage of floating-rate debt is preferable to a similarly leveraged company with a high percentage of floating-rate debt.

The maturity structure of the debt also should be evaluated. What is the percentage of debt that is coming due within the next five years? As this debt is refinanced, how will the company's embedded cost of debt be changed?

The existence of material operating leases can understate the leverage of a firm. Operating leases should be capitalized to give a true measure of leverage.

A company's bank lines often constitute a significant portion of its total debt. These lines should be analyzed closely in order to determine the flexibility afforded to the company. The lines should be evaluated in terms of undrawn capacity as well as security interests granted. In addition, the analyst should determine whether the line contains a "material adverse change" (MAC) clause under which the line could be withdrawn. For example, a company that has drawn down its bank lines completely and is in jeopardy of activating its MAC clause may have trouble refinancing any debt. In a similar manner, undrawn lines should be evaluated in terms of their capacity to replace commercial paper, if needed. In the event that a company's commercial paper rating is downgraded, the company's access to the commercial paper market may evaporate quickly. In this scenario, the company may be forced to draw on its bank lines to replace its maturing commercial paper. A company whose commercial paper is fully backed by bank lines is in a stronger position than one whose bank lines do not cover its outstanding commercial paper.

Exhibit 40-1 shows the key leverage ratios used by Standard & Poor's and the formula for calculating each ratio.

Cash Flow

A third important ratio is cash flow as a percent of total debt. *Cash flow* is often defined as net income from continuing operations plus depreciation, depletion, amortization, and deferred taxes. In calculating cash flow for credit analysis, the analyst also should subtract noncash contributions from subsidiaries. In essence, the analyst should be concerned with cash from operations. Any extraordinary sources or uses of funds should be excluded when determining the overall trend of cash-flow coverage. Cash dividends from subsidiaries also should be questioned in terms of their appropriateness (too high or too low relative to the subsidiary's earnings) and also in terms of the parent's control over the upstreaming of dividends. Is there a legal limit to the upstreamed dividends? If so, how close is the current level of dividends to the limit?

Net Assets

A fourth significant ratio is net assets to total debt, which gauges a company's ability to repay debt by liquidating assets to generate cash. This is not something companies do under normal circumstances; their ordinary practice is to refinance debt as it comes due or repay it from operating cash flow. Asset liquidation for debt repayment is most apt to occur when a company is under financial strain, when asset values are likely to be depressed. Therefore, analysts must be mindful that at the point at which liquidation value becomes relevant, it may differ significantly from the value currently reflected on the balance sheet and also from the present market value.

Discrepancies between book value and liquidation value arise from the inherently illiquid nature of many fixed assets. Consider a specialized piece of heavy equipment in a mine in a remote area. The balance sheet value associated with this asset is its purchase price less depreciation charges recorded since the equipment was acquired. Not reflected in that valuation are the costs of transporting the equipment to a buyer. Moreover, the depreciation charges, which were set at the time of the machinery's purchase, may not take into account the possibility of subsequent introduction of a competing, more cost-effective model, which would reduce the value of earlier-generation equipment.

To identify gaps between book value and liquidation value, analysts can obtain information on sales of comparable assets. In the energy sector, for example, widely reported sales of oil reserves provide dollars-per-barrel benchmarks. Acquisitions of retailing chains and restaurants similarly furnish useful estimates of current market value of comparable properties.

Even when such market-based data can be found, however, debt holders must be cautious about concluding that their principal will be fully covered in liquidation. For example, suppose that during a period of airline industry prosperity an airline sells bonds collateralized by planes. The prices then being paid for used aircraft may imply that the collateral's asset value comfortably exceeds the face amount of the bonds. The bonds may come due, however, when the notoriously cyclical airline business is in a downturn, making it difficult for the borrower to refinance the debt. Demand for used aircraft is likely to be minimal at that point, reducing the liquidation value of the collateral to much less than the bonds' face amount.

Takeovers, recapitalizations, and other restructurings increase the importance of asset coverage protection. Unfortunately for some bondholders, mergers or takeovers may decimate their asset coverage by adding layers of debt to the corporate structure that is senior to their holdings. While the analyst may find it difficult to predict takeovers, it is crucial to evaluate the degree of protection from takeovers and other restructurings that the bond indenture offers.

In extreme cases, the analyst must consider asset coverage in the case of bankruptcy. This is particularly important in the case of lease obligations because the debtor has the ability to reject leases in bankruptcy. In the case of lease rejections, the resulting asset protection may depend on a legal determination of whether the underlying lease is a true lease or a financing arrangement. Even if the lease if determined to be a true lease, the determination of asset protection is further complicated by a determination of whether the lease relates to nonresidential real property or to personal property. The difference in security (i.e., recovery in a bankruptcy) is significant. Damages under a lease of nonresidential real property are limited to three years of lease payments. Damages under a lease of personal property are typically based on all amounts still due under the lease.

In addition to the major variables just discussed, the analyst also should consider several other financial variables, including intangibles, unfunded pension liabilities, the age and condition of the plant, and working capital adequacy.

Intangibles

Intangibles often represent a small portion of the asset side of a balance sheet. Occasionally, particularly with companies that have or have had an active acquisition program, intangibles can represent a significant portion of assets. In this case, the analyst should estimate the actual value of the intangibles and determine whether this value is in concert with a market valuation. A carrying value significantly higher than market value indicates a potential for a write-down of assets. The actual write-down may not occur until the company actually sells a subsidiary with which the intangibles are identified. However, the analyst should recognize the potential and adjust capitalization ratios accordingly.

Unfunded Pension Liabilities

Unfunded pension liabilities also can affect a credit decision. Although a fully funded pension is not necessary for a high credit assessment, a large unfunded pension liability that is 10% or more of net worth can be a negative. Of concern is the company with unfunded pension liabilities high enough to interfere with corporate planning. For example, in the late 1980s, a steel company with high unfunded pension liabilities might have delayed or decided against closing an unprofitable plant because of the pension costs involved. The analyst also should be aware of a company's assumed rate of return on its pension funds and salary-increase assumptions. The higher the assumed rate of return, the lower the contribution a company must make to its pension fund, given a set of actuarial assumptions. Occasionally, a company having difficulty with its earnings will raise its actuarial assumption and thereby lower its pension contribution and increase earnings. The impact on earnings can be dramatic. In other cases, companies have attempted to "raid" the excess funds in an overfunded retirement plan to enhance earnings.

In periods of declining interest rates, the analyst also must consider the discount rate companies use to discount their future obligations. Companies generally use the yield of AA corporate bonds as a discount factor, a benchmark that has been criticized by market analysts.

Age and Condition of Plant

The age of a company's plant also should be estimated, if only to the extent that it differs dramatically from industry standards. A heavy industrial company with an average plant age well above that of its competitors is probably already paying for its aged plant through operating inefficiencies. In the longer term, however, the age of the plant is an indication of future capital expenditures for a more modern plant. In addition, underdepreciation of the plant significantly increases reported earnings.

The availability of information regarding the average age and condition of plants varies among companies. On the one hand, airline carriers readily provide the average age of their fleet and the money they will save as they replace older aircraft with more fuel-efficient aircraft that require fewer people in the cockpit. On the other hand, the average age of a plant compared with the industry average is not always available for some companies such as paper producers. Furthermore, companies with older plants generally emphasize the capital improvements that have been made to them over the years, which distort direct comparisons. In this case, it is helpful to read closely several years of management's explanation of operating results in the annual reports. Often this section will include mentions of above-average maintenance expense and machines that were out of service for a period of time for maintenance. Such comments indicate that the plants and machines may not be as efficient as portrayed initially.

Working Capital

A final variable in assessing a company's financial strength concerns the strength and liquidity of its working capital. *Working capital* is defined as current assets less current liabilities. Working capital is considered a primary measure of a company's financial flexibility. Other such measures include the current ratio (current assets divided by current liabilities) and the acid test (cash, marketable securities, and receivables divided by current liabilities). The stronger the company's liquidity measures, the better it can weather a downturn in business and cash flow.

In assessing this variable, the analyst should consider the normal working capital requirements of a company and industry. The components of working capital also should be analyzed. Although accounts receivable are considered to be liquid, an increase in the average days a receivable is outstanding may be an indication that a higher level of working capital is needed for the efficient running of the operation. Furthermore, companies frequently have accounts receivable financing, some with recourse provisions. In this scenario, comparisons among companies in the same industry may be distorted.

The state of contraction or expansion also should be considered in evaluating working capital needs. Automobile manufacturers typically need increased working capital in years when automobile sales increase.

Analysis of the Components of Return on Equity

Once the preceding financial analysis is complete, the bond analyst traditionally examines the earnings progression of the company and its historical return on equity (ROE). This section of analysis often receives less emphasis than the traditional ratio analysis. It is equally important, however, and demands equivalent emphasis. An analysis of earnings growth and ROE is vital in determining credit quality because it gives the analyst necessary insights into the components of ROE and indications of the sources of future growth. Equity analysts devote a major portion of their time to examining the components of ROE, and their work should be recognized as valuable resource material.

A basic approach to examining the components of ROE breaks down return on equity into four principal components: pretax margins, asset turnover, leverage, and one minus the tax rate. These four variables multiplied together equal net income/stockholders' equity, or return on equity, as shown below:

$$\text{Net income/equity} = (\text{net pretax income/sales} + \text{operating pretax income/sales}) \times (\text{sales/assets}) \times (\text{assets/equity}) \times (1 - \text{tax rate})$$

The analyst should examine the progression of these four components of ROE for a minimum of five years and through at least one business cycle. The progression of each variable should be compared with the progression of the same variables for the industry, and deviations from industry standards should be further analyzed. For example, perhaps two companies have similar ROEs, but one company is employing a higher level of leverage to achieve its results, whereas the other company has a higher asset-turnover rate. Since the degree of leverage is largely a management decision, the analyst should focus on asset turnover. Why have sales for the former company turned down? Is this downturn a result of a general slowdown in the industry, or is it that assets have been expanded rapidly, and the company is in the process of absorbing these new assets? Conversely, a relatively high rise in asset-turnover rate may indicate a need for more capital. If this is the case, how will the company finance this growth, and what effect will the financing have on the firm's embedded cost of capital?

The analyst should not expect similar components of ROE for all companies in a particular industry. Deviations from industry norms are often indications of management philosophy. For example, one company may emphasize asset turnover, and another company in the same industry may emphasize profit margin. As in any financial analysis, the trend of the components is as important as the absolute levels.

Nonfinancial Factors

After the traditional bond analysis is completed, the analyst should consider some nonfinancial factors that might modify the evaluation of the company. Among these factors are the degree of foreign exposure, the quality of management, and ownership. The amount of foreign exposure should be ascertainable from the annual report. Sometimes, however, specific country exposure is less clear because the annual report often lists foreign exposure by broad geographic divisions. If there is concern that a major portion of revenue and income is derived from potentially unstable areas, the analyst should carefully consider the total revenue and income derived from the area and the assets committed. Further consideration should be given to available corporate alternatives should nationalization of assets occur. Additionally, the degree of currency exposure should be determined. If currency fluctuations are significant, has management hedged its exposure?

The internationalization of the bond markets and the ability of countries to issue debt in other countries highlight the importance of understanding the effect of currency risks. For example, many Mexican companies issued U.S. dollar–denominated debt in the early 1990s. This issuance had a positive impact on the financials of these Mexican companies because of the generally lower interest rates available in the United States relative to Mexico. However, when the peso was devalued significantly in December 1994, the ability of some of these companies to meet their U.S. dollar–denominated obligations was questioned. Of particular concern were the companies whose revenues were largely denominated in pesos but whose interest expense was denominated in U.S. dollars.

The quality and depth of management are more difficult to evaluate. The best way to evaluate management is to spend time with management, if possible. Earnings progress at the firm is a good indication of the quality of management. Negative aspects would include a firm founded and headed by one person who is approaching retirement and has made no plan for succession. Equally negative is the firm that has had numerous changes of management and philosophy. On the other hand, excessive stability is not always desirable. In discussing the factors it considers in assigning a credit rating, Moody's Investors Service notes the following regarding the quality of management:

> Although difficult to quantify, management quality is one of the most important factors supporting an issuer's credit strength. When the unexpected occurs, it is a management's ability to react appropriately that will sustain the company's performance.[2]

In assessing management quality, the analysts at Moody's, for example, try to understand the business strategies and policies formulated by management. Following are factors that are considered: (1) strategic direction, (2) financial philosophy, (3) conservatism, (4) track record, (5) succession planning, and (6) control systems.

In recent years, focus has been on the corporate governance of the firm and the role of the board of directors. The bylaws are the rules of governance for the corporation. The bylaws define the rights and obligations of officers, members of the board of directors, and shareholders. Several firms have developed services that assess corporate governance. One type of service provides confidential assessment of the relative strength of a firm's corporate governance practices. The customer for this service is a corporation seeking external evaluations of its current practice. The second is a service that rates (or scores) the corporate governance mechanisms of companies. Generally, these ratings are made public at the option of the company requesting an evaluation.

Analysts should also consider the ownership of a company. If a single family or small group of investors holds a controlling interest, the company may tend to be overly conservative in its response to changes in its markets. Owners also

2. "Industrial Company Rating Methodology," *Moody's Investors Services: Global Credit Research*, July 1998, p. 6.

should be judged in terms of whether they are strategic or financial. Often financial buyers invest for the short to intermediate term, hoping to sell their positions (or the entire company) at a profit. If such a sale involves a leveraged buyout, the credit quality of the bonds is lowered, sometimes dramatically.

COMBINING FINANCIAL AND NONFINANCIAL ANALYSIS

The ultimate credit judgment on a company must consider both its financial risk profile and its business risk profile. Strength in one aspect of credit quality may be offset by weakness in the other. Exhibit 40-2 illustrates one approach to integrating the two modes of analysis.

Standard & Poor's employs a matrix of six levels of business risk, from "excellent" to "vulnerable," and six levels of financial risk, from "minimal" to "highly leveraged." The table shows the midpoint of the range of ratings that may be assigned to a company within a given cell. The actual rating ordinarily will be within one notch of that rating. For example, in most cases a company with a "satisfactory" business risk profile and an "intermediate" financial risk profile will be rated in the range of BBB+ to BBB–.

Certain cells, such as "excellent" business risk profile/"highly leveraged" financial risk profile, are blank. This is because such combinations are extremely improbable. For some companies, overarching risks such as major litigation and balance-sheet-straining acquisitions fall outside the matrix. Finally, the matrix excludes ratings lower than CCC+ because by definition, companies in those categories reflect an acute vulnerability or impending crisis.

Specific obligations may be rated higher than the company rating, based on security, or lower than the company rating, based on subordination within

EXHIBIT 40-2

Business and Financial Risk Profile Matrix

Business Risk Profile	*Financial Risk Profile*					
	Minimal	**Modest**	**Intermediate**	**Significant**	**Aggressive**	**Highly Leveraged**
Excellent	AAA	AA	A	A–	BBB	—
Strong	AA	A	A–	BBB	BB	BB–
Satisfactory	A–	BBB+	BBB	BB+	BB-	B+
Fair	—	BBB–	BB+	BB	BB–	B
Weak	—	—	BB	BB–	B+	B–
Vulnerable	—	—	—	B+	B	CCC+

These rating outcomes are shown for guidance purposes only. Actual rating should be within one notch of indicated rating outcomes.

EXHIBIT 40-3

Financial Risk Indicative Ratios (Corporate)

	FFO/Debt (%)	Debt/EBITDA (x)	Debt/Capital (%)
Minimal	Greater than 60	Less than 1.5	Less than 25
Modest	45–60	1.5–2	25–35
Intermediate	30–45	2–3	35–45
Significant	20–30	3–4	45–50
Aggressive	12–20	4–5	50–60
Highly Leveraged	Less than 12	Greater than 5	Greater than 60

the capital structure. Subordination includes *structural subordination*, whereby servicing of a holding company's debt depends on receiving dividends from subsidiaries. By law, dividends can be paid only after the subsidiaries' own debt has been serviced.

Exhibit 40-3 provides a key to the classifications of companies within the six financial risk profile categories. For example, a company with funds flow from operations to debt of 45% to 60%, debt/earnings before interest, taxes, depreciation, and amortization (EBITDA) of 1.5 to 2×, and debt/capital of 25% to 35% is deemed to have "modest" financial risk. S&P characterizes these benchmark ratios as guidelines rather than absolute rules. For instance, a company with very stable financial ratios may qualify for a particular financial risk category despite a somewhat lower FFO/debt percentage or a higher debt/capital percentage than shown in the exhibit. Electric utilities benefit from this leeway because of their demonstrated superiority in access to capital, their liquidity, and their effective management of capital programs and maturity schedules.

INDENTURE PROVISIONS

An *indenture* is a contract that defines the legal rights and obligations of the issuer and the bondholders, represented through the trustee, with respect to a bond issue. The indenture establishes fundamental rules for three primary investor concerns: (1) payments by the issuer to bondholders, (2) limits on the kinds of issuer behavior that may harm bondholders' prospects for repayment, and (3) the enforcement mechanisms available to bondholders if issuers do not fulfill their obligations.

First, the indenture and the related note that represents the debt enshrine a bondholder's individual right to the timely payment of principal and interest. The bond may also be subject to special pricing and redemption provisions, such as a ratings-based coupon step-up, a call schedule, a make-whole redemption, a sinking fund, or a maintenance and replacement fund. These payment provisions are discussed in Chapter 10.

Second, the indenture will contain provisions called *covenants* that attempt to limit some issuer behavior that could increase credit risk. For example, if an issuer doubles its amount of outstanding debt in order to pay dividends to shareholders while neglecting reinvestment in its business, then bondholders will face a greater risk of a payment default on their bonds. A strong Debt covenant or Restricted Payments covenant could limit this kind of recapitalization event. Indenture analysis is principally focused on restrictive covenants not only to help evaluate contractual protections against risky behavior by issuers but also to consider the upside possibility of a consent solicitation or a premium tender for their bonds if the issuer wants to take actions that otherwise would be restricted by the bond covenants. Covenant protections can have important market pricing implications, especially in the leveraged-buyout (LBO) context. When the Texas power company TXU Corp. was acquired in 2007, it had significant bonds outstanding at three different legal entities. The TXU holding company bonds had very weak covenant protections and remained outstanding and traded well below par for years after the LBO, while the TXU Energy subsidiary bonds had stronger covenant protections that would have impeded the optimal LBO financing, and so they were redeemed at a premium. The value of a third set of bonds was relatively protected because they had been issued by a different, state-regulated subsidiary with limits on its ability to borrow.

Covenant protections can vary enormously even among bonds of the same issuer, but they can generally be described as being investment-grade or high-yield type covenants. Some industry groups such as real estate investment trusts (REITs) and finance companies have special covenant features, as explained below. Bear in mind that covenants vary over time as investors become more or less sensitive to event risk and the view of what is "market" practice changes. For example, Change of Control puts and secured debt restrictions became very important for investment-grade bond investors following the 1988 LBO of RJR Nabisco, but then generally waned over the next two decades. Then the buyout boom of the mid-2000s and resulting bondholder losses resurrected these kinds of protections, so that since 2010 the inclusion of a Change of Control covenant has again become standard for both high-yield and investment-grade nonfinancial bonds.

Enforcement is the third primary concern. If there is a *default* under the indenture, then the enforcement of bondholder rights is handled according to detailed rules that are generally similar among all corporate indentures.

Generally, if there is *payment default* because a principal or interest payment is not made on time, then the trustee may act on its own to sue for payment, although an individual bondholder can also sue for payment. If there is a *covenant default,* such as selling an asset in violation of an Asset Sales covenant, then enforcement could occur in several ways. The issuer might realize its mistake and attempt to *cure,* or remedy, the breach if possible. The issuer might ask bondholders for permission in a *consent solicitation* for a *waiver* from having to comply with the indenture provision or for an *amendment* to the indenture so that the covenant is changed. Bondholders or the trustee might become aware of a default and formally give notice of a default to try to *accelerate* the bonds for early payment. Sometimes, the issuer, trustee, and bondholders might disagree about the meaning of an indenture covenant and litigate the matter. For example, when Tyco International split its businesses into three separate, publicly traded companies, bondholders sued to stop the transaction based on a violation of the Mergers covenant, and Tyco paid to settle the litigation. Typically, either the trustee or 25% of bondholders must act in order to declare a default and attempt to accelerate the bonds.

Until the early 2000s, issuers could often obtain a consent solicitation for a negotiated price commonly ranging from 50 to 500 basis points, based upon the perceived need of the issuer and the reasonably likely credit harm to the investor. Indenture litigation was relatively rare. But now, the strength of hedge funds in the bond market has created a transactional mindset that has swept away the old relationship model, where the issuer and investors wanted to be reasonable with each other on the expectation of future bond issuances. Instead, the common response to a consent solicitation is that holders want a costly make-whole redemption instead. Many issuers actively seek to exploit clever loopholes in their indentures that undermine the spirit if not the letter of the deal, while many investors scour the contract to find technical violations on which to threaten a lawsuit if their bonds are not redeemed. Today's more adversarial bond world can see a dozen indenture lawsuits threatened or commenced in a typical year, and there are some hedge fund managers who have made their fortunes and reputations largely on litigating debt contracts. These active credit funds have become the primary guardians of the covenants, who then enlist the trustees to fight alongside them.

Bond indentures should be considered in light of the covenants in bank credit agreements. Historically, loan covenants would be more restrictive than bond covenants. In particular, credit agreements can contain *maintenance covenants* that require the borrower to maintain a certain level of consolidated net worth, a ratio of total debt to cash flow, or some other financial metrics that serve as a proxy for the creditworthiness of the borrower. If a maintenance covenant is breached, then the lenders can seek to accelerate. Bondholders sometimes hope that the more restrictive bank credit agreements will provide some aura of protection to bondholders, but investors should be cautious about this idea. Borrowers often ask lenders for waivers and amendments, and there were numerous examples in which some market participants took credit views based on expected covenant breaches that turned out to be incorrect, such as when MGM Mirage (Resorts) obtained a series of amendments from its lenders in 2009 that involved pledging additional collateral. However, a dramatic and counterintuitive shift has occurred since the 2008 credit crisis: despite the experienced losses from weak covenants in the buyouts and subsequent debt exchanges of 2006–2010, bank and bond covenants became progressively weaker with new issues in the 2010s. This acceptance of worse terms was driven by the decline of relationship banking, the growth of rules-based CLOs, and falling interest rates leading to a reach for yield, such that contractual covenant risk was given little weight amidst a feeding frenzy for higher-yielding credit. In fact, by 2020, over 80% of all large corporate loans in the United States and Europe were being issued with no maintenance covenants at all. These loans are referred to as *covenant lite,* and now sometimes an issuer's loans have even less protective covenants than the bonds!

Note that the prospectus or offering memorandum for a bond will contain a description of the covenants, but it is the indenture that controls as the legally binding contract, and so the indenture should be used for covenant analysis. The indenture of a U.S. issuer usually can be obtained from the SEC's EDGAR website if the issuer is a public company or otherwise files with the SEC. Alternately, the indenture may be obtained from the trustee who is listed in the prospectus or sometimes directly from the issuer.

Outlined below are the most common indenture covenants, and how they vary for investment-grade versus high-yield bonds. Following that is an explanation of some special industry and bond types. Bear in mind that covenants work together as a kind of "system" where one corporate action can implicate multiple indenture provisions.

Typical Bond Covenants

Guarantees/Future Guarantors Covenant

A bond is primarily the obligation of the issuer. Often the issuer is a holding company that relies on its own subsidiaries to upstream cash for the issuer to make payments to bondholders. If the issuer fails to make a payment, then bondholders may want to make a claim for payment against the subsidiaries that hold the operating assets. This is possible if there are *subsidiary guarantees* by which the issuer's subsidiaries promise to pay interest and principal if the issuer does not. A bond may have subsidiary guarantees when it is issued, or a *Future Guarantors covenant* may require subsidiaries to provide guarantees in the future. Guarantees are an important determinant of recoveries in bankruptcy, especially when there may be significant debt, trade claims, or other liabilities against subsidiaries.

A guarantee can put the bondholders' claims on an equal footing with other claims against subsidiaries.

Investment-grade bonds usually do not have subsidiary guarantees, while high-yield bonds typically are offered with these guarantees. Note this seeming paradox that will repeat across covenants and has endured for decades: while the investment-grade investors have relatively the most to lose in seeing their issuers falling from investment-grade to high-yield status in the case of dividends, LBOs, and other dramatic events, it is the investment-grade investors that have the least covenant protections from these kinds of bad actions.

Debt Covenant

The *Debt covenant* limits the amount of additional borrowings by the issuer. A Debt covenant has become rare among investment-grade bonds but is customary for high-yield issues. The typical version says that the issuer and its subsidiaries generally cannot incur debt unless a *Ratio test* is met, which typically requires meeting a pro forma 2X EBIDTA:interest expense coverage ratio or a maximum debt:EBITDA leverage ratio. However, even when the Ratio test cannot be met, certain types of *Permitted Debt* are allowed. Permitted Debt includes specific carveouts such as for a set amount of credit facilities, project and acquisition financing, and a general-purpose debt basket. Generally, a Debt covenant is designed to allow an issuer to borrow more money when its EBITDA and total asset base are increasing. The risk to bondholders is that the new debt remains even if financial results decline because the Debt covenant is not a maintenance covenant.

Importantly, for the Debt covenant and other restrictive covenants, investors must confirm which entities in the capital structure must obey the covenants. Ideally, the issuer and all its subsidiaries would be subject to the covenants, but many indentures exempt so-called unrestricted subsidiaries.

Subsidiary Debt Covenant

Investment-grade bonds occasionally have a *Subsidiary Debt covenant* that is intended to limit the amount of money that can be borrowed by subsidiaries, and therefore, reduce the risk of structural subordination.

Negative Pledge/Liens Covenant

Bondholders generally do not want other debt to be secured ahead of or alongside their bonds because secured debt will recover ahead of unsecured debt in bankruptcy. This concern is addressed by one of two similar provisions that have an important substantive difference. A *Negative Pledge covenant* is used for almost all unsecured bonds and generally requires that if some other debt becomes secured, then the bonds must be equally and ratably secured. The Negative Pledge for an investment-grade bond will typically only restrict pledging some subset of the issuer's total assets (for example, manufacturing plants), allow exceptions to finance capital expenditures and asset acquisitions, and have a *general secured debt carveout* equal to 10% to 15% of a balance sheet metric such as consolidated net tangible assets or stockholders' equity. For a high-yield bond, the covenant will typically apply to all of the issuer's assets, but a lengthy list of *Permitted Liens* will have carveouts matched to particular items of Permitted Debt and other exceptions.

In comparison, a secured bond should have a true *Liens covenant,* which restricts securing other debt and does not give the issuer the option to secure new debt by ratably securing the existing bonds, but would still allow some Permitted Liens. For investors, seeing new secured debt issued can have an immediate negative impact on their existing bond values and reduce their recoveries in bankruptcy. From an issuer perspective, the ability to issue secured debt can allow a financing lifeline when there is a sudden, unexpected event. For example, cruise ship operator Carnival Corp. was a longtime issuer of unsecured bonds with investment-grade ratings, but when the Covid-19 virus froze its revenues in 2020, it found flexibility in its existing Liens covenants to issue $4 billion of new three-year bonds secured by ships and intellectual property to keep the company afloat until sailings could resume.

Sale/Leaseback Covenant

A *Sale/Leaseback covenant* is standard for investment-grade bonds and is especially important when there is significant credit support from owned manufacturing facilities or high-value real estate, such as department stores with owned locations. If a company sells real estate and then takes back a lease on that property, the bondholder is harmed twice: first, because there would be fewer assets to recover against in bankruptcy, and second, because the issuer will have committed itself to future lease payments. Therefore, the covenant usually blocks a sale/leaseback transaction unless it is used to finance a new location or the proceeds of the sale are used to repay long-term debt or acquire new assets. This covenant had been common for high-yield bonds from the late 1980s through the early 2000s, but has largely faded away for that market, in part because the sale would be addressed by the Asset Sales covenant of a high-yield bond, while aspects of the lease would be addressed by the Debt and Liens covenants.

Restricted Payments Covenant

A *Restricted Payments covenant* primarily limits the amount of dividends that can be paid to stockholders. While these dividend restrictions might occasionally appear in investment-grade bond issues, they are now generally restricted to high-yield bonds. Typically, 50% of the issuer's net income can be paid to stockholders, on the theory that the other half of profits should be reinvested in the business or used to pay down debt. Paying dividends based on net income is also usually conditioned upon meeting the pro forma Ratio test of the Debt covenant. This same Restricted Payments covenant will also generally limit stock purchases, repaying subordinated debt before its maturity, and making so-called restricted investments in entities such as joint ventures that might not be obligated to obey the indenture covenants.

Asset Sales Covenant

The Asset Sales covenant is rare for investment-grade bonds but standard for high-yield bonds. The covenant does not prevent asset sales, but generally requires that the proceeds of a sale be used to acquire new assets or repay debt that is secured or otherwise effectively senior to the bonds. If that is not done, then the issuer usually must offer to buy back the bonds at par within a year.

Mergers Covenant

The *Mergers covenant,* also known as the successor obligor provision, is designed to ensure a degree of continuity between the bond debt and the issuer's assets that support the debt. If the issuer merges with another company or transfers "substantially all" of its assets to another company, then the bond obligation must remain with the merged company or bulk of the assets. Otherwise, investment-grade bondholders could be left holding bonds of a mere shell company that has sold off its assets because an investment-grade bond usually does not have an Asset Sales covenant.

High-yield bonds have a similar Mergers covenant, but their version would generally require meeting the Debt covenant's Ratio test as a condition to the merger or asset transfer.

Change of Control Covenant

The *Change of Control covenant* is nearly universal for high-yield bonds and allows bondholders to put bonds back to the issuer at 101% upon a defined Change of Control. This covenant also appears in the majority of nonfinancial investment-grade bonds issued since 2010, but with the additional requirement that the bonds become rated below investment grade. The Change of Control definition may include one or more triggers, such as (1) a sale of substantially all assets, (2) the acquisition of more than half of the issuer's voting stock by a third party, (3) a merger with another company, (4) a liquidation of the company, and (5) a hostile change in the board of directors. The Change of Control put can be blunt protection against the risk of credit-damaging leverage in an LBO, a chance to assess the new ownership of the issuer, or a simple 101% put opportunity for a bond trading below par.

Special Covenants and Situations

Some industries and special situations have bond covenants that vary from the common pattern and we outline these below.

Real Estate Investment Trusts

REITs are almost always investment-grade issuers, and their covenants have a great degree of similarity to each other. The REIT indenture usually has one or more maintenance covenants based on levels of secured debt, unsecured debt, and interest coverage.

Utilities

Utilities tend to be investment-grade issuers yet have traditionally issued secured debt, often under the title of First Mortgage Bonds with indentures that have been used for decades, and sometimes feature maintenance and replacement funds and sinking funds. These secured bonds may limit the amount of additional debt that may be issued under the mortgage to a certain percentage of net property. Today, many utilities issue bonds with limited covenants that look like those of other investment-grade issuers, with only a standard make-whole redemption option. However, investors have some comfort that state utility regulations may effectively limit the leverage of these companies.

Finance Companies

Finance companies are usually investment-grade issuers and have less complex covenants than in the past. A negative pledge type Liens covenant is common, and if the issuer is a finance subsidiary of an operating company, such as how John Deere Capital Corp. is a business of the farm vehicle manufacturer Deere & Company, then the parent may have a support guarantee in which the parent promises to invest in or manage the finance subsidiary for it to maintain a certain net worth or other credit metric.

Banks and Insurance Companies

The holding companies for banks and insurance companies are typically rated investment grade and their bonds will have a limited Liens covenant that restricts pledging shares of major subsidiaries and perhaps a limited kind of Asset Sales covenant that restricts selling significant minority stakes in major subsidiaries. The regulated subsidiaries may issue their own, higher-rated debt, in which the covenants are often less important because state and federal laws practically limit borrowing by regulated subsidiaries.

Split-Rated Issuers

Bonds issued with one investment-grade rating and one high-yield rating often have investment-grade covenants, but perhaps with the addition of a strong Future Guarantors covenant or a limited Restricted Payments covenant that controls dividend payments.

Secured High-Yield Bonds

Traditionally, bank loans were secured and bonds were not. This began to change significantly in the 2000s as bank lenders became comfortable with the idea of allowing bonds to be sold with second liens that would recover behind the bank loans. These bonds are often subject to an *intercreditor agreement* that affirms the primacy of the lenders' liens and limits somewhat the arguments that bondholders can make in bankruptcy.

By 2010 over one-fourth of U.S. high-yield bonds were sold with some collateral protection, and since then, in a typical quarter, somewhere between 20% and 30% of new issues are secured. Not only are first and second liens now routine, but there has also been a proliferation of slices of secured bonds sandwiched in between levels over time, such as the EP Energy 8% 1.25 Lien Notes due 2024, Hovnanian Enterprises 10% 1.75 Lien Notes due 2025, and Halcón Resources 13% Senior Secured Third Lien Notes due 2022. These odd pockets of secured debt are created to take advantage of loopholes in the Liens covenant, to the delight of issuers that want to find incremental financing and for investors who want to make relative-value trades among varying levels of collateral priority. Further, an issuer may have secured bonds that have greater rights than some of its secured loan tranches! There have now been numerous companies with 10 or more different tranches of debt with different recovery rights, such as

Altice, Caesars Entertainment, and Intelsat. This phenomenon has dramatically reshaped the old rules of thumb that "secured" lenders usually recover 80% to 100% of their debt in bankruptcy and that unsecured bondholders get something of a 50% to 80% recovery. In this new era, "it depends on the covenants" more than ever, and positioning and litigating over the fulcrum security has become the key battleground.

Private Bonds

So-called private bonds are usually small offerings that are sold to just a handful of institutions, tend not to trade frequently, and are generally not covered by research or media outlets. These bonds can often be more heavily negotiated and include loan-like maintenance covenants.

UTILITIES

Historically, utilities have been regulated monopolies. These companies generally operate with a high degree of financial leverage and low fixed-charge coverage (relative to industrial companies). These financial parameters have been accepted historically by investors owing to the regulation of the industry and the belief that there is minimal, if any, bankruptcy risk in those securities because of the essential services they provide.

The changing structure of the electric utility industry brought about by significant investment in nuclear generating units and their inherent risk, as well as the transition to deregulation, has changed this belief. Initially, the faltering financial position of General Public Utilities precipitated by the Three Mile Island nuclear accident and the regulatory delays in making a decision regarding the units highlighted the default risk that exists in the industry. Subsequently, the defaults of several Washington Public Power Supply System issues, the restructuring of Tucson Electric Company, and the bankruptcies of Public Service Company of New Hampshire and El Paso Electric Company and the transition to deregulation reemphasized the default risk. In addition, the industry is faced with the acid rain issue and increased uncertainty in construction costs and growth rates.

Segments Within the Utility Industry

There are three major segments within the utility industry: electric companies, gas companies, and telephone companies. This chapter will deal primarily with electric utilities. Many companies are involved in both electric and gas service, so analysis requires a working knowledge of both businesses. A working knowledge of the different facets of the electric utility industry is also required as traditional electric utilities diverge in their strategies, with some companies emphasizing transmission and distribution exclusively while other companies emphasize generation.

Nonfinancial Factors

Although financial factors are important in analyzing any company, nonfinancial factors are particularly important in the electric utility industry and may alter a credit assessment. The following nonfinancial factors are of particular importance to the utility industry: (1) regulation, (2) source of the company's energy, (3) growth and stability of the company's territory, (4) capital structure, (5) degree of activity in international and nonutility investments, and (6) competitive position.

To reflect the importance of nonfinancial factors, S&P utilizes a 10-point business risk assessment. In June 2004 S&P assigned new business profile scores to refine its assessment of relative risk among the utility and power companies. At that point the rating agency also divided the group into subsectors to allow more in-depth statistical analysis of the distribution of its ratings and its rating changes. The subsectors are Transmission and Distribution—Water, Gas, and Electric; Transmission Only—Electric, Gas, and Other; Integrated Electric, Gas, and Combination Utilities; Diversified Energy and Diversified Non-Energy; and Energy Merchant/Developers/Trading and Marketing.

Regulation

The utility industry includes both regulated and unregulated entities. In some cases, the two types coexist as subsidiaries within a single corporate structure. Power generation has been deregulated in some states, with merchant power companies selling electricity at competitive rates, but remains regulated in others. The transmission segment remains highly regulated. Retail distribution is deregulated, with consumers free to choose their providers based on such factors as price and quality of service.

For regulated entities, regulation is perhaps the most important credit analysis variable. Regulators, operating mainly at the state level, largely determine how much profit these businesses earn and retain. If a company has regulated operations in more than one state, the analyst should weight the evaluation of the regulatory environment by the revenues generated in each state.

The evaluation of regulatory commissions is a dynamic process. The composition of commissions changes because of retirements, appointments, and elections. The implications of personnel changes are not clear until decisions are made. For example, it is not always the case that elected commissioners are pro-consumer and appointments by a conservative governor are pro-business. Several brokerage firms can assist in evaluations of commissions.

In addition, the Federal Energy Regulatory Commission (FERC) regulates interstate operations and the sale of wholesale power. Currently, FERC regulation is considered to be somewhat more favorable than that of the average state regulatory commission.

Utilities that are constructing or operating nuclear reactors are also subject to the regulation of the Nuclear Regulatory Commission (NRC). The NRC has broad regulatory and supervisory jurisdiction over the construction and operation of nuclear reactors. Importantly, the NRC approves licensing of nuclear reactors, as well as the transfer of licenses.

Regulation is best quantified by recent rate decisions and the trend of these decisions. Although a company being analyzed may not have had a recent rate case, the commission's decisions for other companies operating within the state may be used as a proxy. Regulatory commissions are either appointed or elected. In either case, the political atmosphere can have a dramatic effect on the trend of decisions.

The regulators determine innumerable issues in a rate decision, although analysts often mistakenly focus only on the allowed rate of return on equity or the percentage of request granted. For example, a commission might rule that an electric utility must reduce rates by 10%. However, if the commission allows the utility to accelerate its depreciation, the negative effect on the cash flow of the company from the rate reduction may be largely offset, particularly if the company had been or was expected to exceed its allowed ROE. The commissions also determine how much of construction work in progress (CWIP) is allowed into the rate base. A company may appear to have a favorable allowed ROE but be hurt by the fact that only a small portion of the company's capital is permitted to earn that return, and the CWIP earns nothing. Allowance of CWIP in the rate base was of critical importance during the 1980s because of the high construction budgets for nuclear generating plants and the length of time these plants were under construction. Some companies have had more than half their capital in CWIP that was not permitted to earn a return.

The importance of whether CWIP is allowed in the rate base is highlighted by the financial distress and January 1988 bankruptcy filing of Public Service Company of New Hampshire (PSNH). PSNH's Seabrook Nuclear Unit I was virtually complete in 1986. However, licensing delays and New Hampshire's statutory prohibition of CWIP in the rate base were major contributing factors in the bankruptcy filing.

In addition, regulators have a high degree of control over the cash flow of a company through the allowance or disallowance of accounting practices and the speed with which decisions are made on cases.

Source of the Company's Energy

The source of the company's energy is a second important variable, with the impact on fuel cost being especially important for merchant generators. Each fuel must be evaluated in the context of the overall cost of operating a plant. For many years, nuclear generation was out of favor because of extensive licensing requirements, high capital costs, and heavy decommissioning expenses. Companies with large dependence on nuclear power were viewed less favorably than those with natural gas or coal units. More recently, nuclear-based generation companies have gained popularity among investors as they have written down their capital costs, while coal has suffered from escalating pollution concerns and the cost of oil and natural gas has risen. Additionally, in the mid 2000s, a number of nuclear-powered utilities were successful in their requests for 20-year license renewals.

Growth and Stability of the Company's Territory

The energy-source variable relates to a third variable—the growth and stability of the company's territory. Although above-average growth is viewed positively in an industrial company, above-average growth gets mixed reviews with respect to an electric utility. An electric utility with above-average growth may face construction earlier than its competitors depending on the supply/demand balance and regulation in its service territory.

Slow growth is not necessarily positive if it places a utility in a position of excess capacity. The increase in cogeneration and the mergers executed in order to better match supply and demand can place a utility at risk. This can result if utility A is selling power to utility B. If the expiration of the contract coincides with utility B's ability to purchase power for less and results in utility B's nonrenewal of the contract, utility A may be negatively affected unless it can sell the power to a third utility. The issue of growth has been complicated by deregulation and the requirement in many states for disaggregation of generation from transmission and distribution, as well as the requirement that customers be allowed to choose their supplier. In this new era, utilities engaged in generation must be able to match supply and demand for power.

Corporate Structure

A fourth variable, whether or not a company is a subsidiary of a holding company, also should be considered. Holding-company status permits nonutility subsidiaries, but these subsidiaries (even if successful) will not necessarily improve the overall credit quality of the company. This depends on the regulatory atmosphere. Furthermore, when there are several electric utility subsidiaries, the parent is more likely to give relatively large equity infusions to the relatively weak subsidiaries. The stronger subsidiary may have to support the other subsidiaries. Finally, holding companies should be analyzed in terms of consolidated debt. Although a particular subsidiary may have relatively strong financial parameters, off-balance-sheet financing may lower the overall assessment.

Competitive Position

A final nonfinancial factor is the competitive position of a utility. An electric utility with a comparatively low rate structure is generally in a stronger position politically to request rate increases or to request a rate freeze than one with rates higher than national averages and particularly one with rates higher than regional averages.

The competitive position of an electric utility is increasingly important as customer choice increases. Companies with high overall rates, and particularly those with high commercial rates, may find themselves losing customers as access to transmission and distribution lines increases.

Financial Analysis

The changing competitive nature of the electric industry resulting from deregulation requires that the traditional evaluation of an electric utility be modified. Although historic ratio analysis still should be conducted, an electric company also should be evaluated in the context of its new competitive situation. Is new generation being constructed in its territory that produces energy at a lower cost than the established generation? How does the company plan to expend its excess cash flow? In an era of consolidation, will the company be acquired or be an acquirer? Will the company remain in generation or sell its generation and deal solely with transmission and distribution? Location is also important. Some merchant power plants have been constructed too far from the power grid to succeed.

The following major financial ratios should be considered in analyzing an electric utility: (1) leverage, (2) pretax interest coverage, (3) cash-flow/capital expenditures, and (4) cash flow/capital.

Leverage

In calculating the debt leverage of an electric utility, long-term debt/capitalization is standard. However, the amount of short-term debt also should be considered because this is generally variable-rate debt. A high proportion of short-term debt also may indicate the possibility of the near-term issuance of long-term bonds. In addition, several companies guarantee the debt of subsidiaries (regulated or nonregulated). The extent of these guarantees should be considered in calculating leverage.

Fixed-charge coverage for the electric utilities is low relative to coverage for industrial companies. This is accepted by investors because of the stability of the industry. However, emphasis should be placed not only on the exact coverage figures but also on the trend and quality of the coverage.

A third important ratio is net cash-flow/capital expendures. This ratio should be approximated for three years (the typical electric company's construction forecast). The absolute level, as well as the trend of this ratio, gives important insights into the trend of other financial parameters. An improving trend indicates that construction spending probably is moderating, whereas a low net cash-flow/spending ratio may indicate inadequate rates being approved by the commissions and a heavy construction budget. Estimates for construction spending are published in the company's annual reports. Although these are subject to revision, the time involved in building generation makes these forecasts reasonably reliable. In calculating cash flow, the standard definition outlined earlier should be followed. However, allowance for funds used during construction (AFUDC) also should be subtracted.

FINANCE COMPANIES

Finance companies are essentially financial intermediaries. Their function is to purchase funds from public and private sources and to lend them to consumers and other borrowers of funds. Finance companies earn income by maintaining a positive spread between what the funds cost and the interest rate charged to customers. The finance industry is highly fragmented in terms of type of lending and type of ownership. This section will briefly outline the major sectors in the industry and then discuss the principal ratios and other key variables used in the analysis of finance companies.

Segments Within the Finance Industry

The finance industry can be segmented by type of business and ownership. Finance companies lend in numerous ways in order to accommodate the diverse financial needs of the economy. Five of the major lending categories are (1) sales finance, (2) commercial lending, (3) wholesale or dealer finance, (4) consumer lending, and (5) leasing. Most often companies are engaged in several of these lines rather than one line exclusively. Sales finance is the purchase of third-party contracts that cover goods or services sold on a credit basis. In most cases, the sales finance company receives an interest in the goods or services sold. Commercial finance is also generally on a secured basis. However, in this type of financing, the security is most often the borrower's accounts receivable. In factoring, another type of commercial lending, the finance company actually purchases the receivables of the company and assumes the credit risk of the receivables.

Dealer or wholesaler finance is the lending of funds to finance inventory. This type of financing is secured by the financed inventory and is short term in nature. Leasing, on the other hand, is intermediate- to long-term lending—the lessor owns the equipment, finances the lessee's use of it, and generally retains the tax benefits related to the ownership.

Consumer lending historically has involved short-term, unsecured loans of relatively small amounts to individual borrowers. In part because of the more lenient bankruptcy rules and higher default rates on consumer loans, consumer finance companies have dramatically expanded the percentage of their loans for second mortgages. The lower rate charged to individuals for this type of loan is offset by the security and lower default risk of the loan.

There are numerous other types of lending in addition to those just described. Among these are real estate lending and export/import financing.

The ownership of a finance company can significantly affect evaluation of the company. In some instances, ownership is the most important variable in the analysis. There are three major types of ownership of finance companies: (1) captives, (2) wholly owned, and (3) independents.

Captive finance companies, such as Ford Motor Credit, are owned by the parent corporation and are engaged solely or primarily in the financing of the parent's goods or services. Generally, maintenance agreements exist between the parent and the captive finance company under which the parent agrees to maintain one or more of the finance company's financial parameters, such as fixed-charge coverage, at a minimum level. Because of the overriding relationship between a parent and a captive finance subsidiary, the financial strength of the parent is an important variable in the analysis of the finance company. However, captive finance companies can have ratings either above or below those of the parent.

A wholly owned finance company differs from a captive in two ways. First, it primarily finances the goods and services of companies other than the parent. Second, maintenance agreements between the parent and the subsidiary generally are not as formal. Frequently, there are indenture provisions that address the degree to which a parent can upstream dividends from a finance subsidiary. The purpose of these provisions is to prevent a relatively weak parent from draining a healthy finance subsidiary to the detriment of the subsidiary's bondholders.

Independent finance companies are either publicly owned or closely held. Because these entities have no parent, the analysis of this finance sector is strictly a function of the strengths of the company.

Financial Analysis

In analyzing finance companies, several groups of ratios and other variables should be considered. There is more of an interrelationship between these ratios and variables than for any other type of company. For example, a finance company with a high degree of leverage and low liquidity may be considered to be of high investment quality if it has a strong parent and maintenance agreements. Variables should be viewed not in isolation but rather within the context of the whole finance company–parent company relationship.

Asset Quality

The most important variable in analyzing a finance company is asset quality. Unfortunately, there is no definitive way to measure asset quality. However, there are several variables that in the aggregate present a good indication of asset quality.

Diversification is one measure of portfolio quality. Is the portfolio diversified across different types of loans? If the company is concentrated in or deals exclusively in one lending type, is there geographic diversification? A company that deals exclusively in consumer loans in the economically sensitive Detroit area would not be viewed as favorably as a company with broad geographic diversification. Accounting quality is also an important factor in assessing portfolio quality. The security for the loans is also an important variable in portfolio quality. The stronger the underlying security, the higher is the loan quality. Analysts should be concerned primarily with the level of loans compared with levels of similar companies and the risk involved in the type of lending. For example, the expected loan loss from direct unsecured consumer loans is higher than for consumer loans secured by second mortgages. However, the higher fees charged for the former type of loan should compensate the company for the higher risk.

Numerous ratios of asset quality such as loss reserves/net charge-offs, net losses/average receivables, and nonperforming loans/average receivables give good indications of asset quality. However, finance companies have a high level of discretion in terms of what they consider and report to be nonperforming loans and what loans they charge off. Therefore, unadjusted ratios are not comparable among companies. In addition, companies periodically change their charge-off policies.

Despite the drawbacks of the asset-quality ratios, they are useful in indicating trends in quality and profitability. Of these ratios, loss reserves/net charge-offs is perhaps the most important ratio in that it indicates how much cushion a company has. A declining ratio indicates that the company may not be adding sufficient reserves to cover future charge-offs. Such a trend may lead to a future significant increase in the reserves and therefore a decrease in earnings as the increase is expensed. Net losses/average receivables and nonperforming loans/average receivables are other indicators of asset quality. An increasing ratio indicates a deterioration in quality. Declines may be exacerbated by an overall contraction or slow growth in the receivables. On the other hand, because of different accounting treatments, a stable net losses/average receivables ratio under deteriorating economic conditions may indicate a delay in loss recognition. Consideration also should be given to the age of receivables. In recent years, some finance companies have increased their lending dramatically over a short period of time and reported material improvement in their overall financial parameters. These results have been misleading in some cases where the dramatic improvement has been driven by inadequate reserves. Often the dramatic improvement has been followed by increased losses as the portfolio ages.

The long-term history of a company is also an indicator of credit quality. Does management have a history of managing risk conservatively? How long has management been in place? Is there pressure on management to accelerate growth? Has management responded to this type of pressure by expanding into more risky businesses either through acquisition or internal expansion?

Leverage

Leverage is a second important ratio used in finance company analysis. By the nature of the business, finance companies typically and acceptably are more highly leveraged than industrial companies. The leverage is necessary to earn a sufficient return on capital. However, the acceptable range of leverage depends on other factors, such as parental support, portfolio quality, and type of business. The principal ratio to determine leverage is total debt to equity, although such variations as total liabilities to equity also may be used. In a diversified company with high portfolio quality, a leverage ratio of 5 to 1 is acceptable. On the other hand, a ratio as high as 7 to 1 is acceptable for a captive with a strong parent and maintenance agreements. The analyst always should view the leverage of a finance company in comparison with similar companies.

Liquidity

The third important variable in finance company analysis is liquidity. Because of the capital structure of finance companies, the primary cause of bankruptcies in this industry is illiquidity. If for some reason a finance company is unable to raise funds in the public or private market, failure can follow quickly. This inability to raise funds could result from internal factors, such as a deterioration in earnings, or from external factors, such as a major disruption in the credit markets. Whatever the cause, a company should have some liquidity cushion. The ultimate fallback, a sale of assets, is only a last resort because the sales could have long-term detrimental effects on earnings. The traditional liquidity ratio is cash, cash equivalents, and receivables due within one year divided by short-term liabilities. The higher this ratio, the higher is the margin of safety. Also to be considered are the liquidity of the receivables themselves and the existence of bank lines of credit to provide a company with short-term liquidity during a financial crisis. Liquidity calculations also should consider contractual obligations to fund loans. In general, the smaller and weaker companies should have a higher liquidity cushion than companies with strong parental backing that can rely on interest-free loans from their parents in times of market stress. Finally, analysts should take into account a company's ability to raise secured funding, either from banks or private investors or through asset-backed securities facilities.

Asset Coverage

A fourth important variable in the analysis of finance companies that is related to the three variables just discussed is the asset coverage afforded the bondholder. In assessing asset protection, the analyst should consider the liquidation value of the loan portfolio.

A definitive assessment of the value of assets is difficult because of the flexibility finance companies have in valuing assets. For example, a finance company that plans to liquidate its commercial real estate portfolio over 12 months in a depressed real estate environment will value its assets much lower than if it planned to sell the same assets systematically over a three- to five-year period. The value of interest-only securities (IOs) created from a finance company's asset securitizations is also subjective and depends on future credit experience and prepayments. Is management conservative or aggressive in valuing these instruments? How has management valued the residuals of automobile leases? Are there periodic write-offs or gains on these loans?

Earnings Record

The fifth variable to be considered is the finance company's earnings record. The industry is fairly mature and is somewhat cyclical. The higher the annual EPS growth, the better. However, some cyclicality should be expected. In addition, the analyst should be aware of management's response to major changes in the business environment. The easing of personal bankruptcy rules over the years and the fact that personal bankruptcy is becoming more socially acceptable have produced significantly higher loan losses in direct, unsecured consumer loans. Many companies have responded to this change by contracting their unsecured personal loans and expanding their portfolios invested in personal loans secured by second mortgages.

Management

The sixth variable to be considered is the finance company's management. This variable is difficult to assess. However, a company visit combined with an evaluation of business strategies and credit scoring methodologies (analysis used for assessing loan applicants) will provide some insight into this variable.

Size

A final factor related to the finance company or subsidiary is size. In general, larger companies are viewed more positively than smaller companies. Size has important implications for market recognition in terms of selling securities and of diversification. A larger company can more easily diversify the types and geographical location of its loans, thereby lessening the risk of its portfolio, than a smaller company can.

In addition to an analysis of the financial strength of the company according to the preceding variables, the analyst must incorporate the net effect of any affiliation the finance company has with a parent. If this affiliation is strong, it may be the primary variable in the credit assessment. The affiliation between a parent company and a finance subsidiary is straightforward; it is captive, wholly owned, or independent. However, the degree to which a parent will support a finance subsidiary is not as straightforward. Traditionally, the integral relationship between a parent and a captive finance subsidiary has indicated the highest level of potential support. However, it is becoming increasingly clear that a wholly owned finance subsidiary can have just as strong an affiliation. For example, General Electric Capital finances few or no products manufactured by its parent, General Electric Company (GE). GE, however, receives substantial tax benefits from its consolidation of its tax return with GE Capital. Additionally, GE has a sizable investment in the finance subsidiary. In this case, the parent also has a formal agreement with GE Capital by which it is committed to infuse capital if fixed charge coverage of 1.1 × is not maintained. Even aside from that mechanism, there is a strong presumption that GE would protect its investment in GE Capital if the finance subsidiary were to need assistance. In other cases, the benefit of a strong affiliation and maintenance agreement may be offset by weakness in the parent company's financial position.

In addition to affiliation, affiliate profitability, and maintenance agreements, the analyst also should examine any miscellaneous factors that could affect the credit standing of the finance company. For example, new legislation could produce significant changes in the finance industry's structure or profitability. Cases in point of recent years include the Bankruptcy Abuse Prevention and Consumer

Protection Act of 2005 and the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010.

THE ANALYSIS OF HIGH-YIELD CORPORATE BONDS

High-yield bonds, sometimes disparagingly referred to as "junk bonds," are corporate issues rated speculative grade (below Baa/BBB–). Like all corporate bonds, they combine interest rate risk with credit risk, but unlike investment-grade issues, credit risk dominates their price movements. The high-yield universe is split between fallen angels, which are bonds rated investment-grade at issuance and subsequently downgraded to speculative grade, and original issue high-yield bonds that were rated speculative grade at issuance. Fallen angels have the disadvantage of the looser covenants associated with their original ratings. In many cases, however, they are run by managers who are strongly motivated to recapture their investment-grade ratings through prudent financial policies that can lead to upgrading. Original issue high-yield bonds offer the advantage of stronger covenants and in some cases, the possibility that as comparatively new issuers that are not yet widely known, they are underrated by the rating agencies and undervalued by bond investors.

Many of the tools employed in evaluating investment-grade bonds can also be applied to high-yield issues, but the emphasis of the analysis is different. In contrast to the investment-grade universe, where it is extremely rare for a company to go directly to default, an average of more than 4% of speculative grade issuers default each year.[3] As a consequence, high-yield analysts must focus intensely on the downside in a company's operations, its sources of liquidity, and the salvage value of its assets in the event of default.

The price of a company's high-yield bonds, like its stock price, can be highly sensitive to minor changes in the earnings outlook. High-yield analysts therefore operate much as equity analysts do in participating in companies' earnings calls and tracking industry data that may shed light on future profits. They go beyond their equity counterparts in studying the details of the issuers' funding capability and covenant provisions, which become highly pertinent under conditions of financial stress.

The following sections address aspects of credit analysis that require expanded attention in the analysis of high-yield corporate bonds.

Competition

In the popular mind, high-yield companies are small players in their markets, yet over the years there have been many exceptions to this stereotype. Examples

3. Source: Moody's Investors Service.

include the three largest U.S. automakers (General Motors, Ford Motor Company, and Chrysler), the world's largest operator of health care facilities (HCA), and the world's largest casino operator (Caesars Entertainment). Size does not automatically confer a competitive advantage, nor do smaller companies invariably report inferior profit margins due to a lack of scale economies. Instead of participating in all market segments, including mature and highly competitive ones, some small companies manage to carve out highly profitable niches. They do not strive to minimize unit costs by maximizing volume, but instead obtain premium prices by offering superior selection or convenience.

By the same token, analysts should not accept at face value the glib assertions of high-yield market promoters that the rating agencies arbitrarily and mistakenly penalize companies for being small. The agencies do not rate companies speculative grade because they are small, but rather because of certain consequences of their smallness.

Some small companies lack geographical diversification and are therefore highly vulnerable to a regional economic downturn. Others have no credible succession plans in place because domination by strong-willed founders makes it difficult for them to attract and retain capable candidates at the next level of management. Neither should analysts assume, as private equity firms probably would like them to, that a high level of equity ownership by key employees is so powerful a motivator that corporate failure is inconceivable.

Cash Flow

One of the most important elements in analyzing a high-yield security is cash flow. In recent years, analysts have concentrated increasingly on *free cash flow* (FCF), defined as cash flow from operations minus capital expenditures. FCF can be calculated as follows:

EBIT × (1 − Tax Rate)

\+ Depreciation and Amortization

− Changes in Working Capital

− Capital Expenditures

= Free Cash Flow

A company that generates free cash flow is not dependent on external financing and therefore should not be stymied by a temporary unavailability of credit. In addition, FCF generators are best positioned to refinance maturing debt during periods when capital markets are open, but only to the strongest high-yield borrowers. For a company in this select group, investors theoretically need concern themselves only with the risk that positive FCF generation will prove unsustainable.

The rise in popularity of free cash flow is partly a reaction to abuse of a popular cash-flow proxy of earlier decades, EBITDA. In the 1990s, competition for deals pushed the debt loads on leveraged buyouts (LBOs) to an extreme that made issuers look very weak by standard financial ratios such as EBITDA/Interest Expense. Underwriters responded by promoting "adjusted EBITDA." The newfangled ratio conveniently eliminated the impact of operating losses that were deemed to reflect "restructurings," which was too often a euphemism for failed investments. Even before this distortion of reality became common, EBITDA had serious shortcomings as a cash-flow measure by virtue of ignoring capital expenditures and working capital requirements. These are essential cash uses that a company may have difficulty funding in a period of tight credit.

For all its faults, EBITDA remains the high-yield market's standard for calculating leverage. Analysts view a company's total debt outstanding as some number of "turns" of EBITDA. Suppose, for instance, that a company's debt is equivalent to four × its EBITDA at a time when corporate buyers and LBO sponsors are paying six × EBITDA to acquire comparable companies. Bondholders will feel comfortable that in the event of default they will fully recover their principal from the proceeds of a sale of the company in bankruptcy. As with free cash flow, the key assumption is that the level of cash generation will not fall. Proceeds equivalent to six × a greatly reduced EBITDA will not be as great as the company's debt load.

Net Assets

In analyzing a bond, the analyst must ascertain or at least approximate the liquidation value of the assets. Are these assets valued properly on the balance sheet? Of particular interest may be real estate holdings. For example, in analyzing the gaming companies, a market assessment of land holdings should be included. On the other hand, one also should consider the likelihood of those assets being available for liquidation, if necessary. To whom do they belong? Are they mortgaged or being used as collateral? Assets are occasionally spun off to the equity owners of the company. In such a circumstance, the bondholders may experience a sudden and dramatic deterioration of credit quality. Other bondholders are secured by specific assets such as railroad cars or a nuclear power station. In these circumstances, the value and marketability of the collateral must be ascertained. Collateral, by definition, must be specific, and so must be the analysis. Ten railroad engines may appear to provide adequate collateral until it is discovered that the engines are not only obsolete but have not been maintained for a number of years. Five aircraft may appear to be adequate collateral until it is discovered that the engines were financed separately and do not constitute collateral.

Particular attention must be paid to the asset protection in a takeover situation. In this instance, assets that originally provided protection for an investor's holdings could be used to secure new debt senior to the investor's position.

The analyst also must focus on the location of the assets. If the assets are in a foreign country, the analyst should be familiar with that country's laws regarding expatriation of funds. In the extreme case, the analyst should be familiar with that country's laws regarding bankruptcy proceedings. Notwithstanding high-yield investors' traditional claim that they focus on the verifiable values of hard assets, it is in fact common to attribute substantial value to certain items that do not even qualify as assets under generally accepted accounting principles. For example, media and telecommunications companies are often evaluated by attributing a dollar amount to each customer or potential customer. Current valuations may be justified by the prices being paid for comparable properties in mergers and acquisitions transactions. In the future, however, the value of these unofficial assets may evaporate as new technologies emerge to provide communications services more cheaply or more effectively. There is also a risk that if a company becomes financially distressed its existing customers (particularly business customers) may switch to other providers.

Management

Management is a critical element in the assessment of any company. Given enough time, poor management can bankrupt the most prosperous enterprise. Conversely, good management is essential to the long-run survival of all firms.

Many successful firms are launched by the top engineers or salespeople at industry-leading firms. They may bring strong talent and motivation, but analysts must evaluate the entire team to ensure that all key functions are in capable hands. Does the company have a strong financial manager? Are proper controls in place? Incentives can also play a significant role in determining a company's long-run success. Ownership of a significant portion of the company by management is generally a positive, if not necessarily a panacea.

There are two principal ways to evaluate management. The first is to judge the team by its results. This is accomplished through financial analysis. The second way is to meet with senior managers to judge first-hand their vision for the firm as well as their understanding of the business. This is achieved by attending new-financing road shows, as well as arranging one-on-one meetings where possible, and participating in companies' quarterly earnings calls.

An analyst must be well-prepared for meetings with management. Lack of preparation creates the risk of being swayed by a slick presentation that lacks true substance. In one presentation to potential bond investors, the senior management of a company that manufactured gas pump nozzles stated that European operations would generate major growth because of increased environmental requirements to reduce gasoline fumes at service stations. In an effort to estimate the potential for this new revenue opportunity, an analyst asked management to discuss the state of European environmental laws and how they differed from laws in the United States. Management was unable to answer the question. The company subsequently filed for bankruptcy.

Leverage

Companies that issue high-yield bonds generally are highly leveraged. Leverage per se is not harmful and in many circumstances is beneficial to growth. However, the degree of leverage should be evaluated in terms of its effect on the financial flexibility of the firm. As pointed out earlier, leverage should be calculated on absolute and market-adjusted bases. The most common approach to market adjustment is to calculate a market value for the equity of the firm. To the extent that the common stock is selling below book value, leverage will be understated by a traditional approach. Some firms also adjust the market value of debt in calculating leverage. This approach is interesting, but a consistent approach must be employed when convertibles are considered in the equity equation. The benefit of adjusting the equity side of the leverage equation is clear. As the market values a company's equity upward, the market is indicating a willingness to support more leverage. A similar increase in the market adjustment of a firm's debt may indicate an upward appraisal of creditworthiness or an overall lowering of interest rates. In either case, the company probably would have the opportunity to refinance at a lower cost and thereby increase profitability.

Care also should be taken to evaluate sources of leverage that are not stated clearly on the balance sheet. These sources arise from the use of complicated financings.[4] For example, consider deferred-coupon bonds that are commonly used by high-yield issuers. Deferred-coupon bonds permit the issuer to postpone interest payment to some future year. As a result, the interest burden is placed on future cash flow to meet the interest obligations. Because of this burden, the presence of deferred-coupon bonds may impair the ability of the issuer to improve its credit quality in future periods. Moreover, if senior bonds have deferred-coupon payments, the subordinated bonds will be adversely affected as the amount of senior bonds increases over time relative to the amount of subordinated bonds. For example, one type of deferred-coupon bond that has been widely used in some years is the payment-in-kind (PIK) bond. With this bond structure, a high-yield issuer has the option either to pay interest in cash or pay the equivalent of interest with another bond with the same coupon rate. If the issuer does not have the ability to pay the interest in cash, payment with another bond will increase future interest expense and thereby adversely affect the issuer's future cash flow. If the PIK bonds are senior bonds, subordinated bonds are adversely affected over time as more senior bonds are added to the capital structure and future interest expense is increased further.

4. William A. Cornish, "Unique Factors in the Credit Analysis of High-Yield Bonds," in Frank K. Reilly (ed.), *High-Yield Bonds: Analysis and Risk Assessment* (Charlottesville, VA: Association for Investment Management and Research, 1990).

Corporate Structure

High-yield issuers usually have a holding-company structure. The assets to pay creditors of the holding company will come from the operating subsidiaries. It is therefore critical to analyze the corporate structure. Specifically, the analyst must understand how cash will be passed between subsidiaries and the parent company and among the subsidiaries. The corporate structure may be so complex that the payment structure becomes confusing.

For example, in the mid 2000s Charter Communications created a dizzyingly complex corporate structure. The cable television systems operator capitalized on its rapidly growing EBITDA to create and further leverage a succession of new intermediate holding companies. Eventually, the operating subsidiaries stood beneath a parent operating company and eight layers of holding companies with names such as Charter Communications Holding Company, LLC, Charter Communications Holdings, LLC, and CCH I Holdings, LLC.

Simply calculating financial ratios for the consolidated company did not produce an accurate picture of Charter's debt-servicing capability. Each holding company's ability to make interest payments depended on dividends from the companies positioned below it on the corporate totem pole. Those companies could not lawfully pay dividends before meeting their own debt service requirements and they were further constrained by restrictions, tied to leverage covenants, on upstreaming of dividends. This was an especially acute concern for holders of a convertible bond of the ultimate holding company, Charter Communications, Inc. (CCI).

Charter kept its highly leveraged web of companies solvent by frequently tapping the capital markets to retire maturing debt. Extensive intercompany loans further complicated the picture. The game ended when a financial crisis shut the markets down. Charter filed for bankruptcy in 2009 and the importance of mastering the intricacies of high-yield analysis once again became apparent. Senior secured lenders at the parent operating company and at the holding companies just above it, who were closest to the assets, recovered 100% of their principal. In contrast, note holders at some of the more remote holding companies recovered negligible amounts. Somewhat anomalously, convertible bondholders at CCI, who were furthest of all from the assets, enjoyed a higher percentage recovery than creditors of some intermediate holding companies. This was achieved partly with cash proceeds of the sale of the convertible issue, which had been retained at CCI to cover interest payments.

Covenants

While an analyst should consider covenants when evaluating any bond issue (investment-grade or high-yield), it is particularly important for the analysis of high-yield issuers. The importance of understanding covenants was summarized by one high-yield portfolio manager as follows:

> Covenants provide insight into a company's strategy. As part of the credit process, one must read covenants within the context of the corporate strategy. It is not sufficient to hire a lawyer to review the covenants because a lawyer might miss the critical factors necessary to make the appropriate decision. Also, loopholes in covenants often provide clues about the intentions of management teams.[5]

Note, however, that some specialized consulting firms offer assistance in interpreting covenants, combining financial sophistication with legal expertise.

Definitions

Great care must be paid to definitions. As discussed earlier with respect to cash flow, definitions can materially skew cash-flow projections. When asked to define certain terms, management often will state that its definitions are "standard." There is no standard definition.

Definitions also should be evaluated in covenants. For example, a "change of control" typically triggers a 101% put option for the bondholder, but the term does not necessarily refer to all changes in controlling interest in the company. A change of control may be defined to include an acquisition of the company but not a merger (in which the company's separate corporate structure disappears). In some cases, acquisition by a major existing shareholder is excluded from the definition.

CREDIT SCORING MODELS

To this point in the chapter, the focus has been on traditional ratios and other measures that credit analysts use in assessing default risk. Several researchers have used these measures as input to assess the default risk of issuers using the statistical technique of multiple discriminant analysis (MDA). This tool is primarily a classification technique that is helpful in distinguishing between or among groups of objects and in identifying the characteristics of objects responsible for their inclusion in one or another group. One of the chief advantages of MDA is that it permits a simultaneous consideration of a large number of characteristics and does not restrict the investigator to a sequential evaluation of each individual attribute. For example, MDA permits a credit analyst studying ratings of corporate bonds to examine, at one time, the total and joint impact on ratings of multiple financial ratios, financial measures, and qualitative factors. The analyst is thereby freed from the cumbersome and

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5. Robert Levine, "Unique Factors in Managing High-Yield Bond Portfolios," in *High-Yield Bonds: Analysis and Risk Assessment*. p. 35.

possibly misleading task of looking at each characteristic in isolation from the others. MDA seeks to form groups that are internally as similar as possible but that are as different from one another as possible.

From the preceding description of MDA it can be seen why it has been applied to problems of why bonds get the ratings they do and what variables seem best able to account for a bond's rating. Moreover, MDA has been used as a predictor of bankruptcy. While the steps involved in MDA for predicting bond ratings and corporate bankruptcies are a specialist topic, the following discussion addresses the results of the work of Edward Altman, the primary innovator of MDA for predicting corporate bankruptcy.[6] The models of Altman and others involved in this area are updated periodically. Here the purpose is only to provide an illustration of how MDA models work.

In one of Altman's earlier models, referred to as the "*Z*-score model," he found that the following MDA could be used to predict corporate bankruptcy.[7]

$$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 1.0X_5$$

where

X_1 = working capital/total assets (in decimal)
X_2 = retained earnings/total assets (in decimal)
X_3 = earnings before interest and taxes/total assets (in decimal)
X_4 = market value of equity/total liabilities (in decimal)
X_5 = sales/total assets (number of times)
Z = Z-score

Given the value of the five variables for a given firm, a *Z*-score is computed. The *Z*-score is used to classify firms with respect to whether or not there is potentially a serious credit problem that would lead to bankruptcy. Specifically, Altman found that *Z*-scores of less than 1.81 indicated a firm with serious credit problems, whereas a *Z*-score in excess of 3.0 indicated a healthy firm.

Subsequently, Altman and his colleagues revised the *Z*-score model based on more recent data. The resulting model, referred to as the "zeta model" found that the following seven variables were important in predicting corporate bankruptcies and were highly correlated with bond rating:[8]

- Earnings before interest and taxes (EBIT)/total assets
- Standard error of estimate of EBIT/total assets (normalized) for 10 years

6. See Chapters 8 and 9 in Edward I. Altman, *Corporate Financial Distress and Bankruptcy: A Complete Guide to Predicting and Avoiding Distress and Profiting from Bankruptcy*, 2d ed. (Hoboken, NJ: Wiley, 1993).
7. Edward I. Altman, "Financial Bankruptcies, Discriminant Analysis and the Prediction of Corporate Bankruptcy," *Journal of Finance* (September 1968), pp. 589–609.
8. Edward I. Altman, Robert G. Haldeman, and Paul Narayann, "Zeta Analysis: A New Model to Identify Bankruptcy Risk of Corporations," *Journal of Banking and Finance* (June 1977), pp. 29–54.

- EBIT/interest charges
- Retained earnings/total assets
- Current assets/current liabilities
- Five-year average market value of equity/total capitalization
- Total tangible assets, normalized

While credit scoring models have been found to be helpful to analysts and bond portfolio managers, they do have limitations as a replacement for human judgment in credit analysis. Quantitative models are effective in identifying companies that share certain characteristics with defaulting companies, but many of the companies identified by the models do not default. One thing a statistical model cannot readily spot is the possibility of bringing in new management that will turn the company around and prevent a default. Therefore, an investor who is faced with a potentially large loss on a distressed company may benefit from assessing a company's prospects for redirecting itself, rather than selling based solely on a quantitative score. In practice, professional high-yield bond and distressed-debt managers do not rely entirely on models such as the Z-score, but at most use them to supplement their own hands-on analysis.

KEY POINTS

- Credit analysis has evolved from exclusive focus on default risk in a buy-and-hold strategy to playing a role in active management of corporate bond portfolios.
- Equity-related information can help to create a systematic analysis, but it is important also to consider other determinants of credit risk.
- Key areas of a credit assessment include industry analysis, financial analysis, and indenture provisions.
- Analysis of high-yield, or speculative-grade, corporate bonds requires particular focus on the downside in a company's operations, its cash flow, and the quality of its management.
- Quantitative credit scoring models cannot replace hands-on credit analysis, but can usefully supplement it.

CHAPTER
FORTY-ONE

THE CREDIT ANALYSIS OF MUNICIPAL GENERAL OBLIGATION AND REVENUE BONDS

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The degree of safety of investing in municipal bonds has been considered second only to that of U.S. Treasury bonds, but beginning in the fourth quarter of the last century, ongoing concerns developed among many investors and underwriters about the potential default risks of municipal bonds.

One concern resulted from the well-publicized billion-dollar general obligation note defaults in 1975 of New York City. Not only did specific investors face the loss of their principal, but the defaults sent a loud and clear warning to municipal bond investors in general. The warning was that regardless of the supposedly ironclad legal protections for the bondholder, when issuers have severe budget-balancing difficulties, the political hues, cries, and financial interests of public employee unions, vendors, and community groups may be dominant forces in the initial decision-making process.

This reality was further reinforced by the federal bankruptcy law that took effect on October 1, 1979, which makes it easier for municipal bond issuers to seek protection from bondholders by filing for bankruptcy. One by-product of the increased investor concern is that since 1975, the official statement, which is the counterpart to a prospectus in an equity or corporate bond offering and is to contain a summary of the key legal and financial security features, has become more comprehensive. As an example, before 1975 it was common for a city of New York official statement for a general obligation bond sale to be only six pages long, whereas for a bond sale in February 2020 the preliminary official statement was 106 pages long.

More recently, highly visible defaults in 2013 and 2014 of $9.5 billion of Detroit's municipal bonds, followed by the defaults in 2014, 2015, and 2016 of $57.2 billion of Puerto Rico municipal bonds, drew increased attention to the reliability of credit ratings on municipal bonds.

The second reason for the increased interest in credit analysis was derived from the changing nature of the municipal bond market. It is now characterized by strong buying patterns by private investors and institutions. The patterns were caused in part by high federal, state, and local income tax rates. Tax-exempt bonds increasingly have become an important and convenient way to shelter income. One corollary of the strong buyers' demand for tax exemption has been an erosion of the traditional security provisions and bondholder safeguards that had grown out of the default experiences of the 1930s. General obligation bond issuers with high tax and debt burdens, declining local economies, and chronic budget-balancing problems had little difficulty finding willing buyers. Also, revenue bonds increasingly were rushed to market with legally untested security provisions, modest rate covenants, reduced debt reserves, and weak additional-bond tests. Because of this widespread weakening of security provisions, it has become more important than ever before that the prudent investor carefully evaluate the creditworthiness of a municipal bond before making a purchase.

This concern has been increased when the rating agencies in 2009 recalibrated their ratings upward on many general obligation and essential service revenue bonds. They argued that municipal bond issues probably should have slightly better ratings relative to corporate bonds in the context of both historical default rates and recovery levels following default. This resulted in higher ratings on many municipal bonds.

In analyzing the creditworthiness of a general obligation, tax-backed, or pure revenue bond, the investor should cover five categories of inquiry: (1) legal documents and opinions, (2) politics/management, (3) underwriter/financial advisor, (4) general credit indicators and economics, and (5) red flags, or danger signals.

The purpose of this chapter is to set forth the general guidelines that the investor should rely upon in asking questions about specific bonds.

THE LEGAL OPINION

Popular opinion holds that much of the legal work done in a bond issue is boilerplate in nature, but from the bondholder's point of view the legal opinions and document reviews should be the ultimate security provisions because, if all else fails, the bondholder may have to go to court to enforce his or her security rights. Therefore, the integrity and competency of the lawyers who review the documents and write the legal opinions that usually are summarized in the official statements are very important.

The relationship of the legal opinion to the analysis of municipal bonds for both general obligation and revenue bonds is threefold. First, the lawyer should check to determine whether the issuer is indeed legally able to issue the bonds. Second, the lawyer is to see that the issuer has properly prepared for the bond sale by enacting the various required ordinances, resolutions, and trust indentures and without violating any other laws and regulations. This preparation is particularly important in the highly technical areas of determining whether the bond issue is qualified for tax exemption under federal law and whether the issue has been structured in such a way as to not violate federal arbitrage regulations. Third, the lawyer is to certify that the security safeguards and remedies provided for the bondholders and pledged by either the bond issuer or third parties (such as banks with letter-of-credit agreements) are actually supported by federal, state, and local government laws and regulations.

General Obligation Bonds

General obligation bonds are debt instruments issued by states, counties, towns, cities, and school districts. They are secured by the issuers' general taxing powers. The investor should review the legal documents and opinion as summarized in the official statement to determine what specific *unlimited* taxing powers, such as those on real estate and personal property, corporate and individual income taxes, and sales taxes, are legally available to the issuer, if necessary, to pay the bondholders. Usually for smaller governmental jurisdictions, such as school districts and towns, the only available unlimited taxing power is on property. If there are statutory or constitutional taxing power limitations, the legal documents and opinion should clearly describe how they affect the security of the bonds.

For larger general obligation bond issuers, such as states and big cities that have diverse revenue and tax sources, the legal opinion should indicate the claim of the general obligation bondholder on the issuer's general fund. Does the bondholder have a legal claim, if necessary, to the first revenues coming into the general fund? This is the case with bondholders of state of New York general obligation bonds. Does the bondholder stand second in line? This is the case with bondholders of state of California general obligation bonds. Or are the laws silent on the question altogether? This is the case for most other state and local governments.

Additionally, certain general obligation bonds, such as those for water and sewer purposes, are secured in the first instance by user charges and then by the general obligation pledge. (Such bonds are popularly known as being "double barreled.") If so, the legal documents and opinion should state how the bonds are secured by revenues and funds outside the issuer's general taxing powers and general fund.

Revenue Bonds

Revenue bonds are issued for project or enterprise financings that are secured by the revenues generated by the completed projects themselves, or for general public-purpose financings in which the issuers pledge to the bondholders tax and revenue resources that were previously part of the general fund. This latter type of revenue bond, sometimes known as a "dedicated tax bond," is usually created to allow issuers to raise debt outside general obligation debt limits, issuance without voter approvals and to get higher credit ratings. The trust indenture and legal opinion for both types of revenue bonds should provide the investor with legal comfort in six bond-security areas:

- The limits of the basic security
- The flow-of-funds structure
- The rate, user-charge, or dedicated revenue and tax covenants
- The priority of pledged revenue claims
- The additional-bonds test
- Other relevant covenants and issues

The Limits of the Basic Security

The legal documents should explain what the pledged revenues for the bonds are and how they may be limited by federal, state, and local laws. The importance of this is that although most revenue bonds are structured and appear to be supported by identifiable revenue streams, those revenues sometimes can be negatively affected directly by other levels of government. For example, the state of Wyoming in the early 1980s issued Mineral Royalties Revenue Bonds. On the surface, the bond issue had all the attributes of a revenue bond. The bonds had a first lien on the pledged revenues, and additional bonds could only be issued if a coverage test of 125% was met. Yet the revenues to pay bondholders were to be received by the state from the federal government as royalty payments for mineral production on federal lands. The U.S. Congress was under no legal obligation to continue this aid program. Therefore, the investor must read carefully the legal documents to learn if there are shortcomings of the bond security.

The Flow-of-Funds Structure

The legal documents should explain what the bond issuer has promised to do concerning the pledged revenues received. What is the order of the revenue flows through the various accounting funds of the issuer to pay for the operating expenses of the facility, payments to the bondholders, maintenance and special capital improvements, and debt service reserves? This sometimes is referred to as the "waterfall." Additionally, the legal documents should indicate what happens to excess revenues after they pass through the waterfall. Do they go to the issuer's general fund or do they stay within the indenture to be used to call bonds or make capital repairs?

The flow of funds of many revenue bonds is structured as *net revenues* (i.e., debt service is paid to the bondholders immediately after revenues are paid to the basic operating and maintenance funds, but before paying all other expenses). A *gross revenues* flow-of-funds structure is one in which the bondholders are paid even before the operating expenses of the facility are paid. Examples of gross revenue bonds are those issued by the New York Metropolitan Transportation Authority. However, although it is true that these bonds legally have a claim to the fare-box revenues before all other claimants, it is doubtful that the system could function if the operational expenses, such as wages and electricity bills, were not paid first.

The Rate, User-Charge, or Dedicated Revenue and Tax Covenants

The legal documents should indicate what the issuer has legally committed itself to do to safeguard the bondholders. If user rates are involved do they only have to be sufficient to meet expenses, including debt service, known as one times debt service coverage? Is the one-time coverage test calculated for the *average annual debt* service requirement or for the higher *maximum annual debt service* one? Additionally, is the coverage requirement for higher amounts such as 1.1 times or 1.25 times so as to provide for reserves? The legal documents should indicate whether or not the issuer has the legal power to increase rates or charges of users without having to obtain prior approvals by other governmental units.

The Priority of Pledged Revenue Claims

The legal documents should state whether or not other levels of government or claimants can legally tap the revenues of the issuer even before they start passing through the issuer's flow-of-funds structure. An example would be the highway revenue bonds issued by the Puerto Rico Highway and Transportation Authority. These bonds are secured in part by the revenues from the Commonwealth of Puerto Rico gasoline tax. Yet, if in a worst-case scenario no other funds are available to pay their debt service, under the Commonwealth's constitution the moneys are first to be applied to the Commonwealth's own general obligation bonds. This feature was reinforced in 2019 when the U.S. Appeals Court upheld the right of the Commonwealth in bankruptcy to withhold revenues.

The Additional-Bonds Test

The legal documents should indicate under what circumstances the issuer can issue additional bonds that share equal claims to the issuer's revenues. Usually, the legal requirement is that the maximum annual debt service on the new bonds as well as on the old bonds be covered by the projected net revenues by a specified minimum amount. This can be as low as one times coverage. Some revenue bonds have stronger additional-bonds tests to protect the bondholders. Also, how the historical revenues are calculated is important. Can the issuer select specific prior months to be used such as 12 out of the last 15 months? Who determines the projection numbers for the future revenues? Is it an independent consultant with expertise in the area? How conservative are the projections and how are they certified? Additionally, the definition of revenues is important. Does it include revenues generated by the enterprise, or could it also include special supplemental payments? These are all questions that have to be addressed by the analyst in reviewing the additional bonds test formula.

Other Relevant Covenants and Issues

Lastly, the legal documents should indicate whether there are other relevant covenants for the bondholder's protection. These usually include pledges by the issuer of the bonds to insure the project (if it is a project-financing revenue bond), to have the accounting records of the issuer annually audited by an outside certified public accountant and provide timely reports to investors, and to employ independent engineers to annually review the capital plant and make mandatory recommendations to keep the facility operating for the life of the bonds.

In addition to the above aspects of the specific revenue structures of general obligation and revenue bonds, two other developments over the recent past make it more important than ever for the investor to carefully review the legal documents and opinions summarized in the official statements. The first development involves the mushrooming of new financing techniques that may rest on legally untested security structures. The second development is the increased use of legal opinions provided by local attorneys who may have little prior municipal bond experience. (Legal opinions traditionally have been written by experienced municipal bond attorneys.)

Legally Untested Security Structures and New Financing Techniques

In addition to the more traditional general obligation bonds and toll road, bridge, and tunnel revenue bonds, there are now more non-voter-approved, innovative, and legally untested security mechanisms. These innovative financing mechanisms include lease-rental bonds, moral obligation housing bonds, "dedicated tax-backed" and structured "asset-backed" bonds, take-and-pay power bonds with step-up provisions requiring the participants to increase payments to make up for those that may default, commercial bank-backed letter-of-credit "put" bonds, and tax-exempt commercial paper. What distinguishes these newer bonds from the more traditional general obligation and revenue bonds is that they have little history of court decisions and other case law to firmly protect the rights of the bondholders. For the newer financing mechanisms, the legal opinion should include an assessment of the probable outcome if the bond security were challenged in court. Note, however, that most official statements do not provide this to the investor.

The Need for Reliable Legal Opinions

For many years, concern over the reliability of the legal opinion was not as important as it is now. As a result of the numerous bond defaults and related shoddy legal opinions in the nineteenth century, the investment community demanded that legal documents and opinions be written by recognized municipal bond attorneys. As a consequence, over the years, a small group of primarily Wall Street-based law firms and certain recognized firms in other financial centers dominated the industry and developed high standards of professionalism.

Now, however, more and more issuers have their legal work done by local law firms, a few of whom may have little experience in municipal bond work. This development, along with the introduction of more innovative and legally untested financing mechanisms, has created a greater need for reliable legal opinions. An example of a specific concern involves the documents the issuers' lawyers must complete so as to avoid arbitrage problems with the Internal Revenue Service.

By 2020, there were thousands of attorneys located throughout the country who were listed in the *Bond Buyers' "Red Book"* or Municipal Marketplace online. They presented themselves as being experts in municipal finance law and provided various security structure and tax opinions. Sorting out quality distinctions in their work and who is well grounded in the law, and who is not, is challenging.

On negotiated bond issues, one remedy has been for the underwriters to have their own counsels review the documents and to provide separate legal opinions.

THE NEED TO KNOW WHO REALLY IS THE ISSUER

Still another general question to ask before purchasing a municipal bond is just what kind of people are the issuers? Are they conscientious public servants with clearly defined public goals? Do they have histories of successful management of public institutions? Have they demonstrated commitments to professional and fiscally stringent operations? Additionally, issuers in highly charged and partisan environments in which conflicts chronically occur between political parties or among political factions or personalities are clearly bond issuers to scrutinize closely and possibly to avoid. Such issuers should be scrutinized regardless of the strength of the surrounding economic environment.

For General Obligation and Tax-Backed Bonds

For general obligation bond issuers, focus on the political relationships that exist among chief executives such as mayors, county executives, and governors, and among their legislative counterparts. Issuers with unstable political elites are of particular concern. Of course, rivalry among politicians is not necessarily bad. What is undesirable is competition so bitter and personal that real cooperation among the warring public officials in addressing future budgetary problems may be precluded. An example of an issuer that was avoided because of such dissension *was* the city of Cleveland. The political problems of the city in 1978 and the bitter conflicts between Mayor Kucinich and the city council resulted in a general obligation note default in December of that year.

For Revenue Bonds

When investigating revenue bond issuers, it is important to determine not only the degree of political conflict, if any, that exists among the members of the bond-issuing body but also the relationships and conflicts among those who make the appointments to the body. Additionally, the investor should determine whether the issuer of the revenue bond has to seek prior approval from another governmental jurisdiction before the user fees or other charges can be levied. If this is the case, then the stability of the political relationships between the two units of government must be determined.

An important example involves the creditworthiness of the water and electric revenue bonds and notes issued by Kansas City, Kansas. Although the revenue bonds and notes were issued by city hall, it was the six-member board of public utilities, a separately elected body, that had the power to set the water and electricity rates. In the spring of 1981, because of a political struggle between a faction on the board of public utilities and the city commissioners (including the city's finance commissioner), the board refused to raise utility rates as required by the covenant. The situation came under control only when a new election changed the makeup of the board in favor of those supported by city hall.

In addition to the preceding institutional and political concerns, for revenue bond issuers in particular, the technical and managerial abilities of the staff should be assessed. The professional competency of the staff is a more critical factor in revenue bond analysis than it is in the analysis of general obligation bonds. The reason is that unlike general obligation bonds, which are secured in the final instance by the full faith and credit and unlimited taxing powers of the issuers, many revenue bonds are secured by the ability of the revenue projects to be operational and financially self-supporting.

The professional staffs of authorities that issue revenue bonds for the construction of nuclear and other public power-generating facilities, apartment complexes, hospitals, water and sewer systems, and other large public works projects, such as convention centers and sports arenas, should be reviewed carefully. Issuers who have histories of high management turnovers, project cost overruns, or little experience should be avoided by the conservative investor or at least considered higher risks than their assigned commercial credit ratings may indicate. Additionally, it is helpful for revenue bond issuers to have their accounting records annually audited by outside certified public accountants so as to provide the investor with a more accurate picture of the issuer's financial health.

ON THE FINANCIAL ADVISOR AND UNDERWRITER

Shorthand indications of the quality of the investment are (1) who the issuer selected as its financial advisor, if any; (2) its principal underwriter if the bond sale was negotiated; and (3) its financial advisor if the bond issue came to market competitively. Additionally, many prudent underwriters will not participate if there are significant credit-quality concerns. Therefore, it is also useful to learn who was the underwriter for the bond sales as well.

Identifying the financial advisors and underwriters is important for two reasons.

The Need for Complete, Not Just Adequate, Investment Risk Disclosures

The first reason relates to the quality and thoroughness of information provided to the investor by the issuer. The official statement, or private-placement papers if the issue is placed privately, is usually prepared with the assistance of lawyers and a financial advisor or by the principal underwriter. There are industry-wide disclosure guidelines that generally are adhered to, but not all official statements provide the investor with complete discussions of the risk potentials that may result from either the specific economics of the project or the community settings and the operational details of the security provisions. It is usually the author of this document who decides what to emphasize or downplay in the official statement. The more professional and established the author is in providing unbiased and complete information about the issuer, the more comfortable the investor can be with information provided by the issuer and in arriving at a credit-quality conclusion.

The Importance of Firm Reputation for Thoroughness and Integrity

By itself, the reputation of the issuer's financial advisor and/or underwriter should not be the determinant credit-quality factor, but it is a fact the investor should consider, particularly in the case of marginally feasible bond issues that have complex flow-of-funds and security structures. The securities industry is different from other industries, such as real estate, in that trading and investment commitments are usually made over the phone or electronically with a formal documented trail following. Many institutional investors, such as banks, bond funds, and insurance companies, have learned to judge issuers by the company they keep. Institutions tend to be conservative, and they are more comfortable with financial information provided by established financial advisors and underwriters who have recognized reputations for honesty. Individual investors and analysts would do well to adopt this approach.

GENERAL CREDIT INDICATORS AND ECONOMIC FACTORS IN THE CREDIT ANALYSIS

The last analytical factor is the economic health or viability of the bond issuer or specific project financed by the bond proceeds. The economic factors cover a variety of concerns. When analyzing general obligation bond issuers, one should look at the specific budgetary and debt characteristics of the issuer, as well as the general economic environment. For project-financing, or enterprise, revenue bonds, the economics are limited primarily to the ability of the project to generate sufficient charges from the users to pay the bondholders. These are known as *pure revenue bonds*.

For revenue bonds that rely not on user charges and fees but instead on general purpose taxes and revenues, the analysis should take basically the same approach as for the general obligation bonds. For these bonds, the taxes and revenues diverted to the bondholders would otherwise go to the state's or city's general fund.

As an example, the bonds of the New York State Municipal Assistance Corporation for the City of New York Bonds (MAC), secured by general New York City sales taxes and annual state-aid appropriations, were structured to appear as pure revenue bonds, but in essence they were not. They incorporated a bond structure created to bail out New York City from severe budget deficits. The creditworthiness of the bond was tied to that of the underlying jurisdiction, which has had portions of its taxing powers and general fund revenues diverted to secure this new revenue-type bailout bond. Besides looking at the revenue features, the investor therefore must look at the underlying jurisdiction. These MACs were first issued in 1975 and refunded through the years. It should be noted that in 2004, the MACs were refunded, now with "Sales Tax *Asset* Receivable Corporation" bonds and stretched out to 2033 for paying off operating deficits of the 1960s.

For General Obligation Bonds

For general obligation bonds, the economic concerns include questions in four specific areas: debt burden, budget soundness, tax burden, and the overall economy.

Debt Burden

In relation to the debt burden of the general obligation bond issuer, some of the more important concerns include the determination of the total amount of debt outstanding and to be issued that is supported by the general taxing powers of the issuer as well as by earmarked revenues.

For example, general obligation bonds issued by school districts in New York State are general obligations of the issuer and are also secured by state-aid payments due the issuer. If the issuer defaults, the bondholder can go to the state comptroller and be paid from the next state-aid payment due the local issuer.

Key debt ratios that reveal the burden on local taxpayers include determining the per capita amount of general obligation debt as well as the per capita debt of the overlapping or underlying general obligation bond issuers. Other key measures of debt burden include determining the amounts and percentages of the outstanding general obligation bonds as well as the outstanding general obligation bonds of the overlapping or underlying jurisdictions to real estate valuations. These numbers and percentages can be compared with most recent year medians, as well as with the past history of the issuer, to determine whether the debt burden is increasing, declining, or remaining relatively stable.

In addition to the general obligation bonds outstanding, the debt of the general obligation bond issuer could include leases, certificates of participation (COPs), appropriation, and "moral obligation" bonds.

Additionally, the amount of the unfunded pension liabilities should be determined. What is the difference between the expected assets of the public employee system at current annual contribution rates, the future benefits to be paid out, and if the issuer has a reasonable plan to eliminate the unfunded liability? Can pension benefits unilaterally be reduced by the local governments? Such steps are allowed in some jurisdictions, but not in others. An example of the latter is New York State, where the state constitution prevents the reduction of pension benefits once they are granted. Therefore, the unfunded pension liabilities of local governments in New York must be taken much more seriously than in states where such guarantees do not exist.

Still another special debt figure that came into the forefront in the first decade of the twenty-first century involves the actuarially determined costs of providing health care for retirees. These are postemployment benefits. In many jurisdictions they are not legally mandatory and are paid on a pay-as-you-go basis. There are usually strong political groups such as unions and the retirees themselves that support these benefits. In some jurisdictions the potential size of this liability is greater than the outstanding general obligation bonds.

For purposes of determining the special debt figure—which represents the potential liability in a worst-case environment—the COPs, appropriation and lease obligations, the moral obligations, the unfunded pension liabilities, and the retiree health care costs should be shown and broken out.

Budgetary Soundness

Concerning the budgetary operations and budgetary soundness of the general obligation bond issuer, some of the more important questions include how well the issuer over at least the previous five years has been able to maintain balanced budgets and fund reserves. How dependent is the issuer on short-term debt to finance annual budgetary operations? How have increased demands by residents for costly social services been handled? That is, how frugal is the issuer? How well have the public-employee unions been handled? They usually lobby for higher salaries, liberal pensions, and other costly fringe benefits. Clearly, it is undesirable for the pattern of dealing with the constituent when demands and public-employee unions results in raising taxes and drawing down nonrecurring budget reserves. Last, another general concern in the budgetary area is the reliability of the budget and accounting records of the issuer. Are interfund borrowings reported? Who audits the books?

It should be noted that by 2020, e-commerce and Internet usage were steadily growing among American consumers. Many states, counties, and city governments over the past 50 years have derived substantial revenues from sales taxes that are not always applied to Internet sales. In some jurisdictions, over 20% of an issuer's revenues may come from local sales taxes. How the growth of the Internet affects this revenue source is uncertain at this time, but at some future date could be a significant negative for the budgets of at least some issuers as well as for their bonds secured by these taxes.

Tax Burden

Concerning the tax burden, it is important to learn two things initially. First, what are the primary sources of revenue in the issuer's general fund? Second, how dependent is the issuer on any one revenue source? If the general obligation bond issuer relies increasingly on a property tax, wage and income taxes, or sales tax to provide the major share of financing for annually increasing budget appropriations, taxes could quickly become so high as to drive businesses and people away. Many larger northern states and cities with their relatively high income, sales, and property taxes appear to be experiencing this phenomenon. Still another concern is the degree of dependency of the issuer on intergovernmental revenues, such as federal or state revenue sharing and grants-in-aid, to finance its annual budget appropriations. Political coalitions on the state and federal levels that support these financial transfer programs are not permanent and could undergo dramatic change very quickly. Therefore, a general obligation bond issuer that currently has a relatively low tax burden but receives substantial amounts of intergovernmental monies should be reviewed carefully by the investor. If it should occur that the aid monies are reduced, as has been occurring under many federal and state programs, certain issuers primarily may increase their taxes instead of reducing their expenditures to conform to the reduced federal grants-in-aid.

Overall Economy

The fourth and last area of general obligation bond analysis concerns the issuer's overall economy. For local governments, such as counties, cities, towns, and school districts, key items include learning the annual rate of growth of the full value of all taxable real estate for the previous 10 years and identifying the 10 largest taxable properties. What kinds of business or activity occur on the respective properties? What percentage of the total property tax base do the 10 largest properties represent? What has been the building permit trend for at least the previous five years? What percentage of all real estate is tax-exempt, and what is the distribution of the taxable ones by purpose (such as residential, commercial, industrial, and public utility)? Last, who are the five largest employers? Concerning the final item, communities that have one large employer are more susceptible to rapid adverse economic change than communities with more diversified employment and real estate bases. For additional information that reveals economic health or decline, one must determine whether the population of the community over the previous 10 years has been increasing or declining by age and income and how the monthly and yearly unemployment rates compare with the national averages, as well as with the previous history of the community.

For state governments that issue general obligation bonds, the economic analysis should include many of the same questions applied to local governments. In addition, the investor should determine on the state level the annual rates of growth for the previous five years of personal income and retail sales.

For Revenue Bonds

Airport Revenue Bonds

For airport revenue bonds, the economic questions vary according to the type of bond security involved. There are two basic security structures.

The first type of airport revenue bond is one based on traffic-generated revenues that result from the competitiveness and passenger demand of the airport. The financial data on the operations of the airport should come from audited financial statements going back at least three years. If a new facility is planned, a feasibility study prepared by a recognized consultant should be reviewed. The feasibility study should have two components: (1) a market and demand analysis to define the service area and examine demographic and airport use trends and (2) a financial analysis to examine project operating costs and revenues.

Revenues at an airport may come from landing fees paid by the airlines for their flights; passenger facility charges (PFCs); concession fees paid by restaurants, shops, newsstands, and parking facilities; and from airline apron and fueling fees.

Also, in determining the long-term economic viability of an airport, the investor should determine whether or not the wealth trends of the service area are upward, whether the airport is dependent on tourism or serves as a vital transfer point, whether passenger enplanements and air cargo handled over the previous five years have been growing, whether increased costs of jet fuel and airport safety would make other transportation such as trains and automobiles more attractive in that particular region, and whether the airport is a major domestic hub for an airline, which could make the airport particularly vulnerable to route changes caused by schedule revisions and changes in airline corporate management.

The second type of airport revenue bond is secured by a lease with one or more airlines for the use of a specific facility such as a terminal or hangar. The lease usually obligates them to make annual payments sufficient to pay the expenses and debt service for the facility. For many of these bonds, the analysis of the airline lease is based on the credit quality of the lessee airline. Whether or not the lease should extend as long as the bonds are outstanding depends on the specific airport and facility involved. For major hub airports, it may be better not to have long-term leases because without leases, fees and revenues can be increased as the traffic grows, regardless of which airline uses the specific facility. Of course, for regional or startup airports, long-term leases with trunk (i.e., major airline) carriers are preferred.

After 9/11, air travel suffered a unique temporary downturn. While air travel remains an essential service, after the terrorist attacks, the analysis of the credit quality of airports and airlines with related bankruptcy issues has undergone increased scrutiny.

Charter School Bonds

Charter school bonds are for publicly funded private schools that offer more institutional and academic flexibility than local public schools. State-aid funding usually follows the student who goes from a traditional public school to a charter school. Bond proceeds go for capital improvements.

Some important credit questions to ask include: (1) How long is the charter granted by the state or local school district, and is it renewable? (2) What is the charter school enrollment history—is it growing? (3) Does the school serve a specialty academic niche, or is it just relieving overcrowding at local public schools? (4) What is its reputation in the community? (5) Is there competition? (6) Is there a waiting list? (7) Is the school prudently run with cash reserves, i.e., how many days of cash are on hand? and (8) How reasonable are the operating and maintenance expenses in relationship to the revenues and debt service requirements?

Continuing Care Retirement Community Bonds

A continuing care retirement community (CCRC) provides housing accommodations and health-related services to elderly persons, typically for the duration of their lifetimes. These nonprofit organizations finance a portion of development and operating costs by issuing bonds secured by the entrance fees and monthly fees paid by their residents. The potential demand for a CCRC is largely affected by the number of elderly persons in the nearby area with qualifying assets and income, the presence and proximity of competitor facilities, and the strength of the local real estate market. Other important considerations include whether advance fee deposits are partially or fully refundable, the experience of the general contractor and management, the background of the sponsor, and the amount of cash reserves on hand. A careful analysis of the data and assumptions of any feasibility study formed is essential.

Dedicated Tax-Backed and Structured/Asset-Backed Bonds

More recently, states and local governments have issued increasing amounts of bonds where the debt service is to be paid from so-called dedicated revenues such as sales taxes, tobacco settlement payments, fees, and penalty payments. Many are structured to mimic the asset-backed bonds that are common in the taxable market. The "assets" providing the security for the municipal bonds are the "dedicated" or "special" revenues instead of credit card receivables, home equity loans, and auto loan repayments that are commonly used to secure the taxable asset-backed bonds.

Additionally, the municipal bonds may be subject to some form of annual legislative appropriation and result from statutes specially created to pledge the identified taxes and revenues and allow for the bond sales. In good economic times many investors as well as the rating agencies tend to blur the credit distinctions between these bonds and the issuer's own general obligation bonds. In fact, many such bonds carry higher credit ratings than the underlying general obligation bonds because the "coverage" on the former appears to be so high. In most instances, the general obligation bonds are legally backed by specific state constitutional provisions, whereas, the dedicated tax and structured/asset-backed bonds are recent legislative creations and have not been tested yet in stressful budgetary, economic, and political environments.

Higher Education Bonds

Debt is often issued by institutions of higher education to finance the costs of building/renovating facilities or purchasing land for expansion. These bonds are secured by revenues of the given project, student charges, and/or a general obligation of the college or university. An investor in higher education bonds should carefully consider the following: (1) Is student demand for the issuing institution strong and growing? (2) Does the school have flexibility to increase tuition or enrollment if needed? (3) How experienced are senior management and the board of trustees? (4) What are the school's various sources of funding? (5) What is the endowment level and how is it trending? (6) How well does the school manage expenses and repay its debts? (7) What is the physical condition of school facilities? and (8) Are there any construction or project-specific risks?

Highway Revenue Bonds

There are generally two types of highway revenue bonds. The bond proceeds of the first type are used to build specific revenue-producing facilities such as toll roads, bridges, and tunnels. For these pure enterprise revenue bonds, the bondholders have claims to the revenues collected through the tolls. The financial soundness of the bonds depends on the ability of the specific projects to be self-supporting. Proceeds from the second type of highway revenue bond generally are used for public highway improvements, and the bondholders are paid by earmarked revenues such as gasoline taxes, automobile registration payments, and driver's license fees.

Concerning the economic viability of a toll revenue bond, the investor should ask a number of questions.

1. What is the traffic history, and how inelastic is the demand? Toll roads, bridges, and tunnels that provide vital transportation links are clearly preferred to those that face competition from interstate highways, toll-free bridges, or mass transit.

2. How well is the facility maintained? Has the issuer established a maintenance reserve fund at a reasonable level to use for such repair work as road resurfacing and bridge painting?
3. Does the issuer have the ability to raise tolls to meet covenant and debt reserve requirements without seeking approvals from other governmental actors such as state legislatures and governors? In those few cases where such approvals are necessary, the question of how sympathetic these other power centers have been in the past in approving toll-increase requests should be asked.
4. What is the debt-to-equity ratio? Some toll authorities have received substantial nonreimbursable federal grants to help subsidize their costs of construction. This, of course, reduces the amount of debt that has to be issued.
5. What is the history of labor-management relations, and can public-employee strikes substantially reduce toll collections?
6. When was the facility constructed? Generally, toll roads financed and constructed in the 1960s tend to be in better financial condition because the cost of financing was much less.
7. If the facility is a bridge that could be damaged by a ship and made inoperable, does the issuer have adequate use-and-occupancy insurance?

Those few toll revenue bonds that have defaulted have done so because of either unexpected competition from toll-free highways and bridges, poor traffic projections, or substantially higher than projected construction costs. An example of one of the few defaulted bonds is the West Virginia Turnpike Commission's Turnpike Revenue Bonds, issued in 1952 and 1954 to finance the construction of an 88-mile expressway from Charleston to Princeton, West Virginia. The initial traffic-engineering estimates were overly optimistic, and the construction costs came in approximately \$37 million higher than the original budgeted amount of \$96 million. Because of insufficient traffic and toll collections, between 1956 and 1979 the bonds were in default. By the late 1970s with the completion of various connecting cross-country highways, the turnpike became a major link for interstate traffic. The bonds became self-supporting in terms of making interest coupon payments. It was not until 1989 that all the still-outstanding bonds were finally redeemed.

More recently, a new group of start-up toll roads has been financed with municipal bonds. The revenue projections for several roads turned out to be overly optimistic. Some have had to draw on the debt reserves. Others have had to be restructured and even defaulted. Examples include the Santa Rosa Bay Bridge Authority in Florida, the Southern Connector Toll Road in South Carolina, and the San Joaquin Toll Road in California.

Concerning the economics of highway revenue bonds that are not pure enterprise type but instead are secured by earmarked revenues, such as gasoline taxes, automobile registration payments, and driver's license fees, the investor should ask the following questions:

- Are the earmarked tax revenues based on state constitutional mandates, such as the state of Ohio's Highway Improvement Bonds, or are they derived from laws enacted by state legislatures, such as the state of Washington's Chapters 56, 121, and 167 Motor Vehicle Fuel Tax Bonds? A constitutional pledge is usually more permanent and reliable.
- What has been the coverage trend of the available revenues to debt service over the previous 10 years? Has the coverage been increasing, stable, or declining?
- If the earmarked revenue is a gasoline tax, is it based on a specific amount per gallon of gasoline sold or as a percentage of the price of each gallon sold? With greater conservation and more efficient cars, the latter tax structure is preferred because it is not as susceptible to declining sales of gasoline and because it benefits directly from any increased gasoline prices at the pumps.
- What has been the history of statewide gasoline consumption through recessions and oil shocks?

Hospital Revenue Bonds

Two unique features of hospitals make the analysis of their debt particularly complex and uncertain. The first concerns their sources of revenue, and the second concerns the basic structure of the institutions themselves.

During the past 45 years, the major sources of revenue for most hospitals have been (1) payments from the federal (Medicare) and combined federal-state (Medicaid) hospital reimbursement programs, and (2) payments from commercial insurers. How well the hospital management markets its service to attract more private-pay patients and commercial insurers, and how conservatively it budgets for the governmental reimbursement payments, which may not keep up with the annual rate of hospital expense increases, are key elements for distinguishing weak from strong hospital bonds.

Particularly for community-based hospitals (as opposed to teaching hospitals affiliated with medical schools), a unique feature of their financial structure is that their major financial beneficiaries, physicians, have no legal or financial liabilities if the institutions do not remain financially viable over the long term. An example of the problems that can be caused by this lack of liability is found in the story of the Sarpy County, Nebraska, Midlands Community Hospital Revenue Bonds. These bonds were issued to finance the construction of a hospital three miles south of Omaha, Nebraska, that was to replace an older one located in the downtown area. Physician questionnaires prepared for the feasibility study prior to the construction of the hospital indicated strong support for the replacement facility. Many doctors had used the older hospital in downtown Omaha as a backup facility for a larger nearby hospital. Unfortunately, once the new Sarpy hospital opened in 1976, many physicians found that the new hospital could not serve as a backup because it was 12 miles further away from the major hospital than the old hospital had been. Because these physicians were not referring their patients to the new Sarpy hospital, it was soon unable to make bond principal payments and was put under the jurisdiction of a court receiver.

The preceding factors raise long-term uncertainties about many community-based hospitals, but certain key areas of analysis and trends reveal the relative economic health of hospitals that already have revenue bonds outstanding. The first area is the liquidity of the hospital as measured by the ratio of dollars held in current assets to current liabilities. In general, a five-year trend of high values for the ratio is desirable because it implies an ability by the hospital to pay short-term obligations and thereby avoid budgetary problems. Days cash on hand is an important measure as well. The second indicator is the ratio of long-term debt to equity, as measured in the unrestricted end-of-year fund balance. In general, the lower the long-term debt to equity ratio, the stronger the finances of the hospital are. The third indicator is the actual debt service coverage of the previous five years, as well as the projected coverage. The fourth indicator is the annual bed-occupancy rates for the previous five years. The fifth is the percentage of physicians at the hospital who are professionally approved (board certified), their respective ages, and how many of them use the hospital as their primary institution.

For new or expanded hospitals, much of the preceding data are provided to the investor in the feasibility study. One item in particular that should be determined for a new hospital is whether the physicians who plan to use the hospital actually live in the area to be served by the hospital. Because of its importance in providing answers to these questions, the feasibility study must be prepared by reputable, experienced researchers.

Housing Revenue Bonds

For housing revenue bonds, the economic and financial questions vary according to the type of bond security involved. There are two basic types of housing revenue bonds, each with a different type of security structure. One is the housing revenue bond secured by *single-family* mortgages, and the other is the housing revenue bond secured by mortgages on *multifamily* housing projects.

Concerning single-family housing revenue bonds, the strongly secured bonds usually have five characteristics:

- The single-family home loan bonds are collateralized by GNMA, FNMA, or FHLMC securities; or the loans are insured by the Federal Housing Administration (FHA), Department of Veteran Affairs (VA), or an acceptable private mortgage insurer or its equivalent. If the individual home loans are not insured, then they should have a loan-to-value ratio of 80%

or less. Prior to 2007, many bonds had acceptable private mortgage insurance; it has not been used much in recent years due to the downgrading of insurers.

- If the conventional home loans have less than 100% primary mortgage insurance coverage, or are not backed by federal collateral, an additional 5% to 10% mortgage-pool insurance policy or its equivalent may be required. Like with primary PMI, this has not been used much in the last decade.
- In addition, there is over-collateralization of the bonds with mortgages or mortgage-backed securities, as well as investments. This is typical of State HFA indentures, which have open liens and regular new issues.
- The issuer of the single-family housing revenue bonds is in a region of the country that has stable or strong economic growth as indicated by increased real estate valuations, personal income, and retail sales, as well as low unemployment rates. This is more of a factor for prepayment speeds.
- State housing finance agency support explicit or implicit.

In the 1970s, state agency issuers of single-family housing revenue bonds assumed certain prepayment levels in structuring the bond maturities. In recent years, most issuers have abandoned this practice but investors should review the retirement schedule for the single-family mortgage revenue bonds to determine whether or not the issuer has assumed large, lump-sum mortgage prepayments in the early year cash-flow projections. If so, how conservative are the prepayment assumptions, and how dependent is the issuer on the prepayments to meet the annual debt service requirements? Of course, while the focus of this chapter is on credit analysis, the investor should be aware that extraordinary redemptions of these bonds can occur from prepayments on the mortgages. Lately only one state housing agency still does this.

It should be noted that since the mid-1990s, issuers have adopted structures similar to those in the taxable mortgage-backed securities market that incorporate prepayment assumptions. In tax-exempt single-family housing bonds, these are usually the planned amortization class (PAC) structures, as well as passthroughs.

State issuing agencies usually have professional in-house staffs that closely monitor the home mortgage portfolios, whereas the local issuers do not. Finally, many state issuing agencies have accumulated substantial surplus funds over the years that can be viewed as an additional source of bondholder protection.

For multifamily housing revenue bonds, there are four specific, although overlapping, security structures. The first type of multifamily housing revenue bond is one in which the bonds are secured by federally insured mortgages. In the past, the federal insurance covers all but the difference between the outstanding bond principal and collectible mortgage amount (usually 1%), and all but the *nonasset* bonds (i.e., bonds issued to cover issuance costs and capitalized interest). The FHA

Risk Sharing Program with State FHAs now cover 100% of the mortgages upfront. The attractiveness of the federal insurance is that it protects the investor against bond default within the limitations outlined. The insurance protects the bondholders regardless of whether the projects are fully occupied and generating rental payments.

The second type of multifamily housing revenue bond is one in which the federal government subsidizes, under the HUD Section 8 program, all annual costs (including debt service) of the project not covered by tenant rental payments. Under Section 8, the eligible low-income and elderly tenants pay up to 30% of their incomes for rent. Because the ultimate security comes from the Section 8 subsidies, which normally escalate annually with the increased cost of living in that particular geographic region, the bondholder's primary risks concern the developer's ability to complete the project, find tenants eligible under the federal guidelines to live in the project, and then maintain high occupancy rates for the life of the bonds. The investor should carefully review the location and construction standards used in building the project, as well as the competency of the project manager in selecting tenants who will take care of the building and pay their rents. In this regard, state agencies that issue Section 8 bonds usually have stronger in-house management experience and resources for dealing with problems than do the local development corporations that have issued Section 8 bonds. It should be noted that the federal government has eliminated appropriations for new Section 8 projects. Since 1995, the federal government has restricted automatic rent increases under the Section 8 program. This has introduced financial pressure.

The third type of multifamily housing revenue bond is one in which the ultimate security for the bondholder is the ability of the project to generate sufficient monthly rental payments from the tenants to meet the operating and debt service expenses. Some of these projects may receive governmental subsidies (such as interest-cost reductions under the federal Section 236 program and property tax abatements from local governments), but the ultimate security is the economic viability of the project. Key information includes the location of the project, its occupancy rate, whether large families or the elderly will primarily live in the project, whether or not the rents necessary to keep the project financially sound are competitive with others in the surrounding community, and whether or not the project manager has a proven record of maintaining good service and of establishing careful tenant selection standards. Many of these unenhanced programs are financed with Low Income Housing Tax Credits which provide significant equity for the projects. These have superior performance, as opposed to "affordable housing" projects of non-profit issuers.

A fourth type of multifamily housing revenue bond is one that includes some type of private credit enhancement to the underlying real estate. These credit enhancements can include guarantees or sureties of an insurance company, securitization by Fannie Mae (Federal National Mortgage Association or FNMA), or a bank letter-of-credit.

Another feature of many multifamily housing revenue bond programs, particularly those issued by state housing agencies, is the state moral obligation pledge or a State FHA general obligation pledge. Several state agencies have issued housing revenue bonds that carry a potential state liability for making up deficiencies in their one-year debt service reserve funds, should any occur. In most cases, if a drawdown of the debt reserve occurs, the state agency must report the amount used to its governor and state budget director. The state legislature, in turn, may appropriate the requested amount, although there is no legally enforceable obligation to do so. Bonds with this makeup provision are called *moral obligation bonds*.

The moral obligation provides a state legislature with permissive authority—*not mandatory authority*—to make an appropriation to the troubled state housing agency. Therefore, the analysis should determine (1) whether the state has the budgetary surpluses for subsidizing the housing agency's revenue bonds, and (2) whether there is a consensus within the executive and legislative branches of that particular state's government to use state general fund revenues for subsidizing multifamily housing projects.

Industrial Revenue Bonds

Generally, industrial revenue bonds are issued by state and local governments on behalf of individual corporations and businesses. The security for the bonds usually depends on the economic soundness of the particular corporation or business involved. If the bond issue is for a subsidiary of a larger corporation, one question to ask is whether or not the parent guarantees the bonds. Is it obligated only through a lease, or does it not have any obligation whatsoever for paying the bondholders? If the parent corporation has no responsibility for the bonds, then the investor must look very closely at the operations of the subsidiary in addition to those of the parent corporation.

For companies that have issued publicly traded common stock, operating data are readily available in the quarterly (10-Q) and annual (10-K) financial reports that must be filed with the Securities and Exchange Commission. For privately held companies, financial data are more difficult to obtain.

In assessing the economic risk of investing in an industrial revenue bond, another question to ask is whether the bondholder or the trustee holds the mortgage on the property. Although holding the mortgage is not usually an important economic factor in assessing either hospital or low-income multifamily housing bonds in which the properties have very limited commercial value, it can be an important strength for the holder of industrial development revenue bonds. If the bond is secured by a mortgage on a property of a major retailer, or an industrial facility such as a warehouse, the property location and resale value of the real estate may provide some protection to the bondholder, regardless of what happens to the company that issued the bonds. Of course, the investor always should avoid possible bankruptcy situations regardless of the economic attractiveness of the particular piece of real estate involved. The reason is that the bankruptcy process usually involves years of litigation and numerous court hearings, about which no investor should want to be concerned.

Land-Secured "Dirt" Bonds

Public infrastructure costs associated with new development projects on raw land are often financed by land-secured bonds, also known as "dirt" bonds. Revenue from the additional tax or assessment placed on the properties benefitting from these improvements is the primary security for the bondholders. Additional security is provided by the ability of the sponsoring governmental entity to commence foreclosure or tax sales if property owners are delinquent on their taxes or assessments. Important credit factors to consider include: (1) Is the development's location, demographics, and competitive position favorable? (2) Does the developer possess sufficient experience and financial resources? (3) Is there a debt service reserve and other funds, and how are they funded? (4) Is the lien created by the tax/assessment fixed or variable, and what is the resulting debt service coverage provided? (5) Is the value of the land relative to the outstanding liens sufficient to discourage property owners from walking away?

Lease-Rental Bonds

Lease-rental bonds usually are structured as revenue bonds, and annual payments, paid by a state or local government, cover all costs including operations, maintenance, and debt service. It should be noted that many Certificate of Participation Bonds, or COPs, are similar in security structure in that they too are dependent on the annual legislative appropriation process. The public purposes financed by these bond issues include public office buildings, fire houses, police stations, university buildings, mental health facilities, and highways, as well as office equipment and computers. In some instances, the payments may come from student tuition, patient fees, and earmarked tax revenues, and the state or local government is not legally obligated to make lease-rental payments beyond the amount of available earmarked revenues. However, for many lease-rental bonds, the underlying lessee state, county, or city is to make payment from its general fund subject to annual legislative appropriation. For example, the Albany County, New York, Lease Rental South Mall Bonds were issued to finance the construction of state office buildings. Although the bonds were technically general obligations of Albany County, the real security came from the annual lease payments made by the State of New York. These payments were appropriated annually. For such bonds, the basic economic and financial analysis should follow the same guidelines as for general obligation bonds.

Public Power Revenue Bonds

Public power revenue bonds are issued to finance the construction of electrical generating plants. An issuer of the bonds may construct and operate one power plant, buy electric power from a wholesaler and sell it retail, construct and operate several power plants, or join with other public and private utilities in jointly financing the construction of one or more power plants. This last arrangement is known as a joint-power financing structure may require the participating underlying municipal electric systems to pay the bondholders whether or not the plants are completed and operating, the focus here is how the investor determines which power projects will be financially self-supporting without the backup security feature.

There are at least five major questions to ask when evaluating the investment soundness of a public power revenue bond:

- Does the bond issuer have the authority to raise its electric rates in a timely fashion without going to any regulatory agencies? This is particularly important if substantial rate increases are necessary to pay for new construction or plant improvements.
- How diversified is the customer base among residential, commercial, and industrial users?
- Is the service area growing in terms of population, personal income, and commercial/industrial activity so as to warrant the electrical power generated by the existing or new facilities?
- Are rates competitive with neighboring IOUs?
- What are the projected and actual costs of power generated by the system, and how competitive are they with other regions of the country? Power rates are particularly important for determining the long-term economic attractiveness of the region for industries that are large energy users.
- How diversified is the fuel mix? Is the issuer dependent on one energy source such as hydro dams, oil, natural gas, coal, or nuclear fuel?

Concerning electrical generating plants fueled by nuclear power, the aftermath of the Three Mile Island nuclear accident in 1979 has resulted in greater construction and maintenance reviews and costly safety requirements prompted by the Federal Nuclear Regulatory Commission (NRC). The NRC oversees this industry. In the past, although nuclear power plants were expected to cost far more to build than other types of power plants, it also was believed that once the generating plants became operational, the relatively low fuel and maintenance costs would more than offset the initial capital outlays. However, with the increased concern about public safety brought about by the Three Mile Island accident, repairs and design modifications are now expected to be made even after plants begin to operate. Of course, this increases the ongoing costs of generating electricity and reduces the attractiveness of nuclear power as an alternative to the other fuels such as natural gas.

Public-Private Partnerships

Privatization is a form of municipal financing where a private company pays a large payment to operate, and often build or improve, a governmental asset (e.g., usually toll roads). The purchaser issues debt to help finance this large upfront cost, and the operating revenues are pledged to repay bondholders. The bonds issued are referred to as private-placement partnership bonds (PPP). Important questions to ask about these bonds are: (1) What is the length of the concession agreement? (2) How are prices or tolls set? (3) Does the governmental entity share in any revenue? (4) Are there any noncompete provisions? (5) What levels of maintenance, capital expenditures, and service are required? (6) What are the conditions and repercussions for nonperformance? (7) What are the assumptions and conclusions of any feasibility study performed? and (8) What is the experience and financial resources of the contractor/operator?

Tobacco Revenue Bonds

Some tobacco bonds are solely secured by revenues in the Master Settlement Agreement (MSA) annually paid to states by cigarette companies. Important credit issues include: (1) the credit quality of the cigarette companies making the annual payments; (2) the consumption assumptions used in sizing the original bond issue, i.e., the degree of leveraging used; (3) current consumption trends and their impacts on cash flows and debt coverage; and (4) the status of the various court cases.

Tribal Casino Bonds

Native American governments in general finance the construction of their casino gaming facilities by issuing debt. Tribal casino bonds derive their revenues from the gaming operations of these facilities. Given the limited diversity of the revenue streams and the lack of hard collateral assets, evaluating the future viability and profitability of the new gaming facility is essential, including analysis of the relevant demographics, competitive factors, and quality of casino management. Buyers should also assess the financial strength, governance structure, and development project expertise of the issuing tribal entity. Other issues to consider include whether the cash trapping and debt service reserve fund features of the issued debt are sufficient, any gaming compact and revenue-sharing arrangements with state governments, and potential regulatory changes.

Water and Sewer Revenue Bonds

Water and sewer revenue bonds are issued to provide for a local community's basic needs and as such are not usually subject to general economic changes. Because of the vital utility services performed, their respective financial structures are usually designed to have the lowest possible user charges and still remain financially viable. Generally, rate covenants requiring that user charges cover operations, maintenance, and approximately 1.2 times annual debt service and reserve requirements are most desirable. On the one hand, a lower rate covenant provides a smaller margin for unanticipated slow collections or increased operating and plant maintenance costs caused by inflation. On the other hand, rates that generate revenues more than 1.2 times the annual debt service and reserve requirements could cause unnecessary financial burdens on the users of the water and sewer systems.

A useful indication of the soundness of an issuer's operations is to compare the water or sewer utility's average quarterly customer billings to those of other water or sewer systems. Assuming that good customer service is given, the water or sewer system that has a relatively low customer billing charge generally indicates an efficient operation and therefore strong bond-payment prospects.

Key questions for the investor to ask include the following:

- Has the bond issuer, through local ordinances, required mandatory water or sewer connections? Also, local board of health directives against well water contamination and septic tank usage can often accomplish the same objective as the mandatory hookups.
- Does the issuer have to comply with an EPA consent decree and thereby issue significant amounts of bonds?
- What is the physical condition of the facilities in terms of plant, lines, and meters, and what capital improvements are necessary for maintaining the utilities as well as for providing for anticipated community growth?
- For water systems in particular, it is important to determine if the system has water supplies in excess of current peak and projected demands. An operating system at less than full utilization is able to serve future customers and bring in revenues without having to issue additional bonds to enlarge its facilities.
- What is the operating record of the water or sewer utility for the previous five years?
- If the bond issuer does not have its own distribution system but instead uses other participating local governments that do, are the charges or fees based on the actual water flow drawn (for water revenue bonds) and sewage treated (for sewer revenue bonds) or on gallonage entitlements?
- For water revenue bonds issued for agricultural regions, what crop is grown? An acre of oranges or cherries in California will provide the grower with more income than will an acre of corn or wheat in Iowa.
- For expanding water and sewer systems, does the issuer have a record over the previous two years of achieving net income equal to or exceeding the rate covenants, and will the facilities to be constructed add to the issuer's net revenues?
- Has the issuer established and funded debt and maintenance reserves to deal with unexpected cash-flow problems or system repairs?
- Does the bond issuer have the power to place tax liens against the real estate of those who have not paid their water or sewer bills? Although the investor would not want to own a bond for which court actions of this nature would be necessary, the legal existence of this power usually provides an economic incentive for water and sewer bills to be paid promptly by the users.

Additional bonds should be issued only if the need, cost, and construction schedule of the facility have been certified by an independent consulting engineer and if the past and projected revenues are sufficient to pay operating expenses and debt service. Of course, for a new system that does not have an operating history, the quality of the consulting engineer's report is of the upper-most importance.

RED FLAGS FOR THE INVESTOR

In addition to the areas of analysis just described, certain red flags, or negative trends, suggest increased credit risks.

For General Obligation Bonds

For general obligation bonds, the signals that indicate a decline in the ability of a state, county, town, city, or school district to function within fiscally sound parameters include the following:

- Declining property values and increasing delinquent taxpayers
- An annually increasing tax burden relative to other regions
- An increasing property tax rate in conjunction with a declining population
- Declines in the number and value of issued permits for new building construction
- Actual general fund revenues consistently falling below budgeted amounts
- Increasing end-of-year general fund deficits
- Budget expenditures increasing annually in excess of the inflation rate
- The unfunded pension liabilities are increasing
- General obligation debt increasing while property values are stagnant
- Declining economy as measured by increased unemployment and declining personal income

For Revenue Bonds

For revenue bonds, the general signals that indicate a decline in credit quality include the following:

- Annually decreasing coverage of debt service by net revenues
- Use of debt reserve and other reserves by the issuer
- Growing financial dependence of the issuer on unpredictable federal and state-aid appropriations for meeting operating budget expenses
- Chronic lateness in supplying investors with annual audited financials
- Unanticipated cost overruns and schedule delays on capital construction projects
- Frequent or significant rate increases
- Deferring capital plant maintenance and improvements
- Excessive management turnovers
- Shrinking customer base
- New and unanticipated competition

INFORMATION SOURCES FOR THE ANALYST

The Official Statement

An official statement describing the issue and the issuer is prepared for new offerings. A preliminary official statement is issued prior to the final official statement. These statements are known as the OS and POS. These statements provide potential investors with a wealth of information. The statements contain basic information about the amount of bonds to be issued, maturity dates, coupons, the use of the bond proceeds, the credit ratings, a general statement about the issuer, and the name of the underwriter and members of the selling group. Much of this information can be found on the cover page or in the first few pages of the official statement. It also contains detailed information about the security and sources of payments for the bonds, sources and uses of funds, debt service requirements, relevant risk factors, issuer's financial statements, a summary of the bond indenture, relevant agreements, notice of any known existing or pending litigation, the bond insurance policy specimen (if insured), and the form of opinion of bond counsel. The official statement contains most of the information an investor will need to make an informed and educated investment decision.

Continuing Disclosure Under Rule 15c2-12

Rule 15c2-12, which took effect in 1995, required dealers to determine that issuers before issuing new municipal bonds made arrangements to disclose in the future financial information *at least* annually as well as notices of the occurrence of any of 11 "material event notices" as specified in the rule. By the beginning of 2020, the amended rule contained 16 material event notices. Also by 2020, the annual report and notices of material events are to be filed with the Municipal Securities Rulemaking Board (MSRB), in an electronic format as prescribed by the MSRB. The MSRB designated its Electronic Municipal Market Access system (EMMA), found at http://emma.msrb.org as the sole repository for such disclosure filings.

It should be noted that many issuers, such as hospitals, toll roads, and CCRCs provide unaudited interim information to bondholders on a quarterly and even a monthly basis.

The National Federation of Municipal Analysts

The National Federation of Municipal Analysts (NFMA) was established in 1983 and by 2020 had a membership of 1,000 municipal professionals, drawing in part from the institutional investors in municipal bonds who advocated increased and timely information for investors. By 2020, its committees have developed detailed disclosure guidelines and risk factors in municipal securities ranging from specific credit sectors to swap structures. They are recommended for municipal bond issuers to use in providing ongoing financial and operating information to investors and analysts. The web site is www.nfma.org.

The Governmental Standards Accounting Board

The Governmental Standards Accounting Board (GSAB) is a nonprofit organization that sets generally accepted accounting standards (GAAP) for state and local governments. Established in 1984 it provides detailed guidelines. For many years it has improved financial reporting standards in reports of state and local governments that are used by analysts, auditors, and other users. By improving the transparency of state and local government accounting, it helps prevent issuers from obfuscating budget deficits and long-term liabilities that in the past had resulted in budgetary disasters and bond defaults.[1]

KEY POINTS

- The five categories of inquiry when analyzing the creditworthiness of a general obligation, tax-backed, or pure revenue bond are (1) legal documents and opinions, (2) politics/management, (3) underwriter/financial advisor, (4) general credit indicators and economics, and (5) red flags, or danger signals.
- From the perspective of the bondholder, the legal opinions and document reviews should be the ultimate security provisions. The reason is that if all else fails, the bondholder may have to go to court to enforce his or her security rights. The relationship of the legal opinion to the analysis of municipal bonds for both general obligation and revenue bonds is the following: (1) the attorney should check to determine whether the issuer is indeed legally able to issue the bonds; (2) the attorney is to see that the issuer has properly prepared for the bond sale by enacting the various required ordinances, resolutions, and trust indentures and without violating any other laws and regulations; and (3) the attorney is to certify that the security safeguards and remedies provided for the bondholders and pledged by either the bond issuer or third parties are actually supported by federal, state, and local government laws and regulations.
- Before purchasing a municipal bond the investor should investigate whether the issuer's officials (1) are conscientious public servants with clearly defined public goals; (2) have a history of successful management of public institutions; and (3) have demonstrated commitments to professional and fiscally stringent operations. In addition, it is important to scrutinize closely (and possibly avoid) issuers in highly charged and partisan environments in which conflicts chronically occur between political parties or among political factions or personalities.

1. The website is www.gasb.org.

- Indicators of the quality of the investment are (1) who the issuer selected as its financial advisor, if any; (2) its principal underwriter if the bond sale was negotiated; and (3) its financial advisor if the bond issue came to market competitively. It is also useful to find out who was the underwriter for the issue.
- An analytical factor to consider in assessing the creditworthiness of an issue is the economic health or viability of the bond issuer or specific project financed by the bond proceeds. The economic factors cover a variety of concerns. When analyzing general obligation bond issuers, the specific budgetary and debt characteristics of the issuer, as well as the general economic environment should be investigated. For project-financing, or enterprise, revenue bonds, the economics are limited primarily to the ability of the project to generate sufficient charges from the users to pay the bondholders. In the case of revenue bonds that rely not on user charges and fees, but instead on general purpose taxes and revenues, the analysis should take basically the same approach as for the general obligation bonds. For these bonds, the taxes and revenues diverted to the bondholders would otherwise go to the state's or city's general fund.

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CHAPTER

FORTY-TWO

CREDIT-RISK MODELING

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Since the turn of the century, we have seen many theoretical developments in the field of credit-risk research. In view of the large-scale changes in market conditions, the entry of more sophisticated market participants, and the increase in complexity of investable assets, most of the research has focused on pricing of corporate debts. But many of these models have failed to describe real-world phenomena such as credit-spreads realistically. This practitioner-oriented chapter attempts to describe the history and future of modeling credit-risk and valuation of credit-risky assets.

Credit-risk is the distribution of financial losses owing to unexpected changes in the credit quality of the counterparty in a financial agreement. Examples range from agency downgrades to failure to service debt to liquidation. Credit-risk pervades virtually all financial transactions. The distribution of credit losses is complex. At its center is the probability of default, by which we mean any type of failure to honor a financial agreement. To estimate the probability of default, we need to specify

- A model of investor uncertainty
- A model of the available information and its evolution over time
- A model definition of the default event

However, default probabilities alone are not sufficient to price credit-sensitive securities. We need, in addition,

- A model for the risk-free interest rate
- A model of recovery on default
- A model of the premium investors require as compensation for bearing systematic credit-risk

The credit premium maps actual default probabilities to market-implied probabilities that are embedded in market prices. To price securities that are sensitive to the credit-risk of multiple issuers and to measure aggregated portfolio credit-risk, we also need to specify

- A model that links defaults of different entities

There are three main quantitative approaches to analyzing credit. In the *structural approach,* we make explicit assumptions about the dynamics of a firm's assets, its capital structure, and its debt and shareholders. A firm defaults if its assets are insufficient according to some measure. In this situation, a corporate liability can be characterized as an option on the firm's assets. The *reduced-form approach* is silent about why a firm defaults. Instead, the dynamics of default are given exogenously through a default rate, or intensity. In this approach, prices of credit-sensitive securities can be calculated as if they were default-free using an interest rate that is the risk-free rate adjusted by the intensity. The *incomplete-information approach* combines the structural and reduced-form models. While avoiding their difficulties, it picks the best features of both approaches: the economic and intuitive appeal of the structural approach and the tractability and empirical fit of the reduced-form approach.

In this chapter we review the three approaches in the context of the multiple facets of credit modeling that were just mentioned. Our goal is to provide a concise overview and a guide to the large and growing literature on credit-risk.[1]

STRUCTURAL CREDIT MODELS

The basis of the structural approach, which goes back to Black and Scholes[2] and Merton,[3] is that corporate liabilities are contingent claims on the assets of a firm. The market value of the firm is the fundamental source of uncertainty driving credit-risk.

Classical Approach

Consider a firm with market value V, which represents the expected discounted future cash flows of the firm. The firm is financed by equity and a zero-coupon bond with face value K and maturity date T. The firm's contractual obligation is to repay the amount K to the bond investors at time T. Debt covenants grant bond investors absolute priority: if the firm cannot fulfill its payment obligation, then bondholders immediately will take over the firm.

1. A more mathematical introduction can be found in Kay Giesecke, "Credit-Risk Modeling and Valuation: An Introduction," in David Shimko (ed.), *Credit-Risk: Models and Management,* Vol. 2 (London: Riskbooks, 2004).
2. Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81 (1973), pp. 81–98.
3. Robert C. Merton, "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29 (1974), pp. 449–470.

EXHIBIT 42-1

Default Interpretation in the Classical Approach

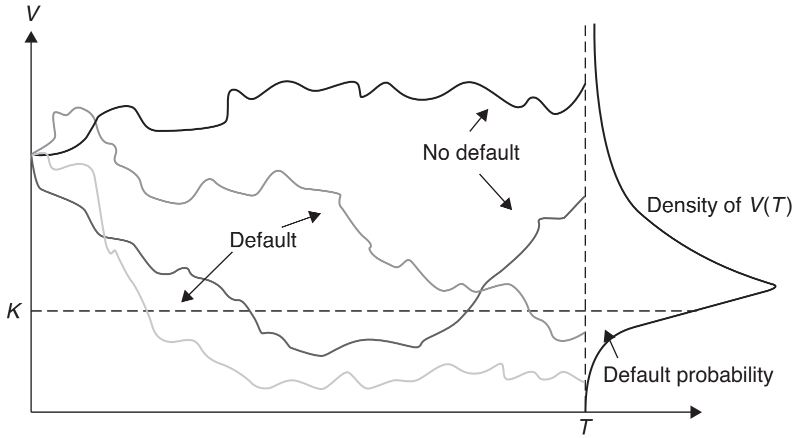


Exhibit 42-1 shows several possible paths of firm value. Default occurs if the firm value at maturity is less than the face value of the debt K. The particular path the firm value has taken does not matter here; only the firm value at T is important. The probability of default therefore is equal to the probability that firm value is below debt face value at maturity. To calculate this probability, we make assumptions about the distribution of firm value at debt maturity. The standard assumption is that firm value is log-normally distributed. The probability of default then is given as the area under the log-normal firm value density between 0 and face value, as shown in the graph. This probability can be calculated explicitly in terms of K, the current firm value $V(0)$, the volatility of firm value, the growth rate of firm value and T.

Assuming that the firm can neither repurchase shares nor issue new senior debt, the payoffs to the firm's liabilities at debt maturity T are as summarized in Exhibit 42-2. If the asset value $V(T)$ exceeds or equals the face value K of the bonds, the bondholders will receive their promised payment K, and the shareholders will get the remaining $V(T) - K$. However, if the value of assets $V(T)$ is

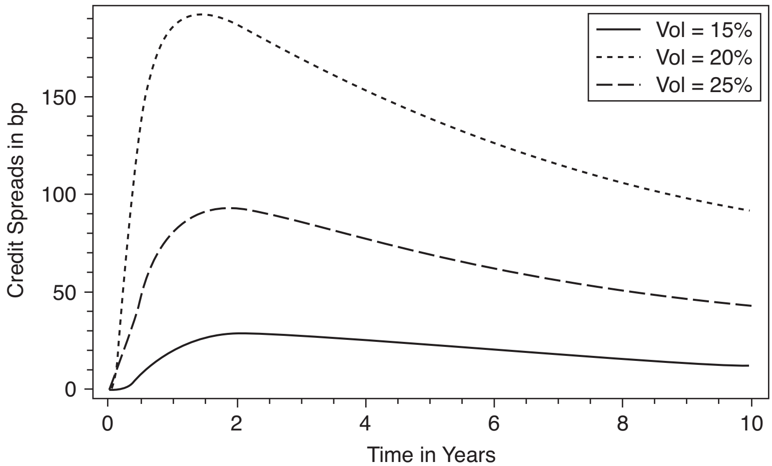
EXHIBIT 42-2

Payoffs at Maturity in the Classical Approach

Event Description	Assets	Debt	Equity
No default	$V(T) \geq K$	K	$V(T) - K$
Default	$V(T) < K$	$V(T)$	0

EXHIBIT 42-3

Term Structure of Credit-Spreads, Varying Asset Volatility, in the Classical Approach



less than K, the ownership of the firm will be transferred to the bondholders, who lose the amount $K - V(T)$. Equity is worthless because of limited liability.

Summarizing, the value of the bond is equivalent to that of a portfolio composed of a default-free loan with face value K maturing at time T and a short European put position on the assets of the firm with strike K and maturity T. The value of the equity is equivalent to the payoff of a European call option on the assets of the firm with strike K and maturity T. Pricing equity and credit-risky debt thus reduces to pricing European options.

The credit-spread is the difference between the yield on a defaultable bond and the yield on an otherwise equivalent default-free zero bond. It gives the excess return demanded by bond investors to bear the potential default losses. The credit-spread is a function of maturity T, asset volatility (the firm's business risk), the initial leverage ratio $K/V(0)$, and risk-free rates.

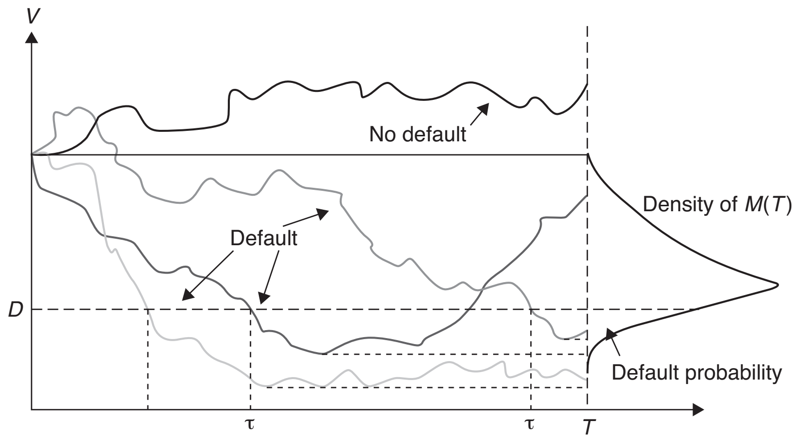
Letting initial leverage be 80% and risk-free rates be 6%, in Exhibit 42-3 we plot the model term structure of credit-spreads for varying asset volatilities. We see clearly that as asset volatility (business risk) rises, then so does the spread required by the market to compensate for the risk of default. Other noticeable traits of this graph are the rapid fall to zero spreads at short maturities and the more pronounced hump-shaped curve as volatility rises higher.

First-Passage Approach

In the classical approach, firm value can dwindle to almost nothing without triggering default. This is unfavorable to bondholders, as noted by Black and

EXHIBIT 42-4

Default in the First-Passage Approach



Cox.[4] Bond indenture provisions often include safety covenants that give bond investors the right to reorganize a firm if its value falls below a given barrier.

First-passage time models generalize the classical model such that a default can occur not only at maturity of the debt contract but also at any point of time. They assume that default happens if the firm value V hits a specified default barrier D. The default barrier in general can be a stochastic process, as is the firm value. For tractability reasons, however, one often works with a simple time-dependent, nonstochastic barrier specification, or just a constant barrier.

Suppose that the default barrier D is a constant between zero and the initial firm value—this is reasonable because we would expect liabilities to be nonnegative and less than current assets. Then the default time is more realistically defined as when the value of the firm crosses below the default barrier. In other words, firms can default at times other than debt maturity. This relaxation of the European nature of the default event in the classical approach provides some more realistic behavior.

Exhibit 42-4 shows several possible paths of firm value and a constant default barrier D. Suppose for the moment that D is equal to the face value of the firm's debt. Default occurs if the firm value falls, at any time before the horizon T, below the default barrier. As shown, different firm-value paths correspond to different default times. Unlike the classical model discussed earlier, here the entire path the firm value follows is relevant. Firm-value paths that imply survival in the classical approach can

4. Fischer Black and John C. Cox, "Valuing Corporate Securities: Some Effects of Bond Indenture Provisions," *Journal of Finance* 31 (1976), pp. 351–367.

imply default in the first-passage approach. Therefore, the first-passage approach implies higher probabilities of default than the classical approach.

The probability of default is given by the probability that the minimum firm value at the horizon $M(T)$ is lower than the barrier D. In order to calculate this probability, we make an assumption about the distribution of future firm values, as in the classical approach. This determines also the distribution of the minimum firm value at the horizon. With log-normal firm values, this distribution is inverse Gaussian. The default probability is given as the area under the inverse Gaussian density curve between 0 and the default barrier D.

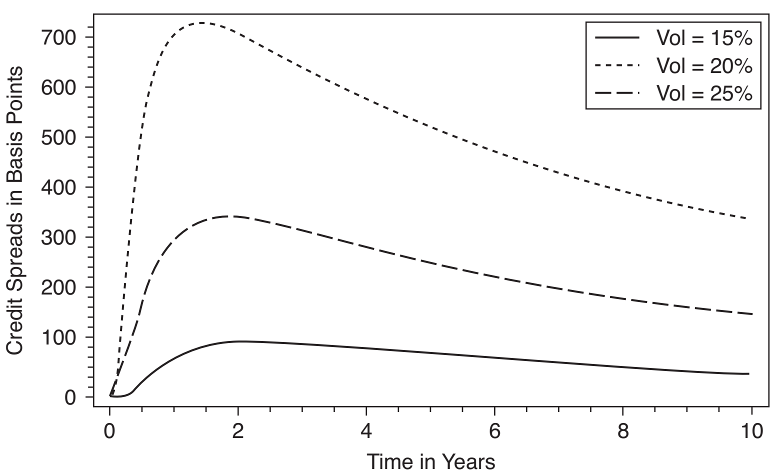
We consider the payoff to investors in the firm's liabilities. For simplicity, we assume that the default barrier is equal to the face value of firm debt. If the firm value never fell below the barrier over the term of the bond, then bond investors receive the bond's face value K and equity investors would receive the remaining $V(T) - K$. However, if the firm falls below the barrier at some point during the bond's term, then the firm defaults. In this case the firm stops operating, bond investors take over its remaining assets, and equity investors receive nothing.

Therefore, the equity position is equivalent to that of a down-and-out call on firm assets with strike equal to the face value of the debt, barrier level equal to the default barrier, and maturity equal to debt maturity. The value of the debt is given as the difference between firm value and equity value. Pricing equity and credit-risky debt thus reduces to pricing European barrier options.

We consider the credit-spread implied by a first-passage model in Exhibit 42-5. We assume that the default barrier is constant and equal to the face value of the bonds. We set leverage equal to 60% and risk-free rates to 6%,

EXHIBIT 42-5

Term Structure of Credit-Spreads, Varying Asset Volatility, in the First-Passage Model



as in Exhibit 42-3. We assume that in the event of default, bond investors recover a fraction of 50% of their initial investment.

With increasing maturity T, the spread asymptotically approaches zero. This is at odds with empirical observation; for many firms, spreads tend to increase with increasing maturity, reflecting the fact that uncertainty is greater in the distant future than in the near term. This discrepancy follows from two model properties: the firm value grows at a positive (risk-free) rate, and the capital structure is constant and assumed known with certainty. We can address this issue by assuming that the total debt grows at a positive rate or that firms maintain some target leverage ratio as in Collin-Dufresne and Goldstein.[5] A critical insight from this plot is that the level of spreads in the first-passage model is much higher and much more realistic than in the classical model. This is due to the fact that default probabilities are higher in the first-passage approach, as we discussed earlier.

Dependent Defaults

Credit-spreads of different issuers are correlated through time. Two patterns are found in time series of spreads. The first is that spreads vary smoothly with general macroeconomic factors in a correlated fashion. This means that firms share a common dependence on the economic environment, which results in cyclic correlation between defaults. The second relates to the jumps in spreads: we observe that these are often common to several firms or even entire markets. This suggests that the sudden large variation in the credit-risk of one issuer, which causes a spread jump in the first place, can propagate to other issuers as well. The rationale is that economic distress is contagious and propagates from firm to firm. A typical channel for these effects are borrowing and lending chains. Here the financial health of a firm also depends on the status of other firms as well.

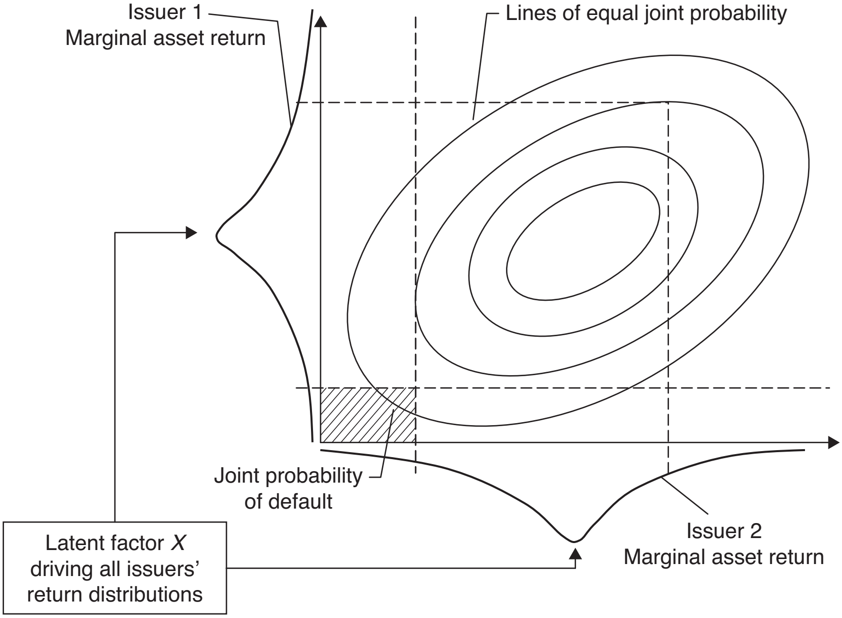
We want to incorporate these two default correlation mechanisms into the structural approach to credit. To introduce cyclic correlation, it is natural to assume that firm values of several firms are correlated through time. This corresponds to common factors driving asset returns. We consider the simplest case with two firms whose firm values are log normal. Our definition of default follows the classical approach.

Exhibit 42-6 illustrates the situation. The axes show the marginal asset return distributions of the two firms. Individual asset returns are normally distributed, hence the bell shape. Individual returns are modeled through a linear factor model, which represents systematic and firm-specific risk. Systematic risk is modeled by a common latent factor X, which drives the systematic variation in the asset returns of both firms. The sensitivity of a firm's return to this common factor controls the asset correlation across firms. This asset correlation drives the default correlation between firms.

5. Pierre Collin-Dufresne and Robert Goldstein, "Do Credit-Spreads Reflect Stationary Leverage Ratios?" *Journal of Finance* 56 (2001), pp. 1929–1958.

EXHIBIT 42-6

Illustrative Example of Structural-Based Joint Default Modeling



The elliptical shapes represent lines of equal joint asset value probability. The shaded area on the bottom left illustrates the joint default probability, as defined by the area under which issuer 1's asset value is below its default barrier and issuer 2's is below its default barrier.

Asset correlation captures the dependence of firms on common economic factors in a natural way. Modeling default contagion effects is much more difficult. A straightforward idea is to consider a jump-diffusion model for firm value. We would stipulate that a downward jump in the value of a given firm triggers subsequent jumps in the firm values of other firms with some probability. This would correspond to the propagation of economic distress. This approach is difficult, however, because of the lack of closed-form results on the joint distribution of firms' historical asset lows. This is what we need to calculate the probability of joint default.

A more successful attempt is to introduce interaction effects through the default barriers D_i. Suppose that the barrier is random and depends on the firm's liquidity state, which, in turn, depends on the default status of the firm's counterparties. If a firm's liquidity reserves are stressed owing to a payment default of a counterparty, it finances the loss by issuing more debt. This increases the default, barrier: the firm is now more likely to default, all else being equal. With no counterparty defaults the default barrier remains unaffected. This model allows a closed-form approximation of the credit portfolio loss distribution.

Credit Premium

Issuers of credit-sensitive securities share a common dependence on the economic environment. It follows that aggregated credit-risk cannot be diversified away. This undiversifiable or systematic risk commands a premium, which compensates risk-averse investors for assuming credit-risk.

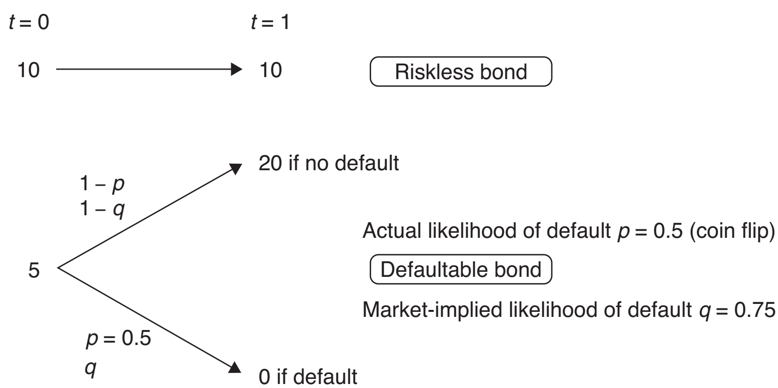
The credit premium is empirically well documented. Its importance relates to the uses of a quantitative credit model. As a default probability forecasting tool, a credit model must reflect the historical default experience. As a tool for pricing credit-sensitive securities, it must fit observed market prices. To make use of both market data and historical default data in the calibration and application of a credit model, we need to understand the relationship between actual defaults and defaultable security prices.

Here the risk premium comes into play: it maps the actual likelihood of default $p(T)$ into the market-implied likelihood of default $q(T)$ that is embedded in security prices.

We examine the difference between the two using a simple example in Exhibit 42-7. We consider a one-period market with two securities, a risk-free bond paying 10 and trading at 10 (risk-free rates are zero) and a defaultable bond trading at 5 that pays 20 in case of no default and zero in case the issuer defaults by the end of the trading period.

EXHIBIT 42-7

Real-World vs. Market-Implied Probability of Default



Suppose that the actual probability of default is $p = 0.5$ (50%, or a coin flip). This is, however, not the probability the market uses for pricing the bond: it would lead to a price of $p20 + (1 - p)0 = 10$, which is double the price at which the bonds are actually trading. At this price, risk-averse investors would rather put their money into the risk-free bond that costs 10 as well, unless they get a discount as compensation for the default risk. The market requires a discount of 5, and the corresponding price reflects the market-implied probability of default q, which satisfies $5 = (1 - q)20$. This yields $q = 0.75$ (75% probability of default), which is bigger than the actual probability of default $p = 0.5$.

To account for risk aversion in calculating the expected payoff of the defaultable bond, the market puts more weight on the unfavorable states of the world in which the firm defaults. In the structural credit models with firm value dynamics as described previously and constant risk-free rates, the situation is only a little more complicated.

In the absence of arbitrage opportunities, the credit-risk premium α is uniquely determined through market prices of credit-sensitive securities such as equity or debt and is measured as the excess return on firm assets over the risk-free return per unit of firm risk measured in terms of asset volatility. If the market is risk-averse, then α is positive: investors in credit-risky firm assets require a return that is higher than the risk-free return. The excess return on any credit-sensitive security is given by its volatility times α.

Calibration

The calibration of a quantitative credit model is closely related to its use. To price single-name credit-sensitive securities using a structural model, we need to calibrate the risk-free rate, the asset volatility, the asset value, the face value of the debt, the default barrier, and the maturity of the debt. The default barrier is relevant only in the first-passage approach. To use the model to forecast actual default probabilities, we need to calibrate additionally the growth rate of firm assets or, equivalently, the credit-risk premium α. In a multiple-firm setting we need to estimate asset correlations in addition to the single-name parameters.

Firm values are not observable. The goal is to estimate the parameters of the firm-value process based on equity prices, which can be observed for public firms. Risk-free interest rates can be estimated from default-free Treasury bond prices via standard procedures. We bypass estimation of face value and maturity of firm debt from balance-sheet data, which is nontrivial given the complex capital structure of firms. In practice, these parameters often are fixed ad hoc, as some average of short- and long-term debt, for example. We introduce a more reasonable solution to this problem later.

We consider the classical approach, as briefly discussed earlier. Given equity prices and equity volatilities, Jones, Mason, and Rosenfeld and many others suggest to back out asset values and asset volatilities by numerically solving a system of two equations.[6] The first equation relates the equity price to asset value, time, and asset volatility and follows from the Black-Scholes pricing function for a European call with strike *K* and maturity *T*. The second equation relates the equity price to asset and equity volatility, the delta of equity, and asset value. This relation is obtained from applying Ito's formula to the first equation.

We can use these two equations to "translate" a time series of equity values into a time series of asset values and volatilities. As for the equity volatility, we can use the empirical standard deviation of equity returns or a true forecasting model such as Barra Equity Risk models. Given a time series of asset returns, the empirical growth rate yields an estimate of the market price of credit-risk. The estimate of the firm growth rate, however, is very poor: it is based on two asset-return observations only.

Further, given the asset-return time series of several firms, asset correlation can be estimated. Alternatively, we can introduce a linear-factor model for normally distributed asset returns that expresses the idea that firms share a common dependence on general economic factors. This is similar to the idea we discussed earlier.

Can We Predict the Future?

To a certain extent, users of structural models implicitly assume that they can. In structural models, firm value is the single source of uncertainty that drives credit-risk. Investors observe the distance of default as it evolves over time. If the firm value has no jumps, this implies that the default event is not a total surprise. There are "predefault events" that announce the default of a firm. In the first-passage approach, we can think of a predefault event as the first time assets fall dangerously close to the default barrier (see Exhibit 42-8).

This has significant implications for the fitting of structural models to market prices. First, since default can be anticipated, the model price of a credit-sensitive security converges continuously to its recovery value. Second, the model credit-spread tends to zero with time to maturity going to zero.[7] Quite telling in this regard are the credit-spreads implied by the classical and first-passage approaches (see Exhibits 42-3 and 42-5). Both properties are at odds with intuition and market reality. Market prices do exhibit surprise downward jumps on default. Even for very short maturities in the range of weeks, market credit-spreads remain positive. This indicates that investors do have substantive short-term uncertainty about defaults, in contrast to the predictions of the structural models.

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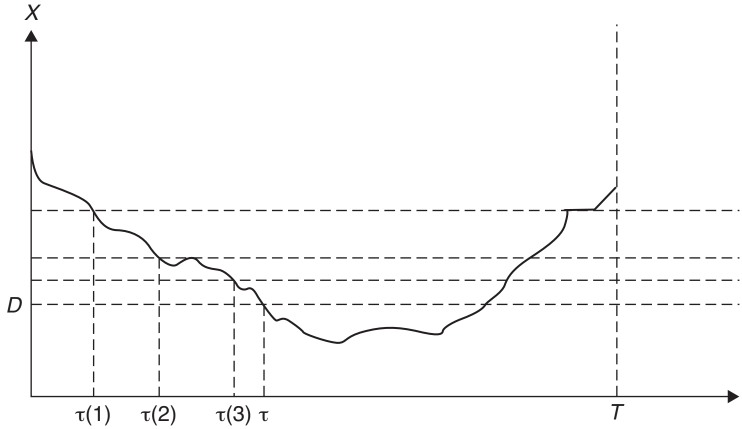
6. E. Jones, Scott Mason, and Eric Rosenfeld, "Contingent Claims Analysis of Corporate Capital Structures: An Empirical Investigation," *Journal of Finance* 39 (1984), pp. 611–627.
7. See Kay Giesecke, "Default and Information," *Journal of Economic Dynamics and Control*, 30 (2006), pp. 2281–2303.

EXHIBIT 42-8

Announcing the Default Timing by a Sequence of "Predefault" Events in the First-Passage Approach



REDUCED-FORM CREDIT MODELS

Reduced-form models were developed in the 1990s.[8] Here we assume that default occurs without warning. This means that investors face short-term credit-risk, which is absent from the structural models discussed previously. This is a desirable model property because it allows us to fit the model to market credit-spreads.

Default Intensity

The rate at which default occurs is called the *default intensity,* and we denote it by λ. We can think of the *intensity* at time t as the conditional probability that default will happen immediately, given that the firm has escaped default by t. As such, it describes the short-term credit-risk investors face.

The intensity is the central ingredient of all reduced-form models. It is modeled as a (nonnegative) stochastic process under the market-implied probability. The time evolution of the intensity reflects changes in the instantaneous default probability of a firm. The intensity model is calibrated from market prices

8. See Philippe Artzner and Freddy Delbaen, "Default Risk Insurance and Incomplete Markets," *Mathematical Finance* 5 (1995), pp. 187–195; Robert A. Jarrow and Stuart M. Turnbul, "Pricing Derivatives on Financial Securities Subject to Credit-Risk," *Journal of Finance* 50 (1995), pp. 53–86; and Darrell Duffie and Kenneth J. Singleton, "Modeling Term Structures of Defaultable Bonds," *Review of Financial Studies* 12 (1999), pp. 687–720.

of credit-sensitive securities issued by the firm. There is a one-to-one relation between the intensity and the corresponding default probabilities.

We give two simple but useful specifications for the intensity and the corresponding default probabilities.

- *Example 1*. Suppose that λ is a constant. Then default is a Poisson arrival, and the default time is exponential with parameter λ. The default probability thus is given by $q(T) = 1 - \exp(-\lambda T)$.
- *Example 2*. Suppose that $\lambda = \lambda(t)$ is a deterministic function of time t. Then default is an inhomogeneous Poisson arrival. A simple but useful parameterization that is frequently used is the assumption that $\lambda(t)$ is stepwise defined over finite periods across the spread curve—these stepwise constants can be calibrated easily from market data.

These examples constitute only a small sample of possible parameterizations of the default intensity. There are many more choices, often borrowed from the classical term-structure models based on the short-term interest rate. This is motivated by the close analogy of defaultable term-structure models and classical, nondefaultable term-structure models to which we turn next.

Valuation

The description of the default dynamics through the market-implied default intensity λ leads to tractable valuation formulas. Below we describe several different specifications of these formulas corresponding to different units for the value recovered by investors at default.

We consider a zero-coupon bond paying 1 at maturity T if there is no default and a fraction $0 < R < 1$ of an equivalent (face value 1, maturity T) but default-free bond at default if default occurs before maturity T. This recovery specification is often called *equivalent recovery*. Given the market-implied probability of default $q(T)$, and assuming that R is a constant, the present value of the bond can be written as $\exp(-rT) - \exp(-rT)(1 - R)q(T)$. Here, r is the constant risk-free rate of interest. Thus the value of the bond is the value of an otherwise equivalent risk-free bond minus the present value of the default loss $(1 - R)$. If the intensity is constant (Example 1) and recovery is zero, we obtain for the bond price today $\exp[-(r + \lambda)T]$. This means that the value of the defaultable bond is calculated as if the bond were risk-free by using a default-adjusted discount rate. The new discount rate is the sum of the risk-free rate r and the intensity λ. This parallel between pricing formulas for defaultable bonds and otherwise equivalent default-free bonds is one of the best features of reduced-form models.

An alternative recovery model is called *fractional recovery of predefault market value*. Here it is assumed that the bond recovers a fraction $0 < R < 1$ of the market value of the bond just prior to default. If the recovery rate and the intensity are constant (Example 1 above), we obtain the following convenient formula for the bond price: $\exp\{-[r + \lambda(1 - R)]T\}$. This is the value of a zero-recovery defaultable bond when the issuer's default intensity is "thinned" to $\lambda(1 - R)$. The intuition behind this is as follows. Suppose that the bond defaults with intensity λ. At default, the bond becomes worthless with probability $(1 - R)$, and its value remains unchanged with probability R. Clearly, the predefault value of the bond is not changed by this way of looking at default. Consequently, for pricing, we can ignore the "harmless" default, which occurs with intensity λR. We then price the bond as if it had zero recovery and a default intensity of $\lambda(1 - R)$. The fractional-recovery pricing formula is then implied by the formula for equivalent recovery.

The results for the valuation of more complex credit-sensitive securities are analogous, and in the general case, a credit-sensitive security can be valued as if it were not sensitive to credit-risk by using an adjusted rate for discounting payoffs.

We take a closer look at the credit-spreads implied by reduced-form models. In the simple case where recovery is zero and some technical conditions are satisfied, we can show that short-term credit-spreads tend to λ and not zero. This should be contrasted with the structural models, where the spread goes to zero with time to maturity going to zero. In the reduced-form models, the default event is unpredictable; it comes without warning. There is always short-term uncertainty about the default event, for which investors demand a premium. This premium, expressed in terms of yield, is given by the intensity.

The unpredictability of default has another important consequence. In line with empirical observation, the model price of a credit-sensitive security will drop abruptly to its recovery value on default. This is in direct conflict with the structural models considered earlier, in which the price converges to its default contingent value and remains there as equity value drops to zero.

Default Correlation

In the reduced-form approach we can introduce cyclical default correlation by assuming that firms' default intensities are correlated through time. Similarly to the structural models of correlated default, we can introduce systematic and firm-specific factors that drive the intensities of firms. The sensitivity of a firm with respect to the systematic factors controls the intensity correlation across firms. This intensity correlation drives the dependence between firm defaults. Joint default probabilities can be calculated by observing that the intensity of the first default in a portfolio of names is the sum of the default intensities of the individual issuers in the portfolio.

Reduced-form models provide a flexible framework for modeling the dynamics of multiple-issuer credit-risk. However, calibration of the model to market variables is not trivial because of the scarcity of default data and the need to model a large number of parameters simultaneously. There are also studies that argue that the approach can be problematic for other reasons.

Taking account of contagious default correlation in the reduced-form approach is not an easy exercise. The idea is that there are correlated jumps in firms' default intensities corresponding to the correlated jumps we observe in credit-spreads. A variant of this assumes that there are marketwide events that can trigger joint defaults.[9] Another variant assumes that the default intensity of a firm depends explicitly on the default status of related counterparty firms in the market.[10] To avoid running into a circularity problem, one can suppose that only the default of designated "primary" firms has an effect on other "secondary" firms.

While Jarrow and Yu[11] focus on the pricing of credit-sensitive securities in the presence of contagion effects, it is difficult to calculate joint default probabilities and portfolio loss distributions within this approach. As Davis and Lo[12] and Giesecke and Weber[13] show, one can obtain tractable closed-form characterizations of loss distributions at the cost of more restricting assumptions that relate to the homogeneity of firms and the symmetry in their counterparty relations.

Calibration

Reduced-form models typically are formulated directly under the market-implied probability. This suggests that we calibrate directly from market prices of various credit-sensitive securities. One often uses liquid debt prices or credit default swap spreads, although Jarrow argues that equity is a good candidate as well.[14] Depending on the characteristics of the calibration security, it may be necessary to make parametric assumptions about the recovery process as well. With fractional recovery and zero bonds, for example, the problem is to choose the parameters of the adjusted short rate model $r + \lambda(1 - R)$ such that model bond prices best fit observed market prices.

Here one can either parameterize the adjusted short rate directly or specify the component processes separately. With a separate specification, identification problems may arise because only the product $\lambda(1 - R)$ enters the pricing formula just described. In general, in the estimation problem one can draw from the experience related to nondefaultable term-structure models given the close analogy to reduced-form defaultable models.[15]

9. See Darrell Duffie and Kenneth J. Singleton, "Simulating Correlated Defaults," working paper, GSB, Stanford University, 1998; and Kay Giesecke, "A Simple Exponential Model for Dependent Defaults," *Journal of Fixed Income* 13 (2003), pp. 74–83.

10. This is due to Robert A. Jarrow and Fan Yu, "Counterparty Risk and the Pricing of Defaultable Securities," *Journal of Finance* 56 (2001), pp. 555–576.

11. Jarrow and Yu, "Counterparty Risk and the Pricing of Defaultable Securities."

12. Mark Davis and Violet Lo, "Infectious Defaults," *Quantitative Finance* 1 (2001), pp. 383–387.

13. Kay Giesecke and Stefan Weber, "Cyclical Correlations, Credit Contagion, and Portfolio Losses," *Journal of Banking and Finance* 28 (2004), pp. 3009–3036.

14. Robert A. Jarrow, "Default Parameter Estimation Using Market Prices," *Financial Analysts Journal* 5 (2001), pp. 1–18.

15. Dai and Singleton provide for an overview of available techniques [Qiang Dai and Kenneth Singleton, "Term Structure Dynamics in Theory and Reality," *Review of Financial Studies* 16 (2003), pp. 631–678]. Standard methods include maximum likelihood and least squares.

INCOMPLETE-INFORMATION CREDIT MODELS

For the purpose of measuring default risk, neither the structural nor the reduced-form model explicitly accounts for the fact that investors rely on information that is imperfect. The framework described in this section addresses this issue directly by giving a common perspective on reduced-form and structural models. This perspective leads to previously unrecognized hybrid models that incorporate the best features of both traditional approaches while avoiding their shortcomings.

Incomplete-information credit models were introduced by several researchers.[16] Giesecke and Goldberg[17] describe a structural reduced-form hybrid default model based on incomplete information. This model, hereafter denoted I^2, is a first-passage time model: it assumes that a firm defaults when its value falls below a barrier. All first-passage time models require descriptions of both firm value and a default barrier. What distinguishes the I^2 model from traditional first-passage time models as we described them earlier is that it assumes that investors do not know the default barrier. The importance of modeling uncertainty about the default barrier is highlighted by high-profile scandals at firms such as Enron, Tyco, and WorldCom. In these cases, public information led to poor estimates of the default barrier.

Both the expected default barrier and the uncertainty around it can be calibrated to available information in the I^2 model. Imagine that a firm is believed to be in good financial health but that a particular analyst thinks otherwise. The analyst can increase the forecasts to line up with her views by raising the expected value of the barrier. She also can adjust the variance of the default barrier to the level of her confidence in reported levels of the firm's liability.

Other incomplete-information models can be envisioned. We can think of a situation where we cannot observe firm values or receive noisy or lagged firm-value information. Another situation is when we are uncertain about both firm values and the default barrier.

With incomplete information, default becomes a surprise event. It cannot be anticipated any more, as it can in the traditional first-passage models. It follows that investors face short-term credit-risk as in the reduced-form models. With short-term uncertainty, the model prices generated by the incomplete-information models provide an excellent fit to market prices. In particular, model prices are consistent with the jumps in prices observed around the default announcement. Model spreads are consistent with the nonzero short-term spreads observed in the credit markets. Exhibit 42-9 shows the term structure of credit-spreads implied by

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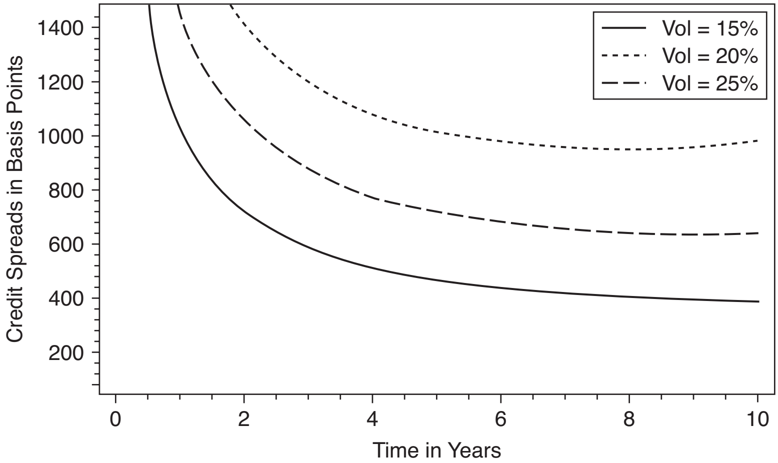
16. See Darrell Duffie and David Lando, "Term Structures of Credit-Spreads with Incomplete Accounting Information," *Econometrica* 69 (2001), pp. 633–664; Giesecke, "Default and Information"; and Umut Cetin, Robert A. Jarrow, Philip Protter, and Yildiray Yildirim, "Modeling Credit-Risk with Partial Information," working paper, Cornell University, 2002. A nontechnical discussion of incomplete-information models is provided in Lisa R. Goldberg, "Investing in Credit: How Good Is Your Information?" *Risk* 17 (2004), pp. S15–S18.

17. Kay Giesecke and Lisa Goldberg, "Forecasting Default in the Face of Uncertainty," *Journal of Derivatives* 12 (2004), pp. 14–25.

EXHIBIT 42-9

Term Structure of Credit-Spreads, Varying Asset Volatility, in the I^2 Model



the I^2 model, assuming risk-free rates of 6%. Strictly positive short spreads reflect the compensation for the short-term credit-risk that investors face.

Giesecke and Goldberg calibrate the I^2 model from market data and further analyze its empirical properties. In particular, the I^2 model output is compared empirically with a traditional first-passage model. Two main conclusions can be drawn. The I^2 model reacts more quickly because it takes direct account of the entire history of public information rather than just current values. Furthermore, the I^2 model predicts positive short spreads for firms in distress. The traditional first-passage model always predicts that short spreads are zero.

Dependent Defaults

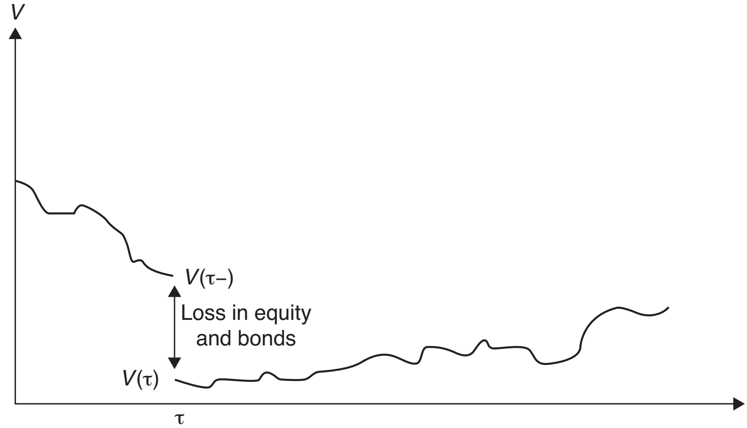
Since incomplete-information models are based on the structural approach, we can model cyclical default correlation through firm-value correlation.

Contagious default correlation arises very naturally with incomplete information. Consider the I^2 model. With defaults of firms arriving over time, we learn about the unobserved default barriers of the surviving firms.[18] This means that we update the distribution we put on a firm's default barrier with the information we extract from the unanticipated defaults of counterparty firms and reassess firms' default probabilities. The situation in which we do

18. This is discussed in detail in Kay Giesecke, "Correlated Default with Incomplete Information," *Journal of Banking and Finance* 28 (2004), pp. 1521–1545.

EXHIBIT 42-10

Firm Value in the Incomplete-Information Model



not directly observe firm values is very similar.[19] In both scenarios, the "contagious" jumps in credit-spreads we observe in credit markets are implied by informational asymmetries.

Credit Premium

The credit-risk premium is the mapping between the actual probability and the market-implied probability. To understand the structure of the premium, we examine the dynamics of firm value and corporate liabilities in the I^2 model. We argued earlier that thanks to the unpredictability of default, prices of credit-sensitive claims including firm equity and debt drop precipitously at default. Empirical observation shows that equity drops to near zero. This makes sense because equity holders have no stake in the firm after default. The value of the bonds is diminished by bankruptcy costs, which is described by some fractional recovery R.

Consequently, firm value, which is equal to the sum of equity and debt values, also drops at default. This is shown in Exhibit 42-10. Therefore, there are two sources of uncertainty related to firm value:

- The first is the diffusive uncertainty.
- The second is the uncertainty associated with the downward jump at default.

19. This is analyzed in Pierre Collin-Dufresne, Robert Goldstein, and Jean Helwege, "Are Jumps in Corporate Bond Yields Priced: Modeling Contagion via the Updating of Beliefs," working paper, Carnegie Mellon University, 2002.

Giesecke and Goldberg show that in the I^2 model the credit-risk premium can be decomposed into two components, which correspond to the two sources of uncertainty:[20]

- The diffusive risk premium α compensates investors for the diffusive uncertainty in firm value. As in the traditional structural models, it is realized as a change to the drift term in firm-value dynamics.
- The default event risk premium β is not present in the traditional structural models. It compensates investors for the jump uncertainty in firm value and is realized as a change to the default probability. Driessen[21] empirically confirms that this event risk premium is a significant factor in corporate bond returns.

Giesecke and Goldberg demonstrate that the assumption of no arbitrage is realized in the mathematical relationships among α, β, the recovery rate assumed by the market, and the coefficients of the price processes of traded securities. The price processes depend explicitly on the leverage ratio, so the premia α and β do as well. As Giesecke and Goldberg discuss,[22] this violates an important condition for the Modigliani and Miller theorem.[23] The I^2 model therefore is not consistent with the Modigliani-Miller theorem. It provides a new way to measure the deviation of real markets from the idealized markets in which the Modigliani-Miller theorem holds.

The structure of the incomplete-information risk premium is analogous to the risk premium in reduced-form models considered in El Karoui and Martellini[24] and Jarrow, Lando, and Yu.[25] The diffusive premium related to the firm-value process corresponds to a premium for diffusive risk in the default intensity process. The event risk premium is analogous to the default event risk premium in intensity-based models. However, in the incomplete-information setting it is defined in the general reduced-form context where an intensity need not exist.

20. Kay Giesecke and Lisa Goldberg, "The Market Price of Credit-Risk," working paper, Cornell University, 2003.

21. Joost Driessen, "Is Default Event Risk Priced in Corporate Bonds," working paper, University of Amsterdam, 2002.

22. Kay Giesecke and Lisa Goldberg, "In Search of a Modigliani-Miller Economy," *Journal of Investment Management* 2 (2004), pp. 1–6.

23. Franco Modigliani and Merton H. Miller, "The Cost of Capital, Corporation Finance and the Theory of Investment," *American Economic Review* 48 (1958), pp. 261–297.

24. Nicole El Karoui and Lionel Martellini, "A Theoretical Inspection of the Market Price for Default Risk," working paper, Marshall School of Business, University of Southern California, 2001.

25. Robert A. Jarrow, David Lando, and Fan Yu, "Default Risk and Diversification: Theory and Applications," working paper, Cornell University, 2003.

Calibration

There is a lively debate in the literature concerning which data should be used to calibrate credit. Jarrow[26] points to a division between structural and reduced-form modelers on this issue. Traditionally, structural models are fit to equity markets and reduced-form models are fit to bond markets. Jarrow argues that the equity and bond data can be used in aggregate to calibrate a credit model, and he gives a recipe for doing this in a reduced-form setting.

Giesecke and Goldberg[27] apply reasoning similar to that of Jarrow to calibrate the I^2 model. The estimation procedure makes use of historical default rates in conjunction with data from equity, bond, and credit default swap markets. Huang and Huang[28] give empirical evidence that structural models yield more plausible results if calibrated to both kinds of data. Importantly, the physical and market-implied probabilities are fit simultaneously. The output of the calibration includes estimates of the risk premium, market-implied recovery, model security prices, and physical probabilities of default.

One issue addressed in Giesecke and Goldberg[29] is the relationship between model and actual capital structures. In the classical setting, equity is a European option, with strike price and date equal to the face value and maturity of a zero bond. This model fits market data only to the extent that firm debt can be represented adequately as a zero bond. Giesecke and Goldberg make use of the flexibility imparted by incomplete information to give a more realistic picture of equity. Specifically, equity is a down-and-out call with a stochastic strike price. This approach sidesteps the intractable problem of describing a complex capital structure in terms of a single face value and maturity date.

KEY POINTS

- Credit-risk is the distribution of financial losses owing to unexpected changes in the credit quality of the counterparty in a financial agreement.
- Estimating probability of default requires the specification of a (1) model of investor uncertainty, (2) model of the available information and its evolution over time, and (3) model definition of the default event.
- Because default probabilities alone are not sufficient to price credit-sensitive securities, it is necessary to have a (1) model for the risk-free

26. Jarrow, "Default Parameter Estimation Using Market Prices."
27. Kay Giesecke, and Lisa Goldberg, "Calibrating Credit with Incomplete Information," working paper, Cornell University, 2004.
28. Jay Huang and Ming Huang, "How Much of the Corporate-Treasury Yield Spread Is Due to Credit-Risk?" working paper, Stanford University, 2003.
29. Giesecke and Goldberg, "Calibrating Credit with Incomplete Information."

interest rate, (2) model of recovery on default, and (3) model of the premium investors require as compensation for bearing systematic credit-risk.

- The credit premium maps actual default probabilities to market-implied probabilities that are embedded in market prices.
- In order to price securities that are sensitive to the credit-risk of multiple issuers and measure aggregated portfolio credit-risk, a model that links defaults of different entities must be specified.
- The three main quantitative approaches to analyzing credit are the structural approach, the reduce-form approach, and the incomplete-information approach.
- The basis of the structural approach is the Black-Scholes-Merton framework, in which corporate liabilities are contingent claims on the assets of a firm. The market value of the firm is the fundamental source of uncertainty driving credit-risk. The structural approach makes explicit assumptions about the dynamics of a firm's assets, its capital structure, and its debt and shareholders. A firm defaults if its assets are insufficient according to some measure. In this situation, a corporate liability can be characterized as an option on the firm's assets.
- First-passage time structural models generalize the classical model such that a default can occur not only at maturity of the debt contract, but also at any point of time.
- Credit-spreads of different issuers are correlated through time and must be incorporated into a credit-risk model. Two patterns are found in time series of spreads: (1) spreads vary smoothly with general macroeconomic factors in a correlated fashion, and (2) there are jumps in spreads that are common to several firms or even entire markets.
- Reduced-form models assume that default occurs without warning. That is, this approach is silent about why a firm defaults. Instead, the dynamics of default are given exogenously through a default rate, or intensity. In this approach, prices of credit-sensitive securities can be calculated as if they were default-free using an interest rate that is the risk-free rate adjusted by the intensity. Default intensity is the rate at which defaults occur.
- The incomplete-information approach combines the best features of the structural and reduced-form models while at the same time avoiding the shortcomings of the two models. More specifically, it combines the economic and intuitive appeal of the structural approach and the tractability and empirical fit of the reduced-form approach.

PART
EIGHT

PORTFOLIO MANAGEMENT AND STRATEGIES

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CHAPTER
FORTY-THREE

INTRODUCTION TO BOND PORTFOLIO MANAGEMENT

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Traditional bond management can be likened to a sailing regatta. The index is the lead boat, since it doesn't have to contend with expenses and transaction costs, and all managers (including index fund managers) are the other boats, trying to make up the distance and pass the index boat—or at least keep pace with it. Strategies that may be used to make up the difference and pass the index lead boat comprise a wide spectrum of styles and approaches. Exhibit 43-1 displays the major elements of these approaches.

In this chapter, we'll examine this spectrum, investigating the pros and cons of matching—and mismatching—bond indexes, and comparing ways of constructing bond portfolios. We'll look closely at the factors to consider when matching a bond index's risk factors, as well as the methods that may provide an edge over an index.

OVERVIEW OF TRADITIONAL BOND MANAGEMENT

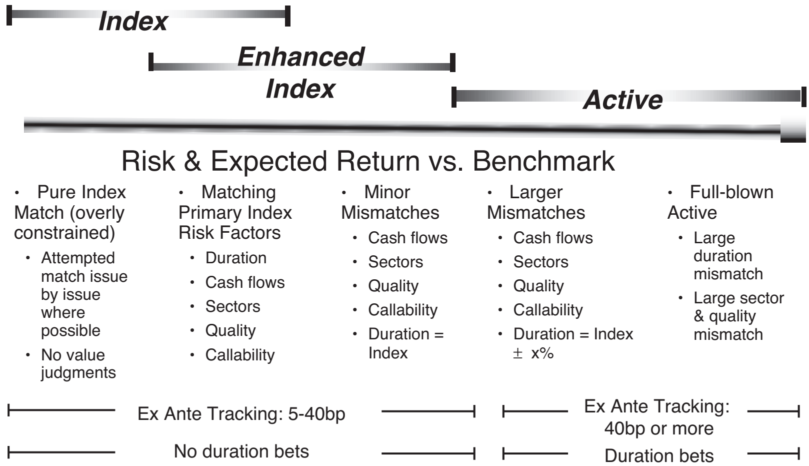
Although bond portfolio management can be complicated, choosing an investment approach starts with a fairly simple question: How much risk would you like to take?

Pure Bond Index Matching

Pure bond indexing offers the lowest risk (and lowest expected return) approach to bond management versus a specific benchmark. This approach essentially guarantees that returns will lag behind the index by the cost difference (expenses plus transaction costs). Pure bond index matching attempts to fully replicate the index by owning all of the bonds in the index in the same proportion as the index. In the bond market, however, this approach is difficult to accomplish and costly to implement. Many bonds in the index were issued years ago, and are illiquid. Also, many bonds were issued at a time when interest rates were significantly different from current rates. Today's bondholders may be unwilling to incur a gain or loss by selling their bonds to an index fund.

EXHIBIT 43-1

Traditional Bond Management Risk Sprectrum



On December 31, 2020, the Bloomberg Barclays US Aggregate Index contained more than approximately 12,000 different issues, including more than 260 Treasury bonds, over 600 federal agency issues, 7,500 credit (corporate and non-U.S. government) issues, 370 asset-backed issues, 3,000 commercial mortgage-backed securities, and 450 broadly categorized mortgage issues (essentially hundreds of thousands of mortgage pools). In the Treasury market, matching an index, security by security, is feasible, although not desirable (for reasons we'll cover later). However, full replication cannot be reasonably implemented in the agency, mortgage, or corporate bond markets. Thousands of agency and corporate issues are locked away in long-term bond portfolios and must be purchased from the investors who own them—often at a large premium. For this reason, full replication of a broad bond index is inefficient, if not impossible. And, as you'll see, it's also unnecessary.

Enhanced Indexing: Matching Primary Risk Factors

This approach involves investing in a large sample of bonds so that the portfolio's risk factors match the index's risk factors. The result is a portfolio that will have higher average monthly tracking differences (standard deviation of tracking differences) than the full-replication approach. But, it can be implemented and maintained at a much lower cost. This lower cost results in *net* investment performance that is much closer to the index. Returning to the regatta analogy, the portfolio boat stays on the same "tack" as the index boat, but "trims its sails" to run more efficiently. Staying on the same tack means that the sails are set to take the portfolio boat in the same direction as the index boat, and are exposed to the same winds and elements. By trimming the sails, the little details of the portfolio boat's sail position and shape result in better performance and more efficient execution than the index boat. The risk factors that need to be matched are duration, cash-flow distribution, sector, quality, and call exposure (more on this later). This approach is considered a form of enhanced indexing because the return is enhanced relative to the full replication indexing approach (more on this later as well).

Enhanced Indexing: Minor Risk Factor Mismatches

This approach allows for minor mismatches in the risk factors (except duration) to tilt the portfolio in favor of particular areas of relative value, such as certain sectors, credit ratings, term structure, call risk, or other factors. Because the mismatches (and impact on tracking) are very small, this is still considered enhanced indexing. These additional enhancements are essentially sail-trimming strategies.

Active Management: Larger Risk Factor Mismatches

This is a conservative approach to active management. The manager will make larger mismatches in the risk factors in an attempt to add greater value. This approach may also make small duration bets. In most cases, the management fee and transaction costs are significantly higher than for pure or enhanced indexing, yet the net investment return is usually lower. These additional costs are the reason a typical index portfolio often outperforms the average active manager in performance universes. Typically, the manager will moderately change tack to seek greater "winds" (for example, longer than benchmark duration to add value from expected lower interest rates) to overcome the strategy's higher cost. As a result, manager risk increases the likelihood that the portfolio will deviate from the market return and structure.

Active Management: Full-Blown Active

This is an aggressive active style in which large duration and sector bets are made, and significant variation from the index can occur. Above-average performance consistency is difficult to find among the managers that employ this approach. As a result, investors who choose this management style need to look deeper than recent performance to distinguish the good from the bad. This approach may involve a significant changing of course relative to the index boat, and may risk significant tracking and portfolio structure variations. Of course, the goal of this riskier strategy is to provide a return that is higher than that of the index.

OVERVIEW OF THE CORE/SATELLITE APPROACH

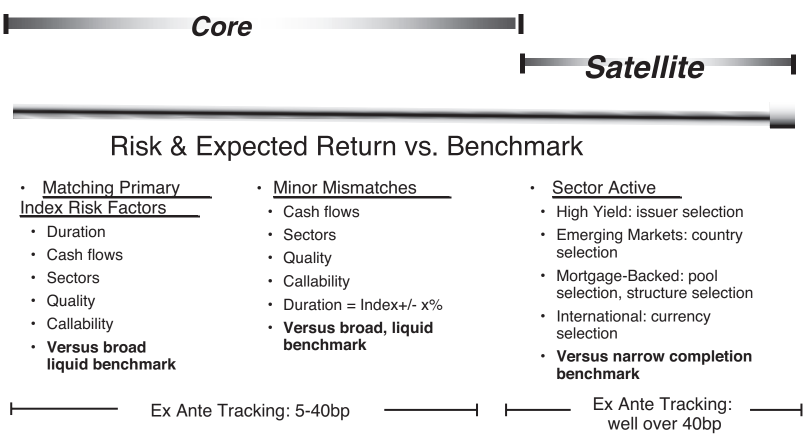
Although these traditional approaches are alive and well, many investment managers have moved a few steps beyond this conventional model and are building portfolios with a conservative, low-cost (often index-based) core, and satellites that may encompass a variety of active strategies. As shown in Exhibit 43-2, a core portfolio is typically managed against a broad, liquid benchmark within a tight risk budget, generally under 40 basis points ex-ante tracking standard deviation versus the benchmark. As we'll see, there are several ways to build the core and the satellite portions of such portfolios.

Risk-Factor Matching

In this strategy, the manager creates a broadly diversified portfolio that closely replicates primary index risk factors such as portfolio duration, key rate durations, sectors, quality, and callability. The ex-ante tracking error is expected to be below 20 basis points. Since this high-quality, liquid bond market is assumed to be efficiently priced, the expected opportunity to outperform the index is very limited. Therefore, the objective is to match and replicate the risks, and generate the returns, of the target benchmark at the lowest possible cost (management fee and transaction costs).

EXHIBIT 43-2

Core/Satellite Risk Spectrum



Minor Mismatching

Here, the manager is given a larger risk budget (20 to 40 basis points) to mismatch relative to a broad liquid benchmark's characteristics such as key rate durations, sector and quality weightings, and even overall portfolio duration, to a limited extent. The expectation is that the manager will add value relative to that broad benchmark. As a result of this expected added value, the manager would also have a higher fee structure.

The Satellite Investments

The satellite portion focuses on the less-liquid sectors that have lower correlations with the broad liquid core. This manager is given a smaller pool of assets and a much larger risk budget relative to the narrow benchmark. This bigger risk budget provides an opportunity for the manager to take meaningful selection, sector, and quality risk relative to the benchmark, with the expectation of adding considerable value.

Examples of such narrow, less-liquid markets include high-yield and emerging market bonds. In the high-yield market, issuer and sector selection are the primary determinants of added value versus the benchmark. Within the emerging bond market, country selection is a driving force in adding value. In many cases, the mortgage-backed market (agency and particularly nonagency) is viewed as a satellite market because of the many structural complexities based on interest-rate volatility risk and credit risk in the nonagency market. Securities exposed to non-U.S. currencies may be considered satellites, as could inflation-protected securities.

A key requirement of the satellite component is that it acts as a diversifier and that it has a higher expected return due to its illiquidity and lower credit quality.

WHY CHOOSE INDEXING?

As we've demonstrated, indexing plays a major role in bond management. Some managers may use indexing for part of a portfolio; for other managers, it may serve as the approach for an entire portfolio. So why is indexing an effective method of bond investing? Put simply, bond indexing, which has proven its mettle over the past two decades, offers broad diversification and low costs. Low costs are vital to bond indexing because lower costs mean tighter tracking of an index. This, in turn, means that an index portfolio will provide competitive performance that is consistent with the market—or market segment—that it tracks. And it means that nonindex (that is, higher-cost) portfolios will have difficulty beating the index portfolio. Finally, indexing provides a major psychological benefit: It allows investors to focus on asset allocation—or, in the case of the core/satellite approach, on selecting the best investment managers.

Broad Diversification

Broad bond index portfolios provide excellent diversification. The Bloomberg Barclays US Aggregate Bond Index, which is designed to capture the entire U.S. investment-grade bond market, had more than 8,200 issues and more than $15 trillion in market value as of early 2020. A large bond index portfolio designed to replicate this Index may have 1,000 to 3,000 or more issues, resulting in significant issuer diversification benefits. Most active portfolios have much heavier specific issuer concentrations, resulting in significant exposure to issuer event (credit) risk.

In addition, an index portfolio designed to match the Bloomberg Barclays US Aggregate Bond Index will have exposure to not only Treasury and agency sectors, but also to mortgages, industrials, electric and telephone utilities, finance, dollar-denominated non-U.S., and asset-backed sectors. Such a portfolio will also have broad exposure to the yield-curve with holdings from one year to more than 30 years to maturity. These sources of diversification result in a portfolio with lower risk for a given level of return than is available from less diversified portfolios.

Low Cost

As we've mentioned, the primary reason for an index fund's competitive performance is lower cost. This lower cost takes two forms: (1) lower management fees and (2) lower transaction costs associated with lower portfolio turnover rates. This lower cost advantage is durable and predictable—year after year.

Competitive Performance

Since index portfolios have lower management fees and lower transaction costs (resulting from significantly lower portfolio turnover), it's not surprising that they usually outperform the average active portfolio in most universes. After all, a broad index, by design, is a representation of the whole pie of investment alternatives. As a result, the sum of all active managers should equal the index in composition. Also, the sum of the investment performance of all active managers (grossed up for the higher management fees and transaction costs) should also equal the index in performance.

Market Performance Predictability

A properly managed broad bond index portfolio can be assured of performing in line with the market as a whole. Regardless of the market's direction, the investor can be assured the performance of a diversified broad bond index portfolio will follow along.

A Time-Tested Track Record

Bond index portfolios have been successfully managed (that is, close tracking to the benchmark) since the early 1980s—through rising and falling interest rate cycles, as well as periods when credit-spreads widened and narrowed. Through all these market changes, bond indexing has proven to provide a more-than-competitive return with low to moderate risk.

Perhaps the most significant benefit of indexing is that it enables investors to concentrate on more important decisions—namely, the proper allocation of assets. Often, time and effort are wasted in the hope of adding 20 to 40 basis points to the very efficiently priced bond portion of a portfolio, while existing misallocation of assets to stocks or international investments results in hundreds of basis points of underperformance for the entire portfolio. Indexing the core portion of the portfolio that represents the highly liquid markets helps facilitate more effective use of limited decision-making resources available to most investors. For those using a core/satellite approach, indexing provides an opportunity to focus on selecting the best managers for the satellites.

WHICH INDEX SHOULD BE USED?

Once you've decided on an indexing approach to bond management, you should focus on the next important question: Which index? A bond index is defined by a set of rules (that is, characteristics) that are then applied to all issues in the marketplace. The rules include maturity, size, sector, and quality characteristics. The issues that fit the rules are then combined, as if in a portfolio, with each issue's weight determined by its relative market value outstanding.

Generally, the broader the index, the better the benchmark. An index we've discussed, the Bloomberg Barclays US Aggregate Bond Index, is the broadest U.S. bond index. As we've mentioned, the Bloomberg Barclays US Aggregate Bond Index consisted of more than 8,200 issues, representing a market value of more than $15 trillion. The composition of the Index, illustrated in Exhibit 43-4, was 41% government (U.S. Treasury and agency) bonds, 23% credit-related (corporate and non-U.S. government) bonds, 3% asset-backed bonds and commercial mortgage-backed bonds, and 28% mortgage-backed securities. Sub-indices of the Bloomberg Barclays US Aggregate Bond Index can be created to capture that result in different risk/return profiles. For example, a credit index may appeal to those who seek higher yields from the spread sectors, or a 1-to-5-year government/credit index would better serve those who are seeking a short-duration portfolio.

An important part of choosing an index is understanding the risks that are involved in the bond market's various segments. Chief among these risks are market value risk and income risk, although the degree to which they apply to a given part of the bond market can vary widely.

Market Value Risk

Generally, the longer a bond portfolio's maturity, the higher is its yield. (This assumes a normally sloped yield-curve.) The total return of a bond is made up of the coupon (or income) component and the principal (or price change) component. Since the yield-curve, which impacts the principal component of total return, is likely to shift, the longer-term bond portfolio will not necessarily have a higher total return. As the maturity or duration of the portfolio lengthens, market value risk rises. In addition, the lower the interest-rate environment, the greater the market value risk, especially for the intermediate-term and long-term portfolios. This is the result of two factors: the portfolio's duration increases as interest rates decrease, and the portfolio's lower yield-to-maturity provides less of a cushion to offset principal losses. Therefore, for investors who are risk-averse in terms of their principal, the short-term or intermediate-term index may be more appropriate than the long-term index.

Income Risk

Many investors invest for income. They spend only the income that their investment distributes, and they avoid dipping into their principal. Foundations and retirees invest for a stable—and hopefully growing—income stream that they can depend on for current and future consumption. It's obvious that if stability and durability of income are the primary concerns, the long-term portfolio is the least risky, and the short-term portfolio the most risky.

Liability Framework Risk

Pension funds and financial institutions invest to finance future liabilities. Long-term liabilities require investments in long-term assets to minimize risk, resulting in both a portfolio and a liability stream that are equally sensitive to interest-rate changes. A portfolio that invests in short-term bonds may look less risky on an absolute-return basis, but it is actually much riskier when the portfolio market value is compared to the present value of the pension liability. (The difference is the surplus or deficit.) This is because of the short-term portfolio's mismatch with its long-term liabilities. The surplus risk will be minimized on a fully funded plan when the duration of the portfolio is matched (or immunized) to the duration of the liability.

Exhibit 43-3 contains a summary comparison showing that the investment with the lowest market value risk has the highest income or liability risk. Likewise, the investment with the highest market value risk has the lowest income or liability risk. Clearly, the risk framework chosen depends on whether the investment objective is principal preservation or income durability.

PRIMARY BOND INDEXING RISK FACTORS

As effective as indexing is as a bond management tool, it doesn't eliminate the risks of bond investing by any means. Successful indexing requires matching the primary risk factors of the benchmark index in a credit-diversified portfolio. This

EXHIBIT 43-3

Bond Market Risk Summary

NAV Type	Market-Value Risk	Income or Liability Risk	Average Maturity	Current Duration	Portfolios
Stable-dollar NAV	Lowest	Highest	30–90 Days	0.1	Money market portfolios
Variable NAV	Low	High	2–4 Years	2.5	Short-term portfolios
	Medium	Medium	7–10 Years	5.0	Intermediate-term portfolios
	High	Low	15–25 Years	10.0	Long-term portfolios

EXHIBIT 43-4

Primary Bond Index Matching Factors

	Government	Corporate	MBS
Modified adjusted duration	x	x	
Present value of cash flows	x	x	
Percent in sector and quality		x	
Duration contribution of sector		x	
Sector/coupon/maturity cell weights		x	x
Issuer exposure control		x	

doesn't mean an index manager must fully replicate an index. Rather, it means that the manager must understand the risk factors and how they're measured. Exhibit 43-4 lists the primary risk factors that apply to the government, corporate, and mortgage sectors; the following paragraphs explain each primary risk factor.

Portfolio Modified Adjusted Duration

The modified adjusted duration (or option-adjusted modified duration) is a simple, single measure of the portfolio's interest-rate risk. It's a great place to start, but is entirely too rough of a measure to adequately track an index. Duration is the average time to receipt of the present value of the bond cash flows. The portfolio duration will give the manager a rough approximation of the price change observed if interest rates rise or fall (in a parallel fashion) immediately by 1%. If rates rise by 1%, a five-year duration portfolio will experience a 5% decline in value [(+1% yield change) × (portfolio duration of 5 years) × (−1)]. If the yield-curve does not move in a parallel fashion, the duration is of limited value. For obvious reasons, it's important to match the duration of the portfolio to the duration of the benchmark index.

Key Rate Durations

A more accurate way to capture yield-curve risk is by matching the key rate durations (known as KRDs) of the index. Yield-curve changes are composed of parallel shifts, curve twists (for example, short rates down, intermediate rates unchanged, long rates up), and curve butterfly movements (for example, short and long rates down, intermediate rates up). By breaking down the index (and portfolio) into a stream of future payments and discounting each payment to the present value and summing these values, one calculates the index (and portfolio) market value. By matching the percent of the portfolio's present value that comes due at certain intervals in time (that is, KRDs) with that of the benchmark index, the portfolio will be largely protected from tracking errors (versus the benchmark) associated with yield-curve changes. Since the portfolio duration is equal to the benchmark index duration, this method will guard against parallel changes in yield. Since all points in time (KRDs) are closely matched in percent, any local term structure movements (non-parallel changes) will not affect tracking because these yield change risks are essentially immunized. For callable securities, the cash flows need to be distributed to the KRDs in accordance with the probability of call. A 10-year bond that is highly likely to be called in three years should have cash flows that are allocated primarily to the three-year KRD.

Percent in Sector and Quality

The yield of the index is largely replicated by matching the percentage weight in the various sectors and qualities, assuming that the replicating portfolio fully accounts for all maturity categories. Matching duration contribution of sectors and qualities, without matching the portfolio percentage weight exposed to the sectors and qualities, may expose the portfolio to significant tracking risk during periods of extreme duress. This is due to the default risk that can reduce the value of all of an issuer's bonds by a given magnitude, regardless of the maturity.

Duration Contribution of Sector

An effective way of protecting a portfolio from tracking differences associated with changes in sector spreads (industry risk) is to match the amount of the index duration that comes from the various sectors. (This can be done without excessively constraining the process, subject to managing the market weights, as we've described earlier.) If this can be accomplished, a given change in sector spreads will have an equal impact on the portfolio and the index.

Duration Contribution of Quality

Similarly, the most effective way to protect a portfolio from tracking differences related to changes in quality spreads (leverage/economic risk) is to match the amount of the index duration that comes from the various quality categories. This is particularly important in the lower-rated categories, which are characterized by larger spread changes.

Sector/Coupon/Maturity Cell Weights

The call exposure of an index is difficult to replicate. By itself, the convexity value (convexity measures how a bond's duration changes as yield levels change) is inadequate since it measures expected changes in duration over a small change in yield levels. In addition, the change in convexity can be very different as yield levels change. Managers who attempt to match only the index convexity value often find themselves having to buy or sell highly illiquid callable securities to stay matched and, in the process, generating excessive transaction costs. A better method of matching the call exposure is to match the sector, coupon, and maturity weights of the callable sectors. By matching these weights, the convexity of the index should be matched. In addition, as rates change, the changes in call exposure (convexity) of the portfolio will be matched to the index, requiring little or no rebalancing.

In the mortgage market, call (prepayment) risk is significant. Clearly, the greater the refinancing activity, the shorter the index duration due to the greater likelihood that the higher coupons (issues priced above par) will be refinanced with lower coupon securities. For this reason, matching the coupon distribution of the mortgage index is critical. The best risk management is accomplished by matching the index weights in a multidimensional matrix of the maturity (balloon, 15-year, 30-year), sector (FNMA, FHLMC, GNMA), coupon (0.5% increments), and seasoning (new, moderate, and seasoned). This level of detail is easily accomplished in a large portfolio (more than $1 billion in assets), but more difficult in smaller portfolios.

The FNMA and FHLMC's government-sponsored enterprises (GSE) disclosures of additional pool detail, such as FICO scores and average loan balances, result in further division of mortgage pricing of specified pools from "to be announced" (TBA) mortgage pricing.

Issuer Exposure

If the major risk factors described above are matched but with a limited number of issuers, one significant risk remains, but it can still be diversified away. Event risk—a risk widely watched during periods of significant corporate leveraging events (leveraged buyouts, LBOs) or during periods of significant economic stress—needs to be measured and controlled. Issuer exposure, like exposure to sector and quality, must first be measured in percentage terms versus the issuer weight in the index, because periods of serious economic distress can cause bond prices, regardless of maturity, to drop precipitously. However, setting market value limits without regard to issuer duration risk and issuer index weights is not adequate. Spreads widen immediately after a negative credit event. Therefore, an additional measure of the issuer event risk impact on a portfolio is the impact on portfolio market value of that spread widening. This can be measured by calculating how much of the portfolio duration (duration contribution) comes from the holdings in each issuer. This calculation should also be figured for the index. The basis-point impact on tracking of a spread-widening event will be the spread change (of the issuer) multiplied by the difference in duration contribution (portfolio − index) multiplied by (−1).

Exhibit 43-5 provides an example of this analysis. Issuer XXX Corp has an equal percent weight to the index, but its duration contribution is 0.16 greater. If an event occurred that would widen XXX Corp spreads by 100 basis points, the portfolio would suffer an unfavorable tracking difference of 16 basis points versus the index (100 basis point spread change × 0.16 duration contribution overweight × −1). If the same 100-basis-point widening were to occur to XYZ Corp bonds, the tracking difference would be a favorable 8 basis points even though the percent weight is matched to the index. For effective index fund management, duration contribution exposure limits (versus the index) need to be set at the issuer level.

ENHANCING BOND INDEXING

In sailing, speed comes from paying close attention to the details, not simply from watching the wind. And in bond management, the return versus the benchmark is a function of more than just interest-rate maneuvering. Portfolio managers can trim their portfolio sails to compete more efficiently in the investment management race. Some trimming strategies include lower costs, issue selection, yield-curve positioning, sector and quality positioning, and call-exposure positioning.

Why Enhancements Are Necessary

Since the index does not incur expenses or transaction costs, enhancements are needed just to provide a net return equal to the index. Operating expenses provide a significant headwind, but transaction costs associated with portfolio growth are a major contributor to return shortfalls.

Exhibit 43-6 shows the transaction costs and resulting tracking error associated with single contribution growth and compares it with multiple contribution growth. In this example, the single contribution portfolio has a tracking error of 18 basis points associated with investing net cash flow. In the multiple-contribution portfolio, the tracking error is significantly higher, at 41 basis points,

EXHIBIT 43-5

Issuer Exposure Comparison (Percent of Market Value vs. Duration Contribution)

	Portfolio			***Index***			***Portfolio – Index***	
	Percent of Market Value	**Duration**	**Duration Contribution**	**Percent of Market Value**	**Duration**	**Duration Contribution**	**Percent Difference**	**Contribution Difference**
XXX Corp	4%	8	0.32	4%	4	0.16	0%	0.16
ZZZ Corp	4%	4	0.16	4%	4	0.16	0%	0.00
XYZ Corp	4%	2	0.08	4%	4	0%	0%	–0.08

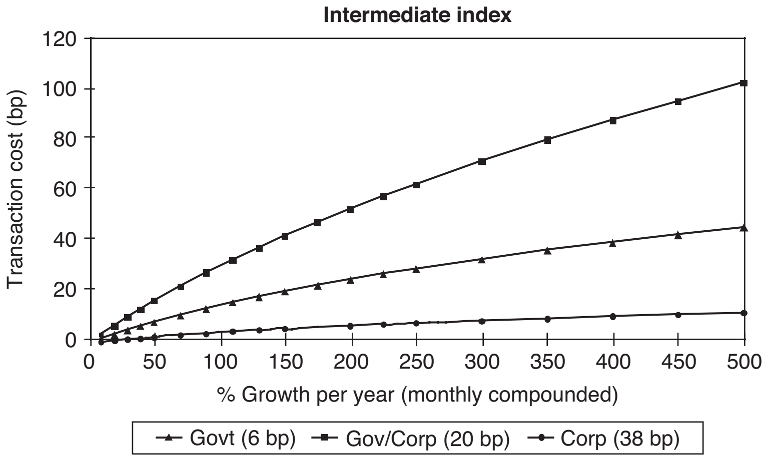
EXHIBIT 43-6

Single Contributionvs. Multiple Contributions

	Portfolio Market Value	Contribution	Trans. Cost ($ at 18 bp)	Now Portfolio Value	Tracking Error from Trans Cost (bp)	(bp)
Single contribution	$ —	$250,000,000	$450,000	$249,550,000	18.0	$\boxed{18.0}$
Multiple contributions	$ —	$ 50,000,000	$ 90,000	$ 49,910,000	18.0	18.0
	$ 49,910,000	$ 50,000,000	$ 90,000	$ 99,820,000	9.0	27.0
	$ 99,820,000	$ 50,000,000	$ 90,000	$149,730,000	6.0	33.1
	$149,730,000	$ 50,000,000	$ 90,000	$199,640,000	4.5	37.6
	$199,640,000	$ 50,000,000	$ 90,000	$249,550,000	3.6	$\boxed{41.2}$
		$250,000,000	$450,000			

EXHIBIT 43-7

Why Enhancements Are Necessary: Return Impact of Transaction Costs over One Year



even though the amount of transaction costs ($450,000) is identical. Therefore, portfolios with high growth rates will suffer additional negative tracking errors. So, enhancements are necessary simply to stay equal to a no-growth or slow-growth portfolio. Exhibit 43-7 shows, in graphical form, the cumulative adverse tracking impact resulting from portfolio growth for Treasury, government/corporate, and corporate portfolios. The greater the growth rate—and/or the less liquid the market—the greater the adverse impact on tracking error.

Lower-Cost Enhancements

One of the simplest, yet most overlooked, forms of enhancement is keeping costs low. Expenses/management fees and transaction costs have a significant impact on portfolio performance.

Active managers work hard—and usually unsuccessfully—to add an incremental 25 to 50 basis points per year to portfolio gross returns. Yet in the mutual fund arena, the average bond fund expense ratio is 50 to 80 basis points greater than that of the lowest-cost index portfolio. As a result, net returns of the high-expense-ratio funds are significantly lower. Even in the indexing arena, expenses vary by large margins. An investor can enhance returns simply by shopping around for the index fund with the lowest expenses, provided the net return is competitive with other index funds. For a plan sponsor with external index fund managers, having the current fund manager and one or two other reputable index fund managers rebid the business every few years will help ensure expenses are as low as possible.

Transaction costs are the other major cost factor. Since bond index funds have low annual turnover (about 40%) versus active portfolios (generally greater than 100%), transaction costs are significantly lower for index portfolios. In addition, electronic trading platforms, which enable managers to increase price competition among dealers, further reduce the transaction-cost impact. It's imperative to include a number of brokers in the bidding process. For rapidly growing portfolios, where most of the transactions are offerings, an effective competitive trading process is essential. An efficient system of comparing the relative value of real-time offerings of target issuers and issues from many different brokers will yield significant transaction cost savings and, as a result, further enhance returns.

Issue Selection Enhancements

For U.S. Treasury securities, the primary tool for selecting cheap bonds is comparing actual bond prices to the theoretical "fitted" price. The theoretical curve minimizes the pricing errors of all Treasury issues in the market, subject to various curve-smoothing rules. Each actual bond's yield is then compared to the bond's fitted yield, which is calculated using the theoretical curve. Bonds yielding more than the fitted yield are cheap; those yielding less are rich. Also useful is an analysis of the recent history of the bond yield versus the fitted yield. This analysis will indicate whether a cheap bond has been getting cheaper or richer.

Corporate issue selection enhancements come primarily from staying clear of deteriorating credits and owning improving credits. The greater the manager's confidence in the ability of the firm's credit analyst to add value via issuer selection, the larger the maximum issuer exposure limit. (See "Primary Bond Indexing Risk Factors—Issuer Exposure" in this chapter.) If the manager does not believe the firm's credit analysts can add value through issuer selection, the diversification among issuers must be greater.

Yield-Curve Enhancements

Various maturities along the term structure are consistently overvalued or undervalued. For example, the 10-year and 30-year Treasury regions tend to be consistently overvalued, due to the liquidity preference of those regions. Strategies that overweight the undervalued maturities and underweight the overvalued maturities, while keeping the same general term structure exposure, have tended to outperform the index. This is similar to looking for the maturities that have the more favorable "rolldown" characteristics—that is, the near-term passage of time may result in the bond rolling down the yield-curve. As a result, the security trades at a lower yield and has more opportunity for price appreciation. Cheap parts of the curve tend to have favorable roll down, while rich parts of the curve (for example, the 30-year area) tend to have little or no roll-down opportunities.

Sector/Quality Enhancements

Sector and quality enhancements take two primary forms: (1) ongoing yield tilt toward short duration corporates, and (2) periodic, minor overweighting or underweighting of sectors or qualities.

The yield-tilt enhancement (also called "corporate substitution") strategy recognizes that the best yield spread per unit of duration risk is available in short-term (under 5-year) corporates. A strategy that underweights 1–5-year government bonds and overweights 1–5-year corporates has tended to increase the yield of the portfolio with a less-than-commensurate increase in risk—except during periods of severe economic stress. An economic downturn that results in significant downgrades from investment-grade to high-yield or leads to significant defaults would prove disastrous to this strategy.

The strategy has proven effective primarily because the yield advantage of a broadly diversified portfolio of short-term corporates requires a significant corporate spread-widening move over a one-year period for short-term corporates to perform as poorly as short-term Treasuries. With the passage of time, the duration of corporate bonds shortens, and the yield spread over comparable Treasury securities generally narrows. These risk-reducing and return-enhancing forces, when combined with the yield-spread advantage, provide compelling reasons to overweight short corporates using a broadly diversified credit portfolio.

The risks involved in the strategy are recessionary spread widening risk and issuer default risk. The recessionary spread widening risk tends to be short-lived and quickly overcome by the increased yield advantage of the strategy. The issuer default risk can be minimized by broad issuer diversification (50 or more issuers), by limiting the strategy to A-rated and higher issuers, and by experienced credit analyst oversight.

The periodic overweighting or underweighting of sectors and qualities is a scaled-back version of active "sector rotation." This can be implemented on a cost-effective basis by allowing new cash flow (net new portfolio growth) to facilitate the mismatching. For example, if spreads are narrow going into the fourth quarter and the manager expects some widening, new money may be invested in Treasury securities to a moderate degree, resulting in a modest reduction in the corporate exposure versus the index. Once the corporate spread widening materializes, Treasury securities (with low transaction costs) can be sold and corporates overweighted. A strategy of outright selling of corporates to buy Treasury securities is always difficult to justify because of the higher corporate transaction costs involved, not to mention the yield "penalty" associated with Treasury securities.

Call Exposure Enhancements

The option-adjusted duration of a callable bond is the average of the model duration, if rates rise and fall marginally. These durations under rising and falling rates can be quite different for bonds trading at a price where the bond changes from trading to maturity, to trading to call (or vice versa). The result is a situation where the bond's actual performance could be significantly different than expected given its beginning-of-period option-adjusted duration.

Generally, the greater the expected yield change, the greater is the desire for more call protection. For premium callable bonds (bonds trading to call), the empirical duration (observed price sensitivity) tends to be less than the option-adjusted duration, resulting in underperformance during periods when rates are falling. For discount callable bonds (bonds trading to maturity), the empirical duration tends to be greater than the option-adjusted duration, resulting in underperformance in rising-rate environments. Any large deviations from the index exposure to call risk should recognize the potential significant tracking implications and the market directionality of the bet.

MEASURING SUCCESS

Of course, you can't manage what you can't measure. Managers understand this, but often find themselves without the proper measurement tools. Specifically, they lack accurate ways to gauge the extent of their bets, and the value added or lost from these bets. We've already covered measuring the extent of the bets in this chapter's sections on risk factors and enhancements. In this section, we'll explore how to measure whether any value has been added—and, if so, where the added value came from.

Outperform Adjusted Index Returns

Returning to the sailing theme, it's always critical to understand how the portfolio boat is faring against the index boat. Is the portfolio gaining any ground on the index? To evaluate relative performance, the portfolio returns must be adjusted for pricing, expenses, and transaction costs for growth and rebalancing. Pricing is a key consideration, especially in enhanced indexing, where deviations versus the index are small and pricing errors can hide valuable information. Whatever benchmark index is used, the portfolio needs to be repriced with the index providers' prices. Small differences in either the pricing time or the pricing matrix may result in significant differences (among pricing services) in periodic returns over short measurement periods. Over longer periods, these pricing differences will wash away. For value-added measurement purposes, though, periodic pricing accuracy is critical.

Since the index does not have transaction costs associated with asset growth, principal reinvestment, or income reinvestment, accurate adjustments to portfolio returns are needed to account for these differences. A simple way is to maintain a trading log with implied transaction costs as a percentage of total portfolio assets. The periodic summation of these implied costs provides a good estimate of tracking error drag associated with growth and income reinvestment.

Finally, an adjustment for expenses is required. As we discussed earlier, keeping expenses low is a simple way to enhance returns. Nevertheless, portfolio returns should be "grossed up" by these expenses to keep the portfolio on an equal footing with the index for measurement purposes.

An enhanced indexing strategy that has good risk management and diversified enhancements should be able to consistently outperform the index during most periods. Falling below the index return over the 12 months would most likely be the result either of not matching the index risk properly, of enhancement strategies that were not adequately diversified, or of significant market stresses (three or more standard deviation events) adversely affecting the enhancement strategies.

Low and Stable Monthly Tracking Differences

The other measure of indexing success is how closely the portfolio is exposed to the same risk factors as the index. This can be measured by evaluating the rolling 12-month standard deviation of *adjusted* tracking differences of the portfolio versus the index. If a portfolio is properly exposed to the index risk factors, the standard deviation will be low and stable over most periods, as we see. Periods of excessive market stress and spread volatility may result in higher standard deviations of tracking differences. However, the increases should be roughly proportional to the spread volatility increase or explainable by idiosyncratic credit risk (sample risk).

Consistent Positive Information Ratios

The information ratio is a good way to evaluate enhanced indexing success. This measures the amount of value added versus the index relative to the risk taken. It can be calculated by dividing the trailing 12-month tracking difference (adjusted for expenses, pricing, and transaction costs of growth) by the annualized trailing 12-month standard deviation of monthly adjusted tracking errors. An effective and diversified enhanced indexing strategy should keep this ratio in the range of 1 to 3 over most periods.

Detailed Performance Attribution

A manager needs excellent performance attribution tools to accurately measure the success of risk factor management and the enhancement strategies. The performance attribution analysis should attribute tracking error to term structure factors, sector bets, quality bets, and issue selection across sectors and qualities.

The term structure attribution should be analyzed at the portfolio level versus the index. The sector and quality attribution (allocation and issue selection) should be analyzed at the sector and subsector levels (detailed sector and maturity categories) with the ability to drill down to issue-level detail. Issue performance should be risk-adjusted (versus Treasury equivalent returns) with subsector, sector, and portfolio returns rolled up from the security level. This level of attribution will provide the manager with the tools to measure, with precision, the risk matching and return enhancing strategies. The result: winning the race against both the index and most managers.

KEY POINTS

- Full replication of a broad bond index is inefficient, if not impossible.
- Active bond managers intentionally position the portfolio with mismatches in risk factors in an attempt to add value above the index return.
- The core/satellite approach often uses low cost index strategies for the core portfolio and a variety of higher cost active strategies for the satellite strategies.
- The satellite portion of a portfolio focuses on the less liquid sectors which are expected to have lower correlations with the broad liquid core and where issue selection is expected to add value.
- Reasons to index bond include broad diversification, low cost, competitive performance, consistent relative performance, market performance predictability, and a time-tested record of success.
- In selecting an index for a given risk level, generally a broader index (sectors, maturities, issuers, etc.) is better than a narrow index.
- Subindices of a broad index can be created to capture different risk/return profiles (e.g., varying durations, varying credit exposures, etc.).
- For investors who are risk-averse (regarding possible loss of principal), a short-term or intermediate-term index is more appropriate than a long-term index.
- If stability and durability of income are the primary concerns, the long-term portfolio is the least risky, and the short-term portfolio the most risky.
- The primary bond index risk factors are portfolio adjusted duration, portfolio key rate duration exposures, portfolio sector and quality exposures (in percent and contribution to duration), mortgage coupon and maturity exposures, and issuer diversification.
- Since index returns are not adjusted to expenses and transactions costs, enhancements are needed just to provide a net return equal to the index.
- Return enhancements to help offset index portfolio management and transaction costs include lowering management and operating

costs, issue selection strategies, yield-curve strategies, sector/quality strategies, and optimal call exposure strategies.

- Measuring success entails evaluating value added relative to a benchmark in the context of risk assumed relative to the benchmark.

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CHAPTER
FORTY-FOUR

TRADING IN THE BOND MARKET

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A substantial part of microstructure market analysis is focused on trading equities. As a natural development of academic research on equities, similar metrics are applied to trading fixed income. However, not only does fixed income behave differently to equities, but the metrics applied to analyzing trading activities, and specifically how bond managers make transactions, are impractical to some extent. At least these metrics and tools need adjustments or require new and sophisticated data to allow for gathering the appropriate information and thus to form a reliable basis for comprehensive investigation of liquidity, spreads, and other trading variables.[1]

Whereas the price of a publicly traded equity share is easily observable, a question such as "What is the price of the current 10-year U.S. Treasury bond?" is misleading. Corporate bonds, for example, trade in the over-the-counter (OTC) market, thus prices are not as observable and reliable as equities. The most applied measure of market liquidity is the bid–ask spread. Bid–ask spreads represent the difference between the highest price that a buyer is willing to pay for a bond and the lowest price that a seller is willing to accept. Moreover, bond prices in the real world are based on quantities traded, or are order-driven as opposed to quote-driven. More precisely, the ask bond price and then the executed price could diverge substantially for an order of \$1 million or \$10 million notional amount. In fact, this is the rule, not the exception. However, the rule makes it clear that price metrics could be approximative solutions within an analytical process. In the above

The authors thank Ronny Weise of Societe Generale for granting permission to use Exhibit 44-7.

The views expressed are those of the authors and do not necessarily reflect those of LBBW Asset Management and BNP Paribas Asset Management.

1. Alvin E. Roth, "Marketplaces, Markets, and Market Design," *American Economic Review* 108(7), 2018, pp. 1609–1658.

example, not only the quoted price but the executed price of a U.S. Treasury bond depends on the notional amount and thus on the order size. In reality, specific metrics are reliable indicators; however, the challenges arise when managing fixed income portfolios with real money, and in particular when managing cash bonds and not synthetic bond replicator products using derivatives.

In this chapter we focus on several problems, issues, challenges, tools, developments, and tendencies that help to mitigate the problems bond portfolio managers face when they trade. This chapter concentrates on how bond portfolio managers trade fixed income securities, and investigates the important aspects, common issues, and recent developments. The asset class to which fixed income securities is mostly related is foreign exchange (FX). In the following, we describe the developments and common ground in trading of both fixed income instruments (e.g., corporate and government bonds) and foreign exchange. However, prior to investigating these issues and challenges, we take one step back and first describe the state of the art and the current development in bond markets, trading, and portfolio management.

FIXED INCOME LIQUIDITY

Bond trading depends on liquidity. Fixed income trading has developed tremendously in recent years. The most important determinant of trading is for the assets to be liquid. Specifically, the structure of the market has changed so much that more and more fixed income instruments are exchanged electronically. What has caused this transition? The development of electronic trading has its drivers. Exploring the drivers of the growth reveals information about the complexity of the fixed income market. This complexity is driven by the growing number of interacting agents and the high number of transactions in today's financial world. However, this complexity is organized. The development of high-frequency trading is a simple catalyst for this progress. Perhaps the strongest driver of the development of electronic trading is liquidity. Specifically, there are three reasons for the growing need for liquidity in fixed income markets:[2]

1. Reduction in supply and demand for liquidity
2. The diverse market drivers of market liquidity
3. A regime shift

Supply–Demand Relationship

The current stage in the financial markets is largely described by lower supply and a large demand for liquidity. As market-maker activities are decreasing for

2. Committee on Global Financial System Fixed Income Market Liquidity, CGFS Papers No. 55, Bank of International Settlements (January 2016).

regulatory and cost-saving reasons, which results in less liquidity, the demand for liquidity remains high. In fact, rapidly decreasing interest rates in recent years have increased the supply of bonds in the market via new issues. Primary bond market activities turned profitable for investment banks. The growth in assets under management of asset managers and increased allocation to fixed income securities helped to grow the market. Now, asset management companies determine the demand for liquidity. This asymmetric structure in the market requires quick order matching, which becomes fragile in times of financial market stress.

What drives fragile markets is the liquidity itself. Whereas U.S. Treasuries, and European, and Japanese government bonds remain the most liquid fixed income securities with tiny bid–ask spreads, the liquidity of corporate bonds with less than investment-grade ratings has declined rapidly. Historical analysis provides information that government bonds barely react to fierce market stress and remain highly liquid. An interesting example is the situation in March 2011, when the Fukushima nuclear power plant exploded. A very few hours after the incident, liquidity in the Japanese bond market disappeared, leaving highly liquid bonds—for example, those of the largest Japanese automakers—completely illiquid.

The research on liquidity is mainly associated with investigating equity market liquidity. For equities, the bid–ask spread is widely used and often applied to fixed income securities. In fixed income, researchers measure liquidity as changes of the Chicago Board Options Exchange Volatility Index (VIX).[3] However, the practical applicability of such metrics departs significantly from theoretical metrics. Loistl and Konstantinov showed that the market emergence points to a larger order size and transactions, which in turn reflect the prices and services provided by market participants.[4] Thus, prices are determined by quantities and not vice versa. Given that the price is a function of the quantity of bonds ordered, the bid–ask spreads depend on market segment and the size of the notional amount. The primary bond market expansion has been tremendous in recent years. However, the expansion in trading volumes is slower than the growth in the market for new issues of corporate debt. The low-interest-rate environment is favorable for debt issuance as companies can refinance their debt at low interest rates.

Complexity of Market Drivers

The financial market as whole is in a state of transition. The growing velocity of information exchange as a result of digitalization and big data handling/storage facilities has enabled less cost-intensive data processing and execution of orders. The substantial growth of digital services and their application in finance have

3. Lidia Bola, "Fundamental Indexing in Global Bond Markets: The Risk Exposure Explains It All," *Financial Analysts Journal* 73(1), 2017, pp. 101–121.

4. Otto Loistl and Gueorgui S. Konstantinov, "Interactions and Interconnectedness Shape Financial Market Research," *Journal of Financial Data Science* 2(2), 2020, pp. 51–63.

made large cost savings possible; however, measures taken by some competitors have forced the crowd to follow. This translates into a shift of operating processes in organizations that has led to re-thinking of the standard business model of execution and trading. As funds grow in size, information flow in the markets has increased, and automated data processing in order management more efficiently satisfies the growing needs for liquidity.

The financial crisis in 2008 marked a focal point in the newest developments of regulation. Driven by a growing need to prevent fraud and enable a much higher level of transparency, banks, nonbank financial institutions, and investors faced the challenge of rethinking their market activities. The change forced financial players to restructure risk-taking and proprietary traders. In fact, market-makers continued to decrease inventories. This remains an issue, because inventories in corporate bonds remain low in difficult market situations, which signals diminishing capacity and inclination to provide market liquidity and funds. In a nutshell, dealers and market-makers engage in transactions only if they can easily and quickly match orders and execute orders. However, in the case of large market volatility, these dealers pull back from the market and cancel market-making activities. This has enormous effects on market liquidity, or more precisely, there is a lack of liquidity exactly when it is most needed.

Monetary policy has changed greatly in recent years. Specifically, central banks are involved in many liquidity-providing activities. The European Central Bank (ECB), the Federal Reserve (Fed), and the Bank of Japan (BoJ) are examples of monetary institutions engaged in providing activities to the market in the form of monetary operations such as asset purchases and the quantitative easing program in 2013. ECB has long been an example of an active market player for its policy for corporate and government bond purchase mechanisms, pumping liquidity into the market, and thus taking over the role of an investment bank market-maker.

An indication of the changing market conditions is the February/March 2020 overall market development as Covid-19 heavily hit worldwide financial markets. As a consequence, the U.S. High Yield All Sectors Option-Adjusted-Spread hit a record high level of 1091 bps. This is a tremendous increase from the average level of roughly 440 bps in normal market conditions. Despite the increased spreads, banks were not interested in taking risks. There were even many bonds for which it was not possible to get bids and to sell. To respond to the increased need for liquidity, central banks started purchase programs to buy corporate debt. However, under §14 of the Federal Reserve Act, the Fed was not allowed to purchase corporate debt securities. With a change in the Fed regulatory structure, purchases are now allowed, thus providing demand for and liquidity to the severely hit U.S. high-yield market. Both Fed and ECB purchase programs are increasing liquidity in the generally illiquid corporate bonds with long-term maturities. Therefore, central bank policy changes the structure of the market, influences bid–ask spreads and market risk, and as a result even shifts bond portfolio allocation to longer-duration bonds, with a biased barbell structure and risk–return profiles. In general, the purchase programs by the central banks announced in the March 2020 as a policy change is an example of the nonstationarity of bond markets, time-varying market risk that cannot be explained by constant factors and exposures. Bond managers must constantly adjust their views and expectations in accordance with the changing bond market structure. Thus, portfolios must be rebalanced as bond market–related factors are time-variant, as shown recently by de Jong and Fabozzi.[5] We will show the bid–ask and market relations in detail in the next sections.

Regime Shift

The market situation changed significantly after the Global Financial Crisis of 2008 (GFC). Pre-GFC market-making differed from post-crisis activities in terms of risk management, counterparty, market, and funding risks. The completely different set-up after 2008, and necessary market adjustments helped with the transition of liquidity to new platforms. In order to improve order matching and execution, technological innovations caused cost reductions. Since then, technology, algorithms, and data gathering/processing have heavily influenced financial markets. Major market-makers considered data processing and the development of algorithms in liquidity prediction. However, in periods of financial stress, banks refrain from providing liquidity. These issues reflect the advantages and disadvantages of circuit breakers.

New Market Environment

The new market environment grows in organized complexity as it allows multiple levels of control, risk management, effectiveness, flexibility, scalability, data processing, monitoring, and cost reduction. The various interacting entities in an electronic exchange allow both vertical and horizon integration of processes. Regulators might further focus on the impact of algorithms in trading. In general, the most liquid segments in the fixed income market such as spot deals in foreign exchange and government bonds have increased in liquidity even further. As a result, market depth has increased, and bid–ask spreads are narrowing. For example, the Committee on the Global Financial System of the Bank of International Settlements reports that global inventories for corporate bonds have been steadily declining since 2008. However, the inventories in government bonds remain stable and have even increased, most notably those of asset management companies and banks in Japan and diverse financial institutions from the Eurozone.

The rise in electronic trading and the set-up of electronic platforms in fixed income market gave birth to the strong growth of robo-advisors. Robo-advisors provide direct business-to-business (B2B) and business-to-clients (B2C)

5. Marielle de Jong and Frank J. Fabozzi, "The Market Risk of Corporate Bonds," *Journal of Portfolio Management* 46(2), 2020, pp. 92–105.

services, without intermediaries. This results in a very cost-effective and less time-consuming way to attract customers and execute trades. Investment managers such as Vanguard and BlackRock are notable examples of asset management companies with large fixed income assets under management, which offer such products. Thus, electronic B2B, and B2C platforms provide order-driven execution, which results in low bid–ask spreads and better liquidity.

TRADING APPROACHES

There are three types of trading. They differ in terms of the specific intention and mechanics.

- Request for quote
- Order-placement
- Auction-driven

The *request for quote* is a convenient way for a bond manager to request bond prices from multiple dealers. Upon receipt of a request, the dealers can respond with price quotes on specific nominal sizes. Execution occurs if a bid is hit or an ask is "lifted" (accepted). In this case, currency management in the case of multiple currency positions can be executed prior to the bond trade, or afterward. The risk in the former is that a price quote can significantly depart from the expected price of a certain nominal amount. As a consequence, a bond manager might withdraw from a trade and leave a currency position in a portfolio. Thus, bonds are often executed first, and foreign exchange transaction placed afterward.

In the case of an *order-placement* bond, managers place orders against quotes provided by market-makers or liquidity providers. Orders are executed when orders (quantities) submitted are matched with the quantities of market-makers. This is a highly specific issue for fixed income securities. The prices are usually quoted, but depend on quantities. Therefore, in corporate bonds and fixed income securities, prices are quoted; however, orders depending on the size, or notional amount, move the price significantly. For example, Bloomberg's operating management system "AIM" is a transparent and reliable system for placing orders, price quotes, and execution. After the order execution, a transaction confirmation is generated that can be assigned automatically to the back- and middle-offices of an asset management company.

When trading multicurrency bonds, the bond manager has several options. The first, and the most inconvenient, is to require automatic conversion in the basis currency. For example, a U.S.-based investor buys a German government bond and a French corporate bond with notional size of 10 million and 5 million, at the price of 102.95 and 109.52, respectively. Automatic conversion of the exchange rate is the most unfavorable choice of action because the seller (bank or market-maker) usually converts the amount using a price close to the middle price (between the bid and ask price) for the FX spot transaction. The second option is for a bond manager to place foreign exchange orders separately and thus use electronic trading for FX spot transactions, which allow for narrow bid–ask spreads and low costs. The third option is for the bond manager to apply an overlay strategy for the foreign-exchange exposure of the portfolio, which we describe in the last section of this chapter.

In general, the investment process determines the order sequence—which exposure should be prioritized.[6] In general, a discretionary manager responsible for both fixed income and foreign-exchange trading can apply tactically different strategies. For overlay strategies, however, the fixed income exposure is first determined, and the weights applied to trade foreign exchange.

New Issues (*Auctions*) are primarily used in new issues or book-building. In a general case, the lead manager of an issue supplies information regarding, for example, the issue size, maturity, yield, spread, issuer rating, and rules. Bond managers indicate interest and thus place orders in the new issues indicating the size and limit on the spread. For example, in a hard currency (EUR) of a BBB+-rated 30-year corporate bond new issue with an issue size of $500 million, a portfolio manager of a $400 million bond fund might place an order of $9 million and indicate a spread limit of +125 basis points.[7] Subsequently, the orders are summed up by the lead manager of the issue and allocation is made after closing the deal. Depending on the interest—for example, a 4.5× oversubscribed new issue might (and most likely will) result in less allocated capital as initially placed.

Now the bond portfolio manager can place a foreign exchange order in the spot market or use currency forwards to allocate capital for the bond for a future settlement day. This is an alpha source for bond managers to tactically make FX deals, in particular in the highly volatile currency market environment. Both trades are easily executed using electronic trading. If, for example, the new issue bond will be settled in seven days, the manager could use his or her skill in the foreign-exchange market to cover the position due in seven days. To illustrate this, imagine a bond manager participates in a new issue of a German corporate bond. The nominal value the bond manager should receive is EUR 10 million at a price of 99.699. The bond manager could buy euros at the spot market now and wait seven days. This is a passive set-up, or a good solution if the euro is expected to appreciate in the next few days. Alternatively, the manager can make a forward transaction. A more aggressive way to act is to consider the current EUR–USD and apply active foreign exchange management. If the manager expects the euro to depreciate in the next few days due to specific reasons, the manager could speculate and short sell and then buy euros cheaper to cover his bond position.

6. For more information, see Chapter 57.

7. These numbers are only informative and for illustrative purposes and may diverge depending on the market, yield curve, sector, and interest environment.

MECHANICS OF BOND AND FOREIGN EXCHANGE TRADING

In this section, we turn our attention to the practical issues of bond trading. Specifically, we describe the relation between liquidity, bid–ask spreads, portfolio size, and portfolio weights that result from portfolio optimizations. Moreover, we show several challenges bond managers face when executing orders and highlight how innovations in the bond market like electronic and algorithmic trading, ETFs, and execution platforms change the market structure. We start with the simple decomposition of bond prices and how they affect portfolio trading in general.

Determinants of Bond Prices

As a starting point, we can define the determinants of bond prices. The price of a fixed income security $P(t,Q)$ can be shown as

$$P(t,Q) = T\left(t, s_t + OAS_t + l_t + e_t\right)$$

In words, the bond price at time t is a function of the (local currency) interest rate curve s used to discount the cash flows, the option-adjusted spread (OAS) as a measure for credit risk, the liquidity premium l (or the degree of exertion to buy or sell a bond), and other residual factors e. A large OAS, or widening spread is a measure for higher risk, and vice versa. It is important to note that a fair value model based on a sector-specific spot curve might estimate the OAS and thus the theoretical price to match the observable bid or ask price of a bond; however, the true, or real, price might diverge from that fair value due to liquidity risk and/or other factors. A central part of the next sections in this chapter is the analysis of the liquidity as measured by the bid–ask spreads and the challenges to trade they pose for bond managers. The liquidity is single security dependent. Thus, a bond market sector liquidity is the sum of the specific single liquidity metrics of the bonds within this sector. However, a bond sector liquidity is vulnerable to several factors, which we show in the next sections.

Trading in the Bond Market

There are two important questions that are almost never explained in textbooks, and which we would like to discuss: How do bond managers trade bonds? How do bond managers calculate the specific quantity of a bond to buy? These questions are most relevant when considering a quantitative investment process with optimizations producing portfolio weights.

Imagine a specific allocation and selection investment process, according to which exact single security weights are derived. Then bond managers have to estimate the amount they need to cover that estimated exposure (weight). The variables the bond manager has to consider are portfolio volume (or available funds), weight, prices, and quantities (notional value). To show the relevance and relation of bond prices, bond notional bid–ask spreads, and even foreign exchange, consider the following simplified example of two 400 million bond portfolios and three bonds in Exhibit 44-1 with different basis currencies (euro and U.S. dollar). It is convenient to express the bid–ask spreads as basis points. Therefore, we compute the bid–ask spreads as log returns of ask and bid prices.

The results of a quantitative process show that the bond manager has three bonds to allocate capital to. The weight in a U.S. Treasury bond is 7.18%. Given quoted bond prices—specifically, the price as the manager buys the bonds—the portfolio weight w_i is multiplied by the portfolio volume V_{PF}, or the capital available for investing. Then, by dividing the product ($V_{PF}\, w_i$) by the ask bond price (102.83), the manager calculates the notional amount, which the manager has to buy. Therefore, we use ask prices. In our case, the notional amount is 27,920,000.

It is important to note that corporate bonds are quoted in 1/8 increments, while government bills, notes, and bonds are quoted in increments of 1/32. It is also important to note that a bond quote is the price at which a bond traded, expressed as a percentage of par value. For example, if a fixed income security is quoted at 102.83 that means it is trading at 102.83% of par value. The percentage notation must be considered when calculating the notional amounts. As the bond portfolio manager can recognize, the prices, bid–ask spreads, and notional amount are directly related. Large swings in the quoted prices would result in different notional amounts, which in turn would change the weight of the single security. This is an important issue as market volatility affects the bond prices and thus spreads. As a consequence, the current portfolio allocation would drift from the desired allocation. To mitigate this risk, basket trades are applied. The following equation describes the technique to estimate the notional amount of bond (q_i):

$$q_i = \frac{Portfolio\ Exposure_{Basis\ Currency}}{P_i^{ASK}} = \frac{V_{PF} * w_i}{P_i^{ASK}}$$

Let us extend the analysis and include foreign exchange and bond portfolio exposure in local currency debt instruments. The second and third bonds with weights of 2.82% and 3.68%, respectively, are allocated in EUR and NZD. Whereas the previous technique applies again, a division for the local currency exposure is necessary as the amount ($V_{PF}\, w_i$) would only estimate the capital allocated in EUR and NZD in the portfolio basis currency (the U.S. dollar for example). Therefore, dividing the product by the current ask price for NZD–USD would adjust the notional amount to reflect local currency exposure. Note, that to correctly adjust the volumes, price notation is used for the foreign exchange ($FX_i^{fx-\mathrm{BASIS}}$). The following equation describes the technique:

$$q_i = \frac{\text{Portfolio Exposure}_{\text{Basis Currency}}}{P_i^{\text{ASK}}} = \frac{V_{PF} * w_i}{P_i^{\text{ASK}} * FX_i^{fx-\text{BASIS}}}$$

EXHIBIT 44-1

A Matter of Basis Currency: U.S. Dollar and Euro Bond Portfolios

U.S. Dollar Portfolio

Bond	Weight	FX	FX ASK	BID	ASK	Bid-Ask	Notional	Exposure in USD
T 1 1/2 08/15/22	7.18%	USD		103.77	102.83	–0.0091	27,920,000	28,709,613
BTPS 1.2 04/01/22	2.82%	EUR	1.135	101.82	101.84	0.0002	9,760,000	11,285,182
NZGB 4 1/2 04/15/27	3.68%	NZD	0.651	125.52	125.78	0.0021	17,940,000	14,699,011

Euro Portfolio

Bond	Weight	FX	FX ASK	BID	ASK	Bid-Ask	Notional	Exposure in EUR
T 1 1/2 08/15/22	7.18%	USD	0.881	102.77	102.83	0.0006	31,700,000	28,711,011
BTPS 1.2 04/01/22	2.82%	EUR		101.82	101.84	0.0002	11,080,000	11,283,650
NZGB 4 1/2 04/15/27	3.68%	NZD	0.574	125.52	125.78	0.0021	20,370,000	14,701,766

Source: Data obtained from Bloomberg, LLC.

It is easy to see that the bond prices are the same for every investor and are unrelated to the portfolio basis currency (U.S. dollar and euro). However, the notional amounts that the bond portfolio manager has to order depend on the basis currency and thus the demanded notional amount is effectively adjusted by the foreign-exchange ask price. A similar rule applies to selling fixed income securities considering bid prices. However, selling is easier as bond managers know the exposure and notional amount in their portfolios. Therefore, rebalancing portfolios is directly affected by bid–ask spreads, which in turn affect notional amounts.

An important adjustment is necessary when estimating the notional amounts for a bond portfolio. Often bonds trade in minimal pieces, or increments depending on the issue (for example 100, 1000, or 100,000,000). For example, a notional of 27,923,344 (which is the exact notional value) is not tradable. A reasonable size would be 27,920,000.

When and How Do Bond Managers Trade?

Bond managers might trade because of redemptions, inflows, allocation adjustments, regulatory issues, urgent client needs for liquidity, and the like. Whereas the question "when" do bond managers trade is to some extent misleading as it refers to timing, necessities, idiosyncratic and many other reasons, the major focus of this chapter is the mechanics of how bond managers trade.

Bond managers have in general two alternatives when trading. The first is discretionary, that is, trading single securities based on relative value analysis, rich/cheap valuation, new issues, portfolio adjustments involving high conviction trades based on news flows, changes in single bond fundamentals, corporate events, down rating or upgrades, and so on. The trading frequency of discretionary bond portfolio managers is irregular. Put differently, discretionary bond managers might implement bets sporadically as an immediate consequence of information flow. It is important to note that discretionary managers might base their decisions both on quantitative tools and/or qualitative analysis. The following simple example illustrates the discretionary style.

Suppose that a bond manager decides to buy long-term Italian government bonds in euros as a consequence of the loose monetary policy and re-started liquidity program of a central bank, despite the fact that spreads are widening, yields are rising, the economic system is becoming fragile, and institutional investors are avoiding Italian debt. At the same time, this decision can be based on quantitative indicators and analysis. Specifically, a discretionary fund manager might employ factor models as add-on tools, which have detected less crowded behavior in Italian debt. In addition, quantitative valuation techniques might provide information on the roll down returns, spreads, and duration positioning. As a consequence, the bond manager of an international bond portfolio might increase the exposure to the EUR-USD exchange rate, and thus emphasizes more carry returns based on a large interest rate differential versus the manager's basis currency (e.g., the U.S. dollar). A comparative analysis might show that an overweight of Italian government bonds versus Italian industrials is currently preferable. As the example illustrates, a single decision might affect more sub-asset classes (geographic allocation, industry, sectors, foreign exchange, duration, maturity allocation, etc.) that are part of a bond portfolio.

The second way is based on basket trades. More generally, basket trades have become the domain for systematic bond portfolios, or bond portfolios managed according to a quantitative investment process. Rebalancing of funds to reflect the changing market conditions or model reallocation, factor exposure, and related issues requires the execution of basket, or portfolio, trades that involve a large number of single constituents. Within a quantitative investment process, the duration, maturity allocation, and other risk-return metrics are considered in a process of rebalancing; thus, a basket comprises several buy and sell orders.

Following are the issues and challenges that affect portfolio trading and specifically the choice of trading method, functionality, and success:

- Bid–ask spreads
- Portfolio size and transaction costs
- Portfolio allocation
- Illiquid fixed income securities
- Market volatility

In fact, these challenges affect the bond manager's activities to a large extent, as markets constantly change, and bond portfolio complexity increases. The natural way to highlight how the different styles deal with and are affected by these four issues is to consider practical examples.

Slimane and de Jong observed that there is a positive relationship between bid–ask spreads, and maturity.[8] Bid–ask spreads are then inversely related to bond issue size, with larger issues having lower spreads. More complex bond portfolios allocated to different sectors, maturities, countries, currencies, and sub-asset classes result in larger bid–ask spreads and liquidity risk. Although the correlation coefficient between bid–ask spreads and credit rating seems to be 0.84, correlation is not causation and in the period after the GFC of 2008, the market has changed tremendously, making it even harder to detect and investigate causation.

Increasing bond market activities from central banks shift the real pricing. Bid–ask spreads are indicative for measuring bond market liquidity. However, they are only approximative solutions as indicators. Bond prices are results of notional amounts exchanged on the market; thus, prices depend on quantities. Bid–ask spreads help to indicate possible liquidity traps, but their magnitude and meaning diverge significantly from the real executed prices that depend on the nominal amount sold or bought, and market demand and supply. During financial turmoil,

8. Mohamed Ben Slimane and Marielle de Jong, "Bond Liquidity Scores," *Journal of Fixed Income* 27(1), 2017, pp. 77–82.

there is heavy involvement of central banks, which supply liquidity and engage in market activities. As mentioned earlier, the Fed, ECB, and the BoJ are just a few important examples for active market players trading fixed income securities. This results in a massive shift in the demand for eligible purchase securities, in particular short-term investment-grade bonds, and less demand for noninvestment-grade securities, which are not included in purchase programs. As a consequence, long-term investment-grade corporate bonds, which in general have a higher credit rating, price, maturity, yield curve, duration, and spread risk, become more liquid. Bid–ask quotes for short-term investment-grade securities become highly attractive and indicate liquidity; however, ask quotes are often only generic. As a result, there are two problems: (1) the biased power of bid–ask spreads to indicate liquidity and (2) the restricted ability to execute trades. The bid–ask spreads are heavily impacted by supply and demand, preferred allocation, interest rate dynamics, fundamentals, business cycle and market volatility, and the quantities exchanged.

The following two examples help to illustrate the problem. In Exhibit 44-2, a bond manager applies both fundamental analysis and quantitative-based yield curve analysis to a specific sector. As a result, a switch in short-term (1.5 years-to-maturity) and mid-term (roughly 5.5 years-to-maturity) bonds seems reasonable. The bond manager sells the short-term bond with a larger spread of 178 bps (rich) and buys a very favorable, fundamentally solid short-term bond with a similar roll down return and an OAS of −10 bps. Additionally, the bond manager sells a fairly valued bond and buys a cheaper alternative with a 1 bp higher roll down and OAS of 0.48%. The buying opportunities are favorable with stronger fundamentals—solid EBITDA margins, thus ability to pay debt. Whereas bid–ask spreads indicate the best liquidity in short-term bond SUFP 2 1/2 09/06/21, no market participant provides a reasonable price for this security, thus the trade is unexecutable (denoted by “N/A”). Counterintuitively, the bid–ask spread does not indicate illiquidity (the highest spread is only 35 bps). On the contrary, the low bid–ask spread suggests sufficient liquidity. A real price of 99.68 is offered for 1.5 million. There is an additional issue regarding the supply and demand, affecting spreads, which we will highlight shortly.

Alternatively, a bond manager tries to sell a high-yield bond with an issue size of $500 million and short-maturity (roughly 3.5 years-to-maturity) as shown in Exhibit 44-3. The bid–ask spread is the difference between the highest price that a buyer is willing to pay for a fixed income security and the lowest price that a seller is willing to accept. Although the quoted bid–ask spread indicates reasonable liquidity, the manager receives a rejected order for a notional amount of 500,000 from five brokers. However, although both the bid–ask and the volume-weighted bid–ask spread does not definitely indicate low volumes, a trade simply is not possible, not even at a price with a reasonable discount on the bid price. Thus, on a single trading level, it is impossible to sell the bond. The only option left is to sell it within a portfolio trade—a basket of securities.

A specific case has to be discussed that reflects the dynamics of the option-adjusted spread and the movement of interest rate curves. From the practitioner’s

EXHIBIT 44-2

Intra-Sectoral Relative Value Trades

Order	Bond	Price (T)	Roll Down	OAS	Debt/ EBITDA	EBITDA Margin	EBIT/ Interest	Size	Bid	Ask	Bid–Ask Spread	Executed
Sell	SIEGR 0 09/05/21	96.630	0.38%	–1.78%	1.6x	12%	6x	2M	99.853	100.001	0.0015	99.902
Buy	SUFP 2 1/2 09/06/21	102.551	0.38%	–0.10%	1.2x	17%	20x	2M	102.679	102.798	0.0012	N/A
Sell	SUFP 0 7/8 03/11/25	98.056	0.29%	0.08%	1.2x	17%	20x	3M	102.255	102.613	0.0035	102.352
Buy	ETN 0.697 05/14/25	96.996	0.30%	0.48%	2.1x	18%	12x	3M	99.288	99.608	0.0032	99.68 (1.5)

Source: Data obtained from Bloomberg, LLC.

EXHIBIT 44-3

Single High-Yield Bond Trade—Illiquidity and Bid–Ask Spreads

NOVO 1 5/8 09/20/23	Bid	Ask	Size ($ Mil)	Bid-Ask Spread	Status
Quote	87.41	89.965	500	0.029	Sell 500K
Broker 1	89	91	1000/1000	0.022	Reject
Broker 2	87.536	89.443	1000/1000	0.022	Reject
Broker 3	87.5	89.5	1000/300	0.023	Reject
Broker 4	67.5	75	1000/1000	0.105	Reject
Broker 5	86.01	89.455	1000/1000	0.039	Reject
Broker 6	86.295	91.208	500/500	0.055	Reject

Source: Data obtained from Bloomberg, LLC.

point of view there are two possible dynamics in the credit spreads and interest rate movements: (1) a technical correlation and (2) fundamental correlation as measured for example between the five-year swap yield and the nonfinancial credit spreads. Whereas in a case of fundamental correlation a rise in yields is compensated by narrowing of spreads due to economic growth, for example, a technical correlation takes place as a result of allocation shifts. In the case of technical correlation, both spreads and yield move in the same direction. The latter case is typical in times with a low yield environment and times of financial stress—for example, in 2003, 2009, 2011, 2016, and 2020. The option-adjusted spreads in combination with liquidity might cause bond prices to drift further from the bid–ask quotes. This is in particular relevant in times of financial market turbulence. For the spread factor price movement, the approach suggested by Ben Dor, Dynkin, Hyman, Houweling, van Leeuwen, and Penninga is a suitable enhancement.[9]

The previous examples show that single trading of bonds electronically can produce unfavorable solutions as it seems to be impossible to sell bonds or, even worse, to consider bond market liquidity as merely measured by bid–ask spreads. This example stresses the challenges when dealing with illiquid securities. Due to the large impact of a "liquidity premium," this premium is only capitalized over long holding periods. However these periods could harm portfolio risk–return profiles. Thus, fund managers can mitigate the impact of illiquid securities by trading them in baskets using "Bid Wanted in Competition" (BWIC).

The bid–ask spreads under normal market conditions for several markets are shown in Exhibit 44-4. Typically, emerging market debt trades at larger spreads than developed market bonds.

9. Arik Ben Dor, Lev Dynkin, Jay Hyman, Patrick Houweling, Erik van Leeuwen, and Olaf Penninga, "Duration Times Spread," *Journal of Portfolio Management* 33(2), 2007, pp. 77–100.

EXHIBIT 44-4

Spreads and Maturities of Emerging Market Debt Instruments

	South Africa	Malaysia	Turkey	Mexico	Hungary	Poland
Tenors	1-30Y	1-20Y	1-10Y	2M-20Y	1-20Y	1-20Y
Liquid Tenors	1-30Y	1-5Y	1-10Y	1,2,5,10Y	1-10Y	1-10Y
Bid-Ask Spread	2-4bps	3-6bps	3-7bps	2-3bps	2-3bps	2-3bps
Trade Size	100K	100K	100K	100K	100K	100K
Money Market	JIBAR	KLIBOR	TRLIBOR	TIIE	BUBOR	WIBOR
Currency	ZAR	MYR	RUB	MXN	HUF	PLN

Source HSBC Fixed Income Rates Research, 2018

Finally, to show the effects of the bid–ask spreads, portfolio size, and transaction costs, we show a basket portfolio that comprises multiple asset classes executed as single trades. A current portfolio basket of $50 million, comprising 63 bonds, is summarized in Exhibit 44-5. Specifically, this is an example of portfolio turnover in international government bonds, financials, foreign exchange, utilities, banks, and domestic government bonds.

EXHIBIT 44-5

Single Bond Electronic Trading of a Real Bond Portfolio

Sector	Bid–Ask Spread	Executed Price (Bid/Ask) vs. Quoted Bid/Ask
GOVERNMENT BONDS (NATIONAL)	0.004	–0.007
BANK	0.057	0.101
FINANCIAL	0.017	0.056
SPECIAL PURPOSE	0.005	0.033
INDUSTRIAL	0.038	0.123
UTILITY	0.017	0.095
GOVERNMENT BONDS (INTERNATIONAL ex EM)	0.011	0.086
FOREIGN EXCHANGE (AUD, CAD, GBP, SEK, NOK)	0.108	0.073

In general, a portfolio basket of that size allows for a quick turnover and moderate transaction costs. When considering bid–ask spreads, one can easily observe that they are narrow, with the largest liquidity issues associated with banks, industrials, and utilities. However, when comparing the bid–ask spreads using the real executed prices, a different picture emerges. Specifically, the bid–ask spreads for the local currency debt, banks, industrials, and utilities are much larger than those initially assumed or revealed by the simple quoted bid and ask prices. More importantly, it is the magnitude of change between the bid–ask quotes and the real execution that matters. Put differently, whereas the bid–ask spread might indicate some liquidity issues for fixed income securities, the real prices indicate that the liquidity issues are much larger. To add additional complexity, the market risk of international bonds comprises multiple interest rate curves, as noted by de Jong and. Fabozzi.[10] More precisely, a bid-size spread signaling sufficient liquidity does not necessary indicate robust price setting.

10. De Jong and Fabozzi, "The Market Risk of Corporate Bonds."

Determinants of Bid–Ask Spreads

The last few examples help to answer the question: What impacts the bid–ask spreads? The bid–ask spreads are heavily influenced by portfolio size, market cycle and market volatility, demand and supply, monetary policy (in particular, purchase programs), and allocation. There is a further important factor that deserves attention. In fact, a low-interest-rate environment is supportive for new issuance. On-the-run bonds come at higher liquidity, and thus the off-the-run securities decrease in liquidity and prices drop as yields rise. As interest rates decrease, yields (and eventually spreads) on outstanding bonds rise relative to new issues that are paying lower cash flows, discounted with lower yields. Remember, there is an inverse relationship between cash flows (coupon size) and duration. Furthermore, lower cash flows are discounted much stronger compared to large coupons. The central bank purchase activities amplify the demand for new issues in the corporate bond market. The new securities become largely oversubscribed in the primary market, leaving existing bonds drying out. Bid–ask spreads and the demand and supply are largely amplified and even exaggerated by central bank purchases, and by demands from investors, and in particular by other bond managers, to buy them and later to sell them to central banks.

Portfolio allocation directly affects portfolio trading in the real world. However, contrary to academic research, aligning target or desired tactical portfolio allocation and a model allocation might be a challenging task. The reason is that the traditional model often does not apply to fixed income allocation and thus is impossible to implement in real portfolios (at least not with cash bonds). For example, fixed income allocation to the BRIC (Brazil, Russia, India, and China) countries in local currency bond exposure is not possible. The reason is that offshore bond managers cannot invest in local currency Brazilian and onshore Chinese bonds. Let us consider an example. Allocation weights in emerging markets must account for low liquidity and even the impossibility to invest if a fund of $1 billion decides to allocate 15% of its assets in an illiquid and small government bond market. Similarly, increasing the portfolio allocation of a mid-size fund by 15% in high-yield European bonds might be a challenging task in a market of rising yields and spreads. A reasonable question is then at what cost is the reallocation possible? A larger transaction cost might evaporate manager alpha in illiquid segments. The last few examples reveal challenges associated with a discretionary management style. The development of electronic trading helps to mitigate these issues.

Therefore, rebalancing portfolios is directly affected by bid–ask spreads, which in turn affect notional amounts. However, market volatility directly affects bid–ask spreads. As spreads are widening and liquidity dries up, the current portfolio allocation departs from what is desired.

There are a four important conclusions: (1) the prices of fixed income securities are determined by notional amount exchanged, (2) the bid–ask spreads as a liquidity indicator are indicative and approximate and depend on market volatility, (3) the portfolio size and allocation affects transactions costs with portfolio baskets of reasonable size ($300 million) gaining from the best execution costs as captured by the bid–ask spreads, and (4) portfolio basket execution of single bonds with a number of brokers using a "best execution" policy, or as BWIC, leads to different results.[11]

The major problem why certain equity-based components cannot be applied strictly to fixed income securities reflect the nonstationarity of bond characteristics. This issue has been recently stressed by de Jong and Fabozzi.[12] Bonds have time-varying risk properties related to maturity, duration, credit rating, interest rate level, credit spread, and slope and curvature of the yield curve. The relationships are simply nonlinear. Adding an explanatory factor in bond investing does not correspond linearly to the existing factor model. Fixed income securities and thus bond portfolios cannot have stationary market risk components as measured by spreads, interest rate risk, credit ratings, prices, and so on. The transition of risk can be only modeled if bond portfolios are rolled and rebalanced so that the market risk remains stable.

The Fundamental Law of Active Management and Bond Trading

To illustrate this relationship more precisely, consider an opportunistic bond portfolio investing globally, in different currencies, corporate sectors, maturities, security types, and so on. Specifically, a portfolio invests in eight asset classes—high-yield, foreign exchange, industrials, utilities, financials, covered bonds, domestic government bonds, and local currency government bonds. If a manager wants to generate a high information ratio, he has to increase his breadth. However, this means, that a fund manager has to predict, or at least *nowcast* (using data analysis from electronic exchange as opposed to forecasting economic variables), different interest rate regimes, credit spreads, durations, convexities, volatilities, currency exchange rates, and so on.

More importantly, these effects interact in multiple ways. Specifically, a U.S. bond manager investing in French investment-grade corporate bond (with a credit rating of A+) is related to the entire Eurozone interest rate dynamics, ECB policy, EUR-USD exchange rate, U.S. yield curve, Fed policy, spread dynamics, and investment flows in the Eurozone as more and more investors pursue European corporate debt for attractive fixed income and variable price-related returns. These effects cannot be modeled linearly using a stationary model, as bond price does not reflect interest rate and spread movement linearly. As Kahn once observed: "It's hard to be a bond manager." This claim can be easily

11. The "Best Execution" policy is set in Article 27 of MiFID II, by the Markets in Financial Instruments Directive (MiFID) as a requirement for fund managers to take all necessary steps to the best order execution for their clients. The following criteria are strict requirements: price, cost, speed, notional, and probability of execution and settlement, as well as other material factors affecting order execution. See https://www.esma.europa.eu/document/best-execution-under-mifid; https://www.sec.gov/fast-answers/answersbestexhtm.html.

12. De Jong and Fabozzi, "The Market Risk of Corporate Bonds."

shown using the Fundamental Law of Active Management and estimating the Information Ration (*IR*) originally proposed by Grinold in in 1989:[13]

$$IR = IC\sqrt{B}\,TC$$

where *IC* is the information coefficient, or the measure of skill as computed as Pearson correlation, or Spearman correlation, and *B* is the breadth, or the number of independent bets, and the *TC* is the transfer coefficient denoting possible restrictions when applying a strategy. The *TC* ranges between 0 and 1, with 1 meaning no restrictions. Furthermore, the *TC* might capture both hard restrictions, like ones on short selling, specific sectors, and so on, and soft restrictions referring to transaction costs resulting from excessive trading. In this line of thought, higher transaction costs and illiquidity directly affect the *TC* coefficient.

As shown in Exhibit 44-6, an opportunistic global bond manager investing in eight assets and rebalancing them on a monthly basis would have higher breadth and would take more risks. The annual breadth would be 96 for eight assets and 960 if the bond manager considered 10 bonds per asset class. Let us assume that the IC is constant at 0.1. Then a low *TC* coefficient as a result of high transaction costs and liquidity pulls the *IR* lower. It is important to note that the numbers are generic for the purpose of illustrating the principles.

EXHIBIT 44-6

Information Ratios with Different Breadth and Transfer Coefficients

IR	*IC*	*B*	*TC*
0.1	0.1	96 (8*12)	0.1
0.31	0.1	960 (8*12*10)	0.1
0.05	0.1	96	0.05
0.15	0.1	960	0.05

These issues make clear that *IR*, transaction cost, portfolio allocation, and illiquidity are interacting factors, which might diminish alpha.

As a consequence, high bid–ask spreads and transaction costs impose serious pressure on a fund manager's information ratio. The recent financial market developments have brought a novel and reliable way to lower the impact of illiquidity in fixed income trading and execution, and this is particularly useful for investment-grade and lower-grade corporate bonds.

13. Richard C. Grinold, "The Fundamental Law of Active Management," *Journal of Portfolio Management* 15(3), 1989, pp. 30–37. See also Richard C. Grinold and Ronald N. Kahn, "Information Analysis," *Journal of Portfolio Management* 18(3), 1992, pp. 14–21.

ELECTRONIC TRADING

Foreign-exchange (FX) markets have surpassed the development of fixed income markets in terms of electronic trading.[14] The global foreign-exchange turnover increased from $1.2 trillion in 2001 to roughly $6.6 trillion in 2019 according to the Bank of International Settlements. Almost every FX spot transaction has been executed fully electronically. In addition, the majority of FX forwards, FX options, and FX swaps are primarily executed using electronic platforms. According to the Securities Industry and Financial Markets Association (SIFMA), roughly 78% of both the volume and the transactions in the FX spot market are executed electronically. Although U.S. Treasuries and European government bonds enjoy large liquidity in the market, their liquidity has recently been driven by a significant number of transactions executed electronically. However, the development in the fixed income markets for investment-grade corporate bonds and high-yield bonds was less promising in 2015. Only slightly more than 20% of the high-yield cash bonds were traded electronically.

Corporate bonds are mostly executed OTC market. For example, in 2014, roughly 50% of the volume traded in European corporate bonds was executed electronically and roughly 74% of investors traded using electronic platforms. Compared to the end of 2008, as the financial crisis hit the markets, roughly 57% of investors traded corporate bonds electronically, which reflected only 20% of the volume. This tendency almost reflects the trading of cash bonds. However, corporate bonds have been executed much more often through electronic exchange since 2009. Investment banks build algorithms based on their transactions and databases to provide internal scores for the liquidity of fixed income securities.

The rise of electronic trading has been driven by the interaction of three factors:

- Technology development
- Increase of regulation
- Structural market change

At first glance, these three factors seem directly related to the drivers of fixed income liquidity. In fact, technology is used to lower costs further. Investors and asset managers face rising pressure as global yields decline. Reducing fees to literally zero in a fierce competition forced the development of new products. As a consequence, the total market structure changed. There has been a substantial growth in the ETFs of both investment-grade (IG) and high-yield bonds. Specifically, investment-grade ETFs rose from $66 billion in 2014 to $163 billion in 2019. High-yield ETFs grew from $42 billion in 2014 to $66 billion in 2019. The total number of fixed income ETFs grew from 291 in 2014 to 389 in 2019. This corresponds to a more than twofold increase of the assets under management

14. Markets Committee, "Electronic Trading in Fixed Income Markets," Bank of International Settlements, January 2016.

in ETFs, which grew from $419 billion in 2014 to $872 billion in 2019. As a consequence of all these factors, the asset management industry has changed to electronic platforms.

Petajisto investigated the ETF market structure and highlighted the differences in asset class pricing and trading.[15] Bond trading differs greatly from trading in equities or other asset classes. One of the reasons is that volume (nominal amount) and prices are not disclosed and transparent to other market participants. Specifically, bond prices are a function of a nominal quantity and thus order-driven prices might diverge from the quoted market prices. Therefore, the quoted bid–ask spreads for fixed income securities are only approximate indications of liquidity. The real bid–ask spreads diverge significantly from the quoted ones. With electronic trading, it is possible to gather data and build algorithms and thus generate a much more reliable picture of bond market liquidity. These two series could converge. However, often these data remain proprietary for the large dealers and market-makers.

A clarification of the platforms and types of order reveals more information regarding the complex nature of international bond portfolio management when also involving foreign exchange transactions.

Types of Trading Platforms and Pricing Technologies

Trading platforms differ by the number of participants and specific methodology.[16] Examples are Inter-dealer, Single-dealer Client, Multi-dealer Client, and Odd-Lot Trading Systems. The most interesting and growing type of system is the *Exchange*. Exchanges are anonymous trading platforms in which buyers and sellers directly match trades. A specific property is the absence of market-makers. Thus, liquidity is directly provided by the trading parties.

The factors driving liquidity and the drivers of the evolution of electronic exchanges gave birth to several cutting-edge platforms, which deserve mention. These electronic exchanges bypass human interaction (voice trading) to make algorithm-based (software) trades. The most common attribute they have is that they are highly sophisticated, algorithm-based, cloud-supported, and data-based structures. Bond pricing is based on algorithms, which also allows for high-frequency trading, storage facilities, documentation, processing, and best execution policies. The following are examples of platforms specializing in fixed income and foreign exchange trading:

- Tradeweb—a broad platform helping a broad range of market participants
- TruMid—a fixed income specialist platform

15. Antti Petajisto, "Inefficiencies in the Pricing of Exchange-Traded Funds," *Financial Analysts Journal* 73(1), 2017, pp. 24–54.
16. Marshall Nicholson, "Electronic Trading For Fixed Income Markets," chapter 4 in Frank J. Fabozzi (ed.), *The Handbook of Fixed Income Securities* (New York, McGraw-Hill, 2012).

- Marketaxess—the largest platform for corporate bonds, with market share of 85%
- Liquidnet—an open-source artificial intelligence platform
- Flextrade—an all-in order/execution management system
- Algomi—a fixed income market aggregation and market surveillance tool
- Bloomberg—the well-known platform

A brief overview of one of the platforms shows the technology-based solutions provide liquidity and prices for corporate bonds.[17] *TruMid* is an example of a high-tech platform whose pricing is based on two different algorithms. The first is a *matrix*-based algorithm searching for commonalities between recently traded bonds with similar characteristics (maturity, credit rating, size, and liquidity). In the language of data analysis, this is an eigenvector centrality score algorithm. The advantage is that such an algorithm provides pricing for less liquid bonds too. Therefore, large market participants and brokers with huge market activities can monitor and extract a large amount of data from the transactions and thus, when executing basket trades, they provide liquidity for less liquid securities. A disadvantage is that the solution depends on the sample size. The second algorithm is an *evaluated pricing* algorithm based on rigorous analysis and human judgment to evaluate new issues, current pricing, and broker/dealer quotes. The price can be adjusted to reflect the most efficient price in the current market stage.

Fixed Income Electronic Trading: Basket Trades

The described methods for trading fixed income securities are employed according to manager-specific needs. However, in a fully quantitative process, portfolio managers reallocate funds and as sellers they often do not like to reveal a strategy change. The appropriate approach is called *Bid Wanted in Competition* (BWIC). The aim is to find the best market price of a basket of securities. The fund manager receives a list with security price ranges and if the manager agrees upon these prices, the basket is executed within a specific, reasonable time. It is intuitive to suggest that achieving the highest possible prices for selling is not possible. However, the seller (i.e., the bond portfolio manager) immediately recognizes that specific prices are in line, some on the lower and some higher spread price range. For example, BWIC trades comprising securities from both developed and emerging markets' government bonds in 2012 (Canada, Sweden, Australia, New Zealand, Russia, Turkey, Hungary, Poland, etc.) resulted in prices that diverged from those expected. However, the BWIC allows favorable price making for different counterparties.

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17. See https://www.trumid.com/files/FVMP-Whitepaper-10-20-17.pdf; https://www.liquidnet.com; https://www.algomi.com; https://www.flextrade.com; https://www.content.marketaxess.com; https://www.tradeweb.com.

There are specific issues related to electronic trading in fixed income, which clearly highlight the advantages of the new systematic trading:

- Traditional execution is limited to discretionary managers and a small number of trades and is cost-intensive and time-consuming.
- Portfolio execution, or basket trades, eliminates inefficiencies from idiosyncratic management choices regarding duration, spread, liquidity, and so on.
- The system allows a large number of trades; thus, an efficient tool for ETFs, passive products, and quant-driven funds.
- The system allows optimized beta hedging, and factor models for risk management and liquidity.
- Portfolio baskets move in close correlation to indexes and ETFs, which results in improved pricing.
- Volatility reduction for a portfolio, compared to single bond trades, results in improved bid–ask spreads and liquidity.
- Portfolio basket trades comprise in general large number of single securities in order to diversify the trade. For example, a meaningful global bond portfolio basket comprises at least 30 fixed income securities.

The mechanics of a portfolio trade can be described in the following way. A portfolio manager sends a list of securities to a broker. For example, a $500 billion portfolio needs to be rebalanced and the portfolio manager expects a quote within 30 minutes. Note that a short time period is always desired as market volatility could cause the final allocation to drift from the target allocation. After careful portfolio analysis, the broker can identify the liquid securities according to their credit rating, spreads, sector, and so on. The broker might analyze the current liquidity and turnover in various activities—for example, rebalancing and transactions in ETFs, daily trading of fixed income instruments, hedging activities in fixed income securities and currencies, rebalancing of index funds, and market-making.

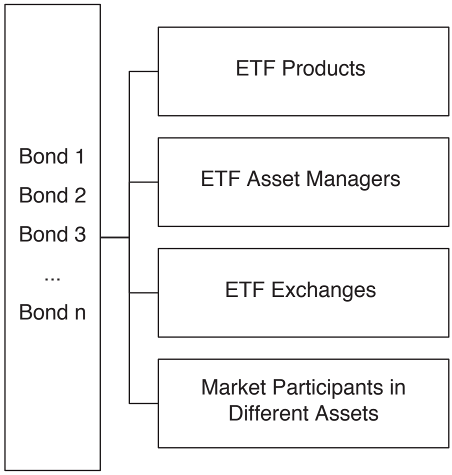
The portfolio basket trades in a similar way to a single security (see Exhibit 44-7.) The advantage is that the components of the portfolio basket, such as different ratings, corporate sectors, and so on, are matched with other clients' needs, authorized participants, asset managers, ETF products and ETF managers, and ETF exchanges. The main advantages of electronic trading are the broad diversification in terms of notional size, strong operating efficiency, quick time to quote, aggressive pricing due to the narrow bid–ask spreads of ETFs, the fast execution, and the flexibility of matching specific portfolio constrains. In short, electronic exchange allows multilevel interaction of trading entities and the price mechanism is order-driven, in contrast to OTC trading, which remains quote-driven.[18] Thus,

18. SIFMA Insights – Electronic Trading Market Structure Primer, October 2019, https://www.sifma.org/wp-content/uploads/2019/10/SIFMA-Insights-Electronic-Trading-Market-Structure-Primer.pdf.

electronic portfolio trading provides sufficient and reliable metrics for liquidity as the trades are order driven. As a result, bid–ask estimates are reliable indicators of liquidity.

EXHIBIT 44-7

Portfolio Trade Decomposition



Source: Societe Generale. Reproduced with permission.

A broad number of active trading counterparties (funds, ETFs, etc.) represent a reliable source of information and contribute to efficient bond pricing. Thus, the portfolio basket can be split into multiple trading blocks. As a result, the time required for executing the whole portfolio basket is much shorter than the time for executing a portfolio engaging in normal trading activities.

This is particularly important for lower-rated portfolios with average ratings below investment grade, and long-term duration. As the liquidity of long duration, lower-credit-rating bonds dries up, portfolio managers often face the impossible situation of needing to rebalance all their funds, or at least to sell a significant portion of the assets held. However, BWIC enables portfolio managers not only to sell illiquid assets, but moreover to preserve market depth and liquidity. Specifically, for large corporate bond funds selling illiquid, long-duration, below-investment-grade bonds, the market price changes by several ticks. Nevertheless, even government bonds can suffer dramatically from illiquidity and their bid–ask spreads can differ substantially during normal conditions and during periods of financial turmoil.

Foreign Exchange Electronic Trading

For many years, the BIS Triennial Central Bank Survey has documented the way trades are executed (i.e., where and how orders are filled) in the FX market. The main trend in FX trade execution is that execution has become increasingly electronic, moving away from traditional "voice" execution. The 2019 Triennial Survey shows that the share of FX trading executed electronically is currently close to 60%. The market segment where electronic trading is the highest is dealer-to-customer transactions. Spot remains the instrument with the highest electronic trading share, which stood at 75% of dealer-to-client transactions. Interestingly, in contrast to its rise in dealer-to-customer markets, electronic spot trading in inter-dealer markets saw a decline in both relative and absolute terms, falling by 7% since 2016 to $368 billion per day in the latest Triennial Survey. As a result, inter-dealer trading accounted for less than a third of the total electronic spot market in 2019. This decline in electronic inter-dealer trading is driven principally by "internalization," whereby dealers temporarily keep risk arising from client flows until it is offset against opposing client flow. The ability of dealers to internalize depends on the ability to attract customers to trading via single-bank platforms or direct price streams.

The 2019 Triennial Survey confirms that, despite the overall trend, electronic trading is not progressing uniformly across all instruments and market segments. For example, inter-dealer trading of FX swaps has remained heavily voice-reliant, while dealer-to-customer trading has moved toward greater use of electronic execution methods.

There are several interrelated reasons for voice trading (i.e., voice execution), as opposed to electronic trading, retaining a higher share in FX swaps. First, swap trades involve particularly large notional amounts. Second, FX swaps are more difficult to price because balance sheet considerations play a larger role.

The 2019 Triennial Survey shows that trading on multi-bank platforms has been the fastest growing execution method from 2006 to 2019. The main driver for this trend is that clients have continued to become more cost-conscious. Trading on multi-bank platforms, or via liquidity aggregators bundling various venues and providers, has now surpassed single-bank platform volumes and other direct forms of electronic trading.[19]

KEY POINTS

- Bid–ask spreads represent the difference between the highest price that a buyer is willing to pay for a fixed income security and the lowest price that a seller is willing to accept. Moreover, bond prices in the

19. Andreas Schrimpf and Vladyslav Sushko, "Sizing Up Global Foreign Exchange Markets," *BIS Quarterly Review*, December 2019, pp. 21–38 and Maximilian Butz and Roel Oomen, "Internalisation by Electronic FX Spot Dealers," *Quantitative Finance* 19(1), 2019, pp. 35–56.

real world are based on quantities traded, or order-driven as opposed to quote-driven. More precisely, the ask bond price and then the executed price could diverge substantially for an order of 1 million or 10 million. In fact, this is the rule, not the exception. The bid–ask spreads are heavily influenced by portfolio size, market cycle, demand and supply, monetary policy—in particular, purchase programs, and allocation.

- As a consequence, high bid–ask spreads and transaction costs put serious pressure on a fund managers' information ratio. Bonds have time-varying risk properties related to maturity, duration, rating, interest level, credit spread, slope, and curvature. The relationships are simply nonlinear. Adding an explanatory factor in bond investing does not sum up to the existing factor model. Fixed income securities and thus bond portfolios cannot have stationary market risk components as measured by spreads, interest rate risk, ratings, prices, and so on.
- Fixed income securities' electronic exchanges are order-driven and not quote-driven. The rise in electronic trading now is significant in the United States, with the rest of the world catching up. The bond market is in a state of transition—from OTC to more electronic trading, allowing for higher liquidity, more transparency, lower costs, more diversification, and flexible execution times.
- The prices of fixed income securities are determined by notional amounts exchanged. Portfolio size and allocation affect transaction costs, with portfolio baskets of middle size gaining from the best execution costs. Portfolio basket execution of single bonds with a number of brokers preserving a "best execution" policy allows for better liquidity, diversification, and transparency.
- Increasing bond market activities from central banks shift the real pricing. Bid–ask spreads are indicative of bond market liquidity. However, they are only approximative solutions as indicators. Bond prices are the result of nominal sizes exchanged, thus prices depend on quantities. Bid–ask spreads help to indicate possible liquidity traps, but their magnitude and meaning diverge significantly from the real executed prices that depend on the nominal amount sold or bought, market demand and supply.

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CHAPTER
FORTY-FIVE

BOND INDEXES AND BOND PORTFOLIO MANAGEMENT

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The analysis of bond indexes is often a starting point in an investment process both for investors and portfolio managers. The reasons are easily understandable as the market for fixed income securities has substantially grown in recent years, even more than in the past. For example, eVestment's database included more than 40,000 funds as of 2015. The number of funds, portfolio allocation, and their size has increased. The net assets of regulated open-end bond funds grew from \$8,395 billion to \$10,633 billion from the first quarter of 2015 to year-end 2019.[1] A report by the Bank for International Settlements found that the assets under management (AUM) in fixed income funds including exchange-traded funds (ETFs) grew from \$0.5 trillion in 2006 to more than \$5 trillion in 2015. The aggregate size of global debt securities market driven by the large new corporate bond issues and sovereign bond debt grew from roughly \$36 trillion to \$95 trillion from 2001 to 2015. Two major groups of investors in fixed income are pension trusts and insurance groups. As the wealth of the private sector grew continuously, the AUM for pension funds grew in parallel. A substantial part of these savings was allocated to fixed income securities. The objective of these funds is to generate relatively safe cash flows. However, with a low-interest-rate environment globally, investors moved to illiquid segments such as global high-yield bonds.

As a consequence, there are two major purposes for bond indexes. The first purpose is for portfolio allocation and performance measurement. The second

The views expressed are those of the authors and do not necessarily reflect those of LBBW Asset Management.

1. The International Investment Fund Association www.iifa.ca and Markets Committee, *Electronic Trading in Fixed Income Markets*, Bank of International Settlements, January 2016.

purpose reflects passive management and products such as bond index funds and smart beta products.

Performance measurement of bond portfolios has gained in importance as a result of the rising number of bond funds. A sophisticated investment process makes it necessary to define a policy portfolio and thus an appropriate investment universe and a reliable source to measure performance. Performance measurement and performance attribution are inevitable for portfolio analysis. To be an appropriate benchmark, a bond index must fulfill certain requirements. As suggested by William F. Sharpe, requirements are:[2]

- *Knowable*: The constituents must be identifiable and both portfolio managers and their clients must agree on the index.
- *Investable and not easily beaten*: Portfolio managers must be able to hold the assets of an index.
- *Low in cost*: It must be possible to obtain and calculate the index and portfolio performance at low cost.
- *Diversified:* It must properly reflect the investment universe.

Whereas the pension fund allocation in the United States favors more equity market exposure in the allocation, the pension funds in Europe are more dedicated to fixed income assets, often exceeding 80% of the strategic asset allocation (SAA). Moreover, the market for fixed income products has grown globally. As markets gain in transparency, flexibility, transaction velocity, and sophistication, the growing allocation to fixed income securities from pension funds and institutional investors and demand for fixed income benchmarks have forced major providers of financial services to implement and manage liquid products based on fixed income benchmark tracking and factor investing. A specific example is smart beta products. These investment vehicles are also called bond index funds. One of the reasons for the growth of passive funds, ETFs, and similar structures is that historically many fixed income portfolio managers have not outperformed their benchmarks over long investment horizons. Bond index funds allow portfolio managers, allocators, and alternative investors like endowments to allocate to smart beta products. The rise of the bond ETFs helped to the development of electronic bond trading, which in turn improved the bond market's liquidity and depth.

BUILDING A BOND INDEX

Bond indexes have a high level of complexity, greatly exceeding that of equities. The compound nature of fixed income instruments makes the bond index

2. William F. Sharpe, "Asset Allocation: Management Style and Performance Measurement," *Journal of Portfolio Management* 18(2), 1992, pp. 7–19.

construction a challenging task. The complexity of fixed income has multiple causes.[3] The most prominent of them are:

- Heterogeneous currency, country, sector, and rating universe and different types of fixed income instruments—bullet bonds, callable and puttable bonds, inflation-linked, mortgage-backed securities, denomination currency, countries, interest rate regimes depending on currencies, ratings, etc. An index can include multiple bonds from the same issuer, denominated in different currencies for example. Alternatively, corporate issues from different subsidiaries can be included in an index with different ratings, cash-flow schemas, and structures. Most importantly, compared to stocks, fixed income instruments have a termination date, or maturity. Thus, at a certain point in time these instruments can no longer be part of an index and must be replaced. On the other hand, if new bonds are issued, they can become part of an index and the number of instruments in the index grows.
- The evolving nature of the fixed income markets and instruments depends on the business cycle, market complexity, and sophistication. The need for new instruments, solutions, and opportunities to diversify portfolios and satisfy investor demand. About 25 years ago, most indices started with a limited number of constituents, but now they include many thousands of instruments. As markets grow, the investors' need for fixed income exposure drove the development of new indexes representative of new investment universes.
- There is a large impact of the volatility of currencies, interest rates, dependencies on equity markets and ratings and their effects on bonds with embedded options, equity valuations reflecting corporate bonds, etc.
- The pricing of fixed income securities can be a challenging task. For example, corporate bonds are priced in an over-the-counter (OTC) market, thus sources of liquidity and transparency can be difficult to evaluate. This poses a serious risk for pricing and thus index construction. However, recent developments in electronic trading systems and platforms allow better price building.
- Many fixed income indexes are rebalanced monthly. That means on the rebalancing date the constituents of the index have to be defined. While some bonds will be dropped from the respective index—for example, because the maturity dropped below the minimum maturity or if an issuer's rating was downgraded below the minimum requirement—other bonds will be added to the index, especially newly issued bonds. After the rebalancing date, some index metrics may change greatly. For

3. Frank K. Reilly and David J. Wright, "Bond Market Indexes," chapter 3 in Frank J. Fabozzi (ed.), *The Handbook of Fixed Income Securities,* 8th edition (New York, McGraw-Hill, 2012).

instance, the average maturity or duration normally increase noticeably, with the effect that both passive and active portfolio managers also have to adjust their portfolios accordingly.

To illustrate how diverse the bond indexes might be, we consider three groups and show their differences in Exhibit 45-1.

The challenges in the construction and evaluation of bond indexes include two main issues. The first refers to the calculation of accrued interest on the bonds in the index. The second, and most specific and important, refers to the reinvestment of bond cash flows, which depends on the index provider. In general, there are a few possibilities in dealing with coupons and accrued interest:

- Immediate reinvestment of bond cash flows in the index
- Investing the cash flows using a money-market rate (LIBOR, EURIBOR, etc.) until the next rebalancing date (e.g., ICE BofA indexes)
- Simple reinvestment of the cash flows on the rebalancing date (e.g., J.P. Morgan indexes).
- No reinvestment of cash flows (e.g., Bloomberg Barclays indexes)

At this point it is necessary to consider the index documentation, since different index providers follow specific procedures. This is a crucial issue since different methodologies impact index metrics such as duration, yield to maturity, and convexity. More precisely, different reinvestment methodologies might result in performance bias of several basis points monthly due to the reinvestment techniques.

DESCRIPTION

Here we will focus on three groups of bond indexes. These are the U.S. investment-grade and high-yield indexes, European investment-grade and high-yield bonds, and international government, corporate, and aggregate bond indexes (i.e., global bond indexes). There are specific issues that are relevant to the indices and which provide overview and specific information regarding the investability and composition of an index. Reilly and Wright showed that among the most important descriptive components are:[4]

- The number of issues—exceeding 20,000 for global aggregate indexes
- The overall maturity—usually above one year of maturity
- The weighting structure—market vs. equal weighting schema
- Pricing sources and systematics—tradable security prices

4. Reilly and Wright, "Bond Market Indexes."

EXHIBIT 45-1

Bond Indexes Descriptive Issues*

Index Name	Short Description	Index Members	Ception	Market Value ($ Bn.)
U.S. Bond Indexes				
Bloomberg Barclays US Corporate	US CREDIT	6,425	Jan 73	6,329
Bloomberg Barclays US High Yield	US HY	2,061	Jul 83	1,310
Bloomberg Barclays US MBS	US MBS	467	Jan 76	6,395
Bloomberg Barclays US Agg Govt/Credit	US GOVT/CREDIT	7,817	Jan 73	16,617
Bloomberg Barclays US Treasury	US TREASURIES	260	Jan 73	8,866
Bloomberg Barclays US Aggregate	US AGGREGATE	11,595	Jan 76	23,622
Bloomberg Barclays Capital High Yield Caa	US HY Caa	327	Jul 83	157
European Bond Indexes				
iBoxx Euro Covered Total Return Index	EURO COVERED	919	Jul 03	119
ICE BofA Euro Broad Market	EURO BROAD	6,033	Dec 95	12,462
ICE BofA Euro Corporate	EURO CORP	3,434	Dec 95	2,583
ICE BofA Euro Government	EURO GOVT	388	Dec 85	7,000
ICE BofA Euro Non-Financial	EURO NON FIN	2,325	Dec 95	1,671
ICE BofA Euro High Yield	EURO HY	601	Dec 97	318

(Continued)

EXHIBIT 45-1

Bond Indexes Descriptive Issues* (*Continued*)

Index Name	Short Description	Index Members	Ception	Market Value ($ Bn.)
International Bond Indexes				
Bloomberg Barclays Global Agg	GLOBAL AGG	25,602	Mar 90	59,017
ICE BofA Global Corporate	GLOBAL CORP	15,025	Dec 96	53,508
Bloomberg Barclays Global Agg Credit	GLOBAL CREDIT	16,051	Sep 00	14,788
ICE BofA Global Fixed Income M	GLOBAL FIXED INCOME	24,124	Dec 96	10,951
ICE BofA Global Government	GLOBAL GOVT	1,060	Dec 85	29,053
Bloomberg Barclays Global High Yield	GLOBAL HY	3,612	Mar 90	2,463
ICE BofA Global High Yield & Cross	GLOBAL HY & CROSS	4,695	Dec 98	3,109
ICE BofA Global High Yield & EM	GLOBAL HY & EM	3,835	Dec 98	2,290
Bloomberg Barclays Emerging Markets IG	GLOBAL EM IG	1,266	Dec 97	1,411
Bloomberg Barclays Global Agg Treasuries	GLOBAL TREASURIES	1,607	Sep 00	31,243
ICE BofA Emerging Markets Corporate	EM CORP	2,433	Dec 98	1,464

* For all bond indexes in this table, the market value weighting methodology is used, rebalancing is done monthly, and the reinvestment type if total return.

Source: Constructed form data obtained from Bloomberg, LLC as of May 2020.

- The reinvestment risk—reinvestment of cash flows
- The issue size of the single constituents—usually >$500 million for corporate bonds

Whereas the previous factors reveal much more strategic and descriptive information about an index, specific information reveals details regarding tactical allocation and possibilities. For this purpose, it is always convenient to show an index in its sector, industry, credit rating, currency, allocation in maturity buckets, etc. In general, the presentation of a matrix structure reveals further details about a benchmark. For this purpose, the following matrices are possible ways to assign the index weights:

- Currency-maturity-buckets—for multi-currency bond indexes
- Country-maturity—for geographically vast indexes
- Sector-maturity—for broad indexes
- Sector-currency—for multicurrency broad and corporate indexes
- Sector-rating—for broad corporate indexes

In fact, the possibilities are vast and refer to specific tactical issues. Using matrix notation is a useful way to derive tactical allocation and estimate the performance attribution.

U.S. Investment-Grade and High-Yield Bonds

The U.S. bond market and the indexes have been central to fixed income management for decades. The most widely used by ETFs and active fund managers are the Bloomberg Barclays Capital Indexes. As a result, the U.S. bond indexes are the most liquid and well developed among all groups and regions. The U.S. bond indexes can be split into two major groups—U.S. investment-grade and U.S, high-yield bond indexes. Although the first group includes the most liquid instruments and diverse groups of fixed income securities like Treasuries, investment-grade corporate bonds (credits), and mortgage-backed and asset-backed securities, the second comprises less liquid bonds. The indexes comprising liquid fixed income securities have a minimum requirement for issue size. In general, an issue size of US$500 million represents the lowest level acceptable for bond managers to invest. During poor market conditions, investment-grade securities and Treasuries in particular are very liquid, thus enabling index pricing and trading. Therefore, market value weighting schemas properly reflect the current market valuation.

The second group comprises high-yield, or lower-rated fixed income securities. These indexes have in general a lower number of constituents, instruments with less liquidity, and fixed income securities with embedded options. These are high credit risk bonds. The liquidity issue that results in serious pricing problems arises from the fact that these instruments have low outstanding volumes, or their issue size is low. An issue size less than US$500 million often translates into low market liquidity. The pricing of high-yield bonds and index calculation thus is a challenging task. This issue becomes more serious during financial turmoil as a liquidity spiral occurs as a consequence of less demand, widening option-adjusted spreads, rising yields, and low trading volumes. Index pricing becomes a major issue during financial market stress.

Of course, alternative differentiation is common in the market as the specific needs require different types of analysis.

European-Investment Grade and High-Yield Bonds

The European market has grown in recent years due to the large regulatory requirements for pension funds. The fixed income SAA in European pension funds exceeds 80%, with a strong focus on European fixed income securities, including government bonds, corporate investment-grade bonds, covered bonds, high-yield bonds, and structured products. The foreign currency exposure has gained attention in recent years. International bond portfolio allocation is common, but does not represent a primary allocation target.

The growth of pension funds in Europe with structured, quantitative, and transparent investment process drives the development of real, tradable, transparent, representative, measurable, known indexes that serve as benchmarks. Some of the most well-known European indexes are ICE BofA European Broad Index, ICE BofA Corporate Bond Index, ICE BofA High Yield Index, J.P. Morgan EMU Government Bond Index, iBoxx Covered Bond Total Return Index, and the ICE BofA Financials index.

Global Bond Indexes

Major index providers for international bond indexes are J.P. Morgan, Citibank, Barclays, and ICE BofA. These indexes show striking similarities, which we will show in the next sections. These similarities result in a similar number of security and risk/return profiles. The number of index constituents increased in the last 20 years as international bond portfolios gained investors' interest. Global bond indexes offer multiple risk and return sources compared to traditional bond indexes. Investing in international bond indexes means taking currency, interest, spread, inflation, political, volatility, liquidity, and reinvestment risks, for example, which exceed the risks associated with domestic bond indexes.

There are two main types of global bond indexes: aggregate and government. Currently, the global government bond indexes have roughly 2,000 constituents. In contrast, the global aggregate indexes contain corporate and government bonds from multiple currencies and countries and have more than 20,000 constituents. The global sovereign indexes contain local currency government bonds from more than 40 countries.

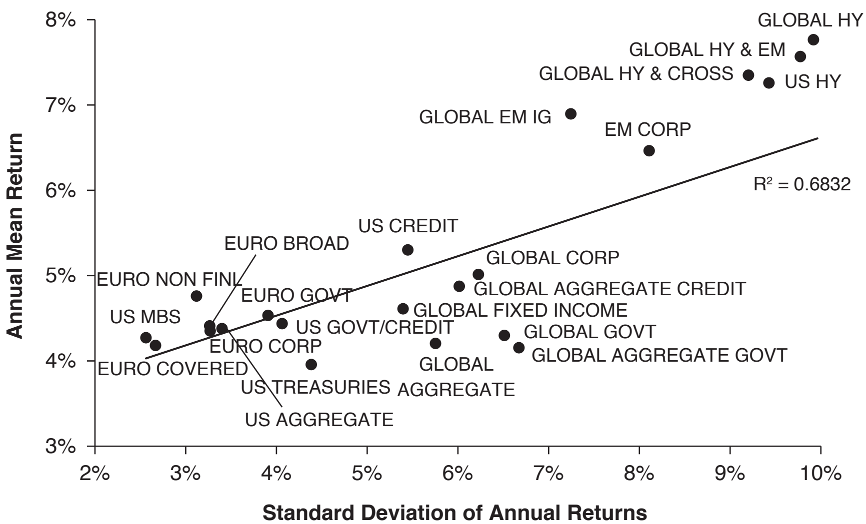
The most useful indexes in international bond portfolios with a focus on government bonds are the FTSE World Government Bond Index, which is identical to the Bloomberg Barclays Global Agg Treasuries Total Return Index, and the ICE BofA Global Government Bond Index. Overall, the Bloomberg Barclays Global Aggregate Index is the broadest globally invested index.

BOND INDEX RISK AND RETURN

As shown in Exhibit 45-2, the risk/return relationship between bond indexes is positive. The risk/return relationship increases as the credit rating of the index constituents decreases. Thus, global broad indexes and U.S. indexes including high-yield bonds have higher returns but suffer from higher risk as measured by the standard deviation. The highest returns in the period from 2000 to 2018 have been associated with the Global HY bond index. Alternatively, the lowest risk/return profile is associated with European Covered Bonds. Interestingly, both U.S. and European Broad indexes (EURO BROAD and U.S. AGGREGATE) offered similar risk/return profiles in the period from 2001 to 2018.

EXHIBIT 45-2

Risk/Return Relationship (January 2001 to December 2018)



U.S. Investment-Grade and HY Bonds

The U.S. indexes are broadly defined by number of securities, issuers, and diversified exposure. The U.S. HY index has a monthly average mean return of 59 basis points; however, its risk is substantial at 2.71% on a monthly basis.

The safest bond index exposure is associated with the U.S. mortgage-backed securities with a standard deviation of 0.75%, which also have positively skewed returns of 0.0882. We show the statistics in Exhibit 45-3.

European Investment-Grade and HY Bonds

Historically, European covered bond returns (iBoxx Euro Covered Bond Total Return Index) have low risk and return compared to the U.S. MBS index. Let us start with the descriptive statistics of the European bond indexes. The summary of the descriptive statistics is shown in Exhibit 45-4. The European HY index has the highest average monthly returns of 50 basis points, combined with an unsurprisingly high level of risk (3.4%). The covered bonds in Europe are among the safest instruments, with monthly index average returns of 26 basis points and standard deviation of the returns of 0.69%.

Global Bond Indexes

The descriptive statistics for the global indexes reveal that the Global HY index has the highest mean return of 65 basis points; however, it shows the highest risk of 2.86% as measured by the standard deviation. In the global bond index universe, the Global FixedIncome index has the lowest risk. This should not be surprising given the broad diversification of the global bond index universe. The statistics for the global bond indices are contained in Exhibit 45-5.

The bond index with the highest tail risk is the ICE BofA EM Corporate Index (EM Corp) with a skew of –4.8181 and kurtosis of 49.838. The risk also stems from the illiquidity of the index constituents.

BOND INDEX RELATIONSHIP

There are different ways to look at bond index relationships. The traditional method is to consider the pairwise Pearson correlations. The U.S. bond indexes show much higher correlations compared to the global bond indexes or the European bond indexes (see Exhibit 45-6). This suggests common underlying dynamics for the U.S. universe. We show the correlation coefficients for the European bond indices in Exhibit 45-7 and the correlation coefficients for the global bond indices in Exhibit 45-8.

EXHIBIT 45-3

Descriptive Statistics for U.S. Bond Indexes 2001–2018

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis
US AGGREGATE	0.0036	0.0045	0.0366	–0.0342	0.0098	–0.3363	4.367
US CREDIT	0.0044	0.0056	0.0658	–0.0809	0.0157	–0.9011	8.951
US GOVT/CREDIT	0.0037	0.0047	0.0443	–0.0428	0.0117	–0.2089	4.7391
US HY	0.006	0.0087	0.1143	–0.1732	0.0272	–1.4436	13.4143
US HY CAA	0.0062	0.0109	0.1759	–0.2672	0.0424	–1.2873	12.4212
US MBS	0.0036	0.0032	0.0385	–0.0189	0.0074	0.1104	5.177
US TREASURIES	0.0033	0.004	0.0517	–0.0449	0.0127	–0.0899	4.4632

EXHIBIT 45-4

Descriptive Statistics for European Bond Indexes 2001–2018

	Mean	Median	Max	Min	Std. Dev.	Skew	Kurtosis
EURO COVERED	0.0026	0.0018	0.0250	–0.0147	0.0069	0.1744	3.3546
EURO BROAD	0.0037	0.0049	0.9288	–0.9309	0.1585	–0.0092	29.9449
EURO CORP	0.0036	0.0043	0.0319	–0.0418	0.0094	–0.5204	5.3280
EURO GOVT	0.0038	0.0055	0.0396	–0.0268	0.0113	–0.0917	3.2689
EURO NON FIN	0.0039	0.0046	0.0263	–0.0348	0.009	–0.3964	3.8598
EURO HY	0.0050	0.0069	0.1169	–0.2064	0.034	–1.3419	11.6615

EXHIBIT 45-5

Descriptive Statistics for International Bond Indexes 2001–2018

	Mean	Median	Max	Min	Std. Dev.	Skew	Kurtosis
GLOBAL AGG	0.0036	0.0041	0.0603	–0.0405	0.0161	–0.0951	3.6655
GLOBAL CORP	0.0042	0.0049	0.0653	–0.0859	0.0180	–0.7034	7.2292
GLOBAL CREDIT	0.0041	0.0053	0.0578	–0.0817	0.0174	–0.6742	6.6326
GLOBAL FIXED-INCOME	0.0038	0.0042	0.0592	–0.0417	0.0155	–0.1156	3.8147
GLOBAL GOVT	0.0036	0.0029	0.0692	–0.0513	0.0188	–0.0083	3.7731
GLOBAL HY	0.0065	0.0094	0.1034	–0.2063	0.0286	–1.9239	17.2582
GLOBAL HY & CROSS	0.0061	0.0101	0.0841	–0.1938	0.0266	–2.0188	17.7722
GLOBAL HY & EM	0.0063	0.0096	0.0981	–0.2043	0.0282	–1.9904	17.4875
GLOBAL EM IG	0.0057	0.0064	0.0913	–0.1602	0.0209	–2.3331	21.7836
GLOBAL TREASURIES	0.0035	0.0029	0.0698	–0.0510	0.0193	–0.0332	3.6925
EM CORP	0.0054	0.0068	0.0714	–0.2299	0.0234	–4.8181	49.8387

EXHIBIT 45-6

Correlation of U.S. Bond Indexes

	US AGGREGATE	US CREDIT	US GOVT/CREDIT	US HY	US HY CAA	US MBS	US TREASURIES
US AGGREGATE	1						
US CREDIT	0.839	1					
US GOVT/CREDIT	0.989	0.86	1				
US HY	0.180	0.550	0.168	1			
US HY CAA	0.047	0.409	0.035	0.934	1		
US MBS	0.902	0.629	0.847	0.022	–0.079	1	
US TREASURIES	0.907	0.579	0.913	–0.180	–0.277	0.841	1

EXHIBIT 45-7

Correlation of European Bond Indexes

	EURO ABS	EURO BROAD	EURO CORP	EURO GOVT	EURO NON FIN	EURO HY
EURO ABS	1					
EURO BROAD	0.804	1				
EURO CORP	0.666	0.778	1			
EURO GOVT	0.753	0.978	0.644	1		
EURO NON FIN	0.670	0.790	0.909	0.683	1	
EURO HY	0.082	0.062	0.477	–0.046	0.431	1

EXHIBIT 45-8

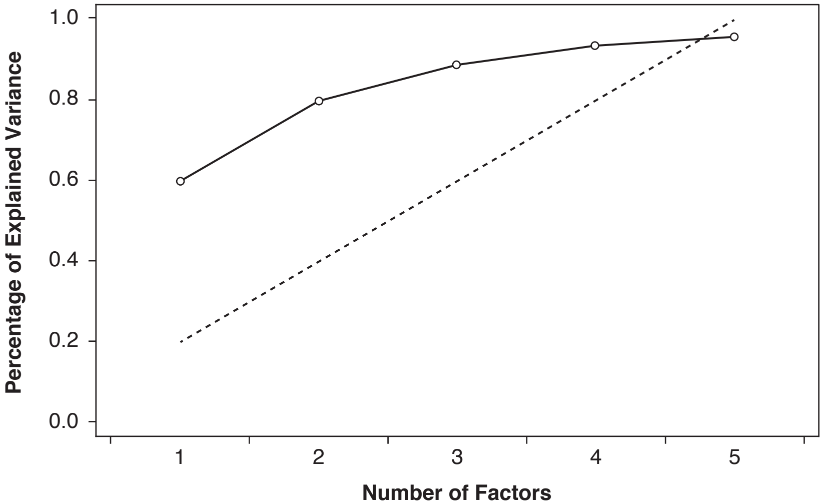
Correlation of International Bond Indexes

	GLOBAL AGG	GLOBAL CORP	GLOBAL CREDIT	GLOBAL FIXED-INCOME	GLOBAL GOVT	GLOBAL HY	GLOBAL HY & CROSS	GLOBAL HY & EM	GLOBAL INV GRADE	GLOBAL TREASURIES	EM CORP
GLOBAL AGG	1										
GLOBAL CORP	0.894	1									
GLOBAL CREDIT	0.908	0.998	1								
GLOBAL FIXED-INCOME	0.998	0.909	0.922	1							
GLOBAL GOVT	0.976	0.788	0.806	0.968	1						
GLOBAL HY	0.408	0.675	0.657	0.444	0.245	1					
GLOBAL HY & CROSS	0.471	0.720	0.705	0.506	0.310	0.994	1				
GLOBAL HY & EM	0.414	0.681	0.663	0.450	0.251	0.998	0.995	1			
GLOBAL INV GRADE	0.621	0.788	0.786	0.652	0.490	0.767	0.809	0.772	1		
GLOBAL TREASURIES	0.981	0.800	0.817	0.971	0.997	0.278	0.342	0.284	0.498	1	
EM CORP	0.585	0.809	0.799	0.615	0.431	0.847	0.875	0.855	0.908	0.450	1

A natural question would be, is there any common factor that explains the variance of bond index returns? Using principal component analysis (PCA) and the groundbreaking work of Robert Litterman and Jose Scheinkman,[5] we show that five factors explain 96% of the variance of bond indexes returns. The first factor explains roughly 60% of the bond indexes variance of returns. The results in Exhibit 45-9 show that the first three factors explain roughly 89% of the variance of index returns.

EXHIBIT 45-9

Principal Component Analysis of Bond Market Indexes: Five Factors



The number of factors is on the x-axis, percentage of the explained variance is on the y-axis

Sometimes questions such as the following can arise: What is the most important bond index? How are bond indexes related? What are meaningful groups to take into account: corporate, government, HY, etc.? Traditional calculus methods cannot provide answer to these questions. Lopez der Prado and Fabozzi argued that portfolio managers and investment professionals need different toolkit to analyze complex market behavior.[6] A novel, data-driven, but very comprehensive approach to considering relationships is to present indexes as a graph, or to cluster the indexes. Specifically, an analysis focuses on the mutual links between the indexes and thus their relationships. Cluster analysis groups indexes

5. Robert B. Litterman and Jose Scheinkman, "Common Factors Affecting Bond Returns," *Journal of Fixed Income* 1(1), 1991, pp. 54–61.
6. Marcos Lopez de Prado and Frank J. Fabozzi, "Who Needs a Newtonian Finance?" *Journal of Portfolio Management* 44 (1), pp. 1–4.

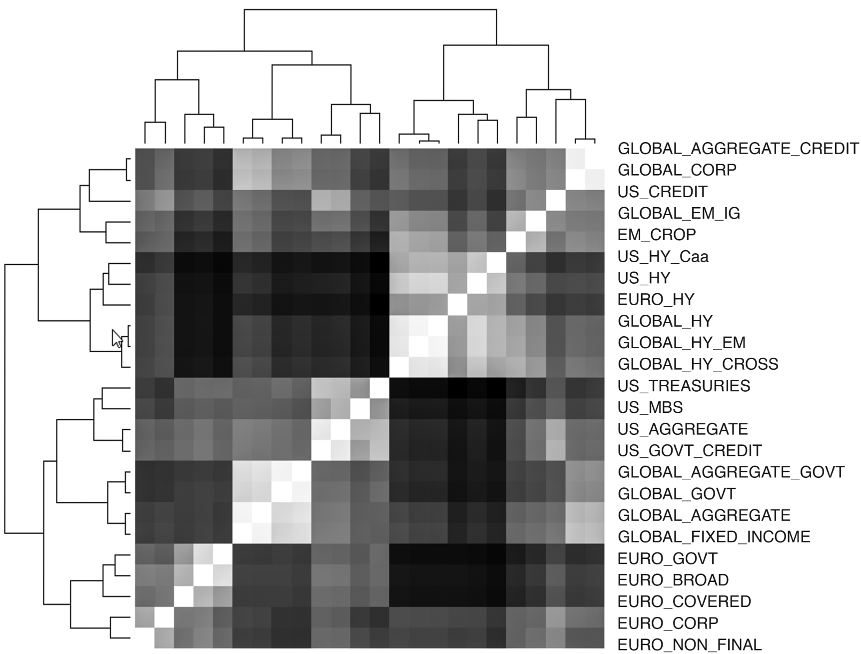
by their correlation similarity into groups. An underlying connecting property might be the Treasury yield curve—for government and investment-grade corporate bonds for example. As a starting point, we incorporate the pairwise correlation coefficients ρ_{ij}, but we transform them into distance metrics, which much more efficiently and correctly display their characteristics:

$$d_{ij} = \sqrt{2\left(1-\rho_{ij}\right)}, \text{ with } i \neq j$$

Exhibit 45-10 contains hierarchical clustering and heat map that show the bond indexes relationship. To identify groups (clusters), we can make a cut-off in the connecting lines and thus show that the bond indexes can be grouped into six clusters. These six clusters comprise indexes that have similar properties. For example, German government bonds and European government bond curves and the factors of shift, slope, and curvature might be central to a cluster comprising both European and global credit and government bond indexes.

EXHIBIT 45-10

Bond Indexes Clusters and Relationship: 2001–2018



In fact, assessing and observing relationships between different bond indexes constitutes a starting point for smart beta or factor investing.

BOND INDEXES AND SMART BETA

Smart beta funds in fixed income are the natural consequence of investor needs.[7] The needs for higher returns, diversification, and/or lower cost are the result of the disruptive innovation in finance called smart beta investing. In general, smart beta strategies are active strategies with some features of passive products. The advantage is that smart beta strategies use simple, quantitative, rule-based approaches to constructing portfolios that have exposure to specific benchmarks. However, they are actively managed products. The natural development followed the rise of factor investing and the arbitrage pricing theory developed by Stephen Ross. Since diverse risk factors explain the variance of returns of diverse indices, research focused on building active factor funds, or smart beta funds.

Factor investing in fixed income offers transparency, scalability, lower costs, and diversification.

As the global growth and demand for fixed income factor solutions increased, investors' focus shifted to finding quantitative smart beta products for fixed income securities. However, active management of bond portfolios has been disappointing, despite the high management fees and additional costs. Previous research has suggested that there is a mean reversion in historical returns of fixed income strategies and that factor exposure is cyclical.[8]

Specifically, there are few possible solutions for smart beta products to apply to fixed income benchmarks. The most widely used is a factor-based approach. There are a number of reasons for this. Factor-based solutions offer the following advantages applied to bond indexes. In fact, to some extent the development of bond benchmarks is closely related to the demand for passive products and the requirements for an index:

- Transparency
- Representative and meaningful index weights
- Liquidity of the tradable instruments and rebalancing
- Index methodology and documentation
- Scalability of products and solutions
- Quantification of investment processes and the growth of factor investing
- Management skill
- Diversification

7. Ronald N. Khan and Michael Lemmon, "The Asset Management Dilemma: How Smart Beta Is Disrupting the Investment Management Industry," *Financial Analysts Journal* 72(1), 2016, pp. 15–20.
8. Andrew Chin and Piyush Gupta, "Using Prime Alpha to Separate Skill from Luck in Fixed income-Fixed income Strategies," *The Journal of Investing* Vol. 26, No. 2 (2017), pp. 102-110.

These issues are closely related to the growing need for investment products. Transparency reflects the growing need for transparent solutions in investment management. Representative and meaningful index weights reflect the weighting schema of an index that properly represents and explains the respective market. For example, the weight of the U.S. dollar in a world government bond index must be meaningful compared to the weight of a smaller government bond market (e.g., Norway). Liquidity issues also reflect the investability of an index. More liquid securities might get higher weights and thus be easy to replicate.

The index methodology and documentation are important issues since investors can gain more insights about the repricing, weighting schema, and rebalancing. On the demand side, investors' growing appetite for scalable, low-cost products is the driving force behind bond index funds. Management skill is related to this, as fewer fund managers outperform benchmarks and investors' desire to reduce fees and costs force them to seek low-cost, transparent solutions. The search for less cost-intensive products, and the cost pressure have pushed forward a broad quantification of the investment processes. This, in turn, requires transparent solutions and methodologies. Smart beta products offer such advantages.

Finally, a transition from specialists to generalist investment teams, combined with cost minimization and a desire for diversification drives the demand for smart beta bond products. Thus, a smart beta bond fund might be a suitable and favorable solution to a broad fixed income allocation. Smart beta products offer a broad set of advantages:[9]

- Flexibility
- Transparency
- Lower fees
- Liquidity
- Diversification
- Active management

As previously noted, smart beta products are factor-based solutions. A factor model explains the variance of index returns. The underlying assumption is that factors explain a significant amount of index returns. Thus, a smart beta approach using factors aims at minimizing the tracking error of a specific index. By employing linear regression, the index returns are explained using a set of reasonable explanatory factors. The higher the explanatory power of a factor model, the higher the possibility to apply a factor model and to build a smart beta portfolio. There are four steps to creating a factor-based smart beta bond index product:

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9. Hossein B. Kazemi, Keith H. Black, and Donald R. Chambers, *Alternative Investments*, Third Edition (Hoboken: New Jersey, Wiley, 2016).

1. Index choice and tracking error estimation based on the investment universe—HY, mortgage-backed securities, or government bonds for example
2. An appropriate choice of an investable and transparent broad factor set—a broad set is desirable
3. The length of the period considered to analyze factor exposure
4. Factor selection of investable factors—depending on the index and investment universe

The factor set should be broad and in many instances depends on the type of bond index considered. However, recent research has shown that the well-known Fama-French factors explain the variance of government, corporate, and high-yield index returns. However, the Fama-French factor model is not sufficient to capture market risk. There are additional factors that deserve attention which explain the variance of bond returns and, specifically, market risk. The research on factor investing in fixed income is extensive. Recent literature has focused much more on the dynamic nature of factors involved in bond investing.[10] The following are the most important factors:

- The duration factor—capturing the risk of changes in interest rates.
- The liquidity factor, or bid–ask spread—explaining the liquidity as measured by turnover, since corporate bonds are not easily tradable.
- The default, or credit factor—gauging the difference in corporate and government bond returns; the factor captures the ability of a company, or government to pay debt.
- The term factor—capturing the slope of the yield curve.

It is important to note that cross-sectional factor models aim to dynamically capture changing index exposure. Thus, model specification is crucial and reflects the problem of data snooping. A factor model has the following general form:

$$R_{i,t} = \alpha_i + \sum_{i=1} \beta_i F_{j,t} + \varepsilon_t$$

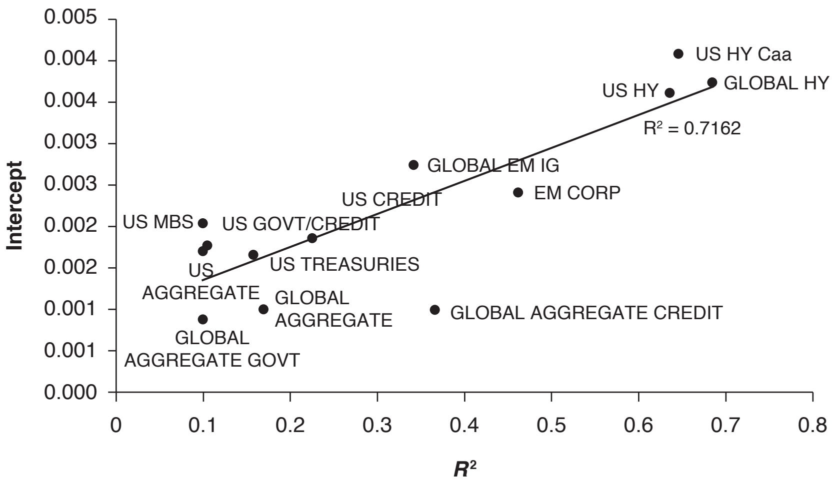
where $R_{i,t}$ is the total return of an index, α is the intercept, β is a coefficient that measures the sensitivity of an index's return to the factor, F is the beta factor premium that requires a systematic risk premium in the market, and ε is the random error term.

10. Marielle De Jong and Frank J. Fabozzi, "The Market Risk of Corporate Bonds," *Journal of Portfolio Management* 46 (2), 2020, pp. 92–105; Lidia Bolla, "Fundamental Indexing in Global Bond Markets: The Risk Exposure Explains It All," *Financial Analysts Journal* 73(1), 2017, pp. 101–120; Gueorgui Konstantinov, "On the Dynamics of EMU Bond Portfolios: Is the Diversification of Risk Factors Driving to Convergence of Fund Exposure?" *Journal of Investing* 26(2), 2017, pp. 91–102; and Demir Bektic, Josef-Stefan Wenzler, Michael Wegener, Dirk Schiereck, and Timo Speilmann, "Extending Fama-French Factors to Corporate Bond Markets," *Journal of Portfolio Management* 45 (3), 2019, pp. 141–158.

Exhibit 45-11 shows the Fama-French factor exposure for a sample of U.S. and international indexes. The R^2 of a factor model is a measure of the bond index variance that can be explained by the Fama-French five-factor model. Large R^2 values indicate that the variance of excess bond index returns can be explained by the Fama-French factors—U.S. HY Caa, Global HY, U.S. HY, and Global EM IG. Smart beta products could apply to these indexes. Alternatively, the Fama-French factors do not explain the variance of returns of both U.S. and global aggregate government bond indexes.

EXHIBIT 45-11

Variance of Excess Bond Index Returns Explained by Five Smart Beta Factors



An important issue is that the market risk is present in every market environment. Bond markets are nonstationary, and only factor models for smart beta that capture market nonstationarity are capable of capturing and explaining the heterogeneous nature of bond index returns. Thus, the major challenges to implementing smart beta index portfolios can be summarized by the following three issues:[11]

- Nonstationarity of bond returns
- Model uncertainty for factors related to bond indexes
- Data snooping and unstable factor premiums

11. Bradford Cornell, "Stock Characteristics and Stock Returns: A Skeptic's Look at the Cross Section of Expected Returns," *Journal of Portfolio Management* 46(7), 2020, pp. 131–142.

Because beta and factor premiums are time varying, for smart beta bond index products to be successful it is much more important to be centered on the main characteristics of the index rather than on the factor loadings. Thus, smart beta products must account for these three issues.

KEY POINTS

- The rising demand for fixed income securities from pension funds and both institutional and retail investors combined with increasing investor sophistication drive the development of new indexes and the expansion of the market.
- The European market has grown in recent years due to the large regulatory requirements for pension funds. The U.S. bond market and the indexes have been central to fixed income management for decades. As a result, these indexes are the most liquid among all groups and regions. The U.S. bond indexes can be split into two major groups—U.S. investment-grade and U.S. high-yield bond indexes.
- Global bond indexes offer multiple risk and return sources compared to traditional bond indexes. Investing in international bond indexes means, for example, taking currency, interest, spread, inflation, political, volatility, liquidity, and reinvestment risks, which exceed the risks associated with domestic bond indexes.
- Bond indexes have a high level of complexity, by far exceeding that of equities. The compound nature of fixed income instruments makes bond index construction a challenging task.
- Bond indexes are important sources of information for both managers and investors as regards performance measurement and new products such as smart beta portfolios.
- Smart beta products are factor-based solutions with growing demand because of the disappointing results, often paired with high fees, of active managers, and demand for transparent strategies.
- A factor model explains the variance of index returns. The underlying assumption is that factors explain a significant amount of index returns. Thus, a smart beta approach using factors aims at minimizing the tracking error of a specific index. An important issue is that the market risk is present in every market environment. Thus, the bond markets are nonstationary and only factor models for smart beta that capture market nonstationarity are capable of capturing and explaining the heterogeneous nature of bond index returns.

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CHAPTER
FORTY-SIX

QUANTITATIVE MANAGEMENT OF BENCHMARKED PORTFOLIOS

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Most fixed income portfolios are managed relative to a benchmark. Depending on the portfolio's investment objective and style, the role of the benchmark varies. At one end of the spectrum are passive indexed portfolios that strive to match benchmark risk exposures and returns as closely as possible. At the other end are active portfolios with high risk tolerance that maximize outperformance by investing freely outside the benchmark that serves only as a nonbinding reference point. The majority of fixed income portfolios fall somewhere between these extremes. Typically, a sponsor, an investment committee, a chief investment officer, or some other party that sets the investment objective specifies both the benchmark and the permissible deviations from it. The portfolio manager is then judged by the achieved outperformance versus the benchmark, and the amount of risk taken to generate this outperformance.

For the portfolio manager, the benchmark represents the zero-risk position. Over time, unless the manager deviates substantially from the benchmark, the portfolio's absolute performance is determined largely by the choice of the benchmark. Consequently, the choice of a portfolio's benchmark is very important.

There is an ever-growing number of published bond market indexes. Often, an appropriate benchmark can be selected from this set of standard indexes.

But there are many cases when none of these serve the goals of the investor or plan sponsor. To ensure that the benchmark correctly reflects a given investment opportunity set and constraints, a new, highly specialized index may need to be constructed. Finally, for some investors, the right benchmark may not even be a traditional total-return market index.

Fixed income markets are very large and diverse, so most indexes tend to include hundreds or thousands of securities. The sources of risk affecting fixed income securities are equally diverse and often difficult to analyze. These conditions may turn even relatively straightforward portfolio tasks into complicated endeavors. For most portfolios, a seemingly trivial problem of "buying the benchmark" means selecting a relatively small subset of constituent securities while ensuring somehow that its behavior will be reasonably similar to the broad universe. Understanding portfolio risk versus a benchmark is equally complicated because of many relevant risk dimensions and intricate interactions among them.

As a result, essentially all functions of the bond portfolio management process are aided greatly by robust quantitative methods. This chapter reviews some major issues facing bond portfolio managers, as well as quantitative approaches for dealing with them: selecting and customizing a benchmark, analyzing portfolio risk and performance, maintaining adequate liquidity, replicating benchmarks, and optimizing portfolio structure to improve its risk-adjusted performance.

SELECTION AND CUSTOMIZATION OF BENCHMARKS

Financial literature lists several desirable qualities for performance benchmarks. A good benchmark is defined as investable, transparent, known in advance, and objective. While all these are important attributes, first and foremost, the benchmark should be *appropriate*. An appropriate benchmark matches the required strategic allocation of portfolio assets, so that the portfolio's performance will be broadly consistent with the investor's overall objectives. A benchmark should also be investable so that a manager can "buy the benchmark" when and if he so decides. When comparing portfolio performance to the benchmark, it is critical to know when any difference owes to the manager's decisions and not to any in-built mismatches beyond the manager's control. Any constraints that limit the portfolio opportunity set must be reflected in the benchmark as well.

An index may provide an accurate gauge of the performance of a particular segment of the fixed income markets, but that does not necessarily make it an appropriate benchmark. For example, while the Bloomberg Barclays U.S. Aggregate Index is a widely used benchmark for the U.S. investment-grade fixed income market, the average duration of this index (5.85 as of January 31, 2020) may make it unsuitable for portfolios funding long-duration liabilities.

Reflecting Investor Opportunity Set and Constraints

When an investment policy requires specific allocations to certain asset classes or imposes other restrictions such as a duration target, a customized index may be a more appropriate benchmark. In the simplest case, a customized index merely changes relative weights of standard components while still including all securities in the standard index. Often, an investment policy may impose a minimum credit-rating threshold on the securities the portfolio can buy. Limitations may be placed on maximum exposure to an industry, country, and so on. Many other security attributes, such as minimum or maximum maturity, age, coupon, and so on, may also be controlled, requiring corresponding changes to the benchmark. In all cases, though, the goal should be to keep the benchmark as broad-based and well-diversified as possible while still meeting all the investment policy requirements. However numerous the modifications to the original market-based index, one important benchmark property always should be preserved: objectivity. The benchmark should be based on a set of rules specified beforehand and kept constant. The rule-based nature of a benchmark also allows for a historical analysis of its past behavior. Such analysis can be quite useful at the stage of selecting a benchmark.

One widely used method to achieve outperformance is investing outside the benchmark. Such investments (e.g., high-yield credit or emerging market debt) are frequently referred to as "core-plus." Even when an exposure to core-plus assets is constantly present in the portfolio, many managers still prefer to keep such assets out of the benchmark. Their motivation, of course, is to keep this potential source of outperformance at their disposal. However, a case can be made for inclusion of frequently used core-plus assets into the benchmark. First, by including these assets in the benchmark, the manager's relative performance can be more fairly measured if the manager has a persistent allocation to these assets. Second, it is often difficult to short-sell core-plus assets. Yet a manager who has expertise in these markets can benefit from a short position just as much and as frequently as from a long position. An easy way to short such assets is to underweight them versus the benchmark. This, of course, is only possible when they are included in the benchmark. Such a benchmark decision should be made only after ensuring that with the inclusion of these asset classes, the benchmark remains appropriate for the portfolio's investment objective and style.

Benchmarks for ESG Investing

A growing number of investors select the companies to invest in based on Environmental, Social, and Governance (ESG)[1] criteria. Several different approaches have been taken to do so. Some investors use negative screening, in which a portfolio mandate precludes investment in an entire industry viewed as objectionable, such as tobacco, weapon manufacturing, or coal mining. Others prefer a more nuanced positive-screening approach, in which companies are ranked by their business practices across a broad range of ESG-related categories and a portfolio is assembled by choosing among the better-ranked companies in each industry.

The implementation of such a policy involves many subjective decisions that can be difficult to encapsulate in strict rules. ESG is an umbrella term that

1. Other terms used in the industry to represent similar considerations include "socially responsible" and "sustainable" investing.

covers a company's impact on the society across a broad range of issues, from carbon footprint to data privacy to diversity of the executive board. Which of these are to be given greater weight when judging a particular company or industry? A number of dedicated providers have emerged that calculate ESG scores for companies, and each has developed its own distinctive methodology for navigating this complex set of criteria; the ranking of firms within an industry can thus vary substantially from one provider to another. Even the ostensibly simpler negative-screening approach is more difficult than it may sound. For example, many modern corporations have diversified business models. What percentage of revenue from an objectionable source should be allowed?

Index providers have designed benchmarks for investors using either of these approaches, often in cooperation with a provider of ESG scores. For example, the Bloomberg Barclays family of indexes includes two types of ESG-related benchmarks produced jointly with MSCI ESG Research. Their Socially Responsible Indices exclude issuers involved in activities that are in conflict with investment policies, values, or social norms, using MSCI's Business Involvement Screening Research to identify exposures to controversial business lines. Another series of benchmarks, the Sustainability indexes, use a best-in-class approach based on ESG ratings from MSCI ESG Research to choose the best-ranked subset of index bonds within each industry.

Once a decision is made to adopt a specific ESG benchmark, managing a portfolio against it should be largely the same as with any other benchmark (except that investors may want to see some additional statistics when comparing the portfolio and benchmark in terms of various ESG metrics). However, when ESG-related constraints are imposed on a portfolio measured against a standard benchmark, or when evaluating a potential change in benchmark, questions may arise about the potential effect of these decisions on portfolio performance. In this context, negative screening of entire industries has a larger effect on the systematic exposures of the portfolio; if bonds from the excluded industries perform better or worse than the market as a whole, portfolio returns will differ from those of the benchmark. Positive-screening techniques should allow managers to integrate ESG ratings into their security selection process without forcing major shifts in overall risk exposures. However, always favoring issuers with high ESG ratings can lead to unintended biases in systematic risk related to quality, spread, and geography. It is therefore essential that a benchmarked portfolio controls for these biases while selecting bonds from high ESG issuers. Research into the historical returns of risk-controlled index-replicating portfolios with an ESG tilt, using ESG ratings from either MSCI ESG Research or Sustainalytics, has shown that this approach has not harmed portfolio performance, and even produced increased returns.[2]

2. See Albert Desclée, Lev Dynkin, Jay Hyman, and Simon Polbennikov, "Sustainable Investing and Bond Returns," October 2016, Barclays Impact Series, No. 1; available on Barclays' public website.

Liability-Based Benchmarks

Sometimes a customized benchmark is necessary not because of sector, quality, or other allocation constraints but because the portfolio is expected to have a particular term-structure exposure. For example, some portfolios are managed to provide a particular cash-flow stream to fund a set of liabilities. At the simplest level, portfolio duration may be kept equal to the duration of the liability stream. Dedication is another widely used method for ensuring the necessary cash flows while (usually) minimizing the portfolio cost. Of course, funding the future liabilities is the main investment objective in such cases. Yet, investment policies of liability funding portfolios can be quite liberal, providing an opportunity for outperformance while still ensuring sufficient cash flows.

Such portfolios would benefit from a diversified benchmark with a cash-flow profile that matches the expected liability stream and at the same time fully reflects the manager's opportunity set. Consider, for example, a liability funding portfolio that is free to invest in any security in the Bloomberg Barclays Credit Index. An appropriate benchmark for such a portfolio could match the sector and quality distribution of the index while matching the cash-flow profile of the liabilities. Such a "liability-based" benchmark retains many of the desirable attributes of a broad market-based index: it is objectively defined, so the portfolio manager can stay neutral to it, and its returns are calculated using market prices. Because this benchmark consists of marketable securities, its performance can be calculated and published by a third-party index provider.[3]

Even outside the asset/liability context, many fixed income portfolios are managed with a specific duration target. If this target is not close to the duration of any standard (published) index, an appropriate benchmark may be constructed as a weighted blend of two published indexes, one of which is longer and the other shorter than the target. Although the weights needed to achieve a desired duration may have to be adjusted at regular intervals, they typically remain fairly stable (e.g., for indexes that consist mainly of option-free securities).

Things get more complicated for portfolios containing a large proportion of securities with embedded optionality. Duration of such portfolios is likely to be unstable, changing in response to interest-rate movements. For example, the duration of mortgage-backed securities (MBS) can be quite volatile. If maintaining a stable duration is important, managers may engage in such techniques as delta hedging to overcome the effect of negative convexity and keep duration relatively constant. Hedging techniques entail various costs, from the more obvious transaction costs to the less obvious but potentially more significant "whipsaw" costs.[4] It is unfair to judge the performance of a manager who must

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3. For a detailed discussion, see chapter 10 in Lev Dynkin, Anthony Gould, Jay Hyman, Vadim Konstantinovsky, and Bruce D. Phelps, *Quantitative Management of Bond Portfolios* (Princeton, NJ: Princeton University Press, 2007).

4. Negative convexity causes duration to decline with falling rates. The term *whipsaw* refers to having to add duration after rates have just fallen and prices have gone up and to shed duration after the opposite movement.

engage in costly delta hedging against a benchmark that does not bear similar costs. Two possible solutions are (1) to apply delta hedging to the benchmark or (2) to construct a "constant duration" index that provides a fairer benchmark for a delta-hedged mortgage portfolio.[5] An example of such a benchmark could be a market-weighted MBS index dynamically hedged according to a set of rules, with a liquid leveraged overlay of Treasuries or futures contracts.

Asset-Swapped Indexes

Some investors can take credit positions but are required to match the interest rate exposure to their funding source (e.g., three-month LIBOR). For example, some bank and insurance investment managers must manage their portfolios to a short duration target for asset-liability management purposes but are free to exercise their credit skills in asset selection. Leveraged investors often concentrate on credit exposure but minimize interest-rate exposure by managing the portfolio duration to the short-term LIBOR funding. In an environment of moderate credit spreads and low interest rates (and worries about rising rates), traditional total return managers are also likely to keep durations very short while maintaining an overweight to spread sectors. These managers want to exercise their credit skills but avoid term-structure risk.

The most straightforward way to create and maintain such exposures is to turn to the floating-rate note market. However, given limited issuance, this may create an unintended concentration of systematic sector exposures or issuer idiosyncratic risk. Ideally, the manager would want to match systematic spread-sector risks (i.e., credit quality and sector exposures) of a broad credit market index while simultaneously removing exposure to all systematic Treasury key-rate risk factors except, perhaps, the shortest (e.g., three- or six-month) key rate. The challenge of designing a benchmark for such a portfolio is to ensure a very short Treasury duration and at the same time match the overall index allocations to the credit sectors.

To exercise their spread-sector timing skills while minimizing interest-rate exposure, investors can buy fixed-rate spread assets on an "asset-swapped" basis. Asset swaps are combinations of a fixed-rate bond (and its credit exposure) and an iinterest rate swap that exchanges the fixed-rate coupons for floating-rate coupons. In essence, an asset swap gives an investor an opportunity to take spread-sector exposure with little term-structure risk.

There are no formal indexes of asset swap performance. To benchmark an asset-swapped portfolio effectively, the benchmark must represent a "neutral" spread-sector allocation. Then the manager's deviations from neutral may lead to outperformance of the benchmark. Using three-month LIBOR as a benchmark is inadequate because LIBOR reflects only a single type of spread risk (i.e., swap

5. Lev Dynkin, Jay Hyman, Vadim Konstantinovsky, and Ravi K. Mattu, "Constant Duration Mortgage Index," *Journal of Fixed Income,* 10 (2000), pp. 79–96.

spreads) and does not represent the wide array of spread-sector choices that may be available to the manager. An ideal design for asset-swapped portfolios is a floating-rate benchmark that reflects a diversified set of spread-sector exposures. One approach to constructing such benchmarks[6] starts with the creation, for each asset class, of a "mirror" swap index, which is a portfolio of interest rate swaps with the same key-rate duration profile as that of the "mirrored" asset class. Then short positions in these mirror-swap indexes are combined with long positions in the corresponding asset-class indexes, as well as with a long position in a short-term asset (e.g., one-month LIBOR). This creates "asset-swapped indexes" for all asset classes in the benchmark. Finally, individual asset-swapped indexes are merged into the final composite benchmark according to the portfolio's "neutral" allocations.

Book Accounting Based Indexes

Fixed income investors typically measure portfolio performance by calculating returns using market prices at the beginning and end of the performance period. Consequently, the portfolio's market value fluctuates with changing Treasury yields, spreads, and prepayments. Most standard fixed income indexes are market return based, and many analytical tools make the same assumption about portfolios.

However, there is a large class of investors (e.g., insurance companies and banks) less concerned about short-term market fluctuations. They purchase fixed income assets to match a set of liabilities whose net present value is based not on market prices, but on book, or purchase, prices. Typically, these fixed income portfolios are relatively static. Investors expect the portfolio to earn an adequate spread over the cost of the liabilities, assuming that the assets do not default or prepay at a rate unanticipated at the time of purchase. Given that liabilities are valued using book accounting, these investors (and their regulators) need to measure asset portfolio performance similarly, either by the portfolio's "book return," which is book income divided by book value, or the portfolio's "book yield," which is its internal rate of return calculated at time of purchase. However, how can such investors measure their investment skill when most indexes are market return based?

Book accounting based investors can measure their performance relative to book accounting based indexes that, in theory, might be replicable investment portfolios. For example, suppose that in January an investor restricted to assets in the Bloomberg Barclays Aggregate Index must fund a newly acquired liability. The investor can passively invest in a book acounting based index constructed as of the end of January. The composition of this index is set to reflect the Aggregate Index as of that date, and its book yield and book return will be calculated every

6. For a detailed description of this methodology, see chapter 12 in *Quantitative Management of Bond Portfolios*.

month. Over the course of the next month, the index will generate cash flow (coupon, prepayments, proceeds from maturities), which is re-invested in the February Aggregate Index. Consequently, by the end of February, the January-constructed book accounting index becomes a conglomeration of the initial investment in the January Aggregate Index plus a smaller investment in the February Aggregate Index. This process is repeated every month. The performance of the January-constructed index, expressed in book accounting terms, reflects what the investor would have achieved by passively investing in the Aggregate Index starting in January, and thus can be directly compared to the book accounting performance of the investor's actual portfolio.[7]

Strategy-Based Indexes

Finally, some portfolio managers must operate under severe performance constraints such as "over the next three months generate as much return as you can, but don't lose any money!" Many official institutions manage their Treasury portfolios under such constraints. What is an appropriate benchmark for these investors? While a cash benchmark (i.e., zero duration) would not suffer any losses, it would severely limit income. In contrast, a longer-duration benchmark would likely generate more income but put the portfolio at risk of losses over the holding period.

The right benchmark would have a duration that maximizes expected returns subject to the risk constraint. But, how best to generate expected returns to determine the benchmark? Using historical Treasury returns data is one approach. An advantage of historical returns is that they are nonsubjective estimates of expected returns. However, historical returns are poor predictors of future returns. Another approach is to use expected returns embedded in the current term structure. These estimates are also nonsubjective (i.e., "no-view") because they assume only that the yield curve will remain unchanged. These no-view expectations reflect current market conditions, whereas historical returns do not.

A benchmark can be constructed using no-view expected returns and historical volatilities to maximize expected return subject to a risk constraint of not having a return less than zero with a pre-specified probability. The solution to this optimization problem is a Treasury portfolio that would serve as the benchmark. The manager would then be responsible for outperforming it. Alternatively, the manager could simply hold the benchmark if he did not wish to take any risk. This "no-view" Treasury benchmark is an example of how benchmarks can be objectively designed to reflect investment goals and constraints.[8]

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7. For a detailed description of book accounting based benchmarks, see chapter 9 in *Quantitative Management of Bond Portfolios*.
8. For a discussion of no-view optimization and benchmarks, see chapter 22 in *Quantitative Management of Bond Portfolios*.

DIVERSIFICATION ISSUES IN BENCHMARKS

Issuer-specific risk always is an important consideration in credit portfolios. Excessive exposure to individual issuers is a concern not just for portfolio managers. Plan sponsors examine benchmark design and pay close attention to large single-issuer concentrations. This is a serious issue even for the users of very broad market indexes. As Exhibit 46-1 shows, as of January 2020, the top 10 issuers in the Bloomberg Barclays U.S. Corporate Index accounted for 16% of the overall market value (reaching as high as 24% in some years). For some plan sponsors, this is too much security-specific risk. An asset manager benchmarked to this index may feel compelled to have exposure to these large-cap issuers simply because they have significant weights in the benchmark. The concerns about the high level of absolute issuer risk in some commonly adopted benchmarks led to a number of developments in benchmark design that attempt to mitigate this risk.

Issuer-Capped Benchmarks

A cap on the market-value weight that an issuer can have in the index limits exposure to the issuer's idiosyncratic risk. When such a cap (e.g., 1%) is imposed, every issuer's capitalization is checked against this ceiling. The market value in excess of the cap is "shaved off" and redistributed to all other issuers in the index in proportion to their market-value weights. Different caps can be chosen for various credit ratings, reflecting the differences in issuer-specific risk between higher and lower credit qualities. While issuer-capped portfolios have existed for quite a while, issuer-capped benchmarks are more recent and emerged in response to the increased levels of issuer-specific risk in credit markets.

	Aaa–Aa	A	Baa	Industrial	Utility	Financial
Average	–2.62%	–0.39%	3.00%	3.17%	1.31%	–4.48%

Issuer-capped indexes may seem very straightforward. However, the cap level and the redistribution rule can have a significant impact on the risk and return characteristics of an index. Some redistribution rules can limit the benefits of issuer-capping by inadvertently introducing unfavorable sector-quality risk exposures relative to the uncapped index.[9]

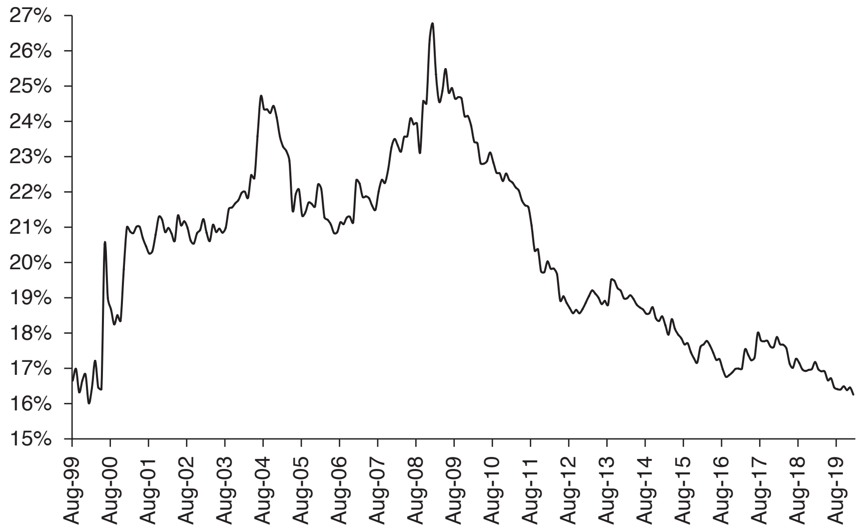
For example, an "index-wide" redistribution rule allocates the "excess" market value across all noncapped issuers in the index in proportion to their weights. However, this procedure may produce an index with very different

9. For a discussion of issuer-capped credit benchmarks, see chapter 13 in *Quantitative Management of Bond Portfolios*.

(and most likely unintentional) sector and quality exposures compared with the uncapped index. For example, Exhibit 46-1 covering the period August 1989 through October 2010 shows that the index-wide redistribution rule in a 1% issuer-capped Bloomberg Barclays Corporate Index produces significant overweights in Baa-rated and industrial issues and a significant underweight to financials compared with the uncapped Corporate Index:

EXHIBIT 46-1

Market-Value Weight of the Top 10 Issuers in the Bloomberg Barclays Corporate Index, August 1999 to January 2020



Source: Barclays

This inadvertent introduction of potentially unfavorable sector-quality risk exposures can be avoided by a "quality-sector-neutral" redistribution rule that preserves the sector and quality profiles of the uncapped index.

Another side effect of capping large issuers in an index is the increase in weights of smaller ones. By construction, in a capped index the market-value weights of smaller issuers exceed their actual weights in the marketplace, sometimes dramatically so. This raises a practical concern that the available market supply may not allow the manager to match (if desired) the required allocation in the issuer-capped index.

Issuer-capping has also been applied to sovereign indexes. The distribution of sovereign issuers is highly concentrated. For example, based on market-value weights, Japan represents about 27% of the Bloomberg Barclays Global Treasury

Index (as of January 2020), and the United States 30%. Within geographical regions these country weights are even larger, as Japan Treasuries account for over 76% of Asian Pacific Treasury bonds, while U.S. Treasuries account for 94% of Treasuries in the Americas. The skewed distribution of sovereign issuers may make issuer-capping attractive to investors. However, as with issuer-capped credit indexes, care must be exercised when redistributing any excess capped market value.

A simple sovereign-capping scheme of redistributing any excess market value above a cap level across all smaller sovereign issuers in the index does little to reduce the volatility of the index. This is because the excess capped market value gets proportionally re-allocated to countries economically closely related to the capped countries. A more productive sovereign-capping scheme is first to cap the market value weight of economic regions, and redistribute excess market value across other regions. Then, cap individual sovereigns within a region and redistribute any excess capped market value within the region. Such a two-tier capping scheme reduces the volatility of the index, compared to the uncapped sovereign index, and does not hurt the index's performance.

An alternative sovereign-capping scheme is to adjust index market value weights depending on the relative economic fundamentals across countries. For example, countries whose Debt/GDP levels are below average would have their index market value weights increased, while countries with above-average debt levels would have their weights lowered.[10] Such "fundamentals-based" weighting schemes have become more popular as sovereign creditworthiness has become less certain.

Despite these subtle issues, issuer-capped indexes are now a permanent fixture of the investment management landscape. With good judgment, investors can design issuer-capped indexes that meet their risk-management preferences in dealing with issuer-specific risk.

Swap-Based Benchmarks

A somewhat radical approach to dealing with issuer-specific risk in credit benchmarks is not to have this risk at all. Apart from the naive solution of adopting an all-Treasury benchmark, one type of popular benchmark is based on interest-rate swaps. Swaps offer excellent liquidity, a virtually unlimited market supply, low idiosyncratic or "headline" risk, and an opportunity to capture some of the long-term spread advantage of investing in non-Treasury product. Swaps have been a key feature of the debt markets since the early 1990s. In fact, in several ways the swap market is larger and more heavily traded than the U.S. Treasury market.

Swap payments are usually based on LIBOR, and therefore, the par swap rate curve can be viewed as a generic yield curve for large, highly rated banks

10. For a detailed description of one such index, see "Barclays Capital Fiscal Strength Weighted Bonds Indices," Barclays Capital, July 2011.

whose interbank lending rates constitute the LIBOR index.[11] Correspondingly, the swap spread (to the Treasury curve) is considered a generic proxy for high-grade credit spreads. (While the swap spread does not reflect the counterparty risk, it can be effectively dealt with via collateral management.)

This relationship between interest rate swap spreads and high-grade credit spreads has prompted some investors to consider swaps as total return benchmarks for their credit portfolios. However, unlike returns on regular fixed income securities, returns on swaps are not directly observable in the marketplace. In addition, while cash fixed income securities have an underlying market value that serves as the base on which to calculate returns, par swaps at initiation have zero market value. While swap yields and spreads are available from many sources, swap returns are not. To create total return indexes for the swap market, a new index methodology is needed.

The Bloomberg Barclays interest rate swap index methodology[12] relies on the creation of hypothetical constant-maturity swap "securities" from the swap curve. At the start of every month a set of par receive-fixed swaps is identified with swap rates taken from the specific maturity points on the swap curve. To create, say, the 10-year swap index, the 10-year par swap is paired with a cash investment in three-month LIBOR equal to the notional amount of the swap. Over the course of the month, the mark-to-market return of the 10-year swap is combined with the mark-to-market of the LIBOR deposit, divided by the initial notional value, to produce a 10-year swap index return. There are as many swap indexes as there are maturity points on the swap curve. Interest rate swap indexes exist for several major currencies.[13]

The individual swap indexes can be combined to produce a swap index with any desired term-structure profile (e.g., to match a particular liability duration target). Recall the earlier discussion on asset-swapped benchmarks where each asset class had an associated swap index (the mirror swap index) with a matched key-rate duration profile. A credit portfolio manager who has a swap index as a benchmark is completely free to hold only those credits that he thinks will outperform and to avoid credits expected to underperform duration-matched swaps. Credits on which the manager is neutral or has no view need not be in the portfolio at all. In contrast, if the benchmark is a market index, the manager is under pressure to have at least some exposure to the largest issuers in the benchmark. Even when managers have a negative view on a large issuer in the corporate index, they are unlikely to hold a zero weight because that creates a large active bet against the benchmark.

11. In the near future LIBOR may be replaced by another benchmark rate, such as Secured Overnight Financing Rate (SOFR).

12. Lev Dynkin, Yuri Greenfield, and Dev Joneja, "The Lehman Brothers Swap Indexes," *Journal of Fixed Income* 12 (2002), pp. 28–42.

13. In addition to interest rate swap indexes, CDX and iTraxx measure the total return of a funded investment ("selling protection") in these popular credit default swap portfolio indexes.

Downgrade-Tolerant Benchmarks

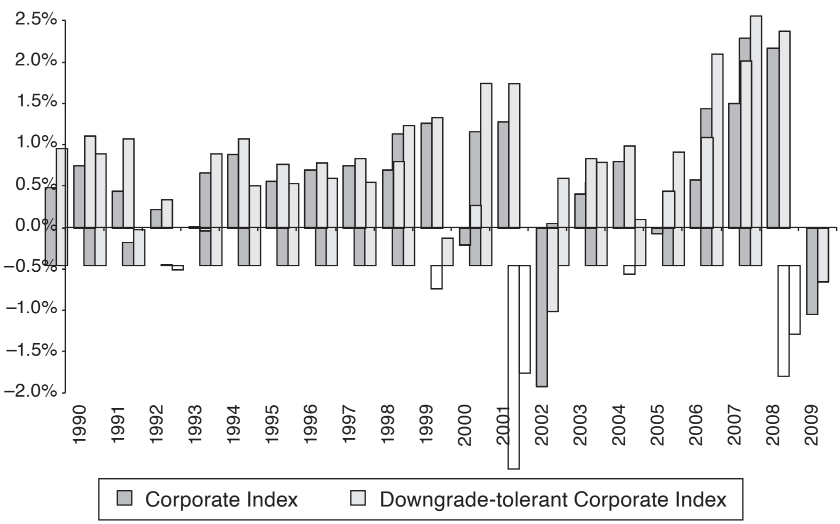
Most investment-grade credit indexes stipulate that a bond downgraded below investment grade be dropped from the index. Accordingly, portfolios benchmarked to the index may have to sell these bonds. Usually, this happens precisely when the spreads of such bonds are particularly wide, often wider than justified by any subsequent default losses. This bad timing may cause the index-benchmarked investors to forfeit, at least partially, the credit spread premium.

An alternative is to design a benchmark that allows managers to hold on to downgraded bonds and choose their own timing in selling such bonds.[14] Such a "downgrade-tolerant" Corporate Index has captured a spread premium almost 80% higher than the standard index. Exhibit 46-2 plots a yearly comparison between the two indexes, for the period from 1990 through 2009. The downgrade-tolerant index delivers a higher premium in every one of these 20 years, with virtually the same risk profile as the standard index![15]

These results suggest that if managers are allowed to hold on to bonds that the Corporate Index discards, they should be able to harvest a considerably higher spread premium and significantly improve their performance versus the benchmark.

EXHIBIT 46-2

Estimated Annual Credit Spread Premium, 1990–2009, % per year



Source: Barclays

14. The performance varies greatly across fallen angels, so there are no clear decision rules as to the best time to sell them. However, there is an overall improvement in the risk-adjusted forward performance of fallen angels as the permitted holding period is increased.

15. See Kwok-Yuen Ng, and Bruce Phelps, "Capturing the Credit Spread Premium," *Financial Analysts Journal* 67(3), 2011, pp. 63–75.

PORTFOLIO ANALYSIS RELATIVE TO A BENCHMARK

The selection of the investment guidelines and appropriate benchmark marks the beginning of the portfolio management process. Once a portfolio is established, investors continually monitor its positioning relative to the benchmark. Apart from investing new funds, periodic transactions help maintain desired exposures and express changes in market outlook.

Certain portfolio-monitoring activities are typically performed at regular intervals (e.g., monthly) and in a set sequence. Other analyses are performed as the need arises and not necessarily in a fixed order. Yet, however different the operational details might be, there are certain common functions that portfolio managers must perform and certain types of tools necessary to do so. Typically, at the start of a performance period, managers will use forward-looking, or *ex ante,* analytics to create and ascertain the desired portfolio positioning. At the end of the period, managers will use backward-looking, or *ex post,* analysis to review and explain the realized performance, which, in turn, guides portfolio adjustments.

Analyzing Portfolio Risk: A Cell-Based Approach

The most obvious way to analyze portfolio-versus-benchmark risk is a structural comparison of the two by partitioning them into a matrix of cells. Different choices of partition variables put the focus on different aspects of portfolio composition. Corporate portfolios, for example, are likely to be divided by quality and industry category (e.g., basic industry, consumer cyclical, and energy). Segmenting by duration highlights the yield-curve exposure. The amount and quality of information a portfolio manager can derive from such reports depend on the appropriateness of the chosen risk dimensions and on the portfolio and benchmark attributes (beyond market-value percentages) available for comparison.

The fundamental assumption behind the use of structural reports is that the contribution of a mismatch in a given cell to the overall portfolio-versus-benchmark risk is primarily a function of the magnitude of the mismatch and the weight of the cell. Clearly, a portfolio that matches its benchmark in all cells (along *all* possible dimensions) is risk-neutral to the benchmark.

While the simplicity of such analysis is attractive, there are two major problems with its basic assumption. First, the risk consequences of a particular mismatch depend not only on its apparent magnitude but also on its nature, that is, the volatility of the underlying exposure. A mismatch in spread duration contribution of 1.0 in a low-risk sector has a very different risk than the same-size mismatch in a high-risk one. Experienced portfolio managers have a feel for the portfolio performance implications from the magnitudes of individual mismatches.

The second problem is equally important and, arguably, more difficult to compensate for with experience. The cross-correlation among the multiple sources of risk in a portfolio makes the task of judging overall risk a daunting one without quantitative tools. Two mismatches in two different cells, each entailing significant risk in isolation, may cancel each other if low (or even negative) correlation between them reduces their joint contribution to risk. Conversely, a few mismatches that could easily be ignored individually may represent a serious risk if the correlations among them are positive and high. Needless to say, when the number of mismatches reaches dozens, as it can even in relatively simple portfolios, finding the common risk denominator by "eyeballing" the structural mismatches is unrealistic.

Analyzing Portfolio Risk: Multifactor Risk Models

One reliable approach to quantifying a portfolio's active risk (i.e., risk versus benchmark) is multifactor risk analysis. Its primary goal is to help managers structure portfolios with desired risk exposures relative to the benchmark. As such, it is generally used not as an *ex post* control tool but rather as an *ex ante* tool for portfolio structuring. One obvious need is to measure the expected risk of return deviation in portfolios that track a benchmark. Another is to form a reliable estimate of risk for active managers with a particular outperformance, or "alpha," target. There is a well-established consensus among investment professionals regarding realistic levels of *information ratio,* or risk-adjusted outperformance, versus the benchmark. A realized information ratio above 0.5 generally is considered to be quite high, with 1.0 often seen as a practical upper limit. As a result, quantifying active risk allows managers to test the feasibility of a specified alpha target. For example, a portfolio with a required alpha target of 50 basis points per year should be allowed an active risk somewhere in the range of 50 to 100 basis points per year. If, as a result of policy constraints, the projected risk is estimated to be much lower, the manager should make a case for either relaxing portfolio constraints or lowering the alpha target.

Active risk has *systematic* and *idiosyncratic* components. The former is a result of the differences between the portfolio and benchmark sensitivities to common market *risk factors* (e.g., movements of the key rates, credit sector spreads, or volatility). The latter, sometimes referred to as "diversifiable risk," reflects unequal exposures (usually overweights in the portfolio) to individual issuers and can be present even when all systematic exposures are eliminated. This type of risk reflects residual spread movements of individual issuers, not explained by anything that happens to their peer group. Apart from the risk of typical idiosyncratic spread movements, there is default risk that is particularly important in lower-quality credit portfolios. In some risk models, default risk is modeled and reported separately from market risk. Conceptually, default risk contains both systematic and idiosyncratic parts. Correlated defaults across different issuers create a systematic risk component. To the extent that defaults are uncorrelated and reflect events specific to a particular issuer, the default risk is idiosyncratic risk. Separating the systematic and idiosyncratic components of default risk is quite difficult.

To quantify the systematic risk, multifactor risk models use historical volatilities and correlations of a relatively small set of risk factors. These are processed into a *covariance matrix* that is the cornerstone of the model. The idiosyncratic risk is quantified by measuring the differences between the portfolio and benchmark concentrations in a specific issue or issuer. These weight differentials are then multiplied by idiosyncratic spread volatilities specific to a given issuer or its peer group.

These risk components are combined to produce the key output of such models—*tracking-error volatility* (TEV), defined as the projected standard deviation of the monthly return differential between the portfolio and the benchmark. TEV is an extremely useful measure because it provides a common unit for many different sources of risk, enhancing comparisons of diverse exposures and greatly facilitating portfolio risk management and risk budgeting. Well-developed models not only compute TEV but also provide useful information on its components, for example, offering detailed analysis of the TEV sources, their relative contribution to the total, and their interdependence.[16]

Of course, the reliance on historical observations exposes the multifactor analysis to criticism that risk-factor correlations are unstable and depend (as do volatilities) on the economic cycle. These concerns, however, are easily addressed.

Different historical periods can be viewed as more or less relevant to the current environment. Some asset classes evolve over time, and their risk characteristics change. For example, the dramatically increased refinancing efficiency in the U.S. residential mortgage market made MBS prepayment history up to the early 1990s largely irrelevant for estimating prepayment risk in subsequent periods. Economic and market conditions also may justify emphasizing a particular historical period while downplaying others. Risk models can accommodate these risk dynamics—for example, by imposing time decay on the historical data series to give greater weight to more recent data.

The idiosyncratic component of active risk presents a bigger challenge to history-based risk models. To quantify the issuer-specific risk, a model needs estimates of residual spread volatility in all market segments. These estimates can be derived only from the historical time series of individual securities' residual returns, that is, parts of each bond's return unexplained by all the systematic risk factors. This requires a large body of individual security-level historical data.

As with systematic risk, there is the issue of choosing a relevant historical period for the idiosyncratic risk estimation. Conservatism is usually a good rule of thumb. After a spike in issuer-specific volatility, such as the one that happened in the U.S. credit market in 2008, a risk model needs to "learn" quickly from recent experience. Applying time decay to the historical data accomplishes this and makes the model produce higher estimates of idiosyncratic risk going forward. Sometimes, however, a risk model should pay less attention to recent experience. After a long period of calm, the model should revert to the equal weighting of historical data to avoid underestimating issuer risk.

16. For an example of such a model, see chapter 26 in *Quantitative Management of Bond Portfolios*.

Analyzing Portfolio Risk: Liquidity

Liquidity is one of the most important characteristics of financial markets. Liquidity has several dimensions and can have different meanings in different contexts. What is more, frequently used definitions of liquidity are often difficult to quantify rigorously and represent market aggregates, such as total trading volume, the number of bonds traded, and dealer inventories. However, a liquidity measure truly useful for portfolio managers has to be security-level. Such a measure can be used for monitoring and analyzing market liquidity while allowing full flexibility in defining the universe of interest, from large fixed income markets like USD investment-grade credit to very narrowly defined market segments suited for some particular inquiry. Investors often compare today's liquidity environment with various periods in the past. Aggregated to market level, a bond-level measure makes such comparisons rigorous, providing hard numbers as opposed to qualitative opinions often unsupported by evidence. It makes it easy to factor liquidity into a multitude of investment decisions: for example, selecting a bond universe for portfolio rebalancing, monitoring desk inventories, testing the feasibility of alpha strategies, and quantifying liquidity risk.[17]

Bond-level liquidity measures can be used by asset managers and plan sponsors in a variety of applications. For example, in portfolio structuring and benchmark replication, liquidity is one of the most important considerations. One of the challenges of managing a portfolio with a limited number of bonds against a broad market index is narrowing down the investable universe. A portfolio manager cannot evaluate thousands of bonds and must impose some selection constraints. Liquidity is always among them. Having a single metric defined consistently for every bond in the benchmark streamlines this process and makes it more robust. Once a liquid investable universe is in place, the manager can proceed to construct or to rebalance a replicating portfolio without worrying about the feasibility of the implementation.

An intra-market liquidity distribution can be as useful as historical liquidity patterns. It provides valuable information about the current market conditions, beyond simple statistics such as a market value-weighted average or median. Side-by-side distributions for various markets highlight differences between their liquidity structures. Cross-sectional distributions for the same market at different points in time can be equally instructive. For example, such analysis reveals that during the Global Financial Crisis of 2008, when market liquidity decreased dramatically, the distribution also became much wider, emphasizing the liquidity gap between more and less liquid market segments.

An important application of bond-level measures is adjusting tail risk models for liquidity. In times of market upheavals that often trigger massive portfolio

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17. An example of such a measure is the transaction cost–based Barclays Liquidity Cost Score (LCS®). LCS measures the cost of an immediate, round-trip transaction of a typical institutional size and is expressed as a percent of the bond's price. See Vadim Konstantinovsky, Kwok Yuen Ng, and Bruce D. Phelps, "Measuring Bond-Level Liquidity," *Journal of Portfolio Management* 42(4), 2016.

liquidations, portfolio managers find it difficult to realize the mark-to-market value of their holdings. As a result, actual losses may far exceed the estimates by traditional VaR models based on published bid prices. To correct for this, one needs to recognize that losses in tail events are exacerbated by high transaction costs.

Among many other applications of bond-level liquidity measures are monitoring and reporting on portfolio liquidity; analyzing liquidity risk; decomposing a bond's spread into risk premium, default, and liquidity components; intra-market liquidity ranking; and understanding drivers of liquidity in various markets.

History-Based Scenario Analysis

In one form or another, scenario analysis is used widely by portfolio managers to study portfolio (and benchmark) behavior in various yield-curve, spread, volatility, prepayment, or exchange-rate environments. Managers may focus on what they consider to be the most likely scenarios or unlikely but potentially damaging scenarios. Scenario analysis complements multifactor risk analysis. It allows managers to stress-test benchmarked portfolios by subjecting them to extreme conditions ("three-standard-deviation events") not necessarily consistent with the history underlying the risk model. Such analysis may highlight potential sources of return deviations that do not manifest themselves under normal (by historical standards) circumstances.

When using scenario analysis, investors usually make explicit forecasts for specific, observable market dimensions: key interest rates, credit spreads for certain market sectors, particular exchange rates, and such. It is very difficult, however, to formulate scenarios that are consistent in both direction and magnitude across many different market sectors and to estimate the probability of such scenarios. This is similar to analyzing risk simultaneously along many dimensions. Thus the solution also can be the same as in multifactor risk models. A covariance matrix estimated from historical observations can be used to build "maximum-likelihood scenarios." Such scenarios incorporate a few explicit forecasts provided by the investor and then infer historically consistent realizations (forecasts) for all other factors in the matrix. Then the full set of stated and derived factor forecasts is translated into expected returns for individual securities.

Explicit forecasts may represent unlikely scenarios. For example, the projection of a one-month parallel yield change of 50 basis points represents a 2.3% probability event if the historical yield curve volatility is only 25 basis points per month (assuming a normal distribution). Similarly, historical correlation patterns would not support an expectation of credit-spread widening at the same time with an increase in Treasury yields because yield and spread changes typically are negatively correlated. A scenario-generation model can be made to assess the likelihood of an explicit forecast in light of the covariances that underlie the analysis and to allow a rescaling of forecasts to meet pre-specified likelihood targets. The views can be relative as well as absolute. A yield-curve slope forecast is an example of a relative forecast because it does not express an opinion on the overall direction of interest rates. Individual forecasts can be accompanied by degrees of confidence in them. For example, investors are often more confident in their views on credit spread movements than on currency and interest-rate changes. A robust scenario analysis framework should be able to incorporate this information.

Attribution of Portfolio Performance Relative to a Benchmark

A comprehensive performance-attribution framework must account for all potential sources of portfolio performance and quantify the contribution from each of these sources. Performance attribution of past returns is perhaps the most important tool that asset managers can use to substantiate their claims on expertise in a given style of investment. If, for example, a fund claims to be adept at finding undervalued credits, performance attribution can be used to determine what share of the fund's past outperformance was due to credit bond selection. Unless there is hard proof that the generated returns came from the advertised source, investors may worry that past superior performance might have been luck rather than skill and may, in fact, be a sign of imprudent risk taking.

Asset management companies also benefit from using performance attribution in the internal analysis of portfolio performance to help determine their skill in managing different kinds of exposures and the areas that may require improvement. Sources of achieved outperformance should be matched with sources of ex ante risk. Quantitative analysis of return deviations from the benchmark may point out unintended portfolio exposures that need to be corrected. This is particularly important for large funds with decentralized decision-making in which separate groups or individuals are responsible for yield-curve positioning, sector and quality allocations, and name selection. Performance attribution can help evaluate individual manager performance in such an organization. Flexibility is critical in this analysis. A performance-attribution framework will only be useful (and used) if it is aligned with the actual decision-making process behind the portfolio investments. This process differs across firms and may vary over time within a single firm.

For multicurrency portfolios, the analysis normally starts at the global level, where outperformance results from two basic sources: exchange-rate exposures and asset allocation exposures to different markets. The ability to implement currency hedges as an overlay using FX futures or forwards empowers managers to separate the asset allocation and currency allocation decisions. The attribution framework should explain the performance due to each.

After multicurrency outperformance is assessed, portfolio positions generally should be segregated by currency, and the performance of each single-currency portfolio evaluated separately (versus appropriate single-currency benchmarks). In a developed fixed income market, such as the United States, local returns can be divided into three main components: Treasury (yield curve), volatility, and spread.

Robust performance-attribution models rely on key-rate durations[18] to compute outperformance owing to the Treasury curve positioning. Both the portfolio and the benchmark are replaced by hypothetical portfolios of Treasuries with exactly the same yield-curve exposures, that is, with matching key-rate duration profiles. Then the returns of these "Treasury-matched" portfolios are compared. Any difference comes exclusively from their disparate curve exposures. The bonds in the Treasury-matched portfolios usually are not real securities but rather points on the par yield curve and contribute no pricing noise (such as owing to the richness of on-the-run issues). The model can break down this component of outperformance even further, to individual key-rate exposures.

A shift in implied volatility affects prices of bonds with embedded optionality. Quantifying outperformance owing to differences in volatility exposure requires a good term-structure model that can estimate the implied volatility of the Treasury curve, and the analytics to compute volatility sensitivity (or vega) for all securities in the portfolio and in the benchmark.

Outperformance owing to spread exposure can be broken into an asset-allocation part (asset class, sector, industry, quality, etc.) and a security-selection part. The former occurs when the portfolio had larger allocations to winning asset classes (or smaller to losing) than the benchmark. Security-selection outperformance comes from picking names that outperform their peers. Both measures depend strongly on the definition of asset classes or security peer groups.

Performance attribution is arguably one of the most complex elements in a suite of methodologies and tools that modern asset managers need. There are many technical points and subtleties, such as aggregating daily results, accounting for intraday trading, or dealing with pricing and return conventions that differ between the portfolio and the benchmark.

QUANTITATIVE APPROACHES TO BENCHMARK REPLICATION

Besides index funds whose investment mandates explicitly call for tracking benchmarks with the minimum possible deviation, "buying the benchmark" is often a reasonable tactic even for managers who normally pursue active strategies. For example, in times when managers have no definite views on particular segments of the market, matching index returns in those segments is a sensible strategy. Sometimes, when managers have accrued significant outperformance before the year is over, they decide to switch to passive benchmarking for the rest of the year to preserve their gains. Finally, investors sometimes use so-called

18. Rather than measuring sensitivity to a parallel shift of the entire yield curve, each key-rate duration measures the sensitivity of a security's price to changes at one specific point (key rate) along the curve, holding the rest of the curve unchanged. Measuring sensitivities to several key rates gives a more detailed view of a portfolio's rates exposure. See Thomas S. Y. Ho, "Key Rate Durations: Measures of Interest Rate Risks," *Journal of Fixed Income* September 1992.

proxy portfolios that replicate broad market indexes for modeling purposes rather than for direct investment. The main reason usually is to apply the same in-house models to both the portfolio and the benchmark, eliminating "model noise" that can be quite significant. Sometimes it is not feasible to include the actual benchmark in the analysis because of constraints on either processing time or data availability. Computer-based analysis gets simpler when applied to a small set of well-priced securities as opposed to potentially thousands of bonds in an index. Hence the term *proxy portfolios*.

As pointed out earlier, the replication of a diverse market index that has multiple sources of return is not trivial and requires complicated techniques and tools. There are two main techniques: replication with actual, or "cash," securities and replication with derivative instruments (e.g., futures and swaps). The replication strategies vary greatly, reflecting diverse characteristics of various fixed income markets, as well as objectives and constraints of different investors. For example, in markets with high idiosyncratic risk, it is relatively more important to match the issuer distribution of the benchmark. Where systematic risks dominate, the replication techniques should pay close attention to matching benchmark allocations along the important risk dimensions. For portfolios experiencing very dynamic cash inflows and outflows, replication strategies using derivatives may be preferred because of their liquidity and low transaction costs. Derivatives replication is also popular with investors engaged in "portable alpha" strategies that use liquid derivatives that require little or no cash investment to replicate index returns and then invest the available cash in overlay strategies outside the index to generate alpha.

Of course, the simplest way to replicate an index is to buy most of its securities. However, this method is practical only for the few largest index funds that have had years to accumulate many of the index issues. For smaller and newer portfolios, maintaining the required proportions of a large number of bonds would lead to buying and selling odd lots with limited availability and overwhelming transaction costs. Furthermore, this strategy is appropriate only for portfolios that intend to remain neutral versus the benchmark for a long time.

For many investors, cash replication involves buying a small set of index bonds to track the index. The problem of selecting the right subset of index securities is solved by one of two basic approaches: cell matching (stratified sampling) or tracking error minimization using a risk model. The relationship between the two parallels closely that between the cell-based and the risk-model approaches to measuring portfolio risk.

Replication with Cash Instruments: Stratified Sampling

Sampling is the "commonsense" approach. To replicate an index, one attempts to match its contribution to each important segment with a few securities. In the simplest case, the total market-value weight of holdings in a particular segment is set to match the index weight. More often, holdings are selected and scaled so that, collectively, they match the segment's contribution to the index duration. To improve tracking further, the manager may target other characteristics of each individual segment, such as convexity or credit quality. Of course, the more securities purchased in each segment, the more closely the portfolio will track the index.

This approach may work quite satisfactorily in homogeneous markets, such as U.S. governments or MBS. One very simple but effective approach to replicate governments requires just six securities. The index is partitioned into three market-specific maturity segments. The choice of these segments may reflect such market characteristics as auction cycles, maturity distribution, or refunding policies. Within each segment, the bonds are divided into two groups: one with durations above the segment's average and one below. One liquid bond is selected from each half-segment. These two bonds are weighted in such a way that the total duration of the pair matches the duration of the segment they represent. The three pairs of bonds are then given appropriate weights to match the contributions of their segments to the index. This simple procedure ensures sufficiently close matching of the term-structure allocation that is the primary source of risk in government markets.

Stratified sampling also works well for the U.S. MBS market that has little idiosyncratic risk. For MBS replication it is usually sufficient to sample the index along just three dimensions: program (GNMA 30-year, conventional 30-year, and all 15-year), seasoning (seasoned, unseasoned), and price (premium, cusp, and discount).[19] Stratified sampling works less well for markets with much idiosyncratic risk (e.g., credit). Simply matching broad risk dimensions still leaves the proxy portfolio vulnerable to issuer-level risk because, by necessity, the proxy portfolio overweights each issuer relative to the benchmark. This important question of how to control the issuer-specific risk of a portfolio is discussed below.

Sometimes stratified sampling is simply the only available replication method—for example, in markets where multifactor risk models are not available. The actual techniques, while still based conceptually on sampling, may get quite sophisticated. First of all, special rules may be used for selecting individual bonds in each segment (e.g., starting from the largest, or most liquid, issuers), as well as for setting the level of diversification in each segment (e.g., based on the segment's historical volatility). The sampling process may be performed within an optimization context. In this case, satisfying constraints is the main goal, with the objective function being a secondary consideration (yield, spread, or liquidity may be maximized, for example). The number of securities that end up in the replicating portfolio can be regulated by tightening or relaxing constraints.

The fundamental issues with replication techniques based on stratified sampling are the same as with the cell-based approach to analyzing risk. Matching some cells may be more critical than matching others because return volatility

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19. Partitioning the MBS universe by price is essentially equivalent to partitioning by coupon. The advantage of using price is that the cutoff levels defining the boundaries do not change over time.

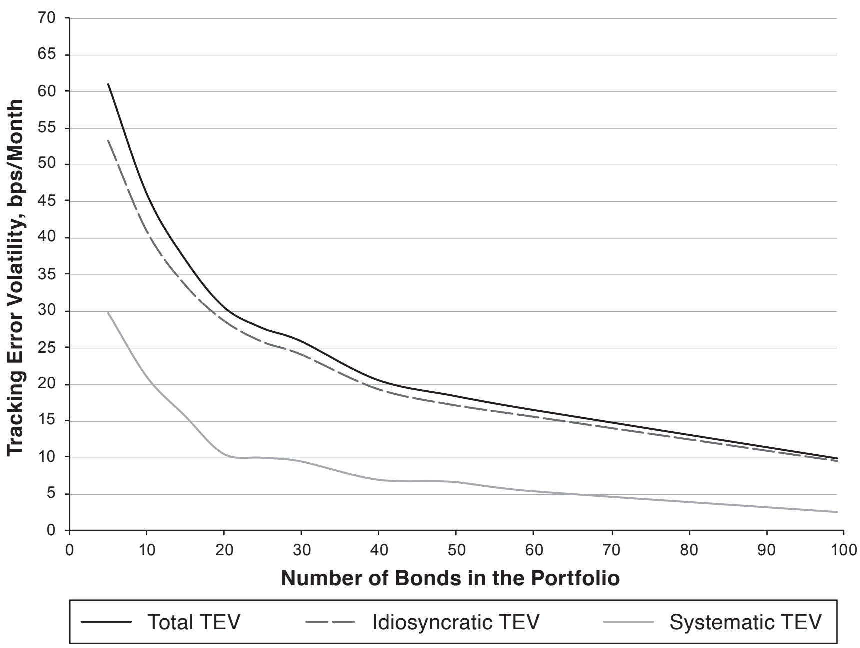
associated with these cells is higher. And sampling-based techniques ignore the all-important correlations among cells.

Replication with Cash Instruments: Tracking-Error Minimization

As mentioned earlier, multifactor risk models usually provide more accurate estimates of portfolio risk than sampling techniques that attempt to match the index risk parameters "naively," often ignoring historical variances and correlations of risk factors. Besides performing their primary function of measuring risk, multifactor models can be augmented with optimization capabilities. Given a set of securities representing the investable universe, a benchmark, and a set of constraints, an optimizer based on a multifactor model can pick a sample of bonds (a portfolio) with the minimum projected tracking error versus the benchmark. This may be done in one step, with the model being essentially a "black box" cranking out a solution. Or the model may allow the manager to step through the optimization one bond at a time, using his knowledge of relative value to select the best bond to buy from a list of candidates.

EXHIBIT 46-3

Tracking Error Volatility vs. the Bloomberg Barclays Corporate Index as a Function of the Number of Bonds in the Portfolio



Source: Barclays

Tracking-error minimization has been used successfully to construct replicating portfolios for broad benchmarks of the U.S. and global government and credit markets. This method also has proved very effective in replicating the Bloomberg Barclays MBS Index.[20]

The realized performance of most actual replicating portfolios has been within the model-projected range. The level of tracking achieved by a replicating portfolio depends, of course, on the number of bonds it contains. As more bonds are added to the portfolio, tracking risk decreases. Exhibit 46-3 illustrates this trade-off by showing how the projected monthly TEV of a corporate replicating portfolio versus the Bloomberg Barclays Corporate Index declines with the increase in the number of securities. At first, adding more securities to the portfolio reduces tracking error quickly, but gradually, the rate of decline slows. The explanation lies in the difference between systematic and idiosyncratic risk. As the plot shows, after the 60-bond level, the systematic risk ceases to be a concern. Consequently, even relatively small portfolios can match the systematic risk exposures of a broad market index surprisingly well. The dominant type of risk for small portfolios is idiosyncratic. By the time the portfolio size reaches 100 bonds, the idiosyncratic risk contributes almost 100% of the total TEV and declines very slowly as more bonds are added to the proxy portfolio.

Multifactor risk models rely on historical experience over the calibration period. Such models may ignore a significant structural mismatch between the proxy and index that historically did not result in return volatility. There is always a chance that historical patterns will not hold over to the next month, and that a mismatch will prove more consequential than the model assumed. This is why stratified sampling analysis may be useful even in the presence of a powerful risk model. It may alert the portfolio manager to structural mismatches ignored by the model. In such cases, managers may use their judgment in deciding whether to rely on historical patterns.

Replication with Derivatives

Derivatives effectively reduce the number of dimensions in the portfolio management problem and simplify asset allocation shifts and deployment of cash inflows. Because of this, derivatives can be particularly useful in replicating the benchmark at the start-up phase, when diversified cash investments in tradable sizes are not easily available. Derivatives can also be used in portable alpha strategies, in which a manager's value-added from one strategy is "transported" into another strategy.

Treasury futures have been widely used as a duration-adjustment tool because of such advantages as no disruption in cash holdings, ease of establishing and unwinding positions, and low transaction costs. A derivatives version of the cell-matching technique using a mix of Treasury futures contracts can be

20. Lev Dynkin, Vadim Konstantinovsky, and Bruce Phelps, "Tradable Proxy Portfolios for an MBS Index," *Journal of Fixed Income* 11 (2001), pp. 70–87.

effective in replicating the term structure exposure of any fixed income index. In one such methodology,[21] an index is divided into maturity (duration) cells, and the market value allocations and dollar durations of each are matched with a combination of cash and the appropriate futures contract. The cash can be invested in Treasury bills or other short-term instruments. For an added benefit, cash may be invested more aggressively into riskier and higher-yielding instruments such as commercial paper or floating-rate notes. For investment funds with frequent and significant cash inflows and outflows, replication of benchmark returns with exchange-traded futures and, increasingly, with ETF are often the preferred strategies. Similarly, a large asset allocation shift may be initiated with futures because of their liquidity and low trading costs. Less liquid cash assets can then be deployed gradually as opportunities arise.

While the term-structure exposure can be matched effectively with Treasury futures alone, spread risk needs to be hedged separately. The next level in derivatives replication techniques introduces Eurodollar futures and swaps to replicate indexes with credit spread exposure. Replication strategies based on these instruments rely on the positive correlation between credit or MBS/ABS spreads on the one hand, and the Treasury-Eurodollar (TED) and swap spreads on the other. These strategies can successfully replicate credit and mortgage benchmarks.

A further enhancement introduces TBAs to replicate the mortgage component and portfolio credit default swaps to replicate the credit component. TBAs offer two key advantages over mortgage pools in replication strategies: they are more suitable for unfunded strategies, and the back office aspects are much simpler because monthly interest payments and principal paydowns are avoided. Portfolio credit default swaps (CDX and iTraxx) are liquid instruments that investors can use to take a long or short position in credit. Credit yields can be broken down into two parts: the swap yield and a credit spread to swaps. Accordingly, the exposure to movements in swap yields can be matched by using interest-rate swaps, and the exposure to movements in credit spreads to swaps—by using CDX. For example, such widely traded portfolio products as CDX.NA.IG represent baskets of equally weighted CDS in 5- and 10-year maturities and can be useful in replicating credit indexes. TBAs and CDX swaps help reduce TEV for derivatives replication of the Bloomberg Barclays U.S. Aggregate Index.[22]

Finally, derivatives can be employed to replicate the broadest, multicurrency fixed income benchmarks. A global index presents investors with a portfolio management problem involving multiple yield curves and exchange rates, as well as credit and issuer risk in several markets. This diversity of exposures makes global indexes particularly good candidates for replication with derivatives.

Typically, the single-market components of a global index are replicated separately and then combined into one tracking portfolio. The greater number of

21. Lev Dynkin, Jay Hyman, and Peter Lindner, "Hedging and Replication of Fixed-Income Portfolios," *Journal of Fixed Income* 11 (2002), pp. 43–63.

22. Lev Dynkin, Anthony Gould, and Vadim Konstantinovsky, "Replicating Bond Indices with Liquid Derivatives," *Journal of Fixed Income* 15 (2006), pp. 7–19.

risk dimensions in a global index provides better opportunities for diversification of the TEV for each subcomponent of the index. For example, the tracking risk associated with replicating the U.S. MBS component is not likely to be highly correlated with the tracking risk in replicating the Euro-credit component. This will reduce the overall portfolio's TEV.

It is apparent that investors have a wide range of choices for derivatives replication of a cash index. For example, an investor wishing to replicate the Bloomberg Barclays U.S. Aggregate Index can choose among the following strategies: Treasury futures only; a blend of futures and interest rate swaps; futures, swaps, and TBAs; futures, swaps, TBAs, and CDX; swaps only; and so on. In addition, it may, at times, be possible for an investor to find a counterparty with whom to enter into a total return swap on the index itself. With an index TRS, the investor agrees to receive the total return on the index from the counterparty in return for paying LIBOR plus a spread. The choice of a derivatives replication strategy will depend on the investor's sensitivity to monthly tracking errors versus cumulative tracking over time, and the cost (both transactions cost and monitoring cost) of maintaining the replication strategy.

Some investors have little time or inclination to manage a large set of derivatives positions. To accommodate these investors some broker/dealers may offer a total return swap based on the total returns of a *basket of derivatives*, with the basket components automatically rebalanced every month to minimize the expected tracking error to the underlying index. Because the replicating basket contains very liquid derivatives instruments (e.g., futures and swaps), such total return bond replicating index swaps are inexpensive and liquid.

CONTROLLING ISSUER-SPECIFIC RISK IN THE PORTFOLIO

Credit crises like the one of 2008 usually prompt portfolio managers to adopt a more disciplined approach to diversifying portfolio risk (although a few years of calm often erode this discipline). At the simplest level, managers try to avoid large exposures to single issuers and hold as many different issuers in their portfolios as practical. A more nuanced approach, described below, places stricter diversification requirements on lower-rated bonds, as event risk is more significant in lower credit strata, both in frequency and in loss severity.

Managers who do not pursue alpha via name selection may not buy cash securities at all, choosing alternative ways of getting credit sector exposure. Such "bondless" portfolios assume the net issuer risk of the benchmark. For sufficiently broad market indexes, such risk is usually much smaller than the issuer risk of a typical cash portfolio. Well-developed and liquid swap markets in several currencies provide a viable means of getting credit exposure without acquiring actual securities and the associated exposure to their issuers. The credit derivatives markets, particularly credit default swaps, provide managers with even more flexibility in controlling credit exposures in their portfolios.

Sufficient Diversification in Credit Portfolios

The need to reduce issuer-specific risk by diversification is obvious to any credit manager. However, diversification should not be viewed as an unqualified benefit, because there is a downside to it as well, from increased transaction costs as more bonds are purchased to the dilution of the value of credit research as bonds with less perceived upside are added solely to increase diversification. This issue has been addressed in a study of optimal diversification levels in credit portfolios.[23] A simple model of downgrade risk was proposed, based on the observed historical underperformance of downgraded bonds and transition probabilities published by rating agencies.

The study helps to answer the following question: for a portfolio of a given number of bonds, how many bonds of each credit quality should be held to achieve the lowest tracking error due to downgrade risk? The optimal allocations are skewed in their diversification levels (i.e., in maximum allowed position sizes) across qualities. For the study period from August 1988 through September 2010, the optimal ratio of position sizes for the three major investment-grade credit categories was found to be roughly 3:1.5:1. In other words, the optimal position size in Baa-rated bonds, for example, was one-third the position size of Aaa-/Aa-rated bonds. Compared to earlier periods, this ratio is not very skewed because, in the credit crisis of 2008 higher quality bonds, primarily A- and Aa-rated financials, experienced significant turmoil.[24] The ratio reflects only one type of idiosyncratic risk—the risk of a credit rating downgrade. Of course, issuer-specific events can give rise to significant spread changes without an accompanying downgrade. Indeed, this type of volatility usually dominates in the higher-quality segment of the market. When one takes into account the spread volatility not caused by rating transitions, the position size ratio becomes less skewed, but still indicates smaller position limits in lower qualities.

Clearly, these ratios should never be used as a literal directive when structuring credit portfolios. They depend heavily on the methodology and the historical period covered by the study. Yet the very clear and enduring lesson is that to lower the overall issuer-specific risk, it is most important to diversify exposures to lower-rated issuers. This conclusion has implications for plan sponsors as well: portfolio guidelines that establish maximum position limits to force diversification should not do so evenly across credit qualities.

To counterbalance the desire to reduce event risk as much as possible, managers should carefully consider the costs associated with increasing the number of issuers in a portfolio. First, transaction costs increase as the portfolio transacts more and in smaller amounts. Second, there is the overhead of monitoring a larger number of issuers. Finally, as managers push to add issuers for diversification's sake, they will be forced to add issuers less highly regarded by their credit analysts. Consequently, the optimal level of diversification is determined by the trade-off

23. For the original study, see Lev Dynkin, Jay Hyman, and Vadim Konstantinovsky, "Sufficient Diversification in Credit Portfolios," *Journal of Portfolio Management* 29 (2002), pp. 89–114.
24. Over the period 1988–2002, for example, the ratio was a more dramatic 10:3:1.

between the reduction of issuer-specific risk and the dilution of outperformance. The development of quantitative models that pinpoint this optimal level is possible but not trivial. Such models need to consider both the marginal cost and the marginal value of credit research, as well as the portfolio's size and many other factors.

Swaps as a Total-Return Investment

Interest rate swaps traditionally have been used as a risk-management tool to adjust portfolios' term structure and spread exposures. However, swaps can be used as a total-return investment as well.

Changes in the credit risk premium influence both swap and credit spreads. Expectations of significant changes in the future Treasury supply, for example, as well as "specialness" of individual Treasury securities affect the spreads over Treasuries of swaps and other spread product. Total returns of interest rate swap indexes can help investors analyze and use swaps as just another asset class, complete with pricing, returns, and analytics.

As mentioned earlier, among the published swap indexes are so-called mirror indexes that match the term-structure (i.e., key rates) exposure of various popular fixed income benchmarks. Despite monthly tracking volatility, over the long period from August 1992 through January 2020, the cash components of the Bloomberg Barclays Aggregate Index performed roughly in line with their mirror swap indexes, as interest-rate exposures are the key determinant of fixed income asset performance. However, during periods of market stress, swaps tend to outperform. In 2008, for example, every single sub-index of the Aggregate Index underperformed its mirror swap index by a wide margin. Although that was a time of extreme market conditions, and there were historical periods when swaps underperformed, it is clear that swaps have a performance potential that investors should consider along with other spread asset classes.

EXHIBIT 46-4

Correlation Matrix: Excess Returns over Treasuries, July 1992 to January 2020

	Aggregate	Credit	Agency	MBS	ABS	5-Yr Swaps
Aggregate	1.00	0.93	0.65	0.68	0.64	0.42
Credit		1.00	0.54	0.43	0.63	0.36
Agency			1.00	0.50	0.35	0.64
MBS				1.00	0.35	0.39
ABS					1.00	0.20
5-Yr Swaps						1.00

Source: Barclays

Swap spreads usually are aligned with credit spreads, although certain factors can cause them to diverge. For example, in a steep yield-curve environment, swapping activity by corporations intensifies, leading to the tightening of swaps spreads unaccompanied by a corresponding tightening of credit spreads. Although such factors diminish the value of swaps as a credit proxy, they promote the role of swaps as a means to diversify systematic risk in total return portfolios. Exhibit 46-4 shows that for the period from July 1992 through January 2020, five-year swaps had a noticeably lower excess return correlation with the Bloomberg Barclays Aggregate Index than did any of the index's four main spread components. The low excess return correlation implies that adding five-year swaps to a diversified portfolio of agencies, credit, mortgage-backed, and asset-backed securities may reduce risk.

The treatment of swaps as a total-return investment should be considered from a tactical as well as a strategic asset allocation perspective. The outperformance and diversification properties of swaps make them a valuable tool for total-return portfolio managers.

Credit Default Swaps as Protection Against Issuer Risk

Credit default swaps (CDS) have a place in many portfolios. CDS can be used to hedge existing credit exposures in the portfolio and to create new exposures that may be difficult to create otherwise, for example, taking short positions to express a negative view. A conventional cash corporate bond bundles exposures to interest rates, swap spread, credit spread (over swaps), and possibly, currency risk as well. CDS allow investors to pick from this bundle of exposures only the desired one. With CDS, investors can separate their views on a particular credit (issuer) from views on the market segment to which that issuer belongs.

Besides their primary function of hedging out the default risk of particular issuers, CDS are used in a number of other ways. Some investors place bets on the "CDS-cash basis," that is, the spread between a CDS and corporate debt of the same issuer, or express relative views on two issuers. Finally, CDS are often more liquid than the underlying corporate bonds, providing an easier and cheaper way to get a desired exposure.

QUANTITATIVE METHODS FOR PORTFOLIO OPTIMIZATION

Optimization has been an important part of investment practice since the introduction of mean-variance analysis more than 60 years ago. The asset management problem lends itself quite naturally to optimization techniques. Almost always, it is a multi-variable, multi-constraint task with a well-defined objective. A portfolio of financial assets has two essential characteristics: investment return and risk (i.e., uncertainty about the magnitude of return). Therefore, the countless optimization methods and tools developed over the past decades target one of these two characteristics while controlling the other.

Historically, the usual objective function of portfolio optimization has been to maximize expected return relative to risk. This requires upfront estimates for expected returns of every asset considered in the optimization. Historical data, whether long-term or recent, are poor predictors of future performance. Analysts' forecasts are imperfect as well. This section examines two examples of optimization techniques that do not rely on explicit predictions of asset performance.

Optimal Risk Budgeting Based on Skill

Management of large, multi-asset portfolios is usually a collective effort. Various managers, analysts, or teams form opinions relevant to particular segments of the overall portfolio. Then all these opinions are considered by some central decision-making authority. This may be a committee of the very same portfolio managers responsible for individual portfolio segments, often supervised by a chief investment officer. Multiple recommendations have to be reconciled: "go long duration," "overweight the 10-year segment of the curve," "underweight industrials," "buy current coupon mortgages," and so on. How can the strategic decision maker establish the magnitudes of exposures along all these dimensions? They need to consider the interaction among all the intended exposures and the resulting overall portfolio risk. But first and foremost, they estimate (explicitly or implicitly) the degree of confidence in each particular recommendation, which depends on the perceived skill of those who made that recommendation.

The manager's skill is a critical factor that largely determines portfolio performance. While this is obvious, oddly enough the notion of skill is rarely used formally when allocating portfolio risk or projecting expected outperformance. Even more surprisingly, skill rarely is measured in any disciplined way.

Several studies have examined the role of skill in the historical performance simulation of various investment strategies.[25] These skill-based historical simulations produced an interesting conclusion. The information ratios of very diverse strategies were very similar for a given skill level. Apparently, when performance is measured on a risk-adjusted basis, the particular nature of an investment strategy plays a minor role. Performance is essentially determined by the skill and dimensionality (the number of independent decisions) of the strategy.

These empirical results confirm the "Fundamental Law of Active Management" defined by Grinold and Kahn.[26] This law states that the information ratio of an investment strategy is determined by two factors: the "information coefficient" based on correlation between predictions and realizations (and closely related to the probability-based skill) and "breadth," or the number of independent decisions made by the strategy.

25. For example, see chapters 24 and 25 in *Quantitative Management of Bond Portfolios*.
26. Richard Grinold and Ronald N. Kahn, *Active Portfolio Management* (New York, McGraw-Hill, 1999).

Because the information ratio is outperformance (alpha) divided by risk (tracking-error volatility), the law can be expressed slightly differently by stating that a strategy's alpha is proportional to risk, skill, and the number of independent decisions.

This idea has fundamental implications for portfolio optimization. Asset managers traditionally have used the mean-variance approach to find the optimal asset allocation that maximizes expected outperformance, or alpha, for a given level of risk (or minimizes risk for a given alpha). The Achilles' heel of this approach is the expected returns of asset classes (or strategies) used in the optimization.

The Barclays proprietary risk-budgeting methodology—*ORBS* (Optimal Risk Budgeting with Skill)—relies on skill levels, breadth, and directional views to allocate the total risk budget among macro strategies to maximize portfolio alpha. Skill at timing a given strategy is defined as a percentage of directionally correct forecasts for this strategy minus the percentage of directionally wrong forecasts. The risk allocated to an individual strategy is then translated into the size of an active position that corresponds to that risk. At the core of this risk-budgeting methodology is a covariance matrix of returns for the asset classes underlying all considered strategies. This framework is very flexible and can be applied to essentially any set of asset classes and investment strategies with any number of different constraints.

Asset Allocation for Buy-and-Hold Investors

A corporate bond provides investors with a relatively small spread over Treasuries during its lifetime in compensation for the risk of a large, albeit unlikely, loss from default. While default risk is issuer-specific and can be reduced via diversification, correlation of defaults among issuers makes it impossible to eliminate it completely. This asymmetric risk/return profile of credit investing corresponds most closely with the considerations of a long-term investor who intends to hold bonds to maturity. In contrast, most total-return investors have a much shorter time frame and perceive a very different, less asymmetric risk/return profile. For a total-return investor, the dominant risks are spread volatility (essentially symmetric) and possible loss of liquidity. At least in investment-grade markets, credit-quality deterioration typically occurs gradually, so the primary risk for a total-return investor is not default but rather downgrade and the accompanying spread widening.

This difference in perspective has major implications for buy-and-hold investors. The spreads observed in the market result from interactions among all market participants, many of whom are total-return investors. If these investors expect high short-term spread volatility or liquidity risk, they can drive spreads much wider than would be justified by long-term default risk alone. This action can work to the benefit of long-term credit investors unaffected by short-term risks.

The asymmetric nature of the risk/return profile for long-term investors should be reflected in their asset allocation process. The most common approach to asset allocation, mean-variance optimization, generally is not suitable for buy-and-hold investors. In mean-variance optimization, risk is represented by the standard deviation of asset returns, which implies a symmetric distribution. For very asymmetric return profiles, standard deviation is not a particularly helpful measure of risk. In fact, no single measure of risk is universally appropriate for dealing with extreme, or "tail," events. The treatment of this "tail risk" must be customized to the needs and risk tolerance of each investor. One approach to asset allocation focuses on the downside risk, that is, the part of the return distribution that is below a certain minimum required return. This approach, though, requires a fuller description of the return distribution; the mean and standard deviation are not sufficient.

The central problem in the buy-and-hold asset allocation process is the fundamental trade-off between current credit spreads and expected horizon defaults. When is credit "cheap" from a buy-and-hold perspective? The answer depends on the level of default risk in the portfolio. To what extent can the default risk be reduced by issuer diversification, that is, how many issuers should a portfolio contain to limit default loss to a certain threshold with a given level of confidence? Or what allocation among different credit qualities will maximize spread within a given limit of the tail risk? Sophisticated quantitative models and techniques have been developed to address these matters.[27] There is an extensive body of research literature dealing with modeling default risk and particularly with default correlation.

SUMMARY: PORTFOLIO MANAGEMENT TOOL SET

The challenge for building a good quantitative portfolio-level system comes from the simultaneous need for broad asset class coverage and consistency of analytics across all asset classes. Specialized systems usually offer advanced analytics for specific asset classes. The objective for a portfolio system is to treat a wide range of asset classes within a single consistent framework without giving up too much accuracy.

At the foundation of a powerful analytical suite are basic security-level analytics, such as cash-flow projection, spread-to-price conversion, and duration calculation. The word *basic* belies the enormous complexity of this task. The variety of financial assets available to investors is ever-expanding and necessitates powerful underlying yield-curve, mortgage-prepayment, option-pricing, and volatility models that need to be maintained and updated.

Built on security pricing models is a broad set of portfolio-level analytics, that is, portfolio management tools that help managers analyze portfolio risk exposures, estimate the effect of various changes to portfolio structure, construct

27. See chapter 16 in *Quantitative Management of Bond Portfolios*.

optimal portfolios, and attribute achieved performance. An important part of this analytical suite is a multifactor risk model. When such a model is enhanced with optimization capabilities, it becomes a powerful tool for portfolio construction.

A useful complement for history-based risk modeling is flexible scenario analysis. An advanced scenario analysis engine is able to expand a few user-provided inputs into a complete set of maximum-likelihood scenarios for all relevant risk factors. A flexible performance attribution model is another essential component of the analytical suite. Various portfolio optimization tools, such as the risk-budgeting framework described earlier, complete the picture. Each of these building blocks requires sophisticated financial modeling and computer implementation effort. The added challenge is to ensure consistency among various tools. The conclusions a manager derives from the risk model should not contradict those from scenario analysis. The ex post return analysis should attribute the achieved outperformance to the risk exposures highlighted in the ex ante risk analysis.

KEY POINTS

- Portfolio management entails two essential functions: forming market views at a macro and/or security level and optimally implementing those views in the portfolio.
- Portfolio managers usually focus on the first task. Success in uncovering relative value by market timing, sector, or name selection requires experience and intuition and is usually equated with portfolio management talent.
- Constructing actual portfolios that reflect the desired views is just as vital for ultimate performance. It is this task that is greatly aided by quantitative methods and benefits from the methodologies, tools, and studies described in this chapter.
- Quantitative approaches can add value at each step of the portfolio management process: selection, customization, and replication of benchmarks; construction and optimization of benchmarked portfolios; risk analysis; performance attribution; and empirical support of investment decisions.

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CHAPTER
FORTY-SEVEN

FACTOR INVESTING IN FIXED INCOME SECURITIES

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Factor investing offers access to structural sources of long-term excess returns (i.e., the factor premiums) that are well-grounded in economic theory. Factor investing has been a well-embraced concept in equity markets for many years. More recently, it has been applied to fixed income markets, providing investors opportunities for attractive risk-adjusted returns. In this chapter, we explain the concept of factor investing and how it works in fixed income markets. We discuss academic evidence and empirical results on factors in government bonds and in investment-grade and high-yield corporate bonds. Factor investing in fixed income securities offers superior risk-adjusted returns., Fixed income portfolios with positive exposure to factors generate consistently higher returns than the index, without taking on additional risk. A multi-factor fixed income portfolio is an efficient way to earn market risk premiums for interest rate and credit risks, as well as to consistently add value from fixed income factor premiums.

FACTOR INVESTING

Investors are increasingly allocating to factors to build investment portfolios. A factor is a characteristic of a group of assets that systematically drives its returns and thereby accrues a premium in excess of the market return. Factor investing is the practice of allocating to factors as building blocks of portfolios with the goal to efficiently harvest these factor premiums. Factor investing differs from traditional investing in the sense that it follows a systematic, rules-based approach to select securities. A well-documented example is the value factor premium: securities that are attractively priced relative to their fundamental value, e.g., stocks exhibiting a low book-to-price ratio, tend to outperform in the long run. An equity portfolio consisting of stocks with a low book-to-price ratio should thus in the long run benefit from this exposure to the value factor and generate a higher return than a comparable portfolio consisting of stocks with a high book-to-price ratio.

Factor investing originates from a tremendous amount of academic research conducted since the 1960s in the field of asset pricing. Most notably was the development of the Capital Asset Pricing Model (CAPM). In the CAPM, there is a single structural return driver, the market factor, that compensates investors for exposure to nondiversifiable and systematic market risk. Since the 1970s, the investment industry started to incorporate these findings by offering easy, transparent, and often lower-cost exposures to the main market factors via the launch of equity and bond index funds. Nowadays, by far most investors allocate to these market factors in their portfolios. Research on the CAPM was followed by the development of another major asset pricing theory that allows for multiple factors driving returns, Stephen Ross's Arbitrage Pricing Theory (APT). Since the start of the 1970s, academics have put forward convincing evidence for the existence of such additional factors that provide a return over and above the market factor. Well-known examples are the value factor,[1] the momentum factor,[2] and the low-risk factor,[3]

Since the 2010s, factor investing has taken an enormous growth in equity markets. An important trigger was the (nowadays dubbed) "professors' report" of three renowned professors: Andrew Ang, William Goetzmann, and Stephen Schaefer. These professors were commissioned by the Norwegian Government Pension Fund, one of world's largest investment funds, to investigate its performance after large losses in the 2008 financial crisis. They critically evaluated the active performance of the fund and found that 97% of the fund's return could be explained by movements in the benchmark and that approximately 70% of the remaining active performance could be explained by exposures to various systematic factors. Their analysis further highlighted that these factor exposures were actually a by-product of bottom-up active manager selection by the fund.

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1. See, for example, S. Basu, "Investment Performance of Common Stocks in Relation to Their Price-Earnings Ratios: A Test of the Efficient Market Hypothesis," *Journal of Finance* 32, 1977, pp. 663–682, and Eugene F. Fama and Kenneth R. French, "The Cross-Section of Expected Stock Returns," *Journal of Financial Economics* 33, 1992, pp. 3–56.
2. Narasimhan Jegadeesh and Sheridan Titman, "Returns to Buying Winners and Selling Losers," *Journal of Finance* 48, 1993, pp. 65–91.
3. Robert A. Haugen, and A. James Heins, "On the Evidence Supporting the Existence of Risk Premiums in the Capital Market," Working Paper, http://ssrn.com/abstract=1783797.

This all triggered the professors to advise the Norwegian Fund to incorporate an explicit top-down exposure to proven factors to maximize returns. We believe this recommendation is applicable to a very broad investor base.

In the ensuing years, factor investing has rapidly gained popularity among investors around the world. Asset managers and index providers have also dived in and increased the breadth of their offering in this field. Estimates of the amount of money invested in factor strategies vary from one source to another, ranging from USD 1 to 2 trillion globally in most cases. In a report published in 2017, Morgan Stanley estimated that almost USD 1.5 trillion was invested in smart beta, quant, and factor-based strategies and that assets under management have been growing by 17% per year on average since 2010.[4] According to a survey by FTSE Russell, already 58% of asset owners worldwide have implemented smart beta—in other words, factor-based strategies—in their portfolios in 2019.[5] This growth has not only taken place in equity markets, but also in multi-asset and fixed income portfolios.

There are several reasons for the popularity of factor investing, as it brings several benefits to investors. First, factor portfolios deliver higher Sharpe ratios than the market over the long term, as we also will show in this chapter for fixed income markets. Second, factors provide a diversifying source of returns, both over market exposure and discretionary sources of alpha. In fact, as shown by Ang, Goetzmann, and Schaefer[6] and by Van Gelderen and Huij,[7] factors are responsible for a part of the alpha of successful managers. Third, factor investing has a strong rules-based foundation and therefore has the potential to make the investment process more transparent and is often accompanied by lower costs than traditional active management. These reasons are also highlighted by asset owners in the annual industry survey by FTSE Russell, with the top four reasons to engage in factor investing being "return enhancement," "risk reduction," "improve diversification," and "cost savings."

In fact, factor investing is seen by many investors as a third way of investing, as summarized in the Exhibit 47-1: it has features in common with passive investing, such as its transparent and systematic, rules-based nature and lower costs, but also with active investing, as its positioning deviates from the market, aims to add additional performance, and has the ability to integrate other goals, such as Environmental, Social, and Governance (ESG) considerations.

4. "Quant Investing – Bridging the Divide," Morgan Stanley Research, October 2017.

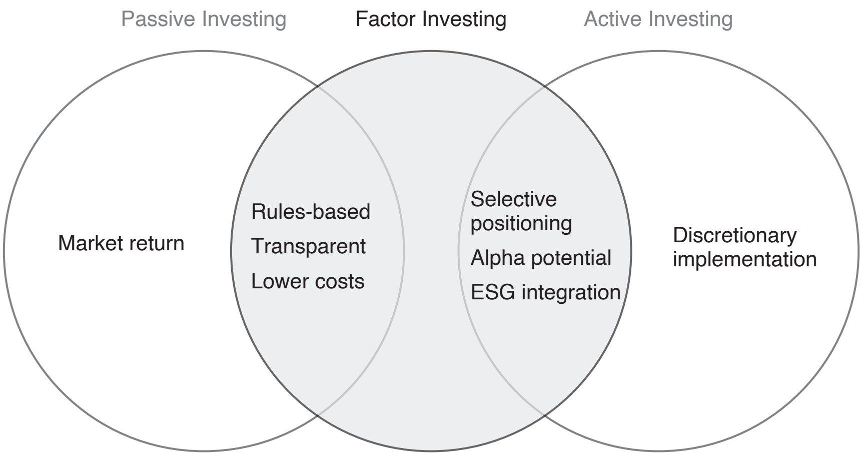
5. "Smart Beta: 2019 Global Survey Findings From Asset Owners," FTSE Russell, 2019.

6. Andrew Ang, William N. Goetzmann, and Stephen M. Schaefer, "Evaluation of Active Management of the Norwegian Government Pension Fund – Global," Columbia Business School report, 2009.

7. Eduard van Gelderen and Joop Huij, "Academic Knowledge Dissemination in the Mutual Fund Industry: Can Mutual Funds Successfully Adopt Factor Investing Strategies?" *Journal of Portfolio Management*, 2014, pp. 157–167.

EXHIBIT 47-1

Factor Investing as a Third Way of Investing Between Passive and Active Investing



Although most research on factor investing focuses on the equity market, the concepts and benefits of factor investing apply equally well to other markets, including fixed income markets, as we will describe in this chapter.

WHICH FACTORS?

A key question to answer in factor investing is which factors should an investor focus on? This is especially relevant as academics have documented a "zoo of factors" (for example, in equity markets alone over 300 factors have been documented), and many only seem to work over short periods of time or in a limited number of segments of the market. In other words, many documented factors are not well-exploitable factors for investors. Further, researchers are subject to data-mining biases (often unintentionally and unconsciously), implying that the findings of many documented studies will fail to hold out-of-sample. For example, a study by Harvey, Liu, and Zhu[8] analyzed over 300 stock factors and found that most of these factors are likely to be "false positives." Another study, by Hou, Xue, and Zhang,[9] also found that most stock anomalies reported in the academic literature failed to hold up when thoroughly tested.

8. Campbell R. Harvey, Yan Liu, and Caroline Zhu, ". . . and the Cross-Section of Expected Returns," *Review of Financial Studies* 29, 2016, pp. 5–68.
9. Kewei Hou, Chen Xue, and Lu Zhang, "Replicating Anomalies," *Review of Financial Studies* 33, 2020, pp. 2019–2133.

So how exactly should we choose which factors to invest in? To be relevant for investors we believe a factor should meet five strict criteria:

1. *Performing*: A factor should produce better risk-adjusted returns than the broad market over the long term.
2. *Proven*: A factor should be able to overcome attempts (within academia and in-house research) to discredit its validity.
3. *Persistent*: A factor should be observable in different markets, stable over time, and robust to different definitions.
4. *Explainable*: A factor should have a plausible economic rationale for its existence, with strong academic underpinnings.
5. *Executable*: A factor should be implementable in practice and outperform after trading costs and other market frictions.

In other words, factors should be well-grounded in economic theory and have earned sizable net premiums over the long run that are robustly observed. In this chapter, we focus on four universal, common factors that pass these criteria: value, momentum, low risk, and size, where the latter applies specifically to corporate bonds.

- *Value* is the tendency of cheap securities, relative to their fundamentals, to outperform over the longer term, and for expensive securities to underperform.
- *Momentum* is the tendency of securities that have performed well in the recent past to continue to perform well, and for securities that have performed poorly to continue to perform poorly.
- *Low risk* refers to the observation that low-risk securities tend to earn higher risk-adjusted returns than high-risk securities.
- *Size* is the tendency of bonds issued by companies with little debt outstanding to outperform the market.

FACTORS PREMIUMS IN GOVERNMENT BONDS

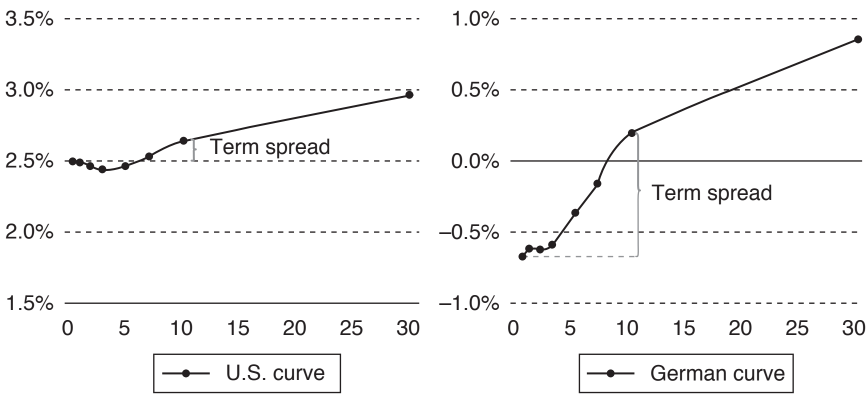
Having explained the concept of factor investing and the factor selection, we next turn to the theoretical and empirical grounds of factor premiums in global government bond markets. We examine three factors for developed market government bonds: value, momentum, and low risk.

Value

Value investing entails buying cheap assets and avoiding expensive ones. This requires a measure of relative valuation. In the case of stock selection, the price of a stock can be compared to its book value to measure whether the stock is over- or undervalued. For government bonds, however, there is no direct equivalent to the book value. A widely used value measure for government bonds in the academic literature is the term spread: the difference between the bond yield and the cash rate. In the example shown in Exhibit 47-2, the U.S. 10-year yield of 2.65% is just 0.15% above the dollar cash rate of 2.5%, while the German 10-year yield of 0.2% is 0.85% above the euro cash rate of –0.65%. Put differently: a German bond pays its owner a premium of 0.85% per year to hold a 10-year bond rather than cash, while a U.S. bond offers its buyer only 0.15% more than cash. The term spread is thus higher for German bonds than for U.S. bonds, even though the U.S. bond yield is higher than the German yield.

EXHIBIT 47-2

U.S. and German Yield Curve, Example for January 2019



Source: Robeco, Bloomberg.

The term spread is directly related to the yield available to an international bond investor who hedges currency risk. When hedging a foreign currency, one pays the foreign short-term rate and receives the local cash rate instead. The yield on a foreign bond investment, taking into account the FX hedging costs, is thus equal to the foreign bond yield minus the foreign cash rate, plus the local cash rate. In the example above, a U.S. investor who buys the German bond and hedges the currency risk faces negative hedging costs of –0.65% – 2.5% = –3.15%. The yield of the German bond hedged to U.S. dollar is thus 0.20% – (–3.15%) = 3.35%. This is indeed 0.85% higher than the U.S. cash rate, with 0.85% being the German term spread. The term spread can thus be used to compare the valuation of bonds from different countries on an FX-hedged basis.

The academic foundation for the term spread as a value measure is phrased in terms of forward rates. The term spread is large when yields on long-term bonds are higher than those on short-term bonds, so when future yield rises are already discounted in the current bond prices. In this case, the forward rate is higher than the current yield.

Fama already showed in 1984 that forward rates can be used to forecast bond returns: bonds for which large yield rises are discounted generally outperform bonds for which smaller yield rises are discounted.[10] This result thus underpins value investing in government bonds using the term spread as value measure.

Momentum

The momentum effect is that past winners tend to be future winners and, similarly, that past losers tend to be future losers. The momentum factor for equities thus selects stocks that have performed better than their peers, as this outperformance is likely to continue. For government bonds, this effect also exists and has been demonstrated in academic papers[11] comparing bonds from different countries. The momentum factor thus compares U.S. government bonds to, for example, Australian and Japanese government bonds, based on their recent performance. This performance is measured in terms of the excess return of the country's bonds over cash. This boils down to comparing international bonds based on currency-hedged returns, and thus purely based on the performance of the local bond market and independent of the movements in the currency. The momentum factor favors government bond markets that are performing well over markets that lagged recently.

Low Risk

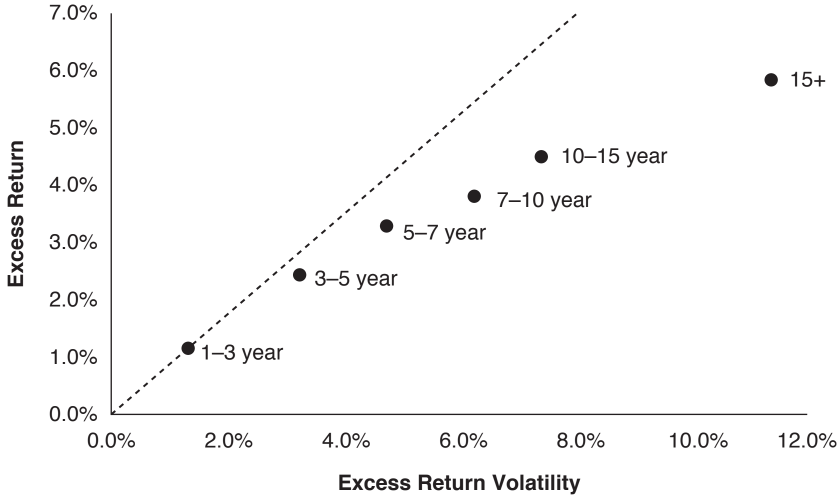
The low-risk effect is that low risk securities within an asset class outperform the higher risk securities in the same asset class. The academic literature on equities provides extensive explanations for the low-risk effect, most notably leverage constraints of investors and behavioral biases.[12] These explanations are not specific for equities and apply to other asset classes as well, including government and corporate bonds. The first paper to document the low-risk effect in government bonds is Haugen and Heins.[13] They show that U.S. Treasury bonds with lower risk generate higher risk-adjusted returns. Their findings go against the basic CAPM notion that portfolios with higher risk should deliver higher returns. Surprisingly, the 1975 published article resulting from this working paper omitted

10. Eugene F. Fama, "The Information in the Term Structure," *Journal of Financial Economics* 13, 1984, pp. 509–528.
11. See, for example, Cliff S. Asness, Tobias J. Moskowitz, and Lasse Heje Pedersen, "Value and Momentum Everywhere," *Journal of Finance* 68, 2013, pp. 929–985.
12. See, for example, David Blitz, Eric Falkenstein, and Pim van Vliet, "Explanations for the Volatility Effect: An Overview Based on the CAPM Assumptions," *Journal of Portfolio Management*, 2014, pp. 61–76.
13. Robert A. Haugen and A. James Heins, "On the Evidence Supporting the Existence of Risk Premiums in the Capital Market," Working Paper, http://ssrn.com/abstract=1783797, 1972.

the results for bonds entirely.[14] The low-risk effect was therefore only formally documented in 2006 for U.S. Treasuries, and in subsequent studies for international bonds.[15] Maturity is typically used as risk measure in these studies given that interest rate sensitivity rises with maturity. The low-risk effect in government bonds thus means that shorter-dated bonds generate higher Sharpe ratios than longer-dated bonds. This can be seen in Exhibit 47-3 for U.S. Treasuries: longer-dated bonds have generated higher returns, but not sufficiently so to compensate for their higher risk.

EXHIBIT 47-3

Average Excess Return and Volatility for U.S. Government Bonds of Various Maturities, 1999–2019



Source: Robeco, J.P. Morgan.

Factor Portfolios in Government Bonds Show Superior Risk-Adjusted Returns

We next examine the performance of portfolios of government bonds selected based on the value, momentum, and low-risk factors. To evaluate the aforementioned factors, we use monthly data from 1994 to 2019 for the constituents of

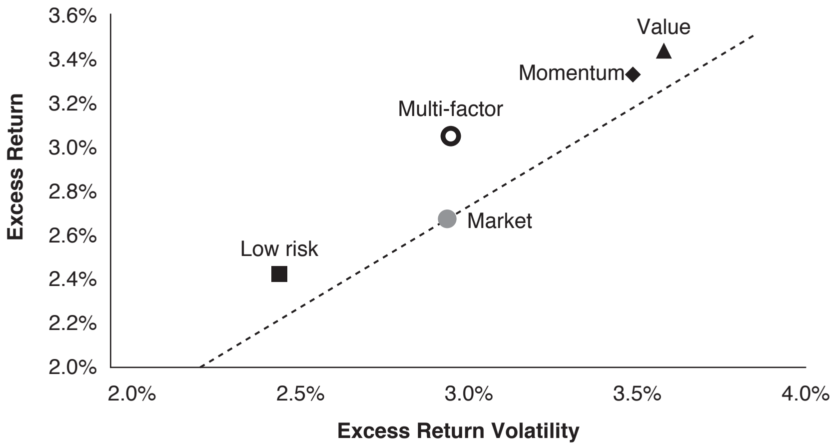
14. Robert A. Haugen, and A. James Heins, "Risk and the Rate of Return on Financial Assets: Some Old Wine in New Bottles," *Journal of Financial and Quantitative Analysis*, 1975, pp. 775–784.

15. Eugene A. Pilotte and Camden Frederic P. Sterbenz, "Sharpe and Treynor Ratios on Treasury Bonds," *Journal of Business* 79, 2006, pp. 149–180, and Andrea Frazzini and Lasse Heje Pedersen, "Betting Against Beta," *Journal of Financial Economics* 111, 2013, pp. 1–25.

the J.P. Morgan global government bond Index: Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, the United Kingdom, and the United States. We use the following maturity buckets: 1–5 years, 5–10 years, and 10+ years. The low-risk factor is constructed by being the 1–5Y maturity bucket of each country. Following Exhibit 47-3, it therefore has a lower return and a lower volatility than the market (which invests in all maturities), but a better Sharpe ratio. The value portfolio each month buys the four countries with the highest term spread. The momentum portfolio each month buys the four countries with the highest past 12-month returns.

EXHIBIT 47-4

Excess Return vs. Excess Return Volatility for Factor-Sorted Portfolios, Global Government Bonds, 1994–2019

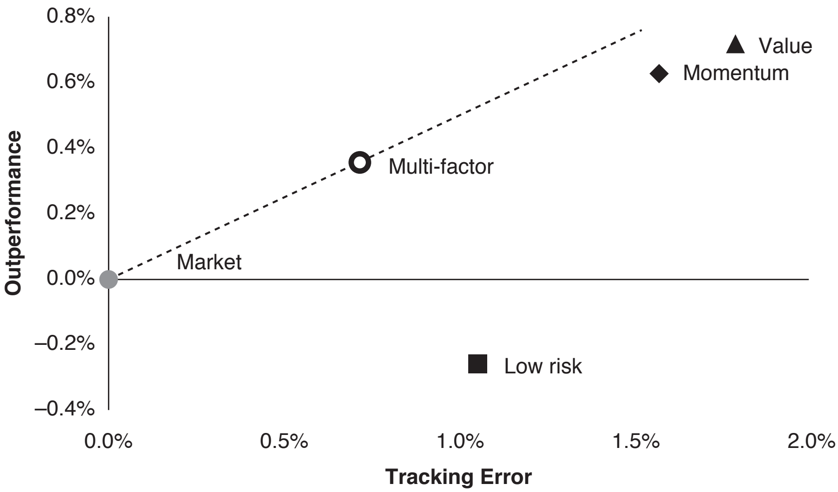


Source: Robeco, J.P. Morgan.

Exhibit 47-4 plots the results. Shown are the excess return and its volatility of the factor portfolios and of the global government bond market. The dotted line in the exhibit illustrates all risk/return combinations with the same Sharpe ratio as the market. The Sharpe ratio of the market is 0.87 (as we have seen a secular decline in yields over our sample). All three factor portfolios are located above the dotted line (i.e., they achieve higher risk-adjusted returns than the market portfolio). Note that the excess return is somewhat lower for the low-risk portfolio than for the market, but this is more than compensated for by its lower volatility. The value and momentum portfolios have a higher volatility, but this is more than offset by a higher return. Hence, each of the factor portfolios offers a higher Sharpe ratio than the government bond market portfolio, with 0.95 for low risk, and 0.91 for both momentum and value. To examine the added value of a combined, multi-factor portfolio we also combine the above three factors in an equally weighted factor portfolio. This portfolio has a similar risk level as the market and higher returns, with a Sharpe ratio of 0.99 which is significantly higher than the 0.87 Sharpe ratio for the market.[16]

EXHIBIT 47-5

Outperformance vs. Tracking Error for Factor-Sorted Portfolios, Global Government Bonds, 1994–2019



Source: Robeco, J.P. Morgan.

Exhibit 47-5 shows the same portfolios, evaluated relative to the market, so plotting tracking error versus outperformance. That means the market automatically has zero outperformance and zero tracking error (versus itself). The dotted line represents the portfolios with the highest information ratio (i.e., outperformance/tracking error) over the market. From a relative perspective, the low-risk factor portfolio on average underperforms the market. However, please note that this is expected, as it also runs at a lower absolute level of risk. When correcting for the lower bond market risk, the low-risk factor offers a positive alpha over the market portfolio, in line with the superior Sharpe ratio of the low-risk factor. Momentum and value offer outperformance over the market. Similarly, the multi-factor portfolio, by construction, has the average outperformance of

16. Here and later we use the Jobson-Korkie test (J. D. Jobson, and Bob M. Korkie, "Performance Hypothesis Testing with the Sharpe and Treynor Measures," *Journal of Finance* 36, 1981, pp. 889–908) for Sharpe ratios, corrected by Memmel (Christoph Memmel, "Performance Hypothesis Testing with the Sharpe Ratio," *Finance Letters* 1, 2003, pp. 21–23).

the three individual factors and hence also outperforms the market. Due to the diversification benefits between the factors, the tracking error of the multi-factor portfolio is lowest (the correlations between factors vary between –0.28 to 0.01). Consequently, it offers the highest information ratio, as represented by the dotted line.

FACTOR PREMIUMS IN CORPORATE BONDS

Next, we turn to the theoretical and empirical grounds of factor premiums in global corporate bond markets, both in the investment-grade (IG) and high-yield (HY) segments. In contrast to the academic literature on equity markets, where factors have been extensively documented since the 1970s, the evidence for corporate bond markets is more recent and more limited.[17] Below we show evidence for four factors: value, momentum, and low risk, just like for government bonds, as well as a corporate bond-specific size factor. Other factors have been investigated too in the academic literature. For example, Kyosev, Hanauer, Huij, and Lansdorp[18] document a quality factor for corporate bonds. We do not include the quality factor here because we focus on factors that can be calculated with bond market information, while the quality factor requires accounting data of the firm. Other studies have investigated a carry factor but found that it does not offer a significant premium over the market;[19] therefore, we do not include the carry factor here. In what follows we use the factor definitions of Houweling and Van Zundert,[20] who examine thoroughly the presence of factors in developed corporate bond markets. Other studies on developed markets include Israel, Palhares, and Richardson[21] and Bektic,Wenzler, Wegener, Schiereck, and Spielmann.[22] For evidence of factor premiums in emerging market corporate bond markets we refer to Dekker, Houweling, and Muskens.[23]

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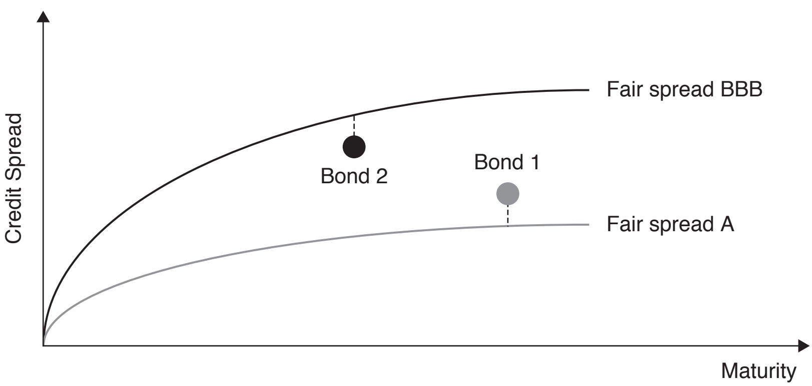
17. For an early treatment, see Jouke Hottinga, Erik van Leeuwen, and Judith van IJserloo, "Successful Factors to Select Outperforming Corporate Bonds," *Journal of Portfolio Management*, 2001, pp. 88–101.
18. See Georgi Kyosev, Matthias X Hanauer, Joop Huij, and Simon Lansdorp, "Does Earnings Growth Drive the Quality Premium?" *Journal of Banking & Finance* 114, 2020, forthcoming.
19. See, for example, Ronen Israel, Diogo Palhares, and Scott Richardson, "Common Factors in Corporate Bond Returns," *Journal of Investment Management* 16(2), 2018, pp. 17–46.
20. Patrick Houweling and Jeroen Van Zundert, "Factor Investing in the Corporate Bond Market," *Financial Analysts Journal*, 2017, pp. 100–115.
21. Ronen Israel, Diogo Palhares, and Scott Richardson, "Common Factors in Corporate Bond Returns," *Journal of Investment Management* 16(2), 2018, pp. 17–46.
22. Demir Bektic, Josef-Stefan Wenzler, Michael Wegener, Dirk Schiereck, and Timo Spielmann, "Extending Fama-French Factors to Corporate Bond Markets," *Journal of Portfolio Management* 2019, pp. 141–158.
23. Lennart Dekker, Patrick Houweling, and Frederik Muskens, "Factor Investing in Emerging Market Credits," Working Paper, http://ssrn.com/abstract=3457127, 2019.

Value

Value investing entails buying cheap assets and avoiding expensive ones. L'Hoir and Boulhabel[24] and Correia, Richardson, and Tuna[25] are early studies on value investing in the corporate bond market. They show that bonds that are undervalued versus their "fair" value subsequently outperform the market, and bonds that are overvalued, underperform. They estimate the fair credit spread using a variety of risk measures. Exhibit 47-6 illustrates the value concept for corporate bonds, using rating and maturity as risk measures, by plotting the fair value credit spread curves for rating categories A and BBB. Bond 1 is an A-rated bond that is above the curve of A-rated bonds, and is therefore a cheap bond; bond 2, on the other hand, is an expensive BBB-rated bond versus its peers. Following Houweling and Van Zundert,[26] we choose rating, maturity and the three-month change in the credit spread as risk measures in a cross-sectional regression on credit spreads. The value factor portfolio consists of the 10% most undervalued bonds (i.e., bonds whose market spread is high compared with the fair value spread of other bonds with similar risk).

EXHIBIT 47-6

Example of the Value Factor in Corporate Bonds



Source: Robeco.

24. See Mathieu L'Hoir and Mustafa Boulhabel, "A Bond-Picking Model for Corporate Bond Allocation," *Journal of Portfolio Management*, 2010, pp. 131–139.
25. See Maria Correia, Scott Richardson, and Irem Tuna, "Value Investing in Credit Markets," *Review of Accounting Studies*, 2012, 17, pp. 572–609.
26. Patrick Houweling and Jeroen Van Zundert, "Factor Investing in the Corporate Bond Market," *Financial Analysts Journal*, 2017, pp. 100–115.

Momentum

The momentum effect is that past winners tend to be future winners and, similarly, that past losers tend to be future losers. Previous research shows that this effect is strong in the high-yield market, but weaker in investment grade. Just like for government bonds, we sort corporate bonds on past returns to construct the momentum factor. Specifically, we follow Jostova, Nikolova, Philipov, and Stahel[27] by defining momentum as the past six-month credit return. The 10% bonds with the highest past returns are selected for the momentum factor portfolio.

Low Risk

The low-risk effect is that low-risk securities within an asset class outperform the higher-risk securities in the same asset class. Previous studies show that corporate bonds with lower risk generate higher risk-adjusted returns, where maturity and/or rating are typically used as risk measures.[28] So, portfolios of shorter-dated and higher-rated bonds historically had higher Sharpe ratios than the market. This is demonstrated in Exhibit 47-7, which shows credit return and credit volatility of corporate bond portfolios created within the U.S. Investment Grade market by first assigning bonds to maturity terciles (each containing one-third of the index constituents) and then to rating groups within those terciles. Clearly, shorter-dated bonds had lower volatilities than longer-dated bonds, as expected given their lower duration, but they did not have lower returns, thus generating higher Sharpe ratios. Within the rating dimension, lower-rated bonds did have higher returns, but not sufficiently so to compensate for their higher volatility. Within each maturity segment, bonds with lower ratings thus had lower Sharpe ratios than bonds with higher ratings.

To construct our low-risk factor portfolio for investment grade, we first select all bonds rated AAA to A– and so exclude the riskiest bonds rated BBB+, BBB, or BBB–. Each month we then select those with the shortest maturity, so the portfolio is made up of 10% of the total number of bonds. For high yield, we follow the same procedure, selecting bonds rated BB+ to B– and excluding the riskiest ratings CCC, CC, and C.

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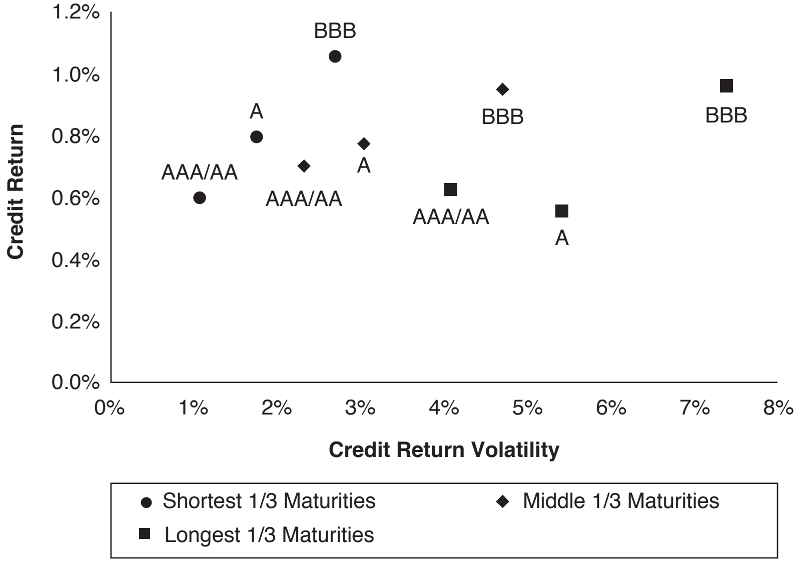
27. See Gergana Jostova, Stanislava Nikolova, Alexander Philipov, and Christof W. Stahel, "Momentum in Corporate Bond Returns," *Review of Financial Studies* 26(7), 2013, pp.1649–1693.

28. See for example Antti Ilmanen, Rory Byrne, Heinz Gunasekera, and Robert Minikin, "Which Risks Have Been Best Rewarded?" *Journal of Portfolio Management*, 2004, pp. 53–57.

EXHIBIT 47-7

Credit Return vs. Credit Return Volatility for Maturity X Rating Double-Sorted Portfolios, USD Investment-Grade Corporate Bonds, 1994–2019



Source: Robeco, Bloomberg Barclays.

Size

The size effect is the tendency of bonds issued by companies with little debt outstanding to outperform the market. Smaller companies tend to be under-researched because investors typically aim to efficiently cover a large percentage of the market capitalization using a limited number of analysts. From that perspective, it is more efficient to cover companies with a larger weight in the index than those with a smaller index weight. Therefore, to define the size factor in the corporate bond market, we use the total size of a company's public debt rather than the size of an individual bond. In addition to an "under-researched" or information compensation, the size factor also captures an illiquidity compensation, as smaller companies tend to issue smaller bonds and smaller bonds tend to be less liquid than larger ones. Every month the size factor portfolio invests in 10% of the bonds belonging to the smallest companies in the index.

Factor Portfolios in Corporate Bonds Show Superior Risk-Adjusted Returns

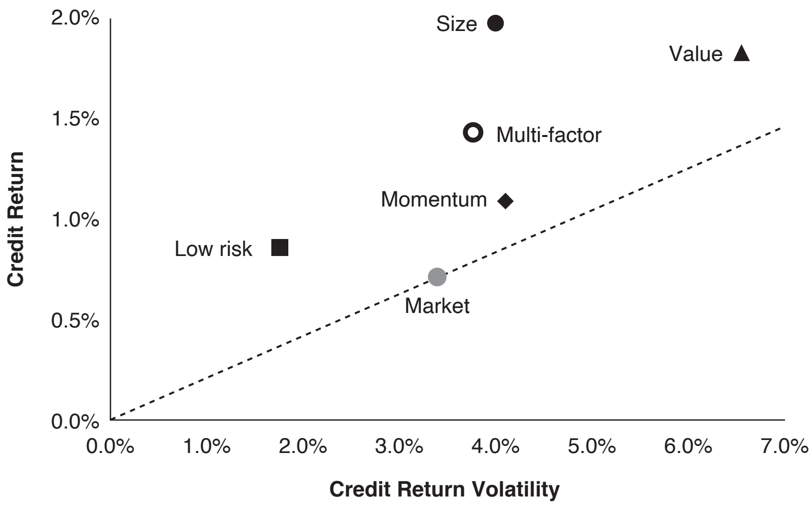
To evaluate the factors, we use 26 years of monthly data from January 1994 to December 2019 on all constituents of the Barclays U.S. Aggregate Corporates index, U.S. High Yield Corporates index, Euro Aggregate Corporates index, and

Euro High Yield Corporates index, hence covering a global sample of corporate bonds. Every month, we create equally weighted portfolios based on the factor definitions described above. In addition to the single-factor portfolios, we also construct a multi-factor portfolio that invests equal proportions in each of the single-factor portfolios. We analyze the credit return of each bond (i.e., its excess return over duration-matched Treasuries) to properly filter out the interest rate component (i.e., the term premium). We have two reasons for doing this, namely, (1) most institutional investors manage the interest rate exposure of their total portfolio separately, for example, using interest rate swaps or bond futures, and (2) investors buy corporate bonds primarily to harvest the default premium rather than the term premium because the latter can be more efficiently harvested by investing in government bonds.

Exhibit 47-8 plots the credit volatility and credit return of each factor portfolio in the investment-grade market. We note that each factor has a distinctive risk/return profile. The low-risk portfolio has a somewhat higher return than the market, but a much lower volatility. Value, on the contrary, has a higher volatility, but this is more than compensated for with a higher return. Momentum and size have a volatility similar to that of the market, but with higher returns. The Sharpe ratios of the size portfolio (0.49) and the low-risk (0.49) are significantly higher than the market Sharpe ratio of 0.21, while the Sharpe ratios of value (0.28) and momentum (0.27) are closer to that of the market, yet still higher. The multi-factor portfolio is in between (Sharpe ratio of 0.38, which is significantly above the market), with a volatility that is similar to the market and return that is 0.70% higher.

EXHIBIT 47-8

Credit Return vs. Credit Return Volatility for Factor-Sorted Portfolios, Global Investment-Grade Corporate Bonds, 1994–2019

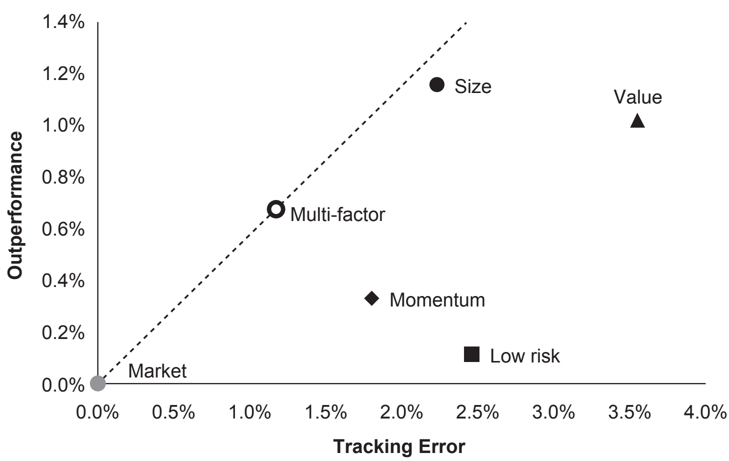


Source: Robeco, Bloomberg Barclays.

Exhibit 47-9 shows the same portfolios, evaluated relative to the market, so plotting tracking error versus outperformance. The results show that from this perspective the individual factors are less attractive. Low risk and value have particularly large tracking errors due to their large beta deviations. For value, a substantial outperformance of 1.1% a year compensates for this, but low risk only offers a modest outperformance of 0.1%, resulting in an information ratio of around 0. However, it has among the highest Sharpe ratios. This highlights the importance of a long investment horizon because the single factor-portfolios can be risky in the short term for benchmarked investors. The multi-factor portfolio, on the other hand, combines its high Sharpe ratio of 0.38 with an attractive information ratio of 0.62. The reason is that it diversifies across the individual factors, mitigating the possible underperformance of one or more factors for prolonged periods of time. This leads to a lower tracking error than that of the individual factors, while maintaining the outperformance.

EXHIBIT 47-9

Outperformance vs. Tracking Error for Factor-Sorted Portfolios, Global Investment-Grade Corporate Bonds, 1994–2019

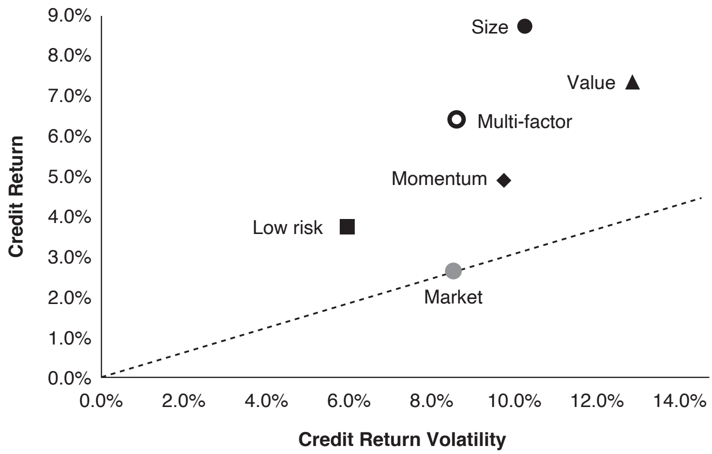


Source: Robeco, Bloomberg Barclays.

Exhibits 47-10 shows the risk and return of the high-yield factor portfolios. The results are similar to those for investment grade. Low risk has a much lower volatility than the market and value a higher volatility. The Sharpe ratios of the four factors range from 0.47 (momentum) to 0.71 (size) and are all significantly larger than the market Sharpe ratio of 0.30. The multi-factor portfolio's volatility is again similar to the market's, but its Sharpe ratio is twice as high (0.61 versus 0.30) due to its higher return. Exhibit 47-11 shows the high-yield factor portfolios in a relative risk framework. As in investment grade, low risk has the lowest information ratio, only 0.26. The other factors have information ratios ranging from 0.47 (momentum) to 0.74 (size). Again, combining the four factors in a multi-factor portfolio leads to the highest information ratio, 0.83.

EXHIBIT 47-10

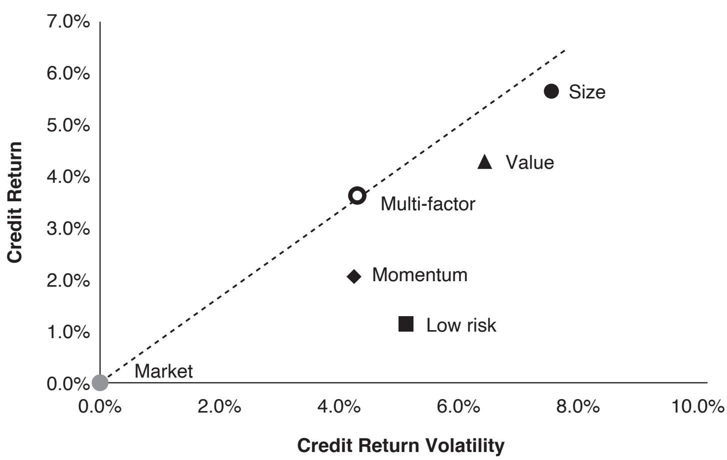
Credit Return vs. Credit Return Volatility for Factor-Sorted Portfolios, Global High-Yield Corporate Bonds, 1994–2019



Source: Robeco, Bloomberg Barclays.

EXHIBIT 47-11

Outperformance vs. Tracking Error for Factor-Sorted Portfolios, Global Investment High-Yield Bonds, 1994–2019



Source: Robeco, Bloomberg Barclays.

FIXED INCOME FACTORS IN MULTI-ASSET PORTFOLIOS

Having established the evidence on factor premiums within the government bond segment and the investment-grade and high-yield corporate bond segments, we next examine factor portfolios that bring together these segments across the overall global bond market. In addition, as investors usually invest not only in fixed income but also in other asset classes, most importantly equities, we also examine the added value of factor investing in fixed income securities in a multi-asset portfolio context.

To this end, we first construct equity factor portfolios. We obtain monthly returns for the value (i.e., book-to-market ratio) and momentum (i.e., past 12-month returns skipping the last month) factors for the global stock universe over the period January 1985 until December 2019.[29] We augment these factors with a low-risk factor portfolio (i.e., past 36-month stock volatility) based on Hanauer and Windmueller.[30] For all three equity factors, we follow the Fama-French methodology of averaging the small cap and large cap top factor portfolios. Therefore, we tilt factor portfolios to smaller caps, as for corporate bonds. Blitz, Baltussen, and Van Vliet,[31] among others, show that equity factor premiums tend to be stronger in smaller caps, and hence having exposure to smaller caps leads to more efficient factor portfolios.

For government bonds and corporate bonds, we use the same data as in the previous sections, and use returns in excess of the one-month T-bill rate for all assets. Note that this implies that for corporate bonds, we add back the interest rate return component to the corporate bond indices and factor portfolios to compare the asset classes on an equal footing (in previous sections we analyzed the excess returns over duration-matched government bonds).

First, we show the Sharpe ratios of all asset classes and the associated multi-factor portfolios in Exhibit 47-12. In every asset class, factor portfolios offer superior risk-adjusted returns versus passively investing in the market index. We also show an overall fixed income portfolio, constructed by equally weighting the government bond, investment-grade, and high-yield corporate bond portfolios (labelled "Bonds" in Exhibit 47-12). Historically, the Sharpe ratio increases from 0.85 to 1.12 when investing in the global multi-factor fixed income portfolio instead of in the market. In other words, factor investing in fixed income securities offers superior risk-adjusted returns.

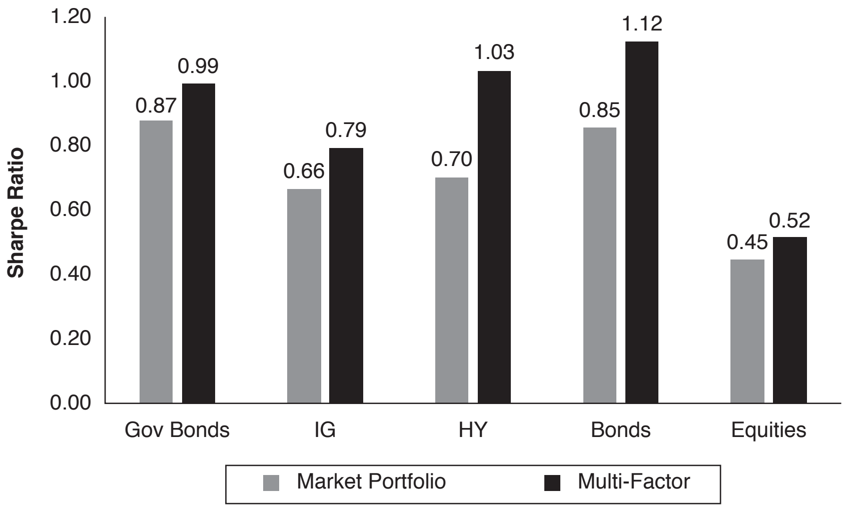
29. The returns are obtained from the online data library of Professor Kenneth French (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html). We also obtain the equity market portfolio from this source.

30. Matthias X. Hanauer and Steffen Windmueller, "Enhanced Momentum Strategies," Working Paper, http://ssrn.com/abstract=3437919, 2019.

31. David Blitz, Guido Baltussen, and Pim van Vliet, "When Equity Factors Drop Their Shorts," *Financial Analyst Journal*, 2020, pp. 73–99..

EXHIBIT 47-12

Sharpe Ratios Market and Factor Portfolios over the Risk-Free Rate for Government Bonds, Investment Grade (IG), High Yield (HY), Fixed Income in general (Bonds), and Equities



Source: Robeco, Bloomberg Barclays, Data Library Kenneth French. Period: 1994-2019.

Next, we analyze the correlation between the outperformances of the multi-factor portfolios across the various asset classes, as shown in Exhibit 47-13. Outperformance is computed versus the respective market index for each asset class. Overall, correlations are low, which suggests that harvesting factor premiums in multiple asset classes is beneficial. The highest correlation is observed between the investment-grade and high-yield multi-factor corporate bond portfolios, which makes sense given that these segments both consist of corporate bonds.

EXHIBIT 47-13

Correlation Matrix of Outperformances of Global Government Bond ("Govt"), Global Investment-Grade Corporate Bond ("IG"), Global High-Yield Corporate Bonds ("HY"), and Global Equity ("Eq") Multi-factor Portfolios over Their Respective Market Portfolio, 1994–2019

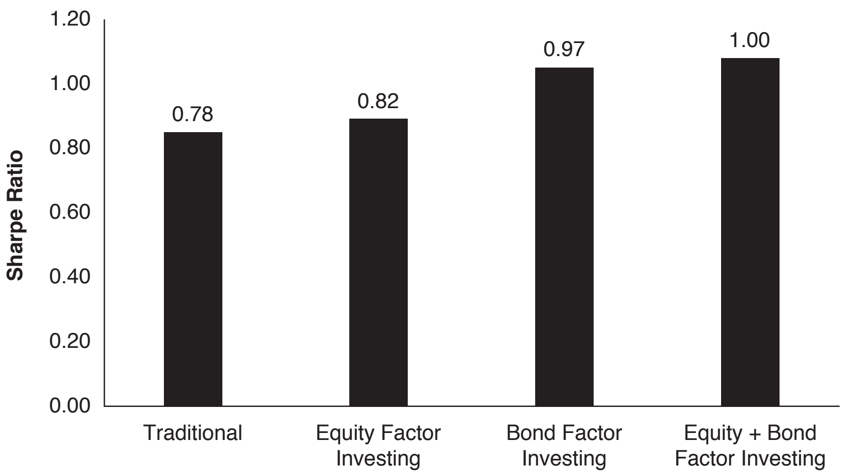
	Govt	IG	HY	Eq
Govt		–0.01	0.01	0.09
IG			0.55	0.12
HY				0.12

Source: Robeco, Bloomberg Barclays, Data Library Kenneth French. Period: 1994–2019.

An investor might already be allocating his equity portfolio to factors and wondering about the added value of factor investing in his fixed income portfolio. To answer this question, we analyze a simple multi-asset portfolio containing 25% allocations to equities, government bonds, investment-grade corporate bonds, and high-yield corporate bonds. First, we evaluate a traditional portfolio, in which all asset class allocations are invested in market index portfolios. Next, we test three alternative allocations, where we (1) allocate only the equity portfolio to a multi-factor equity portfolio, (2) allocate only the bond portfolios to the multi-factor portfolios, and (3) allocate both the equity and bond portfolios to the multi-factor portfolios. The results are shown in Exhibit 47-14.

EXHIBIT 47-14

Sharpe Ratios Multi-Asset Portfolios over the Risk-Free Rate



Source: Robeco, Bloomberg Barclays, Data Library Kenneth French. Period: 1994-2019.

Factor investing also offers superior risk-adjusted returns in a multi-asset context. When only applying equity factor investing, the Sharpe ratio of a passive traditional multi-asset portfolio improves from 0.78 to 0.82, an improvement of 5%. With bond factor investing (but no equity factor investing), the Sharpe ratio improves from 0.78 to 0.97, an improvement of 24%. When applying multi-asset factor investing (so both in equities and bonds), the Sharpe ratio is highest at 1.00, a 27% improvement over the passive multi-asset portfolio.

KEY POINTS

- Factor investing offers access to structural and persistent sources of returns (i.e., the factor premiums) over the long run that are well grounded in economic theory.
- Factor investing provides investors with attractive risk-adjusted returns, diversification, increased levels of transparency via a disciplined, rules-based investment processes, and is often accompanied by lower costs than traditional active management.
- Factors like value, momentum, low risk, and others provide consistent and attractive returns across government bonds, investment-grade corporate bonds, and high-yield corporate bonds.
- Multi-factor fixed income portfolios are an effective way to apply factor investing in fixed income, and consistently add value for a variety of investors.
- Complementing equity factor investing with fixed income factor investing offers superior risk-adjusted returns for multi-asset investors.

CHAPTER
FORTY-EIGHT

ACTIVE FACTOR FIXED INCOME INVESTING

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Fixed income investing has undergone a sea change in the past decade. By tossing out some active management orthodoxies and embracing new technologies and quantitative techniques, we can capture unique insights and excess returns. Several investment shops, however, have cast this as a binary choice between relatively new quantitative approaches and "traditional" active approaches, practitioners of which remain steadfast in the fundamental economic laws of capital markets. We think this quantitative versus active debate sets up a false dichotomy. In this chapter, we provide an active fixed investment management approach driven by quantitatively derived insights.

ACTIVE QUANT FIXED INCOME

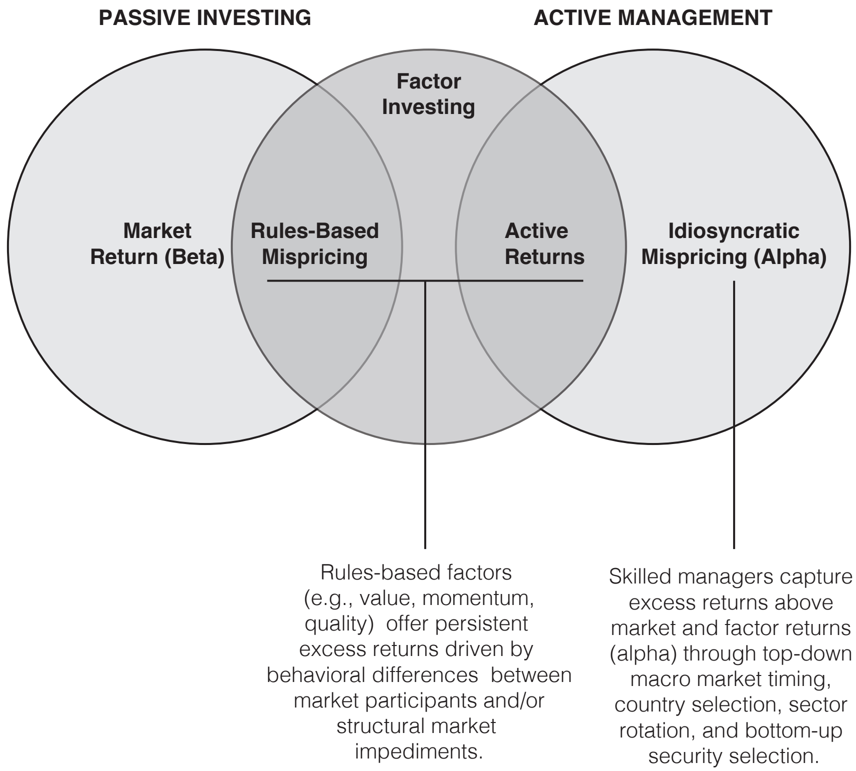
Investing in fixed income markets has undergone a significant transformation in recent years. For starters, factor investing that was originally popularized by index providers like MSCI and commonly found in equity portfolios is now spreading into fixed income.[1] Sometimes called "smart beta" or "systematic investing,"

1. Sophie Baker, S, "Factor-Based Investing Arrives for Fixed Income," *Pension & Investments* 16O) ctober 2017).

these quantitative ("quant") investment strategies seek to capture excess returns by using rules-based factors. Factors, like value, momentum, and quality, explain the outperformance of certain securities relative to other securities in the same asset class. These quant-oriented approaches belong to a new investment category (shown in Exhibit 48-1) that theoretically sits between passive index strategies offering market beta and active managers who deliver alpha (i.e., excess returns not explained by the overall market's rate of return, or beta).[2]

EXHIBIT 48-1

Factors Sit Between Beta and Alpha



2. Jennifer Bender, Remy Briand, Dimitris Melas, and Raman Aylur Subramanian. "Foundations of Factor Investing," MSCI Research Insight, December 2013.

Factor investing is still relatively new, but the underlying asset pricing mechanisms have been studied for decades in academic literature by the likes of Eugene Fama and Kenneth French,[3] who explained equity market excess returns, and the risk factor pioneer Barr Rosenburg. The real sea change came when quant managers and index providers devised transparent methods to measure and capture these factors. Suddenly, active managers did not need an army of credit analysts pouring through corporate financial statements to construct cash-flow models. Why bother if quantitative programs could achieve the same results with a factor lens?

The arrival of bond factor strategies has sparked some robust exchanges between quants and active bond managers. One such exchange that made headlines in 2018 started when a white paper by a quantitative asset management firm asserted that most active bond managers offer little in the way of true alpha. Any excess returns, it was claimed, comes mostly from "passive" exposure to corporate credit risks.[4] Members of one active bond portfolio management firm fired back in its own paper, pointing out in careful detail why the claim was false.[5] Rather, it argued, skillful security selection from seasoned credit analysts still matters.

Factor investing, however, is not the only quantitative trend bubbling up in fixed income. Among active managers and hedge funds, whose primary mission is generating alpha, an explosion of big data and machine learning algorithms has ushered in a new investing paradigm that some call the "Fourth Industrial Revolution."[6] If machines can drive cars and translate human speech, then algorithms can surely pinpoint market signals and investible opportunities that traditional active managers might miss. In this machine versus human scenario, some hedge funds now claim that data science and machine learning models hold the keys to unlocking real alpha and effectively managing risks.

It is worth stating upfront that we think this quant versus active and machine versus human debate sets up a false dichotomy. Look under the hood of any bond factor strategy or quant-oriented hedge fund, and you will find a deep roster of classically trained economists, portfolio managers, and traders—all steeped in the fundamental laws of economics. Machine learning algorithms cannot entirely replace human intuition. Further, since machine learning models are applicable for the regimes in the training period, they cannot account for the regime transition into regimes that are not in the training periods. So sophisticated models, if not properly guided by professionals with specific financial expertise,

3. Eugene F. Fama and Kenneth R. French.. "The Cross-Section of Expected Stock Returns," *The Journal of Finance* 47(2), 1992, pp. 427–465, and Eugene F. Fama, Kenneth R. French, "Common Risk factors in the Returns on Stocks and Bonds," *Journal of Financial Economics* 33(1), 1993, pp. 3–56.
4. AQR, "The Illusion of Active Fixed Income Diversification," *Alternative Thinking* 7 (December 2017).
5. Jamil Baz, Mukundan Devarajan, Mahmoud Hajo, and Ravi Mattu, "When Alpha Meets Beta: Managing Unintended Risk in Active Fixed Income," PIMCO, *Quantitative Research*, May 2018.
6. Marko Kolanovic and Rajesh T. Krishnamachari, "Big Data and AI Strategies—Machine Learning and Alternative Data Approach to Investing," J.P. Morgan, May 2017.

can lead to erroneous conclusions. Fundamental credit analysts still uncover valuable insights that factor-based equations gloss over and do not understand. A purely quantitative approach (which we do not think exists in all practicality) is no match for navigating highly dynamic capital markets driven by the economic forces of profit maximization.[7]

Factors Are Not Foolproof

So, why do some factor-based managers shun "active investing approaches" in their marketing pitches? It is unclear, especially given recent evidence that factors alone are not foolproof solutions. Case in point: factor-based equity strategies suffered from "terrible" performance in 2019—a blunt confession from a quant pioneer at Morningstar's annual mutual fund conference.[8]

Why the bad performance? Amidst the late-cycle market gyrations of 2019, factors like value and momentum that historically moved in opposite directions began moving in unison. Quantitative managers long recognized that systematic factors are sensitive to macroeconomic forces; individually, they can underperform for long stretches of time. Building noncorrelated multifactor strategies theoretically alleviated this problem. These diversified factor strategies appeared to work . . . until they didn't. Anxious equity investors were told to remain calm and sit tight; this mercurial environment will be short-lived.

Some managers think static multifactor exposures are partly to blame. Factor exposures should fluctuate dynamically in response to shifting macro forces like the rate of unemployment or the overall credit quality of corporate debt markets. Others pound the table and proclaim this poor showing is proof that skilled security selection trumps factors. There is also another suggestion: Why not capture unique insights from traditionally active approaches and factor approaches at the same time?

Some managers refer to this combination of perspectives as "orthogonal thinking"—a term used in science to describe a process where unique insights are discovered by drawing on seemingly unrelated perspectives. This orthogonal process was a crucial element, for example, in the discovery of human genetic code when physicists moved into the field of biology.

Machine Learning to the Rescue?

If factor-based strategies are not fool-proof solutions, does machine learning offer a better way to generate alpha? The headlines coming out of tech hubs like Silicon Valley tell us data-driven algorithms are accomplishing the unthinkable.

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7. Eugene F. Fama, "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance* 25(2), 1970, pp. 383–417.

8. Justina Lee, "AQR's Asness Is Right. It's a 'Crappy' Time for Factor Investing," *Bloomberg Markets,* May 15, 2019. Available at https://www.bloomberg.com/news/articles/2019-05-15/aqr-s-asness-is-right-it-s-a-crappy-time-for-factor-investing.

Machines now have computer vision, pack groceries in warehouses, drive cars, and predict your creditworthiness or even how you will vote.

In some areas, machines really do have the upper hand. Who else but a machine can identify cats in a stack of 20 million pictures with 95% accuracy in less than five minutes? In other areas, humans still prevail. Consider a commuter successfully navigating their car through rush hour traffic while holding a work conversation (something computers cannot do) and a crying baby in the back seat. Meanwhile, self-driving cars are still crashing into stationary objects and can become disoriented in the rain.

Now, step out of that car and ask yourself this: How can algorithms navigate incredibly complex capital markets that are overflowing with signals and noise? It turns out, algorithms are hard-pressed to complete basic tasks inside the noisy environment of finance where signals are weak and transitory. Scientists describe these environments as having low signal-to-noise ratios.

But there's good news. Algorithms can be highly effective when paired with skilled investment professionals (economists and portfolio managers). By themselves, machines have trouble anticipating the complicated human responses of politicians and central bankers that can drive market regime changes. However, when operating within the framework of an economist's hypothesis, for example, algorithms can forecast expected returns with much welcomed precision—far better than traditional statistical methods, where forecasts remain deeply shrouded in approximation and estimation errors.

Actively Guiding Quantitative Insights

We think the future of fixed income investing requires moving beyond the active versus quant stalemate. So, the ideal investment process starts with two familiar dimensions: top-down macroeconomic research and bottom-up fundamental security analysis.

The reasons for this division of labor are relatively straightforward: The performance of nearly every fixed income security (outside sovereign bonds) is influenced by unique mixtures of macroeconomic fundamentals—like inflation and stages of credit cycle—and sources of bottom-up mispricing tied to individual credit issuers. The skills of a trained economist are different from a credit analyst who specialized in the micro economy of an industry. It takes both viewpoints to capture excess returns, as shown in Exhibit 48-2.

Two additional dimensions—active fundamental and quantitative science—are also necessary for alpha generation, also illustrated in Exhibit 48-2. Factor-based security selection and machine learning techniques bring new skills and fresh insights to fixed income investing. The goal of combining active with quantitative views, however, is not to mix them inside a portfolio like a kitchen blender.

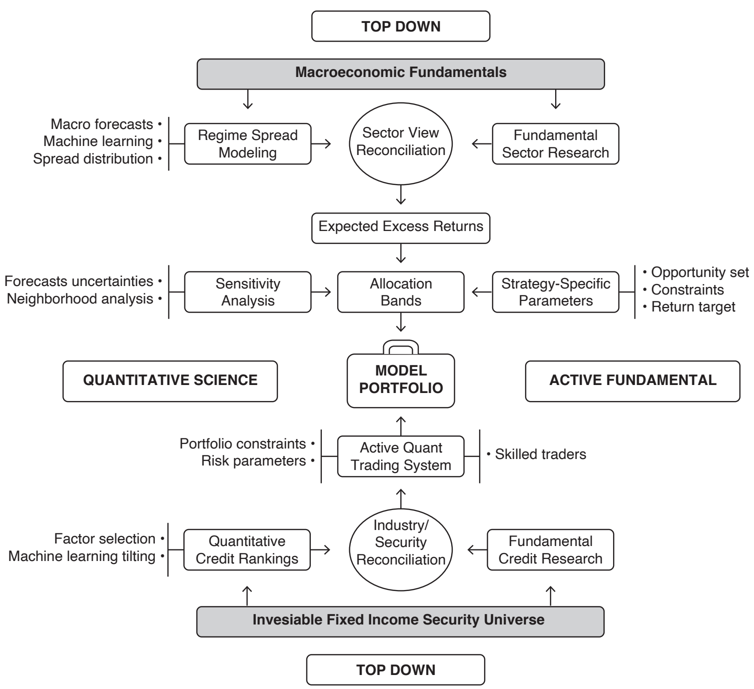
In some instances, quantitative techniques can sharpen fundamental insights with greater precision. Other times, they can challenge assumptions made by fundamental credit analysts and portfolio managers. Through discussion, quantitative views might lead fundamental analysts toward a different conclusion or reconfirm their original hypothesis after a healthy debate and deeper inspection.

It has been our experience that quantitative methods ultimately work best when combined with "traditional" human insights derived from the academic disciplines of macroeconomics and fundamental security analysis. Yes, machines offer much-needed precision in predicting asset returns. But we still need deep human expertise to make sense of market complexity. Machines are not good at assessing turning points in the business cycle or anticipating crowding behaviors from profit-driven traders.

In the next section, we explore top-down macroeconomic research and bottom-up security selection, as shown in Exhibit 48-2. In terms of top down, we discuss the process of transforming macroeconomic research into precise return forecast with algorithms. These serve as a bridge for communicating macroeconomic views across sector teams who speak different languages. In terms of bottom up, we compare factor-driven insights with fundamental credit analysis. Although factors offer precision across a breadth of securities, deep credit research is still critical for assessing risk premia.

EXHIBIT 48-2

Active Quant Investment Process



Source: Franklin Templeton, for illustrative purposes only.

ACTIVE QUANT TOP DOWN

In this section, we provide details of the top-down approach for the asset allocation process. This is accomplished by translating macroeconomic forecasts from economists to sector returns using tree-based machine learning algorithm. These sector return forecasts in turn provide asset allocation, that is, sector weights, across fixed income sectors.

Anchored in Macroeconomics

Developing a well-informed macroeconomic outlook is critical to identifying what academic finance refers to as "risk premia" (i.e., expected returns in excess of the risk-free rate). This type of research is typically the cornerstone of the investment process for active fixed income managers and quant-oriented hedge funds who are paid to deliver alpha. Given the complexity and dynamic nature of capital markets, experienced economists are critical to understanding how a myriad of economic variables can shape expected asset returns.

The sets of signals a macroeconomic team uses to generate an outlook are generally quite diverse and driven by an understanding that business cycles are themselves an aggregation of sub-cycles that drive growth (e.g., personal consumption, residential and nonresidential loans, industrial production, services, external demand, etc.). These sub-cycles are interdependent and jointly drive monetary and fiscal policy feedback loops, which in turn impact asset returns.

The Science of Translation

Forecasting sector returns has traditionally been a laborious exercise ripe with measurement errors. Analysts typically use statistical techniques like mean reversion (a theory that asset prices eventually revert to long-term averages) or smoothing techniques like moving averages to extrapolate price trends. Some analysts prefer looking backward in time to cherry-pick a previous environment they think best matches the current market regime. All of these methods are prone to subjectivity and the likelihood that bond returns may take longer than expected to return to average. Luckily, data scientists have found a better way.

Published research on machine learning forecasting of asset returns reflect our own experience modeling expected sector returns (i.e., spreads) using proprietary algorithms. The researchers find that algorithmic models—particularly regression trees that accommodate complex nonlinear relationships between multiple variables—improve return over traditional approaches and can in turn improve portfolio Sharpe ratios.[9] A key strength of algorithmic regression trees is their ability to logically capture complex nonlinear interactions between multiple

9. Shihao Gu, Bryan Kelly, and Dacheng Xiu, "Empirical Asset Pricing via Machine Learning," *Review of Financial Studies* 33(5), 2020, pp. 2223–2273.

variables—relationships that human analysts typically find difficult to map out, even with substantial effort and time.

Our active quant process starts with a macroeconomic outlook provided by trained economists. In the case of our macroeconomic team, they provide our data science team with a range of economic forecasts across variables such as oil prices, exchange rates, equities, rates, and inflation-related instruments. The data science team translates these views into standardized macro variables that feed into the regression tree algorithm, as shown in Exhibit 48-3.

The output from the regime modeling algorithm effectively serves to translate the macroeconomic team's outlook into sector views that each sector team can understand. The algorithm serves as a bridge to having more fruitful discussions between team members, allowing them to compare and contrast forecasts.

We then translate the reconciled sector views into 12-month expected returns across the global multisector fixed income universe. This forms the basis of our proprietary sector allocation process. Determining the optimal mix of weights starts by acknowledging spread uncertainties, which are calculated by using the volatility and correlations of a covariance matrix and our market regime models. The results point to an ideal allocation or "starting point" along efficient allocation frontier. Next, by analyzing all the mandated portfolio constraints, the data science team generates a range of allocations that all fall within the "neighborhood" of the ideal starting point—and that still meets the portfolios' risk and return parameters.

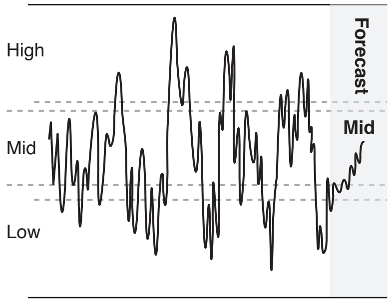
As illustrated in Exhibit 48-4, this optimization process gives managers the flexibility to allocate across allocation bands. In this hypothetical example, the portfolio managers chose to underweight U.S. investment-grade credit by the minimum allowed underweight, while overweighting bank loans and credit risk transfers. This process ensures that risk premia in our portfolios are efficiently allocated across the portfolio manager's highest conviction views and done in a manner that is consistent and repeatable.

EXHIBIT 48-3

Example Macro Variables Feed Our Regression Tree Algorithms

MACROECONOMIC FORECASTS

Forecasting performance (i.e., spreads) starts with our team's 12-month macro outlook. We analyze a series of macro variables, including equities, commodities, currencies, and inflation to forecast not just the level of each variable but also the trend and volatility (where applicable). Instread of assigning numerical values, the team determines whether variables will fall into the low, mid, or upper ends of their historical ranges. In this hypothetical example, we think the oil trend will increase to mid-range over the next 12 months.*



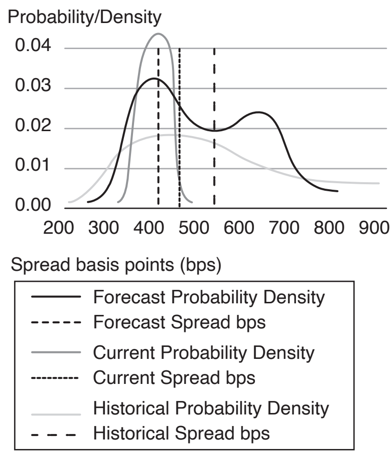
MACHINE LEARNING INPUTS

With outlooks in hand for a range of macro variables, our data science team uses a machine learning decision tree to convert these variables into a macroeconomic regime forecast. Within the context of this expected regime, the algorithm calculates how different sectors will respond by producing spread forecasts* across our fixed income universe (bank loans, high yield, taxable munibonds, etc.). This algorithm helps teams of poeple who may speak different languages communicate in a formalized, repeatable manner.

	Oil		U.S. Dollar		Yield Curve	
	Current	Forecast	Current	Forecast	Current	Forecast
Level	Mid	Mid	High	High	Low	Mid
Trend	Low	Mid	High	High	Mid	High
Volacility	Mid	Mid	Low	Low	Low	Mid

BOND SPREAD FORECASTS

Our spread forecasts allow each sector team to visualize how the expected macro regime might impact spreads in their setor. Importantly, the output not only indicates whether spreads might tighten or widen, but also indicates the distribution of spreads as represented by the shape of the curve. In this hypothetical illustration, we see expected spreads are likely to increase (per the dotted black line) while the spread distribution is quite wide (per solid black line).* This bimodal curve suggests a high degree of uncertainly—spreads could remain relatively unchanged or widen dramatically. The data team explains macro variables have the most impact on spreads.

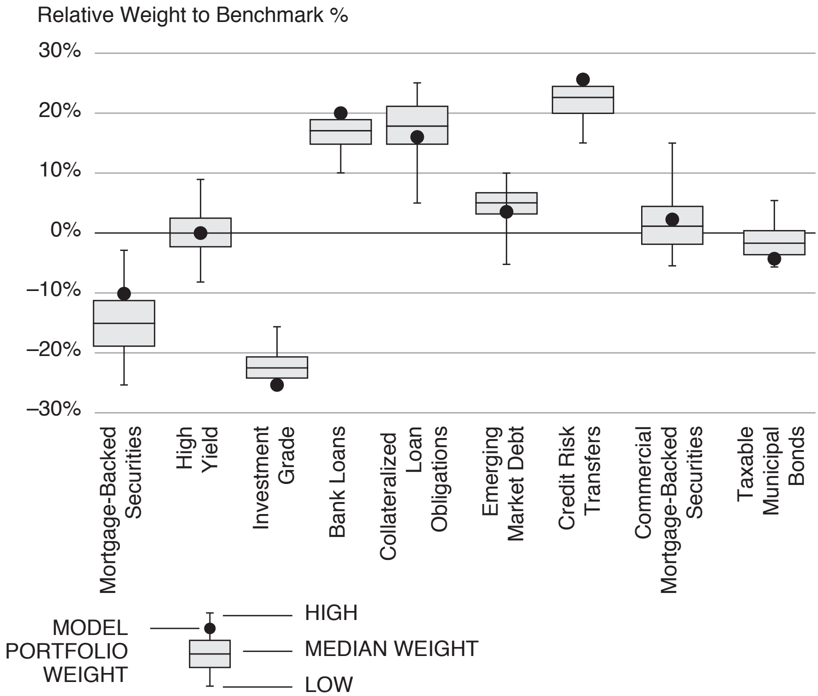


Source: Franklin Templeton, for illustrative purposes only.

* This hypothetical example is not a prediction or projection of any investment or investment strategy's performance. It is a hypothetical illustration intended solely to provide insight into how securities are analyzed.

EXHIBIT 48-4

Portfolio Allocation Parameters



Source: Franklin Templeton, for illustrative purposes only.

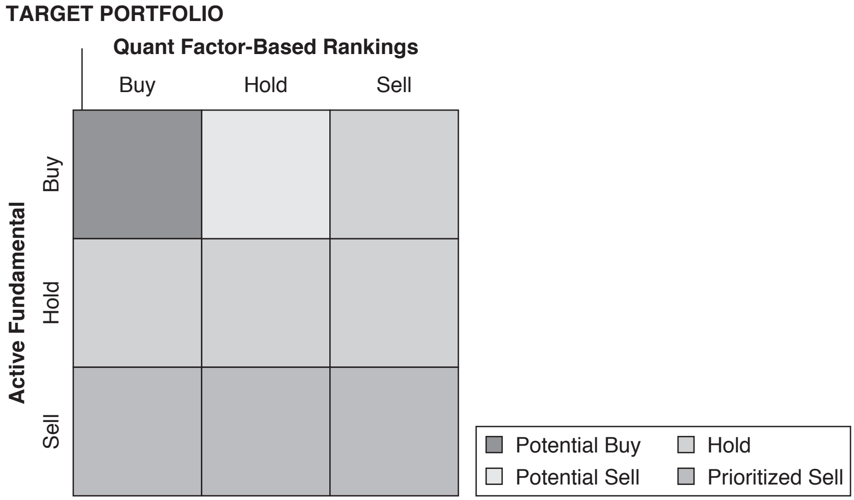
ACTIVE QUANT BOTTOM UP

In this section, we provide details of the bottom-up approach for the security selection process of corporate credit portfolios. This is accomplished by identifying factors that drive corporate credit portfolio returns. This approach explicitly accounts for the macroeconomic sensitivity of the factors, by dynamically weighting factors ("factor-tilt") using machine learning, so as to maximize portfolio Sharpe ratio. It is worth noting that this factor-tilt approach is not specific to corporate credit portfolio and can be used for any asset class, for example, Fama-French factors for equity portfolios. The return forecast then used in conjunction with credit analyst recommendations to arrive at the optimal corporate bond portfolio using the process shown in Exhibit 48-5.

This approach also allows for calculation of subsector allocation—in this case, industry weights of corporate credit portfolio.

EXHIBIT 48-5

Combining Active and Quant Recommendations



Source: Franklin Templeton, for illustrative purposes only.

Removing Blind Spots

When you boil down the key benefits of bond factor strategies, the standard marketing pitch usually goes something like this: factor-based bond strategies systematically implement fundamental investment ideas (using factors like value or momentum) without taking on risks that would not be compensated (i.e., excessive credit or interest rate risks). The claim implies that active managers may be doing the opposite—implementing fundamental ideas unsystematically (perhaps sloppily) that leads to risk exposures that will not pay off.

We agree that factor-based strategies offer some advantages, including the ability to methodically analyze a wide breadth of securities using precise measures that are not subject to bias. But factors also have an Achilles' heel: they are blind to what is causing bond spreads to widen or tighten. On the surface, wide spreads might look attractive to a factor, but the factor can be entirely unaware that long-term storm clouds are signaling caution. This blindness can be risky if not supplemented with fundamental research from a seasoned credit analyst.

It is the job of the credit analyst to understand how both macro- and microeconomic mechanisms can drive asset prices and explain what is potentially in store for future returns. The credit analyst brings a wealth of information to bear on his or her analysis, from the intricacies of a corporate business model, the peculiar genius (or folly) of a management team, to environmental, social, and governance issues.

In the simplified illustration, Exhibit 48-5, we have captured how our active quant process brings together factor-based security rankings and active fundamental credit recommendations together into prioritized potential buy and sell lists at the security level.

It is important to understand, the factor models and credit analysts operate independently from each other, ensuring each team's views remain their own. At the industry level, the "best ideas" from each side are presented in formalized "industry reconciliation" meetings where credit analysts, portfolio managers, and the data teams discuss why and how the views are either synchronized or opposed. Opposing views are welcomed and typically lead to deeper analysis and discussion before a resolution is made.

Taken together, the active quant process combines potential buy and sell lists with frank discussions and analysis. The goal is to populate the portfolio with the team's highest conviction (i.e., highly scrutinized) securities within an industry that also satisfy other risk and strategy-specific constraints.

Factor-Based Security Rankings

Factor-based investing initially became popular as a stock selection strategy by identifying broad, persistent drivers of excess return through quantifiable factors that historically earned positive long-term results. Similar to equity factors, the factor styles for corporate bonds with the longest track records include value, momentum, and quality factors. Each of these factors is grounded in commonly observed market dynamics, such as behavioral biases and structural impediments (rules and restrictions) that create opportunities that fundamental factor investors can exploit:

Value factors: The basic concept driving value factors is that cheap bonds (i.e., spread relative to fundamental risks) have tended to outperform expensive bonds over the long run. There are a multitude of ways to construct a value factor, though most methods start with a bond's current option-adjusted spread (OAS) and compares this to a range of risk characteristics such as credit rating and/or return volatility. Our data science team uses three distinct factor calculations that fall under the value umbrella. The first is the Spread-to-Credit relative value factor, which focuses on OAS relative to credit risks (i.e., credit ratings) and cyclicity, by controlling for industry. The second two factors measure also include credit ratings and industry, but also account for volatility/momentum and spread duration. Measures of volatility and momentum are 12-month excess return volatility and 3-month spread change, respectively.

Momentum factor: Corporate bonds from publicly listed issuers with strong recent equity performance tend to perform well since the bonds are senior to equity in the capital structure. Our data scientists use three-month equity return to construct the equity momentum factor.

Quality factors: Corporate bonds with low probabilities of default can outperform higher-yielding credit during credit downturns. Our data scientists use two distinct measures: (1) leverage, which captures the ratio of total debt to the sum of net debt and market equity (i.e., enterprise value), and (2) coverage, which is based on corporate profitability (i.e., earnings before interest, taxes, depreciation and amortization, EBITDA) relative to 12-month interest expenses.

Historically, factor-based bond managers combine multiple factors into a diversified strategy to help mitigate underperformance of any single factor. All bonds factors are sensitive to macroeconomic changes and therefore can underperform for stretches of time. Factor styles like value and quality tend to have low correlations and have different sensitivities to the macro environment. So, maintaining fixed exposures to a group of style factors has generally reduced the length of underperformance regardless of shifting macro environments.

But, what if we could implicitly forecast the near-term credit cycle? Then a machine learning algorithm could dynamically optimize factor weighs according to expected macro environment, with a goal of reducing potential drawdowns, by tilting away from the factors that are expected to underperform. This in turn increases portfolio's Sharpe ratio.

Algorithmic Factor Tilting

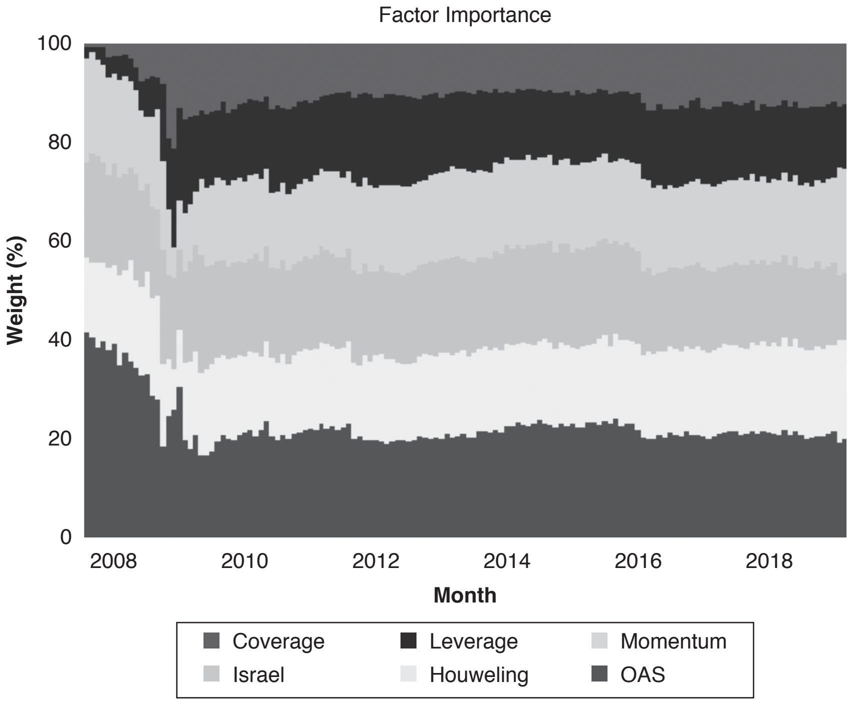
To forecast the credit environment, we use a customized gradient-boosting algorithm, which uses macroeconomic features such as the unemployment rate, the U.S. Federal Reserve's balance sheet, and the credit quality of the investment grade and high-yield bond markets. Based on the combination of these variables, the algorithm predicts the future relative performance of our six style factors spanning the value, momentum, and quality categories. In back-testing, the algorithm dynamically adjusted factor exposures during global financial crisis by increasing exposures to quality factor while decreasing exposure to other factors.

As shown in Exhibit 48-6, the algorithm began in July 2007, with 76% exposure to value, 21% to momentum, and just 3% to quality. For historical context, four months later, in October 2007, the Dow Jones Industrial Average peaked at over 14,000 points. As economic conditions worsened the following year, the algorithm incrementally increased exposure to quality factors while decreasing exposure to other factors. Following the dramatic collapse of Lehman Brothers in September 2008, which triggered a global panic, the algorithm increased quality exposures to 41% in November 2008.

Instead of a static buy-and-hold approach, our factor tilt algorithm shift factor exposures dynamically to better match overarching macroeconomic environments.

EXHIBIT 48-6

Factor Tilt



FOUR-DIMENSIONAL CHESS

In today's rapidly evolving investment landscape, the ability to deliver consistent excess returns to investors has seen profound changes in the tools and techniques available to institutional fixed income managers. Outspoken quants who championed the arrival of factor-based strategies are challenging the status quo—daring active managers to prove their worth.

Many active heavyweights say they are more than ready (thrilled in fact) to meet this challenge, while simultaneously getting their arms around big data and machine learning techniques to sharpen their edge. By incorporating data science alongside human insights, a simpler two-dimensional process of top-down and bottom-up analysis has morphed into four-dimensional chess that incorporates fundamental research and quantitative science.

Some managers claim that quants have the upper hand given today's digital technologies. This is not how things are shaping up in practice, however. Algorithms cannot drive themselves in noisy financial environments nor operate successfully without human intuition. Data scientists who lack financial expertise and intuition often do not produce desired investment results.

In the end, the most important skill sets in fixed income investing remain the ability of trained professionals to explain the underlying economic mechanisms that drive market regimes and the signals that data science can track and analyze. The future of fixed income lies in successfully marrying quantitative science with fundamental-based active management.

The fixed income portfolio management team should formulate a seamless active quant approach—where portfolio managers, analysts, traders, and data scientists work as one team to create a synergistic loop between quantitative and fundamental analysis. We believe marrying data science and fundamental expertise will allow for better portfolio performance by enabling managers to better navigate challenging investment environments.

KEY POINTS

- The active quant approach presented in this chapter combines unique insights from traditionally active and quantitative factor approaches at the same time.
- The active quant portfolio incorporates best ideas from both quantitative research/data scientists and credit analysts.
- The top-down active quant approach allows for sector allocation for fixed income sectors by translating macroeconomic forecasts from economists to sector returns.
- The factor tilt machine learning approach presented here for corporate credit maximizes portfolio Sharpe ratio by accounting for factor sensitivities to macro environment. This factor tilt approach is also applicable to other asset classes, such as Fama-French factors for equity portfolios.
- The active quant bottom-up approach in addition to providing security selection also provides subsector allocation (e.g., in the of case corporate credit portfolio, it provides industry weights).

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CHAPTER
FORTY-NINE

INTRODUCTION TO MULTIFACTOR RISK MODELS IN FIXED INCOME AND THEIR APPLICATIONS

Barclays

Risk management is an integral part of the investment process. Risk models are central to this practice, allowing managers to quantify and analyze the risk embedded in their portfolios. Risk models provide managers with insight into the different sources of risk in a portfolio, helping them to control their exposures and understand the contributions of different portfolio components to total risk. They help portfolio managers in their decision-making process by providing answers to important questions such as: How does my long-duration exposure affect portfolio risk? Does my underweight in diversified financials hedge my overweight in banks? Risk models are also widely used in various other areas such as in portfolio construction, performance attribution, and scenario analysis.

In this chapter we introduce linear multifactor risk models and illustrate how they can be helpful for the analysis of the risk of fixed income portfolios. We review the major sources of risk in fixed income securities and introduce a set of appropriate risk factors. We also present several applications of risk models for effective portfolio construction and management. In Chapter 50 we will go through a detailed risk model report of a specific portfolio and highlight the information and insights it can provide to a portfolio manager.

MOTIVATION AND STRUCTURE UNDERLYING FIXED INCOME MULTIFACTOR RISK MODELS

In this section, we discuss the motivation and structure behind fixed income multifactor risk models.

This chapter was coauthored by Anthony Lazanas, António Baldaque da Silva, Radu C. Gabudean, and Arne D. Staal when they were employees of Barclays.

Let us assume that a portfolio manager wants to estimate and analyze the volatility of a large portfolio of fixed income instruments. A straightforward idea would be to compute the volatility of the historical returns of the portfolio and use this measure to forecast future volatility. However, this framework does not provide any insight into the relationships between different securities in the portfolio or the major sources of risk. For instance, it does not assist a portfolio manager interested in diversifying a portfolio or constructing a portfolio that has better risk-adjusted performance. Additionally, the characteristics of a fixed income portfolio change substantially over time, for instance, as instruments mature or are subject to credit events.

Instead of estimating the portfolio volatility using historical portfolio returns, a portfolio manager could utilize a different strategy. The portfolio return is a function of individual instrument returns (e.g., Treasury securities, corporate bonds, credit derivatives, municipal bonds, interest rate swaps, and so on) and the market weights of these securities in the portfolio. Using this, the forecasted volatility of the portfolio (σ_P^f) can be computed as a function of the weights (w) and the covariance matrix (Σ_S) of the instrument returns in the portfolio:

$$\sigma_P^f = \sqrt{w^T \times \Sigma_S \times w}$$

where the superscript T denotes a matrix transpose. This covariance matrix can be decomposed into individual instrument volatilities and the correlations between returns.

Volatilities measure the riskiness of individual instrument returns, and correlations represent the relationships between the returns of different instruments. By measuring these correlations and volatilities, the portfolio manager can gain insight into her portfolio related to the riskiness of different parts of the portfolio or how the portfolio can be diversified. As outlined above, to estimate the portfolio volatility we need to estimate the correlation between each pair of instruments. Unfortunately, this means that the number of parameters to be estimated grows quadratically with the number of instruments in the portfolio.[1] For most practical portfolios, the relatively large number of constituents makes it difficult to estimate the relationship between instrument returns in a robust way. Moreover, this framework uses the history of individual instrument returns to forecast future security return volatility. However, instrument characteristics are dynamic and hence using returns from different time periods may not produce good forecasts.[2] These drawbacks constitute the motivation for multifactor risk models discussed in this chapter.

One of the major characteristics of multifactor models is their ability to describe the return of a portfolio using a relatively small set of variables, called *factors*. These factors should be designed to capture broad (systematic) market fluctuations, but should also be able to capture specific nuances of individual portfolios.

1. As an example, if the portfolio has 10 instruments, we need to estimate 45 parameters, with 100 instruments we would need to estimate 4,950 parameters.

2. This is especially the case over crisis periods, in which instrument characteristics can change dramatically over very short periods of time.

For instance, a broad fixed income market factor would capture the general movement in the fixed income markets, but not the varying behavior across types of instruments. If, for example, a portfolio is heavily biased toward the long end of the U.S. Treasury yield-curve, or is tilted toward credit bonds of particular industries, the broad market factor may not allow for a good representation of the portfolio's return. Other factors might be needed to capture these more specific sources of risk.

Most factor models are linear, in the sense that the total return is decomposed into the sum of the contributions of the factors (referred to as the *systematic return*) and an idiosyncratic component. *Systematic return* is the component of total return due to movements in the common (market-wide) risk factors. On the other hand, *idiosyncratic return* can be described as the residual component that cannot be explained by the systematic factors. Under most factor models, idiosyncratic returns are uncorrelated across issuers. Therefore, correlations across securities of different issuers are driven by their exposures to the systematic risk factors, and the correlation between those factors.

The following equation demonstrates the systematic and the idiosyncratic components of total return for security s:

$$r_s = L_s \times F + \varepsilon_s$$

The systematic return is the product of the instrument's loadings (L, also called sensitivities) to the systematic risk factors and the returns of these factors (F). The idiosyncratic return is given by ε_s.

Under these models, the portfolio volatility can be estimated as

$$\sigma_p^f = \sqrt{L_p^T \times \Sigma_F \times L_p + w^T \times \Omega \times w}$$

Here L_p are the loadings of the portfolio to the risk factors (determined as the weighted average of individual instrument loadings) and Σ_F is the covariance matrix of factor returns. Ω is the covariance matrix of the idiosyncratic security returns. Typically, the idiosyncratic return of securities is assumed uncorrelated. Therefore, this covariance matrix is diagonal, with all elements outside its diagonal being zero.[3] As a result, the idiosyncratic risk of the portfolio is diversified away as the number of securities in the portfolio increases. This is, of course, the diversification benefit attained when combining uncorrelated exposures.

For most practical portfolios, the number of factors is significantly smaller than the number of instruments in the portfolio. Therefore, the number of parameters in Σ_F is much smaller than in Σ_S, leading to a generally more robust estimation. Moreover, the factors can be designed in a way that they are relatively more stable than individual stock returns, leading to models with potentially better predictability. In this setting, the changing nature of each particular instrument can be captured through its loadings to the different risk factors.

3. In more detailed factor models, idiosyncratic correlation may not be zero. For example, securities of the same issuer have typically positive correlation; in such case, the idiosyncratic covariance matrix is block-diagonal.

Another very important advantage of using factor models is the detailed insight they can provide into the structure and properties of portfolios. These models characterize instrument returns in terms of systematic factors that (can) have intuitive economic interpretations. Linear factor models can provide important insights regarding the major systematic and idiosyncratic sources of risk and return. This analysis can help managers to better understand their portfolios and can guide them through the different tasks they perform, such as rebalancing, hedging, or tilting of their portfolios.

Naturally, the success of a risk model depends on its ability to interpret historical and current data in order to formulate estimates of future portfolio risk. It should therefore seek to discover properties of the data that are *quasi-predictable*; that is, that the error in the estimate of future realizations—given all information known today—is relatively small. For example, it is notoriously difficult to predict the expected return of a financial asset. On the other hand, historical data contain sufficient information to allow risk models to provide good estimates of the volatility of future returns. Nevertheless, one should never forget that even the most sophisticated risk model can only provide an *estimate* of risk. It is well known that financial markets are subject to *event risk* (i.e., a sudden change in market conditions caused by geopolitical or financial events). Such events are usually followed by a period of large negative returns of risky assets, large positive returns of assets considered as safe havens, significantly higher volatility, and very high (positive or negative) correlations. It is impossible for a risk model to predict when such events will occur. Therefore, it is useful to complement model-based risk management and portfolio construction with *what-if analysis,* which estimates portfolio return and risk under *stressed conditions*; that is, scenarios with extreme realizations of market returns and a covariance matrix with much higher volatilities and absolute correlations.

FIXED INCOME RISK MODELS

Fixed income securities are exposed to many different types of risk. Multifactor risk models in this area capture these risks by first identifying common sources along different dimensions, the *systematic fixed income risk factors*. All risk not captured by these systematic factors is considered *idiosyncratic*, and is determined by the choice of systematic risk factors. Typically, fixed income systematic risk factors are divided into two sets: those that influence securities across asset classes (e.g., yield-curve risk) and those specific to a particular asset class (e.g., prepayment risk in securitized products).

There are many ways to define systematic risk factors. For instance, they can be defined purely by statistical methods, observed in the markets (e.g., a yield-curve), or estimated from asset returns. In fixed income, the standard approach is to use pricing models to calculate the analytics that are the natural candidates for risk factor loadings (*L,* in the notation presented earlier). In this setting, the risk factors are either observable (e.g., the movements in the yield-curve) or estimated from regressing cross-sectional asset returns on instrument sensitivities. This is the approach taken in the Global Risk Model,[4] which is the model used for illustration throughout this chapter.

In this risk model, the forecasted risk of the portfolio is driven by both a systematic and an idiosyncratic (also called specific, nonsystematic, or concentration) component. The forecasted systematic risk is a function of the mismatch between the portfolio and the benchmark in the exposures to the risk factors, such as yield-curve or spreads. The (net) portfolio exposures are aggregated from security-level analytics. The systematic risk is also a function of the volatility of the risk factors, as well as the correlations between the risk factors. In this setting, the correlation of returns across securities is driven by the correlation of systematic risk factors these securities load on. Because the model uses security-level returns and analytics to estimate the factors, it can recover the idiosyncratic return for each security. This is the return net of all systematic factors. The use of detailed level analysis of idiosyncratic returns allows for the estimation of rich specifications of idiosyncratic risk.

Systematic Risk Factors

The precise definition of systematic risk factors depends on the purpose of the factor model, but in general we can highlight several categories of risk factors that drive fixed income risk.

Curve Risk

Curve risk is the major source of risk across fixed income instruments. This kind of risk is embedded in virtually all fixed income securities; therefore, mismatches in curve profiles relative to a benchmark are often the main drivers of portfolio risk.

When analyzing curve risk, we should use the curve of reference in which we are interested. Depending on the portfolio and circumstances, this is typically the government or swap curve.[5] In calm periods, the behavior of the swap curve tends to match that of the government curve. However, during liquidity crises (e.g., the Russian crisis in 1998 or the credit crisis in 2008), they can diverge significantly. To capture these different behaviors adequately, one may use the following decomposition: for government products, the curve risk is assessed

4. The model was available through POINT, a portfolio management tool that at the time this chapter was written was an offering by Barclays. It is a multi-currency cross-asset model that covers many different asset classes across the fixed income and equity markets, including derivatives in these markets. At the heart of the model is a covariance matrix of risk factors. The model has several hundreds of factors, many specific to a particular asset class. The asset class models are periodically reviewed. Structure is imposed to increase the robustness of the estimation of such large covariance matrix. The model is estimated from historical data. It is calibrated using extensive security-level historical data and is updated on a monthly basis.

5. Other curves that can be used are, for instance, the municipals (tax-free) curve, the inflation-adjusted (real rate) curve, etc.

using the government curve. For all other products in the portfolio (that usually trade off the swap curve), this risk is measured using both the Treasury curve and swap spreads (i.e., the spreads between the swap and the government curve). Other curve decompositions are also possible.

The risk associated with each of these curves can be described by the exposure the portfolio has to different points along the curve combined with the volatility and correlation of the movement of such curve points. Sometimes a convexity term is required to capture the second-order exposure to curve changes of instruments with long tenors or embedded optionality, such as mortgage-backed securities. For a typical portfolio, a good description of the curve can be achieved by looking at a relatively small number of points along the curve (called key-rates), for example 6-month, 2-year, 5-year, 10-year, 20-year, and 30-year. An alternative set of factors used to capture yield-curve risk can be defined using statistical analysis of the historical realizations of the various yield-curve points. The statistical method used most often is *principal component analysis* (PCA). This method defines factors that are statistically independent of each other. Typically three or four such factors are sufficient to explain the risk associated with changes of yields across the yield-curve. PCA analysis has several shortcomings and must be used with caution. Using a larger set of economic factors like the key-rate points described above is more intuitive and captures the risk of specialized portfolios better. For these reasons, many portfolio managers favor the key-rates approach in most risk analysis problems.

Credit Risk

Instruments issued by corporations or entities that may default are said to have credit risk. The holders of these securities demand additional yield—in excess of the risk-free yield—to compensate for that risk. This extra yield is usually measured as a spread to a reference curve. For instance, for corporate bonds the reference curve is usually the swap curve. The level of credit-spreads determines to a large extent the credit risk exposure associated with the portfolio.[6]

There are several characteristics of credit bonds that are naturally associated with systematic sources of credit-spread risk. For instance, depending on the business cycle, particular industries may be going through especially tough times. So industry membership is a natural systematic source of risk. Similarly, bonds with different credit ratings are usually treated as having different levels of credit risk. Credit rating could be another dimension one can use to measure systematic exposure to credit risk. Finally, the country of the issuer is another source of systematic risk for credit bonds. Given these observations, it is common to see factor models for credit risk using country, industry, and rating as the major systematic risk factors. Recent research suggests that risk models that directly use the spreads of the bonds instead of their ratings perform better for risk analysis

6. Spreads are also compensation for sources of risk other than credit (e.g., liquidity), but for the sake of our argument, we treat them here as major indicators of credit risk.

over relatively short/medium horizons.[7] Under this approach, the loading of a particular bond to a credit-risk factor would be the commonly used spread duration, but now multiplied by the bond's spread. The loading is termed *D*uration *T*imes *S*pread (denoted DTS) and is described in Chapter 53. By directly using the spread of the bond in the definition of the loading to the credit risk factors, we do not need to assign specific risk factors to capture the rating or any similar quality-like effect. It will be automatically captured by the spread level incorporated into the bond's loading to the credit risk factor, and will adjust as the spread of the bond changes. In this setting, we still could use different systematic risk factors, for example, to distinguish among credit risk coming from different industries.[8]

Prepayment Risk

Securitized products are generally exposed to prepayment risk. The most common of the securitized products are the residential mortgage-backed securities (RMBS or simply MBS). These securities represent pools of deals that allow the borrower to prepay their debt before the maturity of the loan/deal, most typically when prevailing lending rates are lower. This option means an extra risk to the holder of the security, the risk of holding cash exactly when reinvestment rates are low. Therefore, these securities have two major sources of risk: interest rate (including convexity) and prepayment risk.

Some part of the prepayment risk can be expressed as a function of interest rates via a prepayment model. This risk will be captured as part of interest-rate risk using the key-rate durations and the convexity. Convexity, which is usually negative for these instruments, is a significant source of risk. Negative convexity has a detrimental effect on the market value of an instrument—compared with one with positive or zero convexity—when interest rates move significantly in either direction. Indeed, decreasing interest rates cause prepayments to increase thereby reducing the price appreciation because of the falling rates. Conversely, rising interest rates intensify the price depreciation the instrument suffers with higher rates.

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7. For details, see Arik Ben Dor, Lev Dynkin, Patrick Houweling, Jay Hyman, Erik van Leeuwen, and Olaf Penninga, "A New Measure of Spread Exposure in Credit Portfolios," Barclays Publications, February 2010.

8. The general principle of a risk model is that the historical returns of assets contain information that can be used to estimate the future volatility of portfolio returns. However, good risk models must have the ability to translate the historical asset returns to the context of the current environment. This translation is made when designing a particular risk model/factor and when implemented delivers risk factors that are as invariant as possible. This invariance makes the estimation of the factor distribution much more robust. In the particular case of the DTS, by including the spread in the loading (instead of using only the typical duration), we change the nature of the risk factor being estimated. The factor now represents percentage change in spreads, instead of absolute changes in spreads. The former has a significantly more invariant distribution. For more details, see Antonio B. Silva, "A Note on the New Approach to Credit in the Barclays Global Risk Model," Barclays Publications, September 2009.

The remaining part of prepayment risk—that is not captured by the prepayment model—must be modeled with additional systematic risk factors. Typically, the volatility of prepayment speeds (and therefore of risk) on MBS depends on three characteristics: program/term of the deal, if the bond is priced at discount or premium (e.g., if the coupon on the bond is bigger than the current mortgage rates), and how seasoned the bond is. This analysis suggests that the systematic risk factors in a risk model should span these three characteristics of the securities.

Implied Volatility Risk

Many fixed income securities have embedded options (e.g., callable bonds). This means that the expected future volatility (implied volatility[9]) of the interest rate or other discount curves used to price the security plays a role in the value of that option. If expected volatility increases, options generally become more expensive, thereby affecting the prices of bonds with embedded options. For example, callable bonds will become cheaper with increasing implied volatility since the bondholder is short optionality (the right of the issuer to call the bond). Therefore, the exposure of the portfolio to the implied volatility of the yield-curve is also a source of risk that should be accounted for. The sensitivity of securities to changes of implied volatilities is typically measured by *vega*, which is calculated using the security pricing model. Implied volatility factors can be either calculated from the market prices of liquid fixed income options (caps, floors, and swaptions), or implied by the returns of bonds with embedded options within each asset class.

Liquidity Risk

Many fixed income securities are traded over-the-counter, in decentralized markets. Some trade infrequently, making them illiquid. It is therefore hard to establish their fair price. These bonds are said to be exposed to liquidity risk. The holder of illiquid bonds would have to pay a higher price to liquidate a position, usually meaning selling at a discount. This discount is uncertain and varies across the business cycle. For instance, the discount can be significant in a liquidity crisis, such as the one of 2008. The uncertainty about this discount means that, everything equal, a more illiquid bond will be riskier. This extra risk can be captured through liquidity risk factors. For instance, in the Treasury markets, one generally refers to the difference in volatility between an on-the-run and an off-the-run Treasury bond as liquidity risk.

Inflation Risk

Inflation-linked securities are priced based on the expectation of future inflation. Uncertainty about this variable adds to the volatility of the bond over and above

9. The volatility is called implied because it is calculated from the market prices of liquid options with the help of an option-pricing model.

the volatility from other sources of risk, such as nominal interest rates. Expected inflation is not an observed variable in the marketplace but can be extracted from the prices of inflation-linked government bonds and inflation swaps. Expected inflation risk factors can be constructed by summarizing this information. The sensitivity of securities to expected inflation is calculated using a specialized pricing model and is usually called *inflation duration*.

Tax-Policy Risk

Many municipal securities are currently tax-exempt. This results in added benefit to their holders. This benefit—incorporated in the price of the security—depends on the level of exemption allowed. Uncertainty around tax policy—tax-policy risk—adds to the risk of these securities. Once again, tax-policy risk factors cannot be observed in the marketplace and must be extracted from the prices of municipal securities. The return of municipal securities in excess of interest rates is driven partially by tax-policy expectations changes. However, it is also driven by changes in the creditworthiness of the municipal issuers as well as other factors. In this case, it is difficult to separate tax-policy risk factors from other factors driving municipal bond spreads. Therefore, instead of specific tax-policy factors, we usually extract factors representing the overall spread risk of municipal securities. This exercise is performed in a similar way to the credit risk model, in which securities are partitioned into groups of "similar" risk by geography, bond type (general obligation vs. revenue), tax status, and the like.[10]

There are other sources of systematic risk we did not detail in this section. They may be important sources of risk for particular portfolios. Specific risk models and factors can be designed to address them.

Idiosyncratic Risk

Once all systematic factors and loadings are determined, the residual idiosyncratic return of a security can be computed as the component of its total return that cannot be explained by the systematic factors. Idiosyncratic return can be a significant component of total return for individual instruments, but tends to decrease rapidly for portfolios of instruments as the number of instruments increases and concentration decreases (the aforementioned diversification effect).

The major inputs to the computation of idiosyncratic risk are instrument characteristics and historical idiosyncratic returns of the instruments. The use of idiosyncratic residual returns allows the risk modeler to find empirical relationships between characteristics such as instrument spread, spread duration, industry membership, and idiosyncratic volatility. This mapping of instrument characteristics to idiosyncratic volatility allows for the modeling of new issues and issues with characteristics that change over time. As mentioned before,

10. For more discussion, see Arne Staal, "U.S. Municipal Bond Risk Model," Barclays Publications, July 2009.

idiosyncratic returns of different issuers are assumed to be uncorrelated. However different securities from the same issuer, or securitized products with related underlying instruments, can show a certain level of co-movement, as they are all exposed to specific events affecting their common issuer that are not captured by systematic risk factors. Interestingly, this co-movement is not perfect or static. Certain news can potentially affect the different securities issued by the same company (e.g., equity, credit default swaps, bonds, or equity options) in different ways. Moreover, this relationship changes with the particular circumstances of the firm. For instance, returns from securities with claims to assets of the firm should be more highly correlated if the firm is in distress. A good multi-asset class risk model should be able to capture these phenomena regarding idiosyncratic risk.

APPLICATIONS OF RISK MODELING

In this section, we illustrate several standard risk model applications used for portfolio management. All applications make use of the fact that the risk model translates the characteristics a portfolio may have across many different dimensions, into a common, comparable set of numbers. In some of them—risk budgeting and portfolio rebalancing—an optimizer that uses the risk model as an input is the optimal setting to perform the exercise.

The investment process of a typical portfolio manager involves different stages. Given the investment universe and objective, the steps usually consist of portfolio construction, risk prediction, and performance evaluation. These steps are iterated throughout the investment cycle over each rebalancing period. The examples in this section highlight the portfolio construction and risk analysis steps that employ a factor model. Additionally, scenario analysis can be employed in both the portfolio construction and risk evaluation phases of the portfolio process. This exercise allows the manager to gain additional intuition regarding portfolio exposures and how the portfolio may behave under particular economic circumstances. It usually takes the form of stress testing potential portfolio losses under historical or hypothetical scenarios. It can also show the sensitivity of the portfolio to particular movements in economic and financial variables. The last application in this chapter illustrates this kind of analysis.

Portfolio Construction and Risk Budgeting

As discussed, fixed income portfolios are exposed to a diverse set of risk factors. During the portfolio construction exercise, the manager must carefully choose the exposure to such factors in order to achieve the highest possible portfolio return subject to risk and other constraints. Risk models help portfolio managers achieve this in an objective and quantifiable way and are increasingly used for portfolio construction, usually with the help of an optimization engine. In this section, we illustrate how a portfolio manager would use this engine to formulate client objectives and constraints in the context of risk model-based portfolio construction.[11]

Portfolio managers can have a broad array of mandates. Some—typically referred to as *indexers*—are required to follow a given benchmark index with the minimum possible deviation. Their goal is to minimize the tracking error volatility of the portfolio versus the index while also keeping portfolio transaction costs as small as possible. Others, the *enhanced indexers*, are allowed some leeway to deviate from the benchmark in order to achieve superior returns. The leeway can be expressed as a set of rules constraining the exposure to risk factors, but it is often prescribed as a *risk budget*; that is, an upper limit in a statistical measure of deviation between the portfolio and its benchmark. The *tracking error volatility* (TEV) of the return of the portfolio net of the benchmark is the most common of such measures. Finally, the *absolute return* portfolio managers, do not have to track a benchmark but are instead aiming at the highest possible portfolio return, potentially subject to leverage, portfolio composition, exposure, and risk constraints. In all cases, the manager has to merge all views and constraints into a final portfolio. When constructing the portfolio, how can the competing views be managed, while respecting the risk budget? How can the views be combined to minimize the risk? What tradeoffs can be made? Risk models are widely used to perform this exercise in a systematic and objective manner: They can measure the risk of each view as well as the correlation between different views, and arrive at portfolios that optimally trade-off the risks and expected returns associated with each of the views.

We illustrate this by a simple example of a portfolio construction exercise using a risk model. Consider a fixed income portfolio manager who is benchmarked to the Bloomberg Barclays US Aggregate Index. The manager's mandate is to outperform the benchmark with a risk-budget of 20 bp/month (i.e., the portfolio's TEV should remain within this bound on a monthly basis). Before formulating views and constraints, and deciding how to implement them, the manager needs to choose an investment universe. Since the benchmark is the Bloomberg Barclays US Aggregate Index, the manager could choose the investment universe to be all issues in this index with outstanding amount in excess of $300 million. The selection of this investment universe ensures that securities with small amounts of outstanding notional will not be selected in the portfolio, potentially increasing overall portfolio liquidity and decreasing transaction costs. With the risk budget in mind, the manager chooses to minimize total portfolio TEV relative to the benchmark. (The manager could potentially consider other risk-based objectives such as maximizing the Sharpe ratio.) This means the manager is giving leeway to the risk model to choose a portfolio from the tradable universe that minimizes the risk relative to the benchmark, in this case the Bloomberg Barclays US Aggregate Index. Finally, the manager formulates constraints and views.

Let us assume for the purpose of this illustration that the amount of funds to be invested is $100 million. With that in mind, and in order to avoid buying small

11. In our examples, we use the POINT optimization engine.

amounts of securities, the manager decides to implement the portfolio using a maximum of 100 positions. Given views on the market environment, the manager wants the portfolio to be long duration against the benchmark, between 0.40 and 0.60 years, and have a spread advantage of 150 bp to 200 bp over the benchmark. Finally, to ensure a certain amount of diversification in portfolio positions, the manager imposes a maximum under/overweight of 3% per issuer relative to the benchmark.[12]

Our portfolio manager incorporates all these settings into an optimization problem, and finds a solution that reflects the optimal tradeoff between the constraints and risks through the optimization engine. The result is a recommended portfolio that satisfies the constraints while minimizing total risk. Specifically, the resulting portfolio—that we will follow throughout this section—consists of 100 securities and has a predicted TEV of 15.1 bp/month, interest-rate duration of 5.44 years, and option-adjusted spread of 206 bp (Exhibit 49-1). Using a factor-based risk model and an optimization engine, the resulting portfolio incorporates the manager's views while staying within its risk budget and ensuring that all additional constraints are satisfied.

Analyzing Portfolio Risk

The main application of risk models is risk measurement of portfolios relative to their benchmark. Risk analysis based on multifactor models can take many forms: from a relatively high-level aggregate approach, to an in-depth analysis of the risk properties of individual instruments and groups of instruments. Multifactor fixed income risk models provide the tools to perform the analysis of portfolio risk in many different dimensions, including exposures to risk factors, security/factor contributions to total risk, and risk analysis at the issuer level. For instance, as previously described, this risk can be decomposed into a systematic and an idiosyncratic component. Exhibit 49-2 shows that the portfolio has total TEV of 15.1 bp/month, systematic TEV of 10.4 bp/month, and idiosyncratic TEV of 10.1 bp/month. Since

EXHIBIT 49-1

Portfolio and Benchmark Characteristics of Sample Portfolio

	Total TEV (bp/month)	Duration (years)	Spread Duration (years)	Spread (bp)
Portfolio	15.1	5.44	5.23	206
Benchmark		5.02	4.92	55

Source: POINT.

12. Another way to ensure diversification would be to include the minimization of the idiosyncratic TEV as a specific goal in the objective function.

systematic risk and idiosyncratic risk are independent, they constitute isolated (uncorrelated) risk sources of the portfolio and therefore we have

$$\text{Total TEV} = \sqrt{\text{Systematic TEV}^2 + \text{Idiosyncratic TEV}^2}$$

An alternative way to describe the manner in which different risk sources impact overall portfolio risk is through *risk attribution*. Risk attribution allows a manager to decompose portfolio volatility in an additive way into contributions to TEV. Exhibit 49-2 reports that the contribution to total TEV (CTEV) from systematic risk factors is 8.3 bp/month, whereas idiosyncratic risk contributes 6.8 bp/month.[13]

The risk attribution approach can be used to further decompose overall portfolio risk into contributions from different buckets. The buckets can represent groups of securities (e.g., industry buckets) or risk factors (e.g., factors related to curve or to credit-spreads). This flexible decomposition allows portfolio managers to gain a detailed understanding of how different securities and risk exposures affect overall portfolio risk.

Exhibit 49-3 shows the isolated TEV as well as the contributions to TEV for the sample portfolio. In this exhibit, we choose to partition risk across systematic risk factors (plus the idiosyncratic risk), but many other partitions are possible. In this example, the largest contribution within systematic risk comes from the exposure to "Curve" factors, with a CTEV of 5.2 bp/month. As we saw before, idiosyncratic exposure is also a large component of the risk in this portfolio, with a contribution of 6.8 bp/month to total risk. Notice the difference between isolated TEV and contribution to TEV for our factor partition—isolated TEV reflects the risk of the partition buckets in isolation—while contribution to TEV includes risk driven by correlations among the different buckets.

EXHIBIT 49-2

Portfolio Risk Results of Sample Portfolio in bp/Month

	Isolated TEV	CTEV
Total	15.1	15.1
Systematic	11.2	8.3
Idiosyncratic	10.1	6.8

Source: POINT.

13. In this case, because the systematic and idiosyncratic components of the TEV are uncorrelated, the CTEV can be computed easily. Specifically, the CTEV from the systematic risk is computed as $11.2^2/15.1 = 8.3$ and from the idiosyncratic as $10.1^2/15.1 = 6.8$. Note that by definition they sum up to the total TEV. In Chapter 50 a more detailed and general discussion is provided.

EXHIBIT 49-3

Portfolio Risk Contributions of Sample Portfolio in bp/Month

Risk Factor Partition Bucket	Isolated TEV	CTEV
Total	15.1	15.1
Systematic	11.2	8.3
Curve	11.4	5.2
Swap Spreads	2.6	0.6
Volatility	0.4	0.0
Spread Gov-Related	3.4	0.0
Spread Credit and EMG	7.5	2.6
Spread Securitized	3.0	–0.1
Idiosyncratic	10.1	6.8

Source: POINT.

In addition to overall portfolio TEV and partition-based contributions to TEV, there are many additional risk analytics that can be computed on the basis of a linear factor risk model, such as betas with respect to the benchmark, liquidation effect to TEV, and marginal contributions to risk. Different users will use these analytics for different purposes and to different degrees.

Portfolio Rebalancing

Most managers rebalance their portfolios at regular intervals to reflect changing views and market circumstances. For instance, as time goes by, the characteristics of the portfolio may drift away from targeted levels. This may be due to the aging of its holdings, changes in the market environment, or issuer-specific events such as defaults. The periodic realignment of a portfolio to its investment guidelines and changing investment views is called *portfolio rebalancing*. Similar needs arise in many different contexts: when managers receive extra cash to invest, receive minor changes to their mandate, want to tilt positions toward their views, and the like. As with the initial portfolio construction, a risk model is very useful in the rebalancing exercise. During rebalancing, typically the portfolio manager seeks to sell bonds currently held and replace them with others having properties more consistent with the overall portfolio goals. Such buy and sell transactions are costly and their cost must be weighed against the benefit from moving the portfolio closer to its desired profile. A risk model can tell the manager how much risk reduction (or increase) a particular set of transactions can achieve in order to evaluate the risk adjustment benefits relative to the transaction cost.

As an example, suppose the portfolio manager in our illustration wants to reduce the imbalances the portfolio has against the benchmark. Specifically, the manager wants to lower the net portfolio duration from 0.42 years to a value between 0.2 years and 0.4 years. After looking at the portfolio's industry profile, the manager also decides to reduce the existing 6% overweight in the banking industry to about 4%. In addition, the manager lowers the minimum acceptable excess spread to 100 bp. To avoid high transaction costs, the manager also imposes the rebalancing to be done with no more than 30 trades. Finally, let us assume no portfolio inflows or outflows so the portfolio market value must remain unchanged. Starting from the original portfolio of 100 securities, a risk model and optimization engine can be employed to achieve optimal rebalancing by adjusting some of the constraints to reflect the portfolio manager's new objectives.

Exhibit 49-4 shows the largest trades suggested by the optimizer, in terms of market value. Not surprisingly, the largest sell recommendations are of financial companies. To replace them, the optimizer—using the risk model—recommends a larger position of Treasury and corporate bonds. (Corporates are required in order to keep the spread of the portfolio at the desired level.)

Interestingly, the rebalancing and extra constraints imposed on the optimization problem did not materially change the risk of the portfolio. Exhibit 49-5 shows that the total TEV of the portfolio actually decreased to 13.4 bp/month. This is largely due to an extra 13 positions added to the portfolio in the rebalanc-

EXHIBIT 49-4

Proposed Trading List

Buys

Identifier	**Description**
912828MZ	U.S. Treasury Notes
74913GAG	Qwest Corporation
03979GAL	Arden Realty INC

Sells

Identifier	**Description**
16132NAV	Charter One Bank FSB
FNA 08000	FNMA Conventional
0258M0BZ	American Express Credit

Source: POINT.

EXHIBIT 49-5

Rebalanced Portfolio and Benchmark Characteristics

	Total TEV (bp/month)	Duration (years)	Spread Duration (years)	Spread (bp)
Portfolio	13.4	5.31	5.06	153
Benchmark		5.02	4.92	55

Source: POINT.

ing (that now has 113 securities). These extra securities allowed the portfolio to reduce both its systematic and idiosyncratic risk.

Scenario Analysis

Scenario analysis is a popular tool both for risk management and portfolio construction. In this section, we illustrate a way to construct scenarios based on factor models. In this context, a portfolio manager expresses views on the returns of particular financial variables, indices, securities or risk factors and the scenario analysis tool (using the risk model) calculates their impact on the portfolio's (net) return.

Typically in this kind of scenario analysis, the views one has are only partial. This means one can have specific views on how particular macro variables, asset classes, or risk factors will behave, but it is unlikely to have views on all risk factors to which the portfolio under analysis is exposed. This is where risk models can be useful. At the heart of the linear factor models lies a set of risk factors and the covariance matrix between them. Under certain statistical assumptions, the covariance matrix can be used to "complete" specific partial views or scenarios and deliver a complete picture of the impact of the scenario in the return of the portfolio. Mechanically, what happens is the following. First, the manager translates the views into realizations of a subset of risk factors. Next the scenario is completed—using the risk model covariance matrix—to get the realizations of *all* risk factors. Finally, the portfolio's (net) loadings to all risk factors are used to get its (net) return under that scenario (by multiplying the loadings by the factor realizations under the scenario). This construction implies a set of assumptions that should be carefully understood. To begin with, it is assumed that the manager can represent or translate views as risk factor returns. So a view about the unemployment rate, which is typically not used as a risk factor,[14] cannot be used in this context. Also, to "complete" the scenario, we generally assume a stationary and normal multivariate distribution among all factors. Although these assumptions make this

14. Unemployment rate is not used as a factor in most short- and medium-term risk models.

analysis less appropriate for looking at extreme events or regime shifts, for instance, the analysis can be very useful in many circumstances.

As an example, consider using factor-based scenario analysis to compute the model-implied empirical durations of the original portfolio of a 100 securities (i.e., before rebalancing) analyzed in detail previously in this chapter. In particular, suppose the portfolio manager has the view that interest rates will fall by 25 bp over the next month. Exhibit 49-6 shows that under this scenario, the portfolio returns 116 bp, against the 111 bp of the benchmark. As expected given the longer duration, the portfolio outperforms the benchmark. Due to the other exposures present in the portfolio and benchmark and their average negative correlation with the curve factors—for instance, a 25-bp fall in rates under this setting implies a 5% increase in corporate spread levels—the model duration implied by the scenario for the portfolio is 4.64 (= 116/25), while the analytical duration is 5.44. The scenario shows a similar decrease in the benchmark's duration. The net model duration of the portfolio is only 0.22, almost half of its 0.42 net analytical duration.

Another characteristic imposed while constructing the portfolio was a targeted higher spread. The portfolio construction exercise resulted in an OAS for the portfolio of 206 bp against a spread level of 55 bp for the benchmark. The portfolio manager might be concerned with portfolio losses should spreads increase. To evaluate this risk, the portfolio manager can construct two scenarios. In the first scenario, credit-spreads widen by 20%, other spread risk factors move as implied by the credit-spread moves, but interest rates remain unchanged. In the second scenario, interest rates moves are implied by the credit-spread move. Exhibit 49-7 displays the results of the two scenarios. In the first scenario, the portfolio suffered significant losses of 0.84%. The benchmark which has a much lower spread, suffers lower losses of 0.64% and the net result is –20 bp of net return. This number is very different from a back of the envelope calculation that uses portfolio-level analytics to estimate the return. The calculation is much more intricate and takes into account the security level portfolio composition, as well as the implied moves of other sources of risk such as swap and mortgage spreads.

EXHIBIT 49-6

Scenario Analysis: Analytical and Model-Implied Durations

		Durations	
Universe	**Return Under Scenario (bp)**	**Scenario (Model-Implied)**	**Analytical**
Portfolio	116	4.64	5.44
Benchmark	111	4.44	5.02

Source: POINT.

EXHIBIT 49-7

Scenario Analysis: Corporate Spread Increase of 20%

	Restriction on YC Movement (Returns in bp)	
Universe	**No Change**	**Implied by Spread Change**
Portfolio	–84	49
Benchmark	–64	58
Net	–20	–9

Source: POINT.

Things look better in the second scenario, where the net return of the portfolio versus the benchmark is only –9 bp. In fact, in this case both the portfolio and the benchmark exhibit positive returns of 0.49% and 0.58%, respectively, illustrating that this is a very different type of scenario. Indeed, the large spread widening implies a 25-bp fall in interest rates, which is sufficient to overcome the losses from the spread widening for both the portfolio and the benchmark. Since the portfolio has interest rate duration that is 0.42 years longer than the benchmark, it enjoys a relative improvement in net return of about –0.42 × –25 bp = +10.5 bp that partially offsets the losses from the widening of credit-spreads.

These very simple examples illustrate how one can look at reasonable scenarios to study the behavior of the portfolio or the benchmark under different environments. This type of factor-based scenario analysis can significantly increase the intuition the portfolio manager has regarding the results from the risk model.

KEY POINTS

- Risk models describe the different imbalances of a portfolio using a common language. The imbalances are combined into a consistent and coherent analysis reported by the risk model.
- Risk models provide important insights regarding the different tradeoffs existing in the portfolio. They provide guidance regarding how to balance them.
- The fundamental systematic risk of all fixed income securities is interest rate and term structure risk. This is captured by factors representing risk-free rates and swap spreads of various maturities.
- Excess (of interest rates) systematic risk is captured by factors specific to each asset class. The most important components of such risk are

credit risk and prepayment risk. Other risks that can be important are volatility, liquidity, inflation, and tax policy.

- Idiosyncratic risk is diversified away in large portfolios and indices, but can become a very significant component of the total risk in small portfolios. The correlation of idiosyncratic risk of securities of the same issuer must be modeled very carefully.
- A good risk model provides detailed information about the exposures of a complex portfolio and can be a valuable tool for portfolio construction and management. It can help managers construct portfolios tracking a particular benchmark, express views subject to a given risk budget, and rebalance a portfolio while avoiding excessive transaction cost. Further, by identifying the exposures in which the portfolio has the highest risk sensitivity, it can help a portfolio manager reduce (or increase) risk in the most effective way.

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CHAPTER
FIFTY

ANALYZING RISK FROM MULTIFACTOR FIXED INCOME MODELS

Barclays

Portfolio managers constantly monitor their exposures, typically net of a benchmark, and routinely ask themselves: What is the portfolio interest-rate duration? How risky is the overexposure to Treasuries? How does it relate to the exposure to credit? What is the exposure to specific issuers? Knowing portfolio holdings and exposures is not enough for portfolio managers, they increasingly rely on quantitative techniques to translate this information into a standard risk language, which allows comparisons across diverse portfolios or situations. Risk models present a consistent view of the portfolio, its exposures, and how they relate to each other. They quantify the risk of each exposure and its contribution to the overall risk of the portfolio.

Chapter 49 covered linear factor models for fixed income portfolios. In this chapter we detail an application of the models for risk forecasting that can be used to monitor risk and gain insightful information regarding the exposures of a portfolio.

APPROACHES USED TO ANALYZE RISK

Throughout this chapter we analyze the risk of a particular bond portfolio, going through the various aspects of risk typically looked at by a manager. We follow a portfolio manager. We assume the following:

- The Bloomberg Barclays US Aggregate Index is the portfolio manager's benchmark.
- The portfolio manager believes interest rates are coming down. To capitalize on this view, the manager seeks to create a portfolio with

This chapter was coauthored by Anthony Lazanas, António Baldaque da Silva, Radu C. Gabudean, and Arne D. Staal when they were employees of Barclays.

interest-rate duration longer than the interest-rate duration of the benchmark. A portfolio with interest-rate duration that exceeds that of the benchmark is referred to as being "long duration" and it outperforms the benchmark when interest rates fall and all other market factors remain unchanged.

- The manager seeks a portfolio with higher yield than the one of the benchmark. Such a portfolio creates superior carry return (also known as *income*) relative to the benchmark but is subject to increased risks. The total yield of a portfolio can be decomposed into a risk-free yield and a spread over the risk-free yield. Because the portfolio is expected to contain securities with longer maturities to satisfy the long duration target, it will earn a risk-free yield that is different from the risk-free yield of the benchmark (higher most of the time since typically interest-rate curves are upward sloping). To further enhance the portfolio yield, the manager wants to target a portfolio spread that is also higher than the spread of the benchmark. Higher spread typically exposes the portfolio to liquidity and issuer default risks. If defaults occur, or if the portfolio manager is forced to sell securities at a significant discount because of lack of liquidity, then the incurred losses may cancel out the higher yield advantage and could lead to portfolio underperformance relative to the benchmark. The manager must be comfortable that such risks are sufficiently compensated by the higher carry return associated with higher portfolio spread.
- The portfolio manager is required to maintain the difference between the returns of the portfolio and the benchmark at around 20 basis points, on a monthly basis. Therefore, the portfolio manager must calibrate the long duration and high-yield portfolio positions in order to abide by this constraint.

To summarize, the portfolio manager has the mandate to track the benchmark, but is allowed to deviate from it up to a point in order to express views that may lead to superior returns. As mentioned in Chapter 49, a portfolio manager with such a mandate is called an *enhanced indexer*. The amount of deviation allowed is called the *risk budget* (20 basis points in our example) and can be quantified using a risk model. The risk model produces an estimate of the volatility of the difference between the portfolio and the benchmark returns, called *tracking error volatility* (TEV).[1] TEV gives the forecasted magnitude of the typical tracking error. The manager should keep the portfolio's TEV at a level equal to or less than that specified in risk budget. The final portfolio, which we will analyze, contains 100 securities and is consistent with the manager's views and risk budget.

1. In this chapter we refer to TEV, risk, and "the standard deviation of the portfolio net returns" interchangeably.

Market Structure and Exposure Contributions

The portfolio manager starts the analysis by comparing the portfolio holdings with the holdings of the benchmark. Exhibit 50-1 shows that the portfolio composition has several important mismatches relative to the benchmark. The portfolio is underweighted in Treasuries and government-related securities by a combined 9.0%. This is compensated with a combined overweight of 11.2% in Corporates, especially in the Industrials and Financials sectors. These sectors have almost double the weight in the portfolio versus the benchmark. Other mismatches include an underweight in agency mortgage-backed securities (agency MBS) by 3.8% and an overweight in commercial mortgage-backed securities (CMBS) by 1.9%. Notice that the quest for yield pushed the manager out of the relatively safe (in terms of default risk) Treasury and agency MBS sectors and into more risky corporate and CMBS sectors.

If the manager were focusing on equities instead of fixed income, this kind of information—for example, applied to the different industries or sectors of the portfolio—would be of paramount importance for portfolio risk analysis. For a fixed income portfolio, this is not the case. Although important, this analysis tells us little about the true active exposures of a fixed income portfolio, owing to the diverse nature of fixed income securities. What if the Treasuries in the portfolio have significantly longer duration than those in the benchmark—would we be

EXHIBIT 50-1

Market Weights for Portfolio and Benchmark

Asset Class	Portfolio	Benchmark	Difference
Total	**100.0**	**100.0**	**0.0**
Treasury & Govt-Related	**36.8**	**45.8**	**–9.0**
Treasury	30.8	33.8	–3.0
Government-Related	6.0	12.0	–6.0
Corporates	**29.9**	**18.7**	**11.2**
Industrials	17.2	9.9	7.3
Utilities	2.3	2.1	0.2
Financials	10.4	6.7	3.7
Securitized	**33.3**	**35.5**	**–2.2**
Agency MBS	28.9	32.7	–3.8
ABS	0.0	0.3	–0.3
CMBS	4.4	2.5	1.9

Source: POINT

really "short" in this asset class? What if the spreads from CMBS in the portfolio are much smaller than those in the benchmark—is the weight mismatch that important?

To answer these kinds of questions, we turn to another typical dimension of analysis: the portfolio exposure to major sources of risk, measured with analytics such as interest-rate duration. Exposures to other sources of risk typically monitored include spread duration, convexity, spread level, and Vega (if the portfolio has many securities with optionality, such as mortgages or callable bonds). Their associated risks have been discussed in Chapter 49.

In Exhibit 50-2 we present these analytics at the aggregate level for the portfolio, benchmark, and the difference between the two. We can see that

- The portfolio is long interest-rate duration (0.38 years), reflecting the forecast the manager has regarding the direction of interest rate moves.
- In terms of spread duration, the mismatch is smaller (0.29 years). The manager wants to minimize the exposure to spread changes as much as possible given the manager has no view on this source of risk. However, the spread duration mismatch cannot be zero because spread risk is related to other risks that she does have a view on, such as rates.
- The portfolio and the benchmark have convexity with opposite signs (0.14 for the portfolio versus –0.04 for the benchmark). This is attributable to the smaller weight MBS have in the portfolio.
- The portfolio also has a higher negative Vega, but the number is reasonably small for both universes.
- The portfolio has significantly higher spread (148 bp) than the benchmark. This mismatch is consistent with the manager's goal of having a higher yield in her portfolio than the benchmark.

EXHIBIT 50-2

Aggregate Analytics

Analytics	Portfolio	Benchmark	Difference
Interest-Rate Duration	5.36	4.98	0.38
Spread Duration	5.20	4.91	0.29
Convexity	0.14	–0.04	0.18
Vega	–0.03	–0.02	–0.01
Spread	204	56	148

Source: POINT

We can combine the analysis in Exhibits 50-1 and 50-2 to create a more detailed picture of where the different risk exposures are coming from. Exhibit 50-3 shows one such example for the portfolio interest-rate duration. The majority of the mismatch in interest-rate duration contribution (market weighted duration exposures) comes from the Treasury component of the portfolio (0.60 years). Interestingly, even though the portfolio is short in Treasuries, it is actually long in terms of interest-rate duration for that asset class. This means that a Treasury sell-off, meaning an increase in rates, would impact the portfolio more negatively than the benchmark. Because the portfolio is net short Treasuries, this result must mean that the Treasury portfolio is longer in interest-rate duration than the benchmark's Treasury component. Conversely, Corporates have negative contribution to net interest-rate duration, even though they are over-weighted in terms of market value. This means that on average the corporate bonds in the portfolio are significantly shorter in interest-rate duration than those in the benchmark. Note that this kind of analysis could be applied to other analytics of interest, such as to spread or spread duration.

Adding Volatility and Correlations into the Analysis

The analysis above gives the manager some basic understanding of the portfolio exposures to different kinds of risk. However, it is still hard to understand how the portfolio manager can compare the level of risk across these different exposures. What is more risky, the long interest-rate duration exposure of 0.38 years, or the extra spread of 148 bp? How can the portfolio manager quantify how serious is the portfolio's Vega mismatch? Specifically, the risk of the portfolio is a function of the exposures to the risk factors, but also of how "risky" each of the factors is.

To enhance the analysis we must bring factor volatilities into the picture. Exhibit 50-4 shows the outcome of this addition to our example. In particular, it

EXHIBIT 50-3

Duration Contribution per Asset Class

Interest-Rate Duration Contribution	Portfolio	Benchmark	Difference
Total	**5.36**	**4.98**	**0.38**
Treasury	2.38	1.78	0.60
Government-Related	0.47	0.50	–0.03
Corporate	1.08	1.23	–0.15
Securitized	1.43	1.47	–0.04

Source: POINT

EXHIBIT 50-4

Isolated Risk per Category

Risk Factors Categories	Risk
Curve	11.3
Volatility	0.2
Spread Government-Related	3.2
Spread Corporate	6.9
Spread Securitized	2.9

Source: POINT

displays the risk of the different exposures of the portfolio in isolation (that is, if the only active imbalances were those from that particular set of risk factors). For example, this exhibit shows that if the only active weight in the portfolio were the mismatch in the yield-curve exposures, the risk of the portfolio would be 11.3 bp/month. By adding volatilities into the analysis, the manager can now quantify that the mismatch of 0.38 years in interest-rate duration "costs" the portfolio 11.3 bp/month of extra volatility, when taken in isolation, and therefore refer to this as the Isolated TEV.[2] Remember that the portfolio's total risk budget is 20 bp/month. Similarly, if the only mismatch were the exposure to corporate spreads, the risk of the portfolio would be 6.9 bp/month. We also see that both the Government-Related and Securitized sectors have nontrivial risk. Interestingly, this is inconsistent with the small interest-rate duration imbalance reported in Exhibit 50-3. Therefore, these sectors must have other sources of risk that are important. By bringing volatilities into the analysis, we can now compare and quantify the impact of each of the portfolio imbalances.

For future reference, let us compute the volatility of the portfolio assuming that all these sources of risk are independent (e.g., correlations are zero). This number is 13.9 bp/month.[3] Of course, this scenario is unrealistic, as these sources of risk are not independent. Also, this analysis does not allow us to understand the interplay between the different imbalances. For instance, we know that the isolated risk associated with the curve is 11.3 bp/month. But this value can be achieved both by being long or short interest-rate duration. So the isolated number does not allow us to understand the impact of the curve imbalance to the total risk of the portfolio. The net impact certainly depends on the sign of the

2. For an explanation of Isolated TEV, see Chapter 49.

3. We arrive at this number by taking the square root of the sum of squares of all the numbers in the table: $13.9 = \sqrt{(11.32{+}0.22{+}3.32{+}6.92{+}2.92)}$.

EXHIBIT 50-5

Contributions to Total Risk per Category

Risk Factors Categories	Risk
Total	**10.4**
Curve	6.9
Volatility	0.7
Spread Government-Related	0.0
Spread Corporate	0.0
Spread Securitized	2.9

Source: POINT

imbalance. For instance, a long exposure in curve may be diversified away by a long exposure in credit (due to negative correlation between rates and credit-spreads). In contrast, an opposite (short) curve exposure would add to the risk of the long exposure in credit. The risk is clearly smaller in the first case.

To alleviate these shortcomings, we bring correlations into the picture. They allow us to understand the net impact of the various exposures to the portfolio's total risk and to detect potential sources of diversification among the portfolio imbalances. Exhibit 50-5 reports the contribution of each of the risk factor groups to the total risk, once all correlations are taken into account. We refer to this quantity as the contribution to tracking error volatility, or CTEV.[4] The total risk (10.4 bp/month) is smaller than the zero-correlation risk calculated before (13.9 bp/month) due to generally negative correlations between the curve and the spread factors. The exhibit also allows us to isolate the main contributors to risk as being curve (6.9 bp/month) and credit-spreads (2.9 bp/month), in line with the evidence from the earlier isolated analysis. However, the risk of the Government-Related and Securitized spreads is significantly smaller once correlations are taken into account.

The difference in analysis between the isolated risk reported in Exhibit 50-4 and the contributions to total risk in Exhibit 50-5 deserves further discussion. For simplicity, assume there are only two sources of risk in the portfolio—yield-curve (Y) and spreads (S). The total systematic variance of the portfolio (P) can be illustrated as follows:

$$\begin{aligned} VAR(P) &= VAR(Y + S) = VAR(Y) + VAR(S) + 2COV(Y, S) \\ &= Y \times Y + S \times S + 2(Y \times S) \end{aligned}$$

4. For a further discussion of this risk measure, see Chapter 49.

where we use the product to represent variances and covariances. Another way to represent this summation is using the following matrix:

$$\begin{bmatrix} Y \times Y & Y \times S \\ Y \times S & S \times S \end{bmatrix}$$

The sum of the four elements in the table is the variance of the portfolio. The isolated risk (in standard deviation units) reported in Exhibit 50-4 is the square root of the diagonal terms. So the isolated risk due to spreads is represented as:

$$Risk_{Spreads}^{Isolated} = \sqrt{S \times S}$$

It would be a function of the exposure to all spread factors, the volatilities of all these factors and the correlations among them.

The contribution to total risk reported in Exhibit 50-5 is:

$$Risk_{Spreads}^{Contribution} = [Y \times S + S \times S] / \sqrt{VAR(P)}$$

that is, from the matrix above, we sum all elements in the row of interest (row 1 for Y, row 2 for S), and normalize it by the standard deviation of the portfolio. This normalization (1) takes into account correlations and (2) ensures that the contributions to risk of all factors add up to the total risk of the portfolio given by[5]

$$Risk_{Curve}^{Contribution} + Risk_{Spreads}^{Contribution} = \sqrt{VAR(P)} = STD(P)$$

The difference between isolated and contribution to risk, due to the interplay of the two sources ($2(Y \times S)$), is allocated equally to each source of risk. In cases when one type of risk on isolated basis is much smaller in magnitude than the other, the ($Y \times S$) term may have an oversized effect. To summarize, isolated risk takes into account only the individual behavior of each source of risk, while the contribution to correlated risk looks at the joint behavior of various risk sources.

The generic analysis we just performed constitutes the first step in the description of the risk associated with a portfolio. The analysis refers to categories of risk factors (such as "curve" or "spreads"). However, a factor-based risk model allows for a significantly deeper analysis of the imbalances the portfolio may have. Each of the risk categories referred to above can be described with a rich set of detailed risk factors. Typically in a fixed income factor model, each asset class has a specific set of risk factors, in addition to the potential set of factors common to all (e.g., curve factors). These asset-specific risk factors are designed to capture the particular sources of risk the asset class is exposed to. In the following section, we go through a risk report built in such a way,

5. In this example, we focus only on the systematic component of risk. Later, the normalization is with respect to the total risk of the portfolio, including idiosyncratic risk.

emphasizing risk factors that are common or particular to the different asset classes. Along the way, we demonstrate how the report offers insights from both a risk management and a portfolio construction perspective.

A Detailed Risk Report

In this section, we continue the analysis of the portfolio introduced previously, a 100-bond portfolio benchmarked against the Bloomberg Barclays US Aggregate Index. The report package we present was generated using POINT, a cross-asset portfolio analysis and construction tool the offered by Barclays, and gives a detailed picture of the risk embedded in the portfolio.[6] The package is divided into four types of reports: summary reports, factor exposure reports, issue/issuer level reports, and scenario analysis reports. Some of the information we reviewed earlier can be thought of as summary reports.

Summary Report

Exhibit 50-6 illustrates a typical risk summary statistics report. It shows that the portfolio has 100 positions, but from only 48 issuers. This number implies limited ability to diversify idiosyncratic risk, as we will see below. The report confirms that the portfolio is long interest-rate duration (5.36 years for the portfolio versus 4.98 years for the benchmark) and has higher yield (4.55% for the portfolio versus 2.97% for the benchmark) and coupon (5.07% for the portfolio versus 4.24% for the benchmark).

The exhibit also reports that the total volatility of the portfolio (127.7 bp/month) is higher than that of the benchmark (121.2 bp/month). This is not surprising: longer interest-rate duration, higher spread, and less diversification all tend to increase the volatility of a portfolio. Because of its higher volatility, we refer to the portfolio as riskier than the benchmark. Looking into the different components of the portfolio volatility, the exhibit reports that the idiosyncratic volatility of the portfolio is significantly smaller than that of the systematic one (10.5 bp/month versus 127.3 bp/month), which is what we expect from a medium-sized portfolio of investment-grade bonds.

Given the fact that the systematic and idiosyncratic components of risk are independent by construction, we can calculate the total volatility of the portfolio as

$$\text{TEV}_{Portfolio} = \sqrt{127.3^2 + 10.5^2} = 127.7$$

6. The model was available through POINT, a portfolio management tool that at the time this chapter was written was an offering by Barclays. It is a multicurrency cross-asset model that covers many different asset classes across the fixed income and equity markets, including derivatives in these markets. At the heart of the model is a covariance matrix of risk factors. The model has several hundreds of factors, many specific to a particular asset class. The asset class models are periodically reviewed. Structure is imposed to increase the robustness of the estimation of such large covariance matrix. The model is estimated from historical data. It is calibrated using extensive security-level historical data and is updated on a monthly basis.

There are two interesting observations regarding this number:

1. The total volatility is smaller than the sum of the volatilities of the two components.
2. The total volatility is very close to the systematic one.

The first observation is the diversification benefit that comes from combining independent sources of risk. The second observation may suggest that the idiosyncratic risk is irrelevant. That is an erroneous and dangerous conclusion, as we will see later. In particular, when managing against a benchmark, the focus should be on the net exposures and risk, not on their absolute counterparts.

In Exhibit 50-6, the total TEV is reported as 14.2 bp/month. This means that the model forecasts the portfolio return to be typically around 14 bp/month higher than or lower than the return of the benchmark. This number is in line with the risk budget of the manager. The exhibit also reports idiosyncratic TEV of 9.6 bp/month, which is close in magnitude to the systematic TEV (10.4). Therefore, when measured against the benchmark, half of the risk is idiosyncratic, contrary to the conclusion one could draw by looking only at the portfolio's volatility. The TEV of the portfolio is also greater than the difference between the volatilities of the portfolio and benchmark. It would be equal to the difference only if the portfolio and benchmark were perfectly correlated.

Finally, the report shows that the portfolio has a beta of 1.05 to the benchmark. This statistic measures the co-movement between the portfolio and the benchmark. We can read it as follows: the model forecasts that a movement of 100 bp in the benchmark leads to a movement of 105 bp in the portfolio in the same direction. Note that a beta of less than one does not mean that the portfolio is less risky than the benchmark; it just means that the portfolio is less sensitive to movements in the benchmark. To see this more clearly, consider the limit case when the portfolio and benchmark are uncorrelated. The portfolio beta in this case is zero but obviously that does not mean that the portfolio has zero risk. Finally, one can compute many different "betas" for the portfolio or subcomponents of it.[7] A simple and widely used one is the "interest-rate duration beta," given by the ratio of the portfolio interest-rate duration to that of the benchmark. In our case this ratio is 5.36/4.98 = 1.08. This implies that the portfolio has a return from yield-curve movements around 1.08 times larger than that of the benchmark. This beta is larger than the portfolio beta (1.05), meaning that net exposures to other factors (e.g., spreads) "hedge" the portfolio's net curve risk.

This first summary report (Exhibit 50-6) allows the manager to get a glimpse into the risk of the portfolio. However, the manager wants to know in more detail what the sources of this risk are. Risk can be broken down along various dimensions, two of which we briefly looked at above: security groups (asset classes) and risk factors. The next two summary reports present the detailed risk breakdown along these two dimensions. In the first, risk is partitioned across

7. For example, see Exhibit 50-13 later in this chapter.

EXHIBIT 50-6

Summary Statistics Report

	Portfolio	Benchmark	
A. Parameter			
Positions	100	7,999	
Issuers	48	834	
Currencies	1	1	
Market Value ($MM)	100	15,133	
Notional ($MM)	97	14,260	
B. Analytics			**Difference**
Coupon	5.07	4.24	0.83
Average Life	7.71	7.04	0.67
Yield to Worst	4.55	2.97	1.59
Spread	204	56	148
Interest-Rate Duration	5.36	4.98	0.38
Vega	–0.03	–0.03	0.00
Spread Duration	5.20	4.91	0.29
Convexity	0.14	–0.04	0.18
C. Volatility			**TEV**
Systematic	127.3	121.1	10.4
Idiosyncratic	10.5	4.7	9.6
Total	127.7	121.2	14.2
D. Portfolio Beta			1.05

Source: POINT

different groups of risk factors. In the second, the partition is across groups of securities.

Exhibit 50-7 shows four different statistics associated with each set of risk factors. The first two were partly explored in Exhibits 50-4 and Exhibit 50-5.[8] The

8. Note that the contribution numbers are different than those from Exhibit 50-5, because there we were looking at the contribution to systematic—not total—risk.

EXHIBIT 50-7

Factor Partition—Risk Analysis

Risk Factor Group	Isolated TEV(bp)	Contribution to TEV (CTEV)(bp)	Liquidation Effect on TEV(bp)	TEV Elasticity (%)
Total	**14.2**	**14.2**	**–14.2**	**100.0**
Systematic Risk	10.4	7.6	–4.5	53.8
Curve	11.3	5.6	–1.1	39.2
Volatility	0.2	0.0	0.0	0.1
Government-Related Spreads	3.2	0.0	0.4	0.1
Corporate Spreads	6.9	2.1	–0.5	15.1
Securitized Spreads	2.9	–0.1	0.4	–0.7
Idiosyncratic Risk	9.6	6.6	–3.8	46.2

Source: POINT

exhibit reports in the first column the isolated TEV, that is, the risk associated with that particular set of risk factors only. We see that in an isolated analysis, the systematic risk and idiosyncratic risk are balanced at 10.4 and 9.6, respectively.

The report also shows the isolated risk associated with the major components of systematic risk. As discussed before, all components of systematic risk have nontrivial isolated risk, but only curve and credit-spreads are relevant when we look into the CTEV. If we look across factors, the major contributors are idiosyncratic risk, curve, and credit-spreads. Other systematic exposures are relatively small.

Another look into the correlation comes when we analyze the liquidation effect reported in Exhibit 50-7. This number represents the change in TEV when we completely hedge that particular group of risk factors. For instance, if we hedge the curve component of the portfolio, the TEV drops by 1.1 bp/month—from 14.1 to 13.0. One may think that the drop is rather small given the magnitude of isolated risk the curve represents. However, if we hedge the curve, we also eliminate the risk reduction effect of the negative correlation between curve and spreads. Therefore, there is a more limited impact when hedging the curve risk than what is expected based on previous numbers. In fact, for this portfolio we see that hedging any particular set of risk factors has a limited effect on the overall risk.

The TEV elasticity reported in the last column gives another perspective into how the TEV changes when risk loadings change. Specifically, it tells the manager what the percentage impact on TEV is if the exposure to that particular set of factors is changed. For example, if the manager reduces the exposure to

EXHIBIT 50-8

Security Partition—Risk Analysis I

		Contribution to TEV		
Security Partition Bucket	**NMW (%)**	**Systematic**	**Idiosyncratic**	**Total**
Total	**0.00**	**7.6**	**6.6**	**14.2**
Treasuries	–3.00	7.7	0.1	**7.8**
Government Agencies	–4.81	1.5	0.3	**1.8**
Government Nonagencies	–1.23	–1.3	0.1	**–1.2**
Corporates	11.18	–0.4	4.6	**4.3**
Agency MBS	–3.82	0.3	0.8	**1.1**
ABS	–0.27	0.0	0.0	**0.0**
CMBS	1.96	–0.2	0.6	**0.4**

Source: POINT

corporate spreads by 10%, the TEV would decrease by 10% × 15.1% = 1.51% and therefore it would become 14.2 bp × (1 – 1.51%) = 14.0 bp.

We perform a similar analysis in Exhibit 50-8, but apply it to a security partition. That is, instead of looking at individual sources of risk (e.g., curve) across all securities, we now aggregate all sources of risk within a security and report analytics for different groups of these securities (e.g., subportfolios). Exhibit 50-8 reports results when securities are grouped by asset class. It shows that the majority of risk (7.8 bp/month) comes from the Treasury component of the portfolio. Most of this risk is systematic, which is what we expect given the typically low idiosyncratic risk of the sector and the significant interest-rate duration mismatch. Corporates are also a major contributor to the portfolio's risk, mostly coming from idiosyncratic risk. This reflects the portfolio's large net market weight (NMW) to this sector. The lack of systematic risk contribution by the corporate sector comes from the hedging effect of spreads to the overall curve risk in the portfolio. Note that because the analysis is at the portfolio level, the interplay between net curve risk of Treasuries and spread risk of corporates is partly reflected in the total risk attributed to corporates. The same story applies to other spread sectors, all of which contribute little to systematic risk. Both agency MBS and CMBS contribute non-trivially to idiosyncratic risk. Since the portfolio manager's goal is the replication of a very large benchmark with only 100 positions, the manager has to be comfortable with the issuers selected. This report highlights the significant name risk to which the portfolio is exposed.

Exhibit 50-9 completes the analysis, reporting other important risk statistics about the different asset classes within the portfolio. These statistics mimic the analysis done in terms of risk factor partitions in Exhibit 50-7, so we will not repeat their definitions and focus on the results. Looking at isolated TEV, we see that Corporates have risk of 16.7 bp/month, which is higher than the total risk of the portfolio. This means that the exposures to the other asset classes, on average, hedge the Corporates portfolio. The same can be said about Treasuries. We can even take the analysis a bit further: the next column shows through the liquidation effect that if we eliminate the imbalance the portfolio has on Corporates, we actually would increase the total risk of the portfolio by 4.6 bp/month. In short, we would be eliminating the hedge this asset class provides to the global portfolio, therefore increasing its risk. Because a similar analysis holds for Treasuries, we can conclude that the exposures to Treasuries and Corporates were built to balance each other in the portfolio. Finally, Exhibit 50-9 also reports the TEV elasticity of the different components of the portfolio. This number represents how much a relative change in NMW translates into a relative change on TEV, so we need to read the numbers with an opposite sign if the NMW is negative. In particular, if we decrease the weight of the agency portfolio (making it more negative, or "more short") by 10%, we would actually increase the TEV by 10% × 12.2 % = 1.22% making it equal to 14.2 bp × (1 + 1.22%) = 14.4 bp. This result shows that the position in agencies provides hedging "on average," but further increasing the exposure to this sector would actually increase the risk of the portfolio. In other words, the hedging went beyond its optimal value.

EXHIBIT 50-9

Security Partition—Risk Analysis II

Security Partition Bucket	Isolated TEV	Liquidation Effect on TEV	TEV Elasticity (%)
Total	**14.2**	**–14.2**	**100.0**
Treasuries	18.8	4.1	53.2
Government Agencies	5.1	–0.9	12.2
Government Nonagencies	3.4	1.4	–7.5
Corporates	16.8	4.6	32.1
Agency MBS	4.3	–0.5	7.6
ABS	0.6	0.1	–0.3
CMBS	3.5	0.0	2.7

Source: POINT

This set of summary reports gives us a clear picture of the major sources of risk and how they relate to each other. In what follows, we focus on the more detailed analysis of the individual systematic sources of risk.

Factor Exposure Reports

At the heart of a multifactor risk model is the definition of the set of systematic factors that drive risk across the portfolio. As described in Chapter 49, there are many different types of risk sources a fixed income portfolio is exposed to. In what follows we focus on the three major types: curve, credit, and prepayment risk. To illustrate credit and prepayment risk, we use the Corporates component and the agency MBS component of the portfolio, respectively. Moreover, to keep the example simple, we show only a partial view of all relevant factors for these sources of risk.

Curve Risk ***Exhibit*** 50-10 details the risk in the portfolio associated with the U.S. Treasury curve. It starts by describing all risk factors the portfolio or benchmark load on. In particular, we use six key-rate (KR) points on the curve plus the convexity term as the risk factors associated with U.S. Treasury risk. They are described in the first column of panel A in the exhibit and measure the risk associated with moves of that particular point on the curve. Exposure to these risk factors is measured by the key-rate durations (KRD) for each of the six points. The description of the loading is in the exhibit's second column, while its value for the portfolio, benchmark, and the difference is displayed in the next columns. Key-rate durations are also called partial durations, as they add up to the interest-rate duration of the portfolio. For instance, for the portfolio, the sum of the key-rate durations is 0.13 + 0.47 + 1.74 + 0.93 + 1.00 + 1.09 = 5.36, the total interest-rate duration of the portfolio. Their loadings are constructed by aggregating partial durations across all the securities.

Looking at the exhibit, we see significant mismatches in the duration profiles between the portfolio and its benchmark, namely at the 10-year and 30-year points on the curve. Specifically, we are short 0.44 years at the 10-year point and long 0.41 years at the 30-year point. Moreover, we are also significantly long at the 5-year and 20-year points. How serious is this mismatch? Looking at the factor volatility column, it can be seen that these points on the curve have been fairly volatile at around 30 bp/month. If we interpret this volatility as a typical move, the first two columns of panel B show us the potential impact of such a movement in the return of the portfolio, net of benchmark. For instance, a typical move up (+32.2 bp/month) in the 10-year point of the Treasury curve, when considered in isolation, will deliver a positive net return of +14.2 bp.[9] In isolation, the positive

9. This number is obtained by simply multiplying the net exposure by the factor volatility. The sign of the move depends on the interpretation of the factor. In the case of the yield-curve movements, we know that $R = -KRD \times \Delta KR$, where KRD is the duration associated with the KR point. In our example $-(-0.44) \times 32.2$ bp = +14.2 bp.

EXHIBIT 50-10

Treasury Curve Risk

A. Exposures and Factor Volatility

Factor Name	Units	Exposure: Portfolio	Exposure: Benchmark	Exposure: Net	Factor Volatility
USD 6M key rate	KRD (Yr)	0.13	0.12	0.01	23.4
USD 2Y key rate	KRD (Yr)	0.47	0.67	–0.19	22.6
USD 5Y key rate	KRD (Yr)	1.74	1.40	0.34	30.9
USD 10Y key rate	KRD (Yr)	0.93	1.37	–0.44	32.2
USD 20Y key rate	KRD (Yr)	1.00	0.76	0.24	29.1
USD 30Y key rate	KRD (Yr)	1.09	0.67	0.41	28.3
USD Convexity	OAC	0.14	–0.04	0.18	4.9

B. Other Risk Statistics

Factor Name	Return Impact of a Typical Move (%): Isolated	Return Impact of a Typical Move (%): Correlated	Marginal CTEV	TEV Elasticity
USD 6M key rate	–0.2	–2.0	3.2	0.2
USD 2Y key rate	4.4	–2.8	4.5	–6.0
USD 5Y key rate	–10.6	–3.9	8.4	20.0
USD 10Y key rate	14.2	–5.5	12.4	–37.9
USD 20Y key rate	–7.1	–6.1	12.3	20.9
USD 30Y key rate	–11.7	–6.5	12.8	36.7
USD Convexity	0.9	1.2	0.4	0.5

Source: POINT

impact is expected because we are short that point of the curve. More interesting may be the correlated number on the exhibit. It states the return impact but in a correlated fashion. In the scenario under analysis, a movement in the 10-year point will almost surely involve a movement of the neighboring points on the curve. So contrary to the positive isolated effect documented above, the correlated impact of a change up in the 10-year point is actually negative, at –5.5 bp. This result is in line with the overall positive interest-rate duration exposure the portfolio has: general (correlated) movements up in the curve have a negative impact on the portfolio's performance.[10] As another expression of the high correlation among curve points, we can see that correlated changes on various points on the curve have a similar impact on the final portfolio, even though their associated exposures vary greatly. Finally, and broadly speaking, the ratio of the correlated impact to the factor volatility gives us the model-implied partial empirical interest-rate duration of the portfolio. For instance, if we focus on the 10-year point, we get 5.5/32.2 = 0.17. This smaller empirical interest-rate duration is typical in portfolios with spread exposure. This spread exposure tends to empirically hedge some of the curve exposure, given the negative correlation between these two sources of risk. In addition, Exhibit 50-10 shows the risk associated with convexity. We can see that the portfolio is long convexity while the benchmark is short, so higher order changes in the yield-curve have an opposite impact on the portfolio than on the benchmark.

There are many other statistics of interest one can analyze regarding the Treasury curve risk of the portfolio. The portfolio manager may ask questions such as: If I want to reduce the risk of my portfolio by manipulating my Treasury curve exposure, what could I change? What is the most effective move? By how much would my risk actually change? The statistics reported in columns "Marginal Contribution to TEV" and "TEV Elasticity (%)" of panel B are typically used to answer these questions. Regarding the marginal contributions, the 30-year point has the largest value, showing us that an increase (reduction) of one unit of exposure (in this case one year of duration) to the 30-year point leads to an increase (reduction) of 12.8 bp in the TEV.[11] In other words, if we want to reduce risk by manipulating the exposure to the yield-curve, the 30-year point seems to present the fastest track. In addition, the exhibit shows that all Treasury risk factors are associated with positive marginal contributions. This means that an increase in the exposure to any of these factors increases the risk (TEV) of the portfolio. This conclusion holds even for factors for which we have negative exposure (e.g., the 10-year key-rate) because increasing exposure to it means decreasing the negative exposure. To

10. This reversal is clearly related to the fact that the 10-year point on the curve is usually highly correlated to the 5-, 20-, and 30-year ones. In our case, our short position on the 10-year point is more than compensated by the positive exposure to the other points in the curve. Netting out, the positive exposure effect (long duration) dominates when all changes are taken in a correlated fashion.

11. The marginal contribution is the derivative of the TEV with respect to the loading of each factor, so its interpretation holds only for small moves. Therefore, a more realistic reading may be that if we reduce the exposure to the 30-year by 0.1 years, the TEV would be reduced by around 1.3 bp.

put it differently, the result is a consequence of the portfolio's overall long interest-rate duration exposure. Adding more duration exposure, regardless of the specific point where the manager does it, will result in an increase in portfolio risk.[12] This result holds because we take into consideration the correlations between the different points in the Treasury curve.

Exhibit 50-10 also reports the TEV elasticity of each of the risk factors, a concept introduced earlier. The interpretation is similar to the marginal contribution, but with normalized changes (percentage changes). This normalization makes the numbers more comparable across risk factors of very different nature. It is also useful when considering leveraging the entire portfolio proportionally. In our case, if we increase the exposure to the 10-year key-rate point by 10%, from –0.44 to –0.484 (effectively reducing the long interest-rate duration exposure), the TEV would be reduced by 3.79% (from 14.2 to 13.7 bp/month).

We now turn the analysis to the other component of the curve risk described above: the risk embedded into the portfolio exposure to swap spreads, that is, the differences between the swap and Treasury curves. Many securities trade against the swap curve, making it the natural choice as the base risk curve for those markets. To unify the analysis with markets that use Treasuries as the base curve, we break the swap curve into the Treasury curve (analyzed in Exhibit 50-10) and excess over the Treasury—the swap spread.[13]

All the securities that typically trade against the swap curve (e.g., corporates and securitized bonds) are exposed, in our methodology, to both Treasury and swap spread (SS) risk. The analysis of the latter follows very closely that of the Treasury curve, so we only highlight the major risk characteristics of the portfolio along this dimension. Exhibit 50-11 shows that in general the exposure to swap spreads is smaller than of the exposure to the Treasury curve. Remember that Treasuries do not load on this set of risk factors, so the market-weighted exposures are consequently smaller. Comparing the swap spread volatilities with those from the Treasury curve (see Exhibit 50-10), we can observe significant differences. Looking at the profile of factor volatilities, one can see that its term structure of volatilities is U-shaped, with the short-end being quite volatile and the 5-year point having the lowest volatility. This is typically the case during periods when liquidity risk is high. Regarding net exposures, the exhibit shows that the largest mismatch is at the 10-year point, where the portfolio is short by 0.35 years. Interestingly, this is not the most expensive mismatch in terms of risk: when looking at the last column, we see that we would be able to change risk the most by manipulating the short end of the exposure to the swap spread curve, namely the 6-month point.

The previous exhibits allow us to understand the portfolio exposures to the different types of curve risk and their impact both on the return and risk of

12. This is a rationale similar to the one used before, where we see all correlated impact with the same sign.

13. For a more detailed discussion, see Chapter 49.

EXHIBIT 50-11

Swap Spread Risk

Factor Name	Exposure (SS-KRD) Portfolio	Exposure (SS-KRD) Benchmark	Exposure (SS-KRD) Net	Factor Volatility	Return Impact Correlated	Marginal Contribution to TEV
6M SS	0.13	0.09	0.04	20.4	–0.8	–2.2
2Y SS	0.47	0.41	0.06	11.5	–0.7	–1.8
5Y SS	0.67	0.85	–0.18	6.8	1.2	–1.0
10Y SS	0.58	0.93	–0.35	8.9	3.1	1.9
20Y SS	0.51	0.57	–0.06	10.4	0.6	1.0
30Y SS	0.47	0.28	0.19	13.3	–2.5	0.5

Source: POINT

portfolios. They also guide us regarding what changes we can introduce to modify the risk profile of the portfolio. We continue our analysis with sources of risk that are more specific to particular asset classes.

Credit Risk Credit risk may be analyzed along various dimensions such as geography, industry, debt seniority, credit rating, or spread level. As discussed in Chapter 49, a powerful determinant of credit risk of a bond for relatively short horizons is given by its *duration times its spread*, or DTS. Under this setting, the spread return of the security is given by the product of its DTS and the percentage change in its spread.[14]

Assuming that the percentage change in spread has similar statistical properties across a group of bonds, we can select this common component as one driver of systematic spread changes, giving rise to the *DTS systematic risk factor*. Apart from DTS, many other characteristics may explain systematic changes in spreads. Examples would be systematic differences along debt seniority or credit rating. However, these differences are typically well captured by the DTS levels of each security. Therefore, they do not justify risk factors in addition to the DTS. On the other hand, there are bonds with similar DTS that may behave very differently, depending on their geography or industries membership, for instance. This difference is relevant enough to grant the typical use of different risk factors across these dimensions. In the framework under analysis here, this is achieved by introducing several DTS factors, one for each combination of region and industry considered in the risk model.

The results of such an approach to the analysis of the portfolio in our example are displayed in Exhibit 50-12, which shows the typical industry risk factors associated with credit risk. The portfolio has exposure to a single region (U.S.) and has net positions in 27 industries, spanning all three major sectors: Industrials (IND), Utilities (UTI), and Financials (FIN). We saw before that the portfolio has significant net exposure to Financials in terms of market weights (3.7%, see Exhibit 50-1). In terms of risk exposure, Exhibit 50-12 shows that the net DTS attached to the Banking industry is 0.62[15], clearly the highest across all sectors. However, the marginal contribution to TEV that comes from that industry is comparable to almost all other industries, even with ones that have an almost zero net exposures, such as Brokerage. This observation suggests that all these industries are close substitutes to each other in the context of the current portfolio.

Another interesting point is highlighted by the fact that the marginal contribution is negative for all industries, even though some (such as Retail and

14. More specifically Spread Return = $-SD \times \Delta S = -SD \times S \times (\Delta S/S) = -DTS \times \%\Delta S$, where SD stands for spread duration, S for spread, and Δ for change.

15. The DTS units used in the report are based on an OAS duration (OASD) stated in years and an OAS in percentage points. Therefore, a bond with an OASD = 5 and an OAS = 200 bp would have a DTS of 5 × 2 =10. The DTS industry exposures are the market-value weighted sum of the DTS of each security in that industry.

EXHIBIT 50-12

Credit-Spread Risk

Factor Name	Exposure (DTS) Portfolio	Exposure (DTS) Benchmark	Exposure (DTS) Net	Factor Volatility	Return Impact Correlated	Marginal Contribution to TEV
IND Chemicals	0.12	0.03	0.09	9.5	–0.8	–1.6
IND Metals	0.00	0.05	–0.05	12.5	0.6	–1.4
IND Paper	0.00	0.01	–0.01	10.5	0.1	–1.6
IND Capital Goods	0.00	0.05	–0.05	9.5	0.4	–2.0
IND Div. Manufacturing	0.20	0.03	0.18	8.6	–1.5	–2.1
IND Auto	0.00	0.01	–0.01	14.1	0.1	–2.0
IND Consumer Cyclical	0.06	0.04	0.02	10.5	–0.2	–2.0
IND Retail	0.38	0.05	0.33	11.0	–3.6	–2.0
IND Consumer Noncyclical	0.06	0.11	–0.05	8.9	0.4	–2.0
IND Health Care	0.22	0.02	0.20	8.7	–1.7	–1.7
IND Pharmaceuticals	0.07	0.05	0.01	9.2	–0.1	–2.0
IND Energy	0.00	0.15	–0.15	10.6	1.6	–1.7
IND Technology	0.00	0.06	–0.06	9.8	0.6	–1.9

(Continued)

EXHIBIT 50-12

Credit-Spread Risk (*Continued*)

Factor Name	Exposure (DTS) Portfolio	Exposure (DTS) Benchmark	Exposure (DTS) Net	Factor Volatility	Return Impact Correlated	Marginal Contribution to TEV
IND Transportation	0.06	0.04	0.02	9.4	–0.2	–1.9
IND Media Cable	0.07	0.06	0.02	10.7	–0.2	–2.0
IND Media Noncable	0.00	0.04	–0.04	10.5	0.4	–2.1
IND Wirelines	0.16	0.14	0.02	10.5	–0.2	–1.8
IND Wireless	0.00	0.02	–0.02	10.6	0.2	–1.5
UTI Electric	0.27	0.17	0.10	9.9	–1.0	–1.7
UTI Gas	0.00	0.08	–0.08	11.5	0.9	–1.5
FIN Banking	1.07	0.44	0.62	13.6	–8.5	–2.3
FIN Brokerage	0.00	0.01	–0.01	11.2	0.2	–2.8
FIN Finance Companies	0.03	0.08	–0.05	16.5	0.8	–2.5
FIN Life & Health Insurance	0.00	0.09	–0.09	14.8	1.3	–2.3
FIN P&C Insurance	0.11	0.05	0.06	8.7	–0.5	–3.2
FIN Reits	0.00	0.03	–0.03	13.2	0.4	–2.3
Non Corporate	0.19	0.26	–0.07	16.7	1.2	–1.2

Source: POINT

Healthcare) are significantly over-weighted. The analysis suggests that if we increase the risk exposure to them, the risk would actually decrease. This result is again driven by the strong negative correlation between spreads in these industries and the yield-curve. For example, the exposure in banking is partially hedging out the significant long interest-rate duration position. This kind of analysis is only possible by accounting for the correlations across factors, underscoring the importance of the quality of the correlation estimates used by the model.

Although the risk factors used to measure risk are predetermined in a given factor model, there is flexibility on the way the risk numbers can be aggregated and reported.[16] For example, the credit risk model used to generate the risk report presented in Exhibit 50-12 does not use credit ratings as drivers of systematic credit risk. Instead, it uses the DTS concept. However, once generated, the risk numbers can be reported using any portfolio partition.

As an example, Exhibit 50-13 shows the risk breakdown by rating. As reported in this exhibit, the majority of risk is coming from the AAA exposure (11.3 bp/month), the bucket with the biggest mismatch in terms of net weight (–12.1%). This bucket includes Treasury and government-related securities, sectors that are underweighted in the portfolio, leading to significant risk. This is even clearer when we look into the isolated TEV numbers. If the manager had mismatches only on AAA's, the portfolio risk would be 22.8 bp/month, instead of the actual 14.2: the other exposures hedge the risk from AAA's. This report also identifies the systematic betas associated with each of the rating sub-portfolios. These betas add up to the portfolio beta, when we use the portfolio weights (not NMW) as weights in the summation. For example, the exhibit allows us to infer that a movement of 10 bp in the benchmark leads to a 12.6 bp return in the AAA sub-component of the portfolio. On the other hand, the beta of 0.22 for the BAA2 component of the portfolio does not signal low volatility for this sub-portfolio. It indicates mainly low correlation with the benchmark, possibly a result of the significant role of idiosyncratic risk for this set of bonds. Systematic betas of zero identify buckets for which the portfolio has (close to) no holdings.

Prepayment Risk Most securitized bonds, such as MBS or asset-backed securities (ABS), have uncertain cash flows due to the borrower's option to prepay the bond at any time. Interest rates strongly drive this prepayment behavior, as explained in Chapter 49, thus adding an extra channel of exposure to interest-rate risk that is absent from other bonds (e.g., corporate bonds with no optionality). Typically, interest and prepayment models can accommodate this feature only imperfectly. Moreover, there are other factors influencing prepayment risk. To accommodate these limitations, risk models incorporate other major characteristics that can be associated with prepayment risk. Examples are the program/term

16. For a detailed methodology on how to performed this customized analysis, see Antonio Silva, "Risk Attribution with Custom-Defined Risk Factors," Barclays Publication, August 2009.

EXHIBIT 50-13

Risk per Rating

Rating	NMW (%)	TEV				Systematic Beta
		CTEV	Isolated	Liquidation	Elasticity (%)	
Total	**0.0**	**14.2**	**14.2**	**–14.2**	**100.0**	**1.05**
AAA	–12.1	**11.3**	22.8	5.8	76.9	1.26
AA1	–0.3	**–0.3**	0.8	0.3	–2.2	0.00
AA2	–1.4	**–0.5**	2.0	0.6	–3.5	3.27
AA3	–1.1	**0.8**	4.7	–0.1	6.2	3.42
A1	–1.5	**–0.9**	2.5	1.1	–6.1	1.73
A2	2.5	**1.1**	5.1	–0.1	7.3	1.13
A3	1.6	**0.7**	7.5	1.2	4.5	0.25
BAA1	–2.0	**–1.9**	5.3	2.7	–13.3	0.69
BAA2	6.8	**2.0**	9.6	0.7	16.9	0.22
BAA3	7.5	**1.9**	9.6	1.2	13.3	0.35

Source: POINT

of the deal, if the bond is priced at discount or premium (i.e., if the coupon on the bond is bigger than the current mortgage rates) and how seasoned the bond is.

Exhibit 50-14 shows a potential set of risk factors that capture these characteristics. Programs identified as having different prepayment characteristics are the Conventional (FannieMae and FreddieMac) 30-year bonds (the base case used for the analysis), the 15-year Conventional bonds, as well as the Ginnie Mae 30- and 15-year bonds. The age of bonds is captured by factors distinguishing between new and aged (seasoned) deals. Finally, each bond is also classified by the price of the security—discount, current, or premium. In this example there are no seasoned discounted bonds, suggesting that the market rates at the time of the analysis are at historical lows. In terms of risk exposures, the exhibit shows that the manager is underweighting 15-year and over-weighting 30-year Conventional bonds (the base case).

Interaction Between Sources of Risk So far we have analyzed the major sources of spread risk: credit and prepayment. To do this, we conveniently used two asset classes—Corporates and Agency MBS, respectively—where one can argue that these sources of risk appear relatively isolated. However, recent developments have made clear that these sources of risk appear simultaneously in other major

EXHIBIT 50-14

Agency MBS (Spread) Prepayment Risk

Factor Name	Exposure (OASD)			Factor Volatility	Return Impact Correlated	Marginal Contribution to TEV
	Portfolio	Benchmark	Net			
New Discount	0.002	0.012	–0.010	26.0	–2.1	3.8
New Current	0.269	0.219	0.050	16.6	0.5	–0.6
New Premium	0.260	0.615	–0.355	20.2	1.1	–1.5
Seasoned Current	0.018	0.003	0.015	19.4	–0.7	0.9
Seasoned Premium	0.810	0.531	0.279	21.2	1.4	–2.0
Ginnie Mae 30Y	0.237	0.291	–0.054	5.4	0.1	0.0
Conventional 15Y	0.000	0.128	–0.128	10.1	–1.0	0.7
Ginnie Mae 15Y	0.000	0.006	–0.006	8.5	0.0	0.0

Source: POINT

asset classes, including nonagency MBS, home equity loans, and CMBS.[17] When designing a risk model for a particular asset class, one should be able to anticipate the nature of the risks the asset class exhibits currently or may encounter in the future. The design and ability to segregate between different kinds of risk depends also on the multitude of the bond indicatives and analytics available to the researcher. For this last point, it is imperative that the portfolio manager understand the pricing model and assumptions made to generate the analytics typically used as inputs in a risk model. This allows the portfolio manager to fully understand the output of the model, as well as its applicability and shortcomings. Other sources of risk—for example, liquidity risk—may be important for particular fixed income portfolios. They were discussed in Chapter 49.

Issue-Level Reports

The previous analysis focused on the systematic sources of risk. We now turn our attention to the idiosyncratic or name-specific risk embedded in the portfolio. This risk measures the volatility the portfolio has because of events specific to the individual issues/issuers it holds. Therefore, idiosyncratic risk is independent across issuers and diversifies away as the number of issuers in the portfolio increases: events with negative impact for some issuers are canceled by events with positive impact for others. Even for medium-sized portfolios, the idiosyncratic risk may be a substantial component of the total risk. Exhibit 50-7 indicates that the idiosyncratic volatility is 10.5 bp/month, more than double the idiosyncratic volatility of the benchmark (4.7 bp/month). When looking at the tracking error volatility net of benchmark, Exhibit 50-6 shows that the idiosyncratic risk is 9.6 bp/month and close to the systematic component (10.4 bp/month). This means that a major component of the monthly net return is typically driven by events affecting only individual issuers. Therefore, monitoring these individual exposures is of particular importance.

The idiosyncratic risk of each bond is a function of two variables: its net market weight and its idiosyncratic volatility. This latter variable depends on the nature of the bond issuer. For instance, a bond from a distressed firm has much higher idiosyncratic volatility than one from a government-related agency.

Exhibit 50-15 provides a summary of the idiosyncratic risk for the top 10 positions by market weight in the manager's portfolio. Not surprisingly, 7 out of 10 are Treasury or agency MBS securities, in line with the constitution of the index used as benchmark. Moreover, these positions have significant market weights, given that the portfolio contains only 100 positions. Even though we see large concentrations, the idiosyncratic TEV for these holdings is small, as they are not exposed to significant issuer risk. The last column of the exhibit shows that within this group the bonds with the highest idiosyncratic risk are corporate bonds, one issued by CVS Corporation (CVS) and another issued by Kennametal

17. For more discussion on this point, see Radu Gabudean, "US CMBS Risk Model," Barclays Publication, October 2010.

EXHIBIT 50-15

Issue Specific Risk

Identifier	Ticker	Description	Maturity	Spread (bp)	Market Weight (%)		Idiosyncratic TEV
					Portfolio	Net	
912828MA	US/T	US TREASURY NOTES	11/30/2016	3	5.02	4.83	0.6
912828NK	US/T	US TREASURY NOTES	6/30/2017	0	3.86	3.68	0.5
912828MD	US/T	US TREASURY NOTES	12/31/2016	2	3.67	3.48	0.4
126650BK	CVS	CVS CORP-GLOBAL	6/1/2012	915	3.06	3.05	3.5
61945AAA	MOS	MOSAIC CO	12/1/2014	400	3.01	3.00	1.4
489170AB	KMT	KENNAMETAL INC	6/15/2012	503	3.00	3.00	2.6
FNA08000	FNMA	FNMA Conventional Long T. 30yr	3/1/2029	189	2.61	2.61	1.4
313771AA	FHLB	FEDERAL HOME LOAN BANK IL	6/13/2016	224	2.55	2.54	1.1
912828NG	US/T	US TREASURY NOTES	5/31/2017	0	2.29	2.10	0.3
FNA04010	FNMA	FNMA Conventional Long T. 30yr	8/1/2040	28	2.15	1.59	0.4

Source: POINT

Inc. (KMT). This is not surprising, as these are the type of securities with larger event risk. Even within corporates, idiosyncratic risk can be quite diverse: in particular, it usually depends on the industry, spread duration, and level of distress of the issuer (usually proxied by rating, or by the spread of the bond). For instance, the net position for both the CVS and KMT bonds is similar (3.06% and 3.00%, respectively), and even though their maturity is similar, the CVS bond spread is higher, resulting in higher idiosyncratic risk (3.5 versus 2.6 bp/month). To manage the idiosyncratic risk in the portfolio the portfolio manager should pay close attention to mismatches between the portfolio and benchmark for bonds with large spreads or long spread durations. These would tend to affect disproportionally the idiosyncratic risk of the portfolio.

Although important, the information in Exhibit 50-15 is not enough to fully assess the idiosyncratic risk embedded in the portfolio. For instance, a portfolio manager could buy credit protection on CVS through a credit default swap (CDS), thereby significantly reducing the exposure to this issuer's bond. The position reported in this exhibit would still look significant because the CDS protection would not be reflected in it.

A better way is to look at idiosyncratic risk at the issuer rather than at the issue level. While idiosyncratic risk is usually independent across issuers, one may not assume that the idiosyncratic risk of securities of the same issuer is uncorrelated because they are all subject to the same company-specific events. A good risk model should account for such correlation and try to quantify it for different issuer and security types. For example, all types of securities (bonds, equities, convertibles, etc.) of an issuer in financial distress tend to move in a correlated fashion because they all represent claims to the same distressed assets. Adding more securities from such an issuer to a portfolio does not generally deliver additional diversification. On the other hand, securities from issuers in strong financial health can move quite differently from each other, driven primarily by liquidity or capital structure effects rather than credit. In this case, a portfolio manager can achieve some diversification of idiosyncratic risk (although limited) even when adding issues from that same issuer into the portfolio.

In order to understand the net effect of all such interactions, it is useful to review the contributions of individual issuers to the portfolio's total idiosyncratic risk. When aggregating risk from the issue (as shown in Exhibit 50-15) to the issuer level, the correlations referred to above should be fully taken into account. Exhibit 50-16 shows the results of this exercise for the 10 issuers with the highest isolated idiosyncratic TEV. The riskiest issuer exposure in the portfolio comes from Mellon Capital, with isolated idiosyncratic risk of 4.0 bp/month. Note that no single security from this issuer appears as a top holding in the portfolio (see Exhibit 50-15). This highlights the importance of aggregating idiosyncratic risk at the issuer level. We can also observe that idiosyncratic TEV is not monotonic in the NMW: Mellon Capital and Ameren Corp have similar NMW, but the former is significantly riskier (4.0 versus 1.3 bp/month). It is also possible to have important idiosyncratic risk even for issuers the portfolio does not hold, namely for bonds from issuers that have significant market weight in the benchmark.

Finally, note that because the idiosyncratic risk across issuers is independent, the cumulative risk of several issuers can be easily calculated. For example, the total idiosyncratic risk of the top two issuers in Exhibit 50-16 is given by:

$$\mathrm{TEV}_{idio}^{BK+GS} = \sqrt{4.0^2 + 3.5^2} = 5.3$$

As is the case in most portfolios tracking a benchmark, most issuers present in the portfolio are over-weighted relative to the benchmark. This is a natural consequence of the fact that, in practice, portfolios hold far fewer positions than the benchmark. It may be difficult for the manager to hold positive views in all issuers selected in the portfolio. In fact, some of these positions may be selected to build exposure to specific systematic factors, such as a particular industry or asset class, and not to a particular issuer. However, it is important that the manager hold positive views for the issuers with the largest contribution to idiosyncratic risk. If this is not the case, then the manager is assuming a significant unintended name risk that should be promptly taken out of the portfolio, in favor

EXHIBIT 50-16

Issuer Specific Risk

Ticker	Name	Sector	NMW (%)	Idiosyncratic TEV
BK	MELLON CAPITAL IV	BANKING	1.50	4.0
GS	GOLDMAN SACHS CAPITAL II	BANKING	0.75	3.5
CVS	CVS CORP-GLOBAL	RETAILERS	3.00	3.5
KMT	KENNAMETAL INC	DIVERSIFIED MANUFACTURING	3.00	2.6
KFW	KREDIT FUER WIEDERAUFBAU	NON-U.S. AGENCIES	–0.03	1.4
MOS	MOSAIC CO	CHEMICALS	3.00	1.4
WFC	WELLS FARGO CAPITAL XIII	BANKING	0.76	1.3
AEE	AMEREN CORP	ELECTRIC	1.27	1.3
PNC	NATIONAL CITY PRE CAP TR I	BANKING	0.78	1.1
JNJ	JOHNSON & JOHNSON	PHARMACEUTICALS	0.54	1.0

Source: POINT

of another issuer with similar characteristics for which the manager does have a positive view. This interactive exercise can easily be performed with a good and flexible portfolio construction tool and the help of an optimizer.

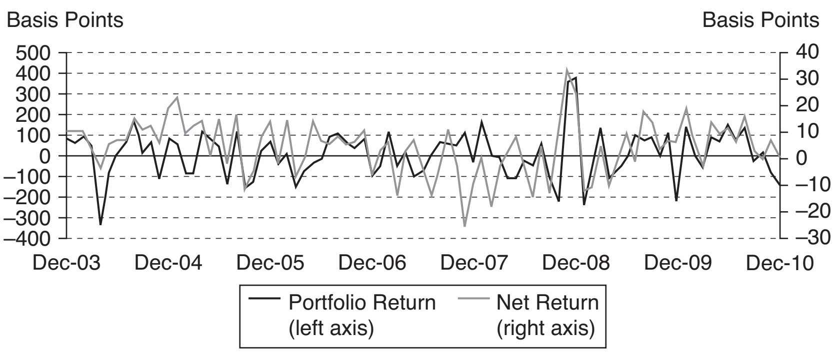
Scenario Analysis Report

Scenario analysis provides an additional perspective on the portfolio's risk. This exercise can be performed in several ways. For instance, a manager may want to reprice the whole portfolio under a particular scenario on risk factors, such as interest rates or spreads, and look at the hypothetical return under that scenario. Alternatively, a portfolio manager may wish to evaluate how the portfolio would have performed under particular historical scenarios (e.g., the 1987 equity crash or the Asian crisis in 1997). One particular problem with this approach is the fact that, given the dynamic nature of the securities, the current portfolio with its current characteristics did not exist during such historical episodes. Some of the portfolio securities may have not even been issued during such periods. A solution might be to price the current securities with the market variables at the time. While a valid solution, it is difficult to implement because pricing models require inputs possibly not available during that historical period.

An alternative is to represent the current portfolio as the set of loadings to all systematic risk factors in a linear factor risk model. We can then multiply these loadings by the historical realizations of the risk factors. The result is a set of historical systematic simulated returns. Exhibit 50-17 presents monthly returns for the period between December 2003 and December 2010. The dark line represents the absolute portfolio returns and the lighter line represents the portfolio's return net of the benchmark. Note that this analysis uses only one set of static portfolio loadings. Therefore, these simulated returns can be interpreted as the hypothetical returns a portfolio with these characteristics would have, if submitted to the historical episodes. As expected, the largest volatility was realized during the crisis of

EXHIBIT 50-17

Historical Systematic Simulated Returns (basis points)



Source: POINT

2007–2009, when the portfolio registered returns between –300 and 400 bp. The largest underperformance against the benchmark occurred in November 2007 at about –25 bp, followed by other months during the crisis such as February and September 2008. The largest outperformance (about +30 bp) was registered at the end of 2008, when the portfolio—being long interest-rate duration—benefited from the sharp drop in interest rates registered during that period.

This analysis has some limitations, especially for the portfolio under analysis, where idiosyncratic exposure is a major source of risk. This kind of risk is always hard to capture and obviously less relevant from an historical perspective, as the issuers in the current portfolio may have not witnessed any particular major idiosyncratic event in the past. However, these and other types of historical scenario analyses are important because they give managers some indication of the magnitude of historical returns the portfolio might have encountered. They are usually the starting point for any scenario analysis. The manager should always complement them with other non-historical scenarios relevant for the particular portfolio under analysis. In particular, the risk model can be used to express such scenarios, as discussed in Chapter 46.

KEY POINTS

- A good risk model provides detailed information about the exposures of a portfolio. Risk analysis starts with weight imbalances in the portfolio, when compared to the benchmark. For fixed income portfolios, the analysis of market weights has to be complemented with other analytics for a better description of the portfolio's exposure to the different sources of risk.
- The relevance of a risk source is given by the product of its volatility—how risky it is—and the portfolio's exposure to it. To get an aggregated description of risk, we have to bring into the analysis correlations between the different risk sources the portfolio is exposed to. The combination of these elements results in the overall risk of a portfolio versus a benchmark, or its tracking error volatility.
- There are many different ways to analyze the risk of a portfolio. We can do it by type of risk factor (e.g., interest-rate risk) or by type of security (e.g., corporates). Many different metrics—such as contribution to TEV, liquidation effect on TEV or TEV elasticity—can provide further understanding of the overall risk of the portfolio.
- Risk analysis can be significantly enhanced using scenario analysis. There are several methods to perform it. One method is to look at the historical performance of a theoretical portfolio with constant loadings. This analysis allows a manager to study the potential behavior of a portfolio with such characteristics across major historical events.

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CHAPTER

FIFTY-ONE

CASH-FLOW MATCHING

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Cash-flow matching has a long and respected history as a way to fund pension benefits. It has its roots in portfolio immunization, first introduced in the high-interest-rate environment of the early 1980s by Martin Leibowitz.[1] The objective of this chapter is to explain cash-flow matching and its application to pension fund management.

WHAT IS CASH-FLOW MATCHING?

Cash-flow matching is a fixed income methodology to match and fund with high certainty a stream of liability cash flows. It has become known as cash-flow driven investment (CDI). In defined benefit pensions, the liability cash flows are an actuarial projected benefit payment schedule. Since actuarial projections are not an exact science, there can be some actuarial noise or uncertainty depending on which projected liability payments you are attempting to match. There are three types of pension liabilities: Retired Lives, Terminated Vested, and Active Lives.[2] Given their greater certainty, cash-flow matching is used only for pension Retired Lives. CDI is a bond portfolio of cash flows that include the principal at maturity (or call date), periodic interest income, and the reinvestment of any excess cash flows greater than the benefit payments that the strategy is funding (liability cash flows). If such reinvestment of excess cash flows is at positive interest rates, the additional earned income will reduce the future funding costs. If risk is defined as the uncertainty of achieving the objective (funding liability payments), then cash-flow matching is one of the best approaches to de-risking a pension liability schedule.

The objective of a pension is to secure benefits in a cost-efficient manner. CDI is one of two ways to secure benefits. The other way is through insurance

1. Martin L. Leibowitz, "The Dedicated Bond Portfolio in Pension Funds – Part 1: Motivations and Basics," *Financial Analysts Journal* 42(1), 1983, pp. 68–75

2. Retired Lives included workers who have terminated employment and are receiving monthly benefit payments. Active Lives includes workers who have not been terminated and benefits are not yet determined.

annuities, which tend to be expensive. Bond mathematics proves that the longer the maturity and the higher the bond yield, the lower the bond cost. It is all about the time value of money (present value versus future value). As a result, CDI will skew the weights of its portfolio holdings to longer maturities to reduce cost. The bond yield curve is typically positive sloping such that the longer the maturity the higher the yield to maturity (YTM). This allows cash-flow matching to use the interest income of longer bonds to partially fund every six months shorter projected liabilities especially if such longer bonds have a greater yield than shorter-maturity bonds. Since projected pension benefits are monthly, cash-flow matching requires sophisticated modeling techniques, such as a cost optimization model, to build a bond portfolio of numerous maturities to cash-flow match efficiently the liability cash-flow projections at the lowest cost to the pension plan sponsor.

The efficiency of the cash-flow matching model is best determined by the amount of excess cash flows to be reinvested. The goal is for no or little excess cash-flow reinvestment, but this is quite difficult to achieve. It is ideal, if not a requirement, that the bonds used for cash-flow matching are free of options that would disturb the certainty of the cash flows such as call options, put options, floaters, pass-throughs, and so on. In addition, the pension plan sponsor will put constraints on the cash-flow matched portfolio (as true for any bond portfolio) from its investment policy statement (IPS). This would include rating, sector, issuer, and issue constraints on the percentage weighting in the portfolio. Fortunately, the fixed income universe available for cash-flow matching is immense allowing for great selection.

An exact match of bond maturities to liability payment dates could theoretically be accomplished by using U.S. Treasury STRIPS (zero-coupon bonds), but this would not be cost effective due to the fact that STRIPS tend to be the lowest yielding fixed-income securities and the time value of money. Such an exact match is referred to as defeasance for accounting purposes, where the liability is defeased and removed from the balance sheet provided the liability cash flows are certain. Prefunded municipal bond issues are an example of a defeasance.

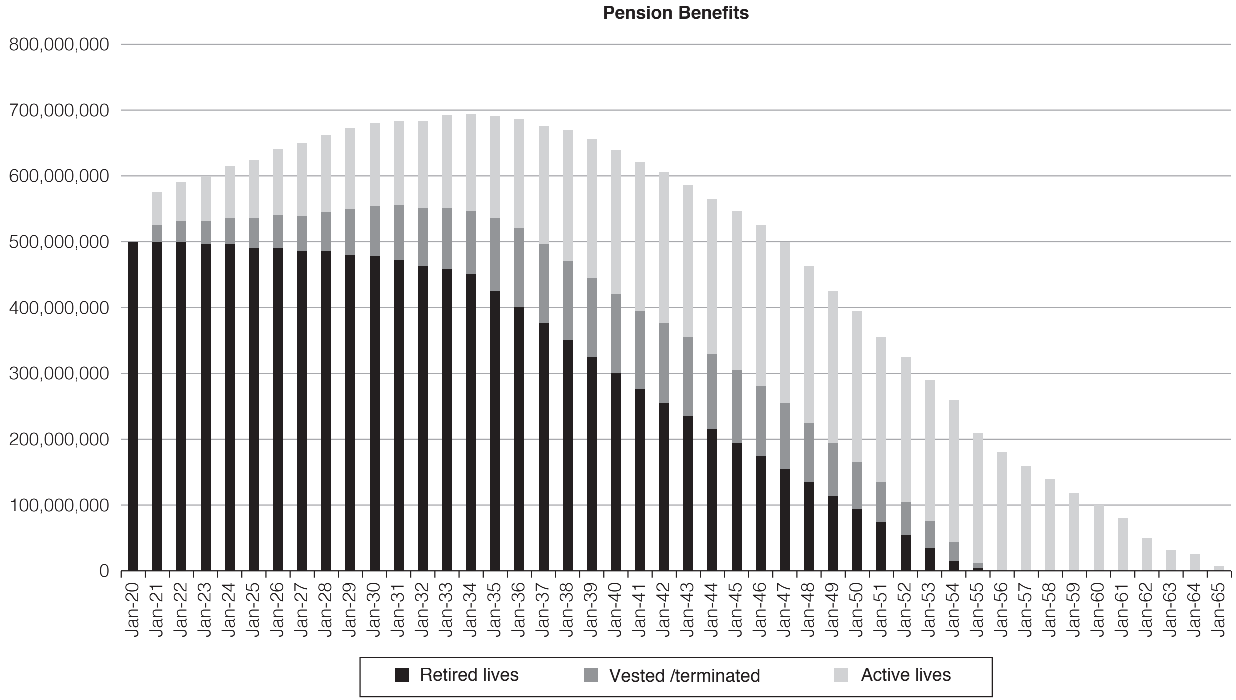
The actuarial projected pension benefit schedule is actually a series of projected benefit schedules for (1) Retired Lives, (2) Vested Terminated,[3] and (3) Active Lives. Exhibit 51-1 shows a typical series of projected benefit payments. The most certain and imminent is the Retired Lives benefit payment schedule. As a result, CDI is a best fit to match and fund Retired Lives and that should be the focus of this investment strategy.

A pension plan's asset allocation should strongly consider Retired Lives in determining the bond allocation and focus rather than versus a generic bond index benchmark whose cash flows look nothing like the Retired Lives benefit schedule. Pension liability cash flows are like snowflakes, you will never find two alike due to a different labor force, salaries, mortality, and plan amendments.

3. Vested Terminated is comprised of workers who have terminated employment but have not started receiving benefit payments.

EXHIBIT 51-1

Projected Benefit Payment Schedules



Source: Nuveen Asset Management, "How Old is Your Pension Plan," 2017.

Retired Lives = terminated employment and receiving monthly benefit payments.

Active Lives = not terminated and benefits are not yet determined

Until you receive the actuarial projection of Retired Lives, the bond allocation is lost without a proper objective. As the actuary updates the projections annually, there may be a need to rebalance the CDI to best match and fit the revised Retired Lives benefit projections.

THE CDI METHODOLOGY

A lower-cost and lower-risk way to secure benefits is to *cash-flow match* the projected future value benefit payments of Retired Lives. In the early 1980s, dedication strategies (cash-flow matching) with corporate bonds was in vogue for pensions. This strategy became less common as pension consultants and accounting rules focused on present values (Funded Ratio and Funded Status), not future values. This led to considerable confusion as to what discount rate to use to calculate the present value of liabilities.

Since contributions are the initial source to fund benefits, current assets need to fund net liabilities (projected benefits minus contributions). So, the first step in CDI is to identify with accuracy what you are funding, which is net liabilities. The next step is to identify a universe of bonds that qualify under the client's IPS (i.e., investment-grade bonds). Then several iterations are needed to create a bond portfolio that can fund monthly net liabilities at low cost that is in conformity to the client's IPS. A cost optimization model is needed here to achieve low cost by skewing the weights to longer maturities and higher-yielding bonds in conformity with the clients' investment policy within the liability benefit payment schedule we are funding. The present allocation to bonds (plus cash) will determine how far out CDI can cash-flow match Retired Lives chronologically (i.e., 1–10 years Retired Lives).

An efficient CDI model should be able to reduce funding costs by 8% to 15% on a 1–10 years Retired Lives projected benefit payment schedule, and much more if the strategy is funding longer liabilities, currently estimated at 25% to 40% on 1–30 years. This is a serious cost reduction and should be a major consideration of any asset allocation strategy as the *core portfolio*. Funding costs reduction is defined as the difference between the total benefits funded and the cost to purchase bonds for the CDI model. In truth, cash-flow matching the liability benefit payment schedule (liability cash flows) at low cost is the ideal way to de-risk a pension plan.

Shown in Exhibit 51-2 is a sample cash-flow matching model. The cash flows from principal and interest are used to fund projected liability payments for Retired Lives out 30 years. Note that the portfolio is skewed to longer maturities to take advantage of bond mathematics and achieve lower cost. In fact, there are no bonds shorter than five years. If there is any excess cash flow, it is reinvested at current U.S. Treasury STRIPS rates for the next benefit payment date(s) to be funded. The total cash flow (annually) is then compared to the benefit payment (annually) and a cumulative difference is shown.

EXHIBIT 51-2

Cash-Flow Matching Model (May 31, 2020)

Payment Year	Principal	Coupon	Reinvestment	Total Cash Flow	Benefit Payment	Cumulative Difference
11/30/2050	21,311,835	552,920	74,379	21,939,133	21,939,133	82,293
11/30/2049	22,251,690	549,264	913,520	23,714,474	23,714,474	82,293
11/30/2048	22,827,363	1,772,029	900,956	25,500,348	25,500,348	82,293
11/30/2047	23,007,720	3,288,970	873,370	27,170,060	27,170,060	82,293
11/30/2046	23,738,170	4,128,424	1,005,689	28,872,283	28,872,283	82,293
11/30/2045	24,826,431	4,750,612	992,946	30,569,989	30,569,989	82,293
11/30/2044	24,332,689	6,934,752	955,072	32,222,513	32,222,513	82,293
11/30/2043	24,799,381	8,149,205	901,990	33,850,576	33,850,576	82,293
11/30/2042	24,489,335	9,916,650	868,234	35,274,219	35,274,219	82,293
11/30/2041	25,132,189	10,497,097	1,114,928	36,744,213	36,744,213	82,293
11/30/2040	24,601,886	12,291,203	1,108,429	38,001,518	38,001,518	82,293
11/30/2039	23,905,823	13,878,625	1,210,418	38,994,866	38,994,866	82,293
11/30/2038	22,906,983	15,799,414	1,220,741	39,927,139	39,927,139	82,293
11/30/2037	22,233,793	17,546,815	1,018,294	40,798,902	40,798,902	82,293
11/30/2036	21,957,028	18,670,389	934,676	41,562,094	41,562,094	82,293
11/30/2035	21,247,502	19,977,162	753,569	41,978,233	41,978,233	82,293

(Continued)

EXHIBIT 51-2

Cash-Flow Matching Model (May 31, 2020) (*Continued*)

Payment Year	Principal	Coupon	Reinvestment	Total Cash Flow	Benefit Payment	Cumulative Difference
11/30/2034	20,195,218	21,086,617	888,699	42,170,534	42,170,534	82,293
11/30/2033	19,128,171	22,564,153	723,767	42,416,091	42,416,091	82,293
11/30/2032	16,395,067	23,895,751	2,079,808	42,370,626	42,370,626	82,293
11/30/2031	11,379,523	24,475,681	4,689,761	40,544,965	40,544,965	82,293
11/30/2030	10,733,387	25,584,007	1,842,195	38,159,588	38,159,588	82,293
11/30/2029	7,524,555	26,563,553	1,618,857	35,706,965	35,706,561	82,293
11/30/2028	5,382,706	26,676,834	1,532,697	33,592,237	33,591,569	81,889
11/30/2027	3,185,113	27,164,053	1,226,431	31,575,597	31,575,597	81,220
11/30/2026	1,846,466	27,268,308	655,756	29,770,530	29,770,530	81,220
11/30/2025	414,709	27,250,572	312,096	27,977,378	27,977,378	81,220
11/30/2024	0	26,338,449	22,523	26,360,972	26,342,921	81,220
11/30/2023	0	24,885,617	21,173	24,906,790	24,888,739	63,170
11/30/2022	0	24,009,873	20,386	24,030,259	24,012,209	45,120
11/30/2021	0	23,350,387	19,796	23,370,183	23,352,133	27,069
11/30/2020	0	9,020	0	9,020	0	9,019
Cash	0	0	0	0	0	0
	469,754,735	499,826,405	30,501,156	1,000,082,295	1,000,000,000	

It is critical that there are no cumulative cash-flow deficits or negative differences. This sample cash-flow model was able to fund $1 billion in projected benefit payments at a cost of $558,334,794 for a funding cost savings of $441,665,206 or 44.2% without any cash-flow deficient years. This is a considerable funding cost savings that could truly help to stabilize a pension fund. If the model is run using only U.S. Treasury STRIPS as a defeasance model, the funded costs savings would be 17.4%, which is still a noteworthy savings. Importantly, the plan sponsor gets this savings upon implementation of the cash-flow matching model rather than having to wait for uncertain future returns, which will take many years to occur as in active bond management.

Matching Retired Lives liabilities chronologically will buy time for the nonbond assets (which we referred to as the "Alpha assets") to perform and outgrow Active Lives liabilities. Given time (10+ years) most nonbond asset classes tend to outperform bonds. Since liabilities behave like bonds given their present value interest rate sensitivity, there is a high probability that nonbond asset classes should outperform liability growth of Active Lives and Terminated Vested over an extended time horizon especially in today's low-yield environment. This outperformance would enhance the funded status allowing for reduced contribution costs or increased Active Lives benefits or both. The benefits of a CDI strategy are numerous:

Secures Benefits: Cash-flow matches and funds monthly Retired Lives benefits chronologically.

Enhances Funded Ratio /Status: CDI portfolios biased to corporate bonds will outyield a liability discount rate, which creates alpha.

Reduces Costs: CDI reduces funding costs (8% to 15+%) and may reduce contribution costs.

Reduces Volatility: Reduces volatility of (1) funded ratio and (2) contribution costs.

Reduces Risk: (1) Risk = uncertainty of funding benefit payments and (2) funds benefit payments (future values have no interest rate sensitivity).

Enhances Return on Assets (ROA): CDI should *outyield* most active bond managers.

Buys Time: (1) CDI matches and funds net liabilities *chronologically,* (2) moves deficit out longer, extending the investment horizon, and (3) buys time for nonbond assets (Alpha assets) to outgrow Active Lives and Terminated Vested.

FUTURE VALUE VERSUS PRESENT VALUE

Actuarial practices use present values (PV) to calculate the pension funded ratio and funded status. But pension benefit payments are future values (FV). This suggests that the future value of assets versus the future value of liabilities is the most critical evaluation. However, it is anyone's guess as to the future value of most asset classes. This is why the PV is used to calculate the funded status. Only bonds (and insurance annuities) have a known future value and have historically been used to cash-flow match liabilities (i.e., defeasance, dedication). To prove this point as to the potential misinformation with using a PV calculation, let's use a simple example.

Consider the following two pensions, A and B, both at $100 million market value and thus having the same funded ratio in PV dollars:

Pension	Composition	Yield to Maturity	PV	FV
A	100% Treasuries	2.00%	$100 million	$181.7 million
B	100% Corporates	3.00%	$100 million	$244.3 million

As can be seen, pension B is 100% invested in corporate bonds that outyield pension A (100% invested in Treasuries) by 100 bps per year over 30 years. Certainly, plan B has a much greater FV (at 34.5% higher) and funded status than plan A if future values are used. This suggests that the funded ratio and funded status may not be that accurate or even good indicators of the true economic solvency of a pension plan.

The point of all this is that we need to focus more on the FV of assets versus liabilities. This is what CDI is all about. It is matching and funding future values (projected benefit payments minus contributions). If you discount liabilities at market rates, they will have discount rates of AA corporates (FASB method) or perhaps, U.S. Treasury STRIPS (defeasance method). A corporate bond portfolio matched to liabilities that outyields liabilities would enhance the funded ratio on a future value basis thereby reducing funding costs. Moreover, a cash-flow matched portfolio skewed to longer maturities reduces funding costs significantly because of the greater yield associated with longer-dated maturities in a positively sloping yield curve. This is due to the time value of money or present values versus future values, which is integral in CDI construction. This is why cash-flow matching of liability future values is the most prudent methodology for lowering risk and cost when de-risking a pension through asset liability management (ALM).[4]

4. For a further discussion, see "Pension Confusion: Present Value vs. Future Value," Ryan ALM, Inc. (2019).

INTEREST RATE RISK

The greatest risk of bonds is their interest rate sensitivity. The longer the maturity and duration of any bond portfolio, supposedly the higher the interest rate risk. But since cash-flow matching is focused on funding projected benefits (future values), interest rate risk is neutralized or eliminated. Critically, future benefit payments are not interest rate sensitive. The volatility of interest rates will not cause any volatility in projected benefits or future values. As a result, CDI is not concerned about interest rates except for the reinvestment of excess cash flows. In contrast to active bond management where rising interest rates are bad in that they deteriorate bond prices, with CDI higher interest rates are good allowing the cash-flow matched portfolio to reinvest at higher interest rates and lower cost.

CDI VERSUS ACTIVE BOND MANAGEMENT

A cash-flow matching strategy is focused on generating asset cash flows that will fund liability cash flows (benefit payments). It is not focused on total returns or performance versus a bond index benchmark. Another benefit with a CDI is the low portfolio turnover, which will reduce transaction costs. Active bond management is focused on outperforming the returns of a generic bond index benchmark. As a result, cash flows are not a consideration here, only the relative total returns to the index benchmark are considered (performance measurement). But no matter what generic bond index is chosen; active fixed income asset management cannot produce enough cash flows to fund benefits, since only interest income is used to fund benefits. As a result, actively managed bonds will require help from the Alpha assets to fund benefits. This will create dilution and disruption of the growth rate of such performance assets. With a CDI strategy in place as the pension plan's *core portfolio* to fund the shorter Retired Lives net liabilities (1–10+ years), the Alpha assets are now free to grow without being diluted or unencumbered to pay any benefits. The return on Alpha assets will be volatile, but the liability Beta assets (CDI) buy time (10+ years) for the Alpha assets to grow. The following example illustrates the cash flow difference of bonds managed to a generic index versus cash-flow matching to liabilities:

Assumptions
Bond allocation = $150 million
Net Benefits = $20 million per year for next 10 years

Bond management vs. generic bond index

- YTM = 2.50% (Index YTM = 2.00%)
- Cash flow = $3.75 million annual ($2.50% × $150 million)
- Annual cash-flow shortfall = $16.25 million ($20 milion − $3.75 million)
- Requires dilution of Alpha assets cash flow to fund net benefits

Cash-flow matching

- YTM = 3.50% (skewed to A/BBB corporate bonds)
- Cash flow = $20 million annual (principal + income + reinvestment of excess)
- No dilution of Alpha assets cash flows (assets allowed to grow unencumbered)

From this illustration, we see that generic bond index management cash flows look nothing like the projected benefit payment schedule of a pension. This leads to a mismatch of cash flows and risk/reward behaviors, which are serious issues over time. Alpha assets need time to perform without any dilution of their cash flows to pay benefits. CDI matches and funds benefit payments chronologically. CDI will outyield most current bond managers and enhance the return on asset assumption (ROA). CDI buys time for Alpha assets to grow unencumbered. Moreover, bonds managed versus generic bond indexes have the following issues:

- Does not fund benefits plus expenses.
- Cash flows do not match a plan's liability cash flows.
- Generic bond index skewed to long bonds and Government securities.
- Low yielding, similar to index benchmark (Aggregate index = 1.42%).

CDI VERSUS LDI

Liability driven investments (LDI) are usually duration-matching strategies or immunization. The pension funded ratio and funded status are present value calculations, anything that affects the PV of liabilities is the concern of LDI or immunization. Since liabilities behave like bonds, then the PV of liabilities is extremely affected by the discount rate(s) used to price liabilities. To immunize the pension against this interest rate risk and sensitivity, LDI uses several approaches with the main focus on duration matching liabilities. LDI may use interest rate swaps, futures, derivatives, risk overlays, and the like to assist in duration matching liabilities. They are all hedging tools to help assets match the liability growth rate. Unfortunately, they do not match or fund the liability cash flows.

There are several difficult, if not erroneous, data-gathering choices in duration matching strategies, as explained below:

1. **Average Duration of Liabilities.** Where do you get the average duration of liabilities? Most, if not all, actuarial reports do not provide this calculation. Moreover, they do not provide the projected liability benefit payment schedule, which you would need to calculate duration. In addition, actuarial reports are annual reports usually lagged three to six months, rendering the information seriously delayed. The duration

calculation is a PV calculation (not a FV) at a precise moment in time such as the balance sheet. As time and interest rates change, so will duration. Moreover, current assets are funding *net liabilities after contributions,* which is not calculated by the actuary. Only a *Custom Liability Index* (CLI) based on each pension's unique projected Retired Lives benefit payment schedule and projected contributions could provide an accurate and monthly projected benefit payment schedule and duration profile. But most LDI strategies try to match the growth rate of total gross liabilities not net Retired Lives after contributions. As mentioned earlier, Active Lives are not certain and contain actuarial noise (assumptions that are hard to forecast and maintain over time).

2. **Discount Rates.** Since the duration of liabilities changes with interest rates (discount rates), this calculation needs to be refreshed and updated on a frequent and accurate basis. According to pension accounting rules[5] and federal funding standards,[6] there is an assortment of discount rates required to price liabilities. Which one to use and what source to use could create several discount rate versions. If a generic bond index is used as a liability proxy, there are more difficulties. Generic bond indexes do not use any of the required pension accounting discount rates, instead preferring market rates! The yield difference could be serious. Any difference in yield creates a difference in the calculation of duration and liability growth rates. Only a custom liability index benchmark using the appropriate discount rates could provide an accurate duration and liability growth rate calculation.
3. **Generic Bond Indexes.** A common proxy for the average duration of liabilities is to use a generic bond market index, often the Bloomberg Barclay's long corporate index. Such a proxy creates several erroneous data issues. This index has no bonds shorter than 10 years and no durations longer than 19 years, although it is heavily skewed to long coupon bonds. This certainly does not represent any pension liability schedule even if the average durations were similar. Accounting standards and actuarial practices price liabilities as a portfolio of zero-coupon bonds with a single average discount rate based on the present value of this zero-coupon liability portfolio. There are no generic bond indexes that use zero-coupon bonds as their portfolio. There are no generic bond indexes that use pension discount rates in accordance with FASB, GASB, and PPA guidelines. Every pension plan's liabilities are different and unique to that plan due to different labor force, salaries, mortality, and plan amendments. There is no way any generic bond market index could represent any pension plan liability term structure. Only a custom liability index benchmark could properly represent and measure any

5. 5 Ryan ALM Inc., cash-flow matching model named Liability Beta Portfolio™.
6. 6 Ryan ALM, Inc., Pension Confusion: Present Value vs. Future Value, 2019.

pension plan's liabilities providing all of the critical data calculations needed to de-risk the plan and manage assets versus liabilities.

4. **Limitations of Duration.** Originally formulated by Frederick R. Macaulay in 1938, the duration calculation was created as a way to measure a bond's average life.[7] Duration is defined as the average life of a bond's cash flow in present value dollars. Hopewell and Kaufman demonstrated that the measure of duration as suggested by Macaulay is related to interest rate sensitivity of a bond and the measure derived is referred to as modified duration.[8] Unfortunately, modified duration has very limited use as an indicator of interest rate sensitivity. It has the following inconsistencies as a way to match price or interest rate sensitivity. I call them the "seven flaws of duration":[9]

   Proportionality: Doubling the duration does not produce twice the total return. Duration only measures price sensitivity and not income returns.

   Same Duration: Even when durations are matched, if income returns are not matched, total returns will not be matched.

   Time: Duration is a present value calculation and changes with time so the ending duration will be different than the beginning duration. The longer the time horizon, the more likely that variations will occur in the duration calculation. Over time, the same-duration zero-coupon bond and coupon bond will diverge significantly on their ending duration.

   Maximum Duration: Duration actually peaks out at high-yields such that an extension of maturity will shorten duration.

   Large Yield Moves: Modified duration times large yield moves results in large price return mismatches. The larger the yield move the larger the error.

   Spot Calculation: Duration is a PV calculation that is only good for a one-day horizon. Every day forward, duration can and should change, especially on zero-coupon bonds.

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7. Frederick Macaulay, *The Movements of Interest Rates: Bond Yields and Stock Prices in the United States since 1856*, New York: National Bureau of Economic Research, 1938.

8. M.H. Hopewell and G.G. Kaufman, "Bond Price Volatility and Term to Maturity: A Generalized Respecification," *American Economic Review* 63(4), 1973, pp. 749–753.

9. For a further discussion, see Ronald J. Ryan, "The Seven Flaws of Duration," Ryan Labs, Inc., 1986.

Averages: Using portfolio average durations gives totally inaccurate information. Duration is a function of coupon, yield, and maturity. If any one of these features is distorted, future duration changes will be distorted. The reason for the distortion is that duration is not linear such that a six-year bond will not exhibit the same price sensitivity as a portfolio of equally weighted 2-year and 10-year duration bonds. The classic example of a portfolio average duration problem was the Lehman Government/Corporate bond index for July 1990, which reported the following: coupon = 9.13%, maturity = 9.99 years, price = $100.00, and YTM = 8.57%. How could a portfolio average coupon of 9.13% at an average price of $100.00 equal an 8.57% YTM?

The resulting portfolio duration of 5.24 years and its interest rate sensitivity is then suspect too. Unfortunately, most bond active management is based on its portfolio average versus the index benchmark portfolio average to determine its risk/reward characteristics.

5. **Interest Rate Sensitivity.** Every one year of duration difference between the liability proxy and the actual duration of each plan's benefit payment schedule results in a 1% mismatch in liability growth for every 100 bps of discount rate change. In truth, the duration mismatch is more likely to be three to five years rather than one year. Given that pension cost for the actuary, administration, asset managers, and consultant are usually way less than 1% a year; such a duration mismatch could be very costly, representing years of pension cost. Moreover, most duration matching strategies are heavily skewed to maturities longer than 10 years. This makes the duration matching strategy extremely interest rate sensitive. Given today's historic low yields, there is a high probability of higher rates and negative growth on duration matching strategies over time.
6. **Funding Liabilities.** Imagine a 12-year average duration liability benefit payment schedule. It could have many different term structure shapes to come up with an average 12-year average duration. Imagine 100% of the assets as the 12-year average duration bond portfolio. If interest rates rise 50 bps in a year, assets and liabilities supposedly would both have a –6% price return (interest rate movement × duration [as a negative number]). If they had the same income return of 4%, they would match again (note that assets usually do not match the income or yield of liabilities). However, if the duration matching assets are used to *fund* liabilities, then a –2% loss (–6% + 4% = –2%) on assets could be funding a one-year liability, which should have a small positive growth rate. So, the assets could be taking a loss each year to fund the next year's liability benefit payments if interest rates continue to rise. This could get to be a serious costly mismatch if interest rates began a secular trend to

higher rates for the next five years. But the point is that there is no cash-flow matching here, only a duration match, so there is both funding and interest rate risk!

7. **Derivatives.** Interest rate swaps and futures are contracts not true nominal assets. There is no cash flow or funds available to make the liability cash-flow payments. They are hedges versus the liability growth rate. In fact, these strategies introduce new risk: counterparty risk, interest rate risk, nonmatching risk of assets purchased (usually equities) versus liabilities and leverage. In addition, interest rate swaps and futures have all of the problems associated with a liability proxy data gathering.

KEY POINTS

- Cash-flow matching is a fixed income methodology to match and fund with high certainty a stream of liability cash flows and has become known as cash-flow matching investment or cash flow driven investment (CDI).
- CDI is the preferred approach to de-risk a pension.
- The pension objective is to secure benefits in a cost-efficient manner. CDI stands alone as the most prudent and efficient way to achieve the true pension objective. Insurance annuities are not cost effective.
- Retired Lives is the most certain and imminent benefit payment schedule. It also represents the employees who have the longest tenure. These are the liabilities that should be cash-flow matched as a high priority and in compliance with the true pension objective.
- CDI reduces the cost to fund Retired Lives immediately upon implementation of the CDI portfolio. The plan sponsor gets these cost savings up front rather than over a long horizon as return-oriented strategies suggest or promise that they will do. The longer the projected benefit payment schedule the higher the funding cost savings. CDI should reduce funding costs by 8% to 15% on 1–10 years of Retired Lives and up to 40% on 1–30 years. The cost savings gets to be invested in the Alpha assets that will likely reduce pension costs in the future.
- The projected Retired Lives benefit payments are future value numbers. Duration matching and performance-oriented strategies all deal with present value numbers (returns, funded ratio, funded status). These projected FV benefits are not interest rate sensitive, whereas PV strategies (liability driven investments, LDI) are extremely interest rate sensitive.
- For LDI, duration matching and immunization strategies are not proper or accurate de-risking strategies.

- LDI does not fund benefit payments and is full of calculation inaccuracies as well as even erroneous data gathering.
- Duration of liabilities is not an easy or static calculation. There are seven flaws of duration that should be known or understood if a pension sponsor wants to focus on duration matching. Since the actuary does not provide the duration calculation, the data miseries start there.

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CHAPTER

FIFTY-TWO

BUILDING CORPORATE BOND PORTFOLIOS

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From an investor's point of view, corporate bonds are all-round securities that can suit many investment purposes. It is the wide range of market exposures that corporate bonds provide that gives them this status, considering that they bear credit risk on a detailed, firm-specific level on top of interest-rate risk and exchange-rate risk. A triple market exposure comes in handy when building investment strategies, the more so since the exposures can be controlled individually on a security level by picking the right bond and/or by making use of derivative instruments. A corporate bond may be held for targeting a specific credit-risk exposure or an interest-rate exposure, or even for the sole purpose of placing a currency bet. For the latter, it suffices to pick a bond that is denominated in the currency with a short duration and with a high credit quality so that the inherent interest-rate and credit-risk exposures become negligibly small.

The exposure to interest-rate risk can be reduced in three ways by (1) selecting bonds of short duration, (2) holding floating-rate notes (FRNs) that pay out coupons that are indexed on the interest rates, or (3) installing a duration hedge via bond futures. A bond's credit risk can also be hedged out, namely, by adding credit default swaps (CDS). In sum, a corporate bond can adopt the risk profile of a currency, of a sovereign bond, or of a pure credit debt-security, and of any combination among those. A corporate bond can even come close to a stock in terms of its risk/return profile. Investors who seek equity exposure via bonds can select low-rated securities or purchase hybrids or convertible bonds with a high potential that they will be converted into the underlying stock.

Furthermore, the risk profile of a corporate bond depends on what investors intend to do with it. If a bond is held until maturity, mark-to-market risk becomes irrelevant, meaning that the market valuation of interest-rate movements and of credit rating downgrades that may occur no longer matter. The only thing that matters is the income that the bond generates (i.e., the coupon payments). Liquidity risk ceases as well. Such an investment bears default risk essentially as well as exchange-rate risk when the bond's currency differs from the local currency of the investor. Note that default risk is not the same thing as credit risk, for it does not cover rating downgrades, which have a real impact on the firm's capacity to attract new capital. For an investor, credit risk and default risk are quite distinct phenomena, and may for that matter be counted separately in the list of market exposures that corporate bonds embed.

The list gets longer when non-standard bonds are taken into consideration. Certain niche-bonds pay out coupons that are indexed to the inflation rate for example, which effectively turns them into inflation hedgers. Covered bonds, which are issued by banks based on pooled mortgage loans, bear real-estate risk to a certain extent. And green bonds, first launched by the World Bank in 2008, add a new exposure: climate risk. These bonds finance firms' transition projects, going toward an environmentally sustainable production line. The risk a green bond bears depends on the timing of its issuance; if it is issued early in the transition project, it bears the risk of the project succeeding. If it is issued late and serves to label an accomplished climate-friendly firm, it represents safety more than risk. From an investor's standpoint, the first green bond is a typical pick for an impact-investing strategy, whereas the second may on the contrary serve as a hedge against climate risk.

The multitude of performance targets that can be envisaged and the number of investment strategies that are being pursued using corporate bonds is fascinating. In this chapter, several of them are discussed, in two sections. The first section covers the so-called buy-and-hold investment strategies, which are passive investments, in the sense that—as the name indicates—the key decisions are made at the launch of the fund. The second section covers the more common actively managed investment strategies. They include the index-tracking strategy, for which the objective is to replicate the performance of the market index, and tilted strategies, whereby outperformance is sought with respect to the market by building tilts, or biases, in the portfolio. Since the latter two strategies are defined with respect to a market index, or benchmark, they are referred to as the benchmarked strategies in this chapter.

BUY-AND-HOLD INVESTING

Investment Objectives

A buy-and-hold portfolio remains unaltered in principle over the entire holding period. Such an investment can serve two purposes: First it can be part of a liability-driven investment (LDI), whereby the primary purpose is to generate cash amounts over time that best match a pre-defined schedule of payment obligations. The second purpose is that it can serve long-term saving schemes. Usually the investment is geared toward seizing a risk premium. Especially for the purpose of long-term savings, bonds are selected that are lowly valued due to a specific concern, and the investor will be compensated if that concern will eventually prove unfounded. Buy and hold is a form of value investing in that sense.

Plenty of occasions for seizing a premium arise in the corporate-bond markets, which in effect trigger plenty of buy-and-hold fund launches.

At times conditions are particularly favorable for initiating buy-and-hold investments. For example, during the sovereign debt crisis in Europe (between 2010 and 2012) the bond markets were rattled by concerns about cumulated sovereign debts of certain Eurozone member states, in particular, Greece. Although the concerns were predominantly about sovereign debt, driving a wedge between the core and the peripheral member states, corporate bonds got dragged into the crisis in the same manner. Bonds that were issued by Portuguese, Italian, Irish, Greek, and Spanish firms—disrespectfully called the PIIGS—got severely hit, and in the belief that the market valuation at the time was not in accordance with the fundamental creditworthiness of the issuing firms, holding these bonds until maturity was an effective means to cash in the value premium.

Another buy-and-hold investment opportunity arose for callable bonds in the late 2000s. Even though for these bonds elaborate calling schemes are designed with precise call dates and prices through time, the standard convention had always been for the issuing firm to call at the first possible date. This was the case until Deutsche Bank, a German commercial bank, decided otherwise in December 2008. This seeming nonevent caused panic and instilled a fear as if bonds, and in particular perpetual bonds, were never going to be called again. That notion of risk, which got the name "extension risk," devalued callable bonds generally. In the belief that the fear was unfounded, opportunity was left for grabs to cash in the so-called extension-risk premium.

Convertible bonds are also interesting picks for buy-and-hold investors at times, particularly those for which the conversion into stock is highly unlikely (i.e., those with a low delta). Such convertible bonds effectively become ordinary corporate bonds without an embedded option, yet with the disadvantage of being relatively illiquid and not eligible to be part of any standard bond market index. Those bonds tend to trade at a discount as a result and that gives them an edge as soon as mark-to-market risk is taken out of the equation. Interestingly, during the Covid-19 crisis in spring 2020 when both the stock and the bond markets were depressed, the low-delta convertible bonds were being targeted by buy-and-hold investors.

The examples given above are typical value investments—deep value—even where the active bet is that undervalued assets will eventually recover. In that respect, the investment strategy is not passive at all; on the contrary, the mark-to-market performance of a buy-and-hold portfolio is liable to be radically different from that of the market index, meaning that its active risk, or tracking error, is high.

Structuring Buy-and-Hold Funds

Buy-and-hold funds are closed-end funds with relatively long running periods, between 5 to 10 years. The way these funds are structured depends on what they are destined for. If a fund serves as part of a liability-driven investment, bonds are selected such that they generate cash at the same pace as that of the scheduled payment obligations. The bond maturity dates must match the schedule closely to avoid cash positions that would otherwise be a drag on the fund's return performance. Hence, the bond maturity date is an important criterion in the selection process, along with the risk of default. In the context of an LDI-investment, a minimum credit rating is usually imposed by the regulator. To mitigate the impact of defaults further, the portfolio is stratified by selecting bonds of distinct sectors and countries, so as to avoid a domino effect.

For buy-and-hold savings products, especially those that make one lump-sum redemption payment at maturity, the bonds' effective maturity dates are selected so as to be grouped together closely toward the redemption date to avoid cash drags. There is usually no credit-rating threshold imposed by the regulator for these products, but there are precise rules about how to communicate the fund's performance and risk outlook. How much the fund is expected to yield must be expressed in terms of the internal rate of return (IRR) that is based on the effective payout schedule and on the management fees that will be charged. In case performance fees are set, the probability that they will be charged must be made explicit at the fund's launch as well.

To provide those estimates, Monte Carlo simulations are run over a large number of credit event scenarios. The scenarios are designed by assigning default probabilities to the bonds that are in the portfolio in accordance with their credit ratings. Default probabilities are estimated and published by rating agencies on a regular basis. The recovery rates that are used in the calculations in case of default are also retrieved from the rating agency statistics. Other than that, default correlations are usually incorporated into the simulation, which account for contagion risk. This is done by taking grouped random draws from a multivariate Gaussian distribution. Correlation levels are set somewhere between 0.3 and 0.6 depending on whether the bond issuers belong to the same economic sectors and/or countries. Based on the simulations, the expected yield, the expected number of defaults, and the amount of fees are estimated.

If the same buy-and-hold fund is to serve several investors who do not share the same risk appetite, tranches can be introduced, in much the same way as in a collateral debt obligation (CDO). Typically, there are three tranche levels in such an investment product—namely, the so-called equity tranche, which is the riskiest one; the mezzanine tranche; and the senior tranche, the least risky one. Investors who have subscribed to the mezzanine tranche for example will start losing income only once the defaults, which may or may not take place, have wiped out the equity tranche entirely. The payouts, which may be paid annually or in a lump sum at the fund's maturity, are fixed per tranche at launch. Again, the risk and return expectations are established by means of Monte Carlo simulation. In these simulations the default correlations that are assumed are critically important compared to a single-tranche fund, as it affects the tranches not in the same way. The higher the contagion risk, the riskier will be the equity tranche.

BENCHMARKED PORTFOLIOS

Portfolio Optimization

Although benchmarked investment strategies always require an active management of the portfolio over the entire life of the fund, they are qualified as passive as soon as the objective is to track, or replicate, the market index. The idea of a tracking strategy is to obtain a neutral exposure to the corporate bond market as a whole. Tracking strategies are often in the form of exchange traded funds (ETFs) or simply via open-end funds. A benchmarked strategy is qualified as active as soon as outperformance is sought via portfolio tilts. Such strategies are commercialized via open-end funds more than via ETFs. This section describes how bond managers approach the portfolio optimization problem that comes into play when pursuing benchmarked investment strategies.

As explained in Chapter 46, there are basically two[1] popular approaches to building corporate bond portfolios: either bond managers engage in traditional mean-variance optimization[2] or they use stratified sampling techniques. Mean-variance optimization is extensively discussed in finance textbooks, albeit the focus in these books is strongly on equities. How the methodology adapts to the bond-investment problem is not evident and is in fact not much commented upon in the literature. A few comments on how mean-variance optimization is, or can be, applied to corporate bond portfolio constructions are made at the end of this section, after discussing the stratified sampling approach. The term *stratified sampling* stems from the field of survey statistics,[3] and was introduced into the finance profession in the early 1980s.[4]

In the sampling approach, the problem of building a portfolio that best fulfils the given target objectives is simplified by dividing it into subproblems. The investment target, which can be the market index or an enhanced index, is divided into cells or samples. The crux is to stratify these samples effectively, meaning that they each possess distinct group characteristics and that in sum they bring about the key characteristics of the investment target. Or to state it more formally, the grid of the sample framework should accord with the covariance structure that underlies the bond price movements. Once the samples are set, the task is to replicate them one by one by "mini-portfolios."

The advantage of the sampling approach is that the risk parameters with which tracking, or replication, capacity is measured are directly observed, as opposed to the mean-variance approach where they must be estimated. Under the

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1. A third technique they mention based on stress scenarios is less popular.
2. Harry Markowitz, "Portfolio Selection," *Journal of Finance* 7(1), 1952, pp. 77–91.
3. Jerzy Neyman, "On the Two Different Aspects of The Representative Method: The Method of Stratified Sampling and The Method of Purposive Selection," *Journal of the Royal Statistical Society* (June 1934), pp. 558–625.
4. By Andrew Rudd, "Optimal Selection of Passive Portfolios," *Financial Management* 9 (1980), pp. 57–66.

premise that the risk of a corporate bond is predominantly determined by two factors—interest rate and credit risk—the risk of a bond is measured via its sensitivities to these factors, in particular by its duration for the first, and by a combination of duration and credit spread level for the second factor. More precisely, as one study[5] demonstrates, a bond's sensitivity to credit risk can be effectively captured by its Duration Times Spread (DTS).

The two bond risk factors mentioned above are central in corporate bond investing. They are called term-structure risk (also called duration risk and interest rate risk) and credit risk. The sensitivities to these factors, measured by duration and DTS, are what the market betas are to equity investing. A corporate bond is an asset with two market betas, so to speak. If the betas of a bond are matched with those of the market index, its return is set to follow the market trend. If the betas are inferior, its return behavior will likely be defensive, or more precisely, both the interest rate and the credit component of the returns will be. And inversely, long duration and high DTS tend to lead to offensive returns, albeit that the terms *defensive* and *offensive* are less used in bond management than they are in equity management. The same additivity rule applies to equity market betas: the overall duration and DTS of a portfolio are the cap-weighted averages of those of its holdings.

Hence, in the sampling problem the active risk of a portfolio is effectively managed by matching its duration and DTS with those of the target market index, sample per sample. The two efforts that are required in the sampling approach, that is, defining the samples and then replicating them, are both challenging. In fact, defining samples can be regarded as a stylized version of risk modelling, whereby the risk factors that play are merely nominated, not fully estimated. Depending on the philosophy of the investment strategy at hand, the sample definition can recognize the importance of an economic sector effect for instance, or of a combination between country and currency effects. An experienced fund manager may agree that the impact of country and currency group effects on the co-movements of bond prices is, loosely speaking, comparable to those of equity prices.

Beyond the abovementioned habitual group effects on price movements, let us not forget certain pricing phenomena that are specific to corporate bonds. First, there is the phenomenon that credit rating categories affect bond prices at least as much as sectors, countries, and currencies do. Price-covariance levels are notably higher within rating categories than they are between them. Second, there is the phenomenon that firm-specific pricing effects group bonds together that are issued by the same firm. These issuer groupings constitute, an additional layer of covariance relationships compared to other asset classes. The covariance structure between corporate bond returns, which must be considered in the sample structure, consists of multiple layers, one on an individual issue level and one or several on an issuer level.

5. Arik Ben Dor, Lev Dynkin, Jay Hyman, Patrick Houweling, Erik van Leeuwen and Olaf Penninga, "Duration Times Spread" *Journal of Portfolio Management* 33(2), 2007, pp. 77–100.

The various pricing effects are all intertwined with each other into what one may rightfully call a Gordian knot. To get an idea of the complexity, consider the following. The U.S. firm General Electric, which has business activities in several economic sectors and in several countries, has about 100 bonds outstanding at any one time that are denominated in several currencies. Furthermore, bonds issued by the same firm do not necessarily belong to the same rating category in case one is subordinated over the other. At times it is not even trivial to establish whether bonds are issued by the same firm. In order to determine whether firms that are part of a same holding group are distinct risk-bearing entities or not, the 60% ownership rule is applied by convention, though that is only a convention and may not correspond to market reality.

Choosing the samples may be an art, but replicating them is another one. The task of building a portfolio for which the active risk is effectively controlled in the context of a multiple-layered framework of cells, each with a double matching criterion (i.e., duration and DTS) is a challenging combinatorial optimization problem. A bond portfolio manager once compared the task with solving sudoku puzzles. Up to a certain level of complexity, a trained manager can work the problem out without the help of sophisticated tools. Building a tracking portfolio takes about 40 minutes. However, the more considerations that come into play and the more granular the samples setting becomes, the more complex the optimization problem, and there inevitably comes a point where the computer outdoes the manager.

Staying with the base case of two bond risk factors, duration and credit risk, the sampling problem can be formulated in the following way with the relevant equations and notation shown in Exhibit 52-1. Let vector x^p contain the portfolio weights that are to be decided for the N bonds in a given investment universe; let vector x^b contain the N benchmark weights, vector d the N bond durations and vector S the N credit spreads. Introduce matrix Y that defines the sample structure consisting of J samples, as is done in (1) in Exhibit 52-1. In order to facilitate the notations, introduce an auxiliary matrix β that specifies the two matching criteria, duration and DTS, as in (2). For a portfolio x^p, pre-multiplying by matrix Y and post-multiplying by matrix β, as is done in (3), makes its two risk exposures apparent sample per sample. Applying the same operation onto the portfolio that is defined in difference with the benchmark, as is done in (4), makes the active risk exposures apparent, sample per sample.

In the sampling problem, the active exposures determine de facto the active risk, rather than the (active) return variance as by Markowitz' definition. But apart from that, the problem formulations can be very similar. The risk objective can be expressed in a quadratic form, as is done in (5), and the return objective in a linear form, as in (6), where the vector C stands for a given bond selection criterion. Vector C can contain a set of return forecasts, or more generally, it can contain any selection criterion. For the purpose of building index-tracking portfolios, C is simply set to zero. The complete objective function, specified in (7), is thus to maximize the return of the portfolio while minimizing risk, whereby the parameter λ expresses, as usual, the investor's aversion to risk.

Several implementation constraints are habitually imposed, four of which are specified below. Equation (8) imposes that portfolio holdings may not be negative, which makes sense since corporate bonds can in any event not be sold short. There is no such thing as primary brokerage in the bond markets. Equation (9) imposes the cardinality constraint, meaning that holdings must be few to keep trading costs down. Equation (10) imposes that the holdings must sum up to 1, or to any given leverage target. Equation (11) imposes the requirement that portfolio holdings must be exact multiples. The latter constraint addresses the situation in the corporate bond markets that securities are traded in lots of designated sizes; there is a fixed initial lot size and thereafter there are fixed increments, both of which may differ from security to security. Note that because of the lot sizes, the portfolio optimization problem is discrete rather than continuous, which adds importantly to the complexity of solving the problem.

On top of this set of constraints, additional ad hoc constraints tend to be imposed, which have to do with market liquidity. Liquidity problems are severe in the corporate bond markets, and there is no easy way of dealing with that. An extra hurdle is that there are no reliable data available on matters such as trading volumes, which can bring the problems to light. The most informative data at hand are the so-called bond liquidity scores, produced by data vendors since 2009, which are essentially proxies for trading costs. These scores reveal, in line with common perception, that trading costs vary significantly between bond issues, ranging from a few basis points for the most liquid bonds down to prohibitive amounts for the least liquid.

To limit trading costs, it therefore makes sense to integrate the liquidity cost scores, or some data equivalent, denoted L, into the portfolio optimization problem. A simple linear cost term as specified by (12) could be inserted into the objective function given by (7); however, note that such term would be valid only if the portfolio is to be built up from scratch. If not, if it concerns a rebalancing with respect to an existing portfolio, denoted by p', specifying a liquidity-cost objective becomes more complex. One way would be to introduce a cost term that takes a quadratic form, as the one given by (13). Optimizing with respect to this cost term has two positive effects, it zooms in on the most liquid bonds and, more importantly, it tends to reduce the portfolio turnover.

It would take a small step to convert the problem formulation given in Exhibit 52-1 into one that corresponds to the mean-variance optimization framework. It suffices to replace the identity matrix I in the objective function given by (7) by a 2×2 factor covariance matrix. The parameters, meaning the variance and covariance of the two risk factors, would need to be estimated since they are not directly observable. The minor modification translates the active risk exposures in effect into active return variances. The formulation that results is in its exact format not used much in practice; however, it does highlight the key features that are commonly present in portfolio optimization applications, namely the central role of the duration- and credit-risk factor, and the sample structure.

EXHIBIT 52-1

The Stratified Sampling Problem

Sample definition	$Y_{NxJ} : y_{ij} = \begin{cases} 1, \textit{ if bond i is in sample j} \\ 0, \textit{ otherwise} \end{cases}$	(1)
Matching criteria	$\beta_{Nx2} = [d \quad d \cdot S]$	(2)
Sample exposures	$Y \cdot x^p \cdot \beta$	(3)
Active exposures	$Y \cdot \mid x^p - x^b \mid \cdot \beta$	(4)
Active risk	$(Y \cdot (x^p - x^b) \cdot \beta)^T \cdot I \cdot (Y \cdot (x^p - x^b) \cdot \beta)$ where I is a two-dimensional identity matrix	(5)
Performance	$C^T \cdot x^p$	(6)
Objective	max. $C^T \cdot x^p - \lambda \cdot (Y \cdot (x^p - x^b) \cdot \beta)^T \cdot I \cdot$ $(Y \cdot (x^p - x^b) \cdot \beta)$ subject to	(7)
Positivity constraint	$\forall_i : x_i^p \geq 0$	(8)
Cardinality constraint	$\sum_i = {}_1^N \textit{ nonzero } (x_i^p) << N$	(9)
Leverage constraint	$\sum_i x_i^p = 1$	(10)
Lot-size constraint	$\forall_i : x_i^p \in \mathbb{N}$	(11)
Linear costs	$L^T \cdot x^p$	(12)
Quadratic costs	$(x^p - x^{p\prime})^T \cdot L \cdot (x^p - x^{p\prime})$	(13)
	$(C_1 \cdot x_1 - C_2 \cdot x_2) - \lambda \cdot \lvert d_1 \cdot S_1 \cdot x_1 - d_2 \cdot S_2 \cdot$ $x_2 - D_j \cdot S_j \rvert$	(14)

The risk model that underpins the problem specification displayed in the equation above for the objective function is, notionally, a linear factor model with two common factors and $J \times 2$ fixed effects. It is not trivial to estimate this model, or in general any risk model, for corporate bonds. What complicates matters is that bond returns are not stationary over time, while that is a precondition for time-regression models to be valid. Note that the return behavior of bonds is not stationary in principle, as the bonds' risk profiles fade in time as they approach the maturity date. The estimation procedures that are usually pursued for modelling asset risk, whereby sensitivities, or *betas*, of individual securities with respect to common risk factors are derived via time-series regressions, fatally fail.

Besides the purely mechanical reason for the nonstationarity issue that is mentioned above, the return behavior of corporate bonds is not time stationary by nature. When a bond loses value, and its credit spread widens, it tends to become more price-sensitive to credit events, to the extent that the amplitude of its price reactions increases. However, as one study[6] points out, since the increase in sensitivity is proportional to the widening of the spread, denoted S, scaling down the returns by dividing them by S, while scaling up the sensitivities, or betas, offsets this nonstationary effect and brings the returns back into the fold (i.e., into a linear framework). It is upon this market observation that the sampling and the mean-variance optimization framework crucially relies.

The observation made above underlines the fact that the credit betas of corporate bonds are not static over time. That has important repercussions for the risk budget of an investment portfolio that seeks to provide an indication of how much assets or asset groups contribute to the overall portfolio risk. As long as the portfolio contains corporate bonds only, the effect of time-varying bond betas is limited, but as soon as these bonds are mixed with other assets, the overall risk budget starts to vary over time depending on the prevailing credit spread levels. In times when corporate bonds are low valued, their contribution to the portfolio risk increases. This indeed has been observed to occur during crisis periods. It is a market phenomenon that is specific to corporate bonds that sets them somewhat apart from other asset classes.

Since it is not valid to run time-regressions on an individual security level, stationarity is usually sought on an aggregate level. On an economic sector level, for example, the characteristics that typify the overall risk profile of corporate bonds in the sector tend to be stationary. What is often ignored is that this is the case essentially because market-index providers deliberately make that happen. Bonds are purposely selected and rolled over in the index constituents so as to convey a stable and representative picture of the corporate bond market as a whole, sector by sector. The validity of the risk models that are estimated on an aggregate corporate bond level therefore relies a great deal on the diligence of the market-index providers.

The mean-variance optimization framework is less popular among bond managers than stratified sampling but is in use nevertheless for assessing corporate bond portfolios in some format or another. It serves for ex post reporting purposes predominantly, typically for regulatory bodies or for clients who are familiar with the mean-variance methodology and its terminology. However, apart from being a means of communication, it is not clear whether many fund managers build their corporate bond portfolios ex ante through mean-variance optimization. The hesitations stem from the fact that the method is less transparent and intuitive compared to sampling techniques.

Portfolio Construction

Even if the formulation of the corporate bond portfolio optimization problem is settled, stipulating which risk measures to use and how to combine them, it is not evident how to derive the optimal portfolio. Moreover, the question of

6. Ben Dor, Dynkin, Hyman, Houweling, van Leeuwen and Penninga, "Duration Times Spread."

constructing corporate bond portfolios has been, as elementary as it may seem, subject to fierce debate in recent years. The debate got going on the building of the so-called factor-investing portfolios. Since Asness, Moskowitz, and Pederson[7] have shown that factor investing makes sense, not only for equities, but for currencies, commodities, and government bonds as well, the attention turned to the one asset class that was left out, which is corporate bonds.

In the idea of carrying over a success story from one asset class to another, the same method of constructing factor portfolios has been proposed for corporate bonds as has been demonstrated to be efficient for equities. Researchers have proposed building bond factor portfolios through rankings.[8] This is done by constructing four bond factor portfolios corresponding to value, momentum, size, and low risk and by retaining the top deciles of bonds that are ranked by the respective criteria. This method has the merit of being transparent and giving full exposure to the factors in question; however, no consideration is given to risk. With reference to the mean-variance optimization framework, the portfolios that are built in this way correspond to the extreme case where the aversion to risk is nil, that is $\lambda = 0$.

Such extreme portfolios will not suit mainstream investment purposes, where risks must be managed. As soon as risk considerations come into play, formally $\lambda > 0$, the portfolio optimization problem underlying a factor-investing strategy becomes more complex. In fact, it corresponds to the problem that is formulated by the set of equations given by (7) to (11) in Exhibit 52-1, whereby the performance target, the vector C, contains the factor selection criterion. In that setting, simple bond rankings will no longer do. How to proceed then? How does a portfolio manager build risk-balanced factor portfolios? Israel, Palhares, and Richardson[9] give an interesting yet not very intuitive account. In their article they give a lengthy description of how they build bond factor portfolios that are adjusted for risk. What follows is a second account given by a fund manager who shall be identified simply as Manager X.

Manager X pursues a factor-investing strategy that is geared to mitigating climate risk. Manager X seeks to protect the invested capital against climate issues that are at play. To do so, Manager X introduces a tilt into the invested portfolio toward low-carbon enterprise. Thus, instead of introducing a value or a momentum tilt, Manager X introduces a carbon tilt, but apart from that the portfolio optimization problem is the same one. The vector C in the performance

7. Clifford Asness, Tobias Moskowitz and Lasse Heje Pedersen, "Value and Momentum Everywhere." *Journal of Finance* 58(3), 2013, pp. 929–985.
8. Demir Bektic, Ulrich Neugebauer, Michael Wegener, and Josef-Stefan Wenzler, "Common Equity Factors in Corporate Bond Markets," chapter 9 in Emmanuel Jurczenko (ed.), *Factor Investing: From Traditional to Alternative Risk Premia* (London: ISTE Press–Elsevier, 2017); Patrick Houweling and Jeroen van Zundert, "Factor Investing in the Corporate Bond Market," *Financial Analysts Journal* 73(2), 2017, pp. 100–115.
9. Ronen Israel, Diogo Palhares and Scott Richardson, "Common Factors in Corporate Bond and Bond Fund Returns," *Journal of Investment Management* 16(2), 2018, pp. 17–46.

objective contains carbon scores that are assigned to all bonds, which measure the tons of carbon dioxide emitted by the issuing firms during a given year divided by the firms' sales revenues over that year. Thanks to these scores, the efficiency of the production processes can be compared among firms, and that irrespective of the firm sizes. The idea is to invest in the best-in-class. To facilitate direct comparison, the scores are normalized, or z-scored, per sector.

Manager X invests in the global investment-grade corporate bond universe, which counts more than 7000 bonds. Manager X starts by reducing the vast universe down to more approachable numbers by applying two filters. First, a liquidity filter is run discarding the bottom third (least liquid bonds). Manager X can opt to apply liquidity cost scores for doing this, or alternatively simply screen on the bonds' debt sizes (which are actually a reasonably good proxy for liquidity). Incidentally, an argument for screening on size is that the carbon data quality is not great anyway for small firms. Manager X then runs an initial carbon filter, again discarding the bottom third of the bonds.

Note that since the carbon data are z-scored per sector, the bottom third will be weeded out within each sector more or less, leaving all sector groups sufficiently populated, which is a necessary condition for being able to control the risk of the portfolio. To generalize on the latter observation, running pre-screens is viable only for investment strategies that have a relative performance objective. In the case of the carbon investment, for example, if the best-in-class philosophy were replaced by an absolute view (in particular, if the goal were to minimize the absolute carbon footprint of the portfolio), the carbon screen would do more harm than good. In that case it would wipe out the carbon-intensive sectors entirely, leaving no possibility to straighten it out.

Among the bonds that remain, which take up a bit less than half of the universe at this point, Manager X starts selecting bonds proceeding in two consecutive steps. First, Manager X picks, among the bonds that are issued by the same firms, those that best represent the issuer groups, and then selects among the issuer groups that result. For most issuer groups, picking two bonds suffices, one with a DTS lower than the group average and the other higher, so that by weighing the two, the mutual DTS can be matched to the group average exactly. For large multinationals as for example for General Electric discussed earlier, it is wise to keep a few more bond issues. The debt structure of such large conglomerates cannot be captured effectively by two bonds. Given that there are around five issues per issuer on average in the global investment-grade universe, this selection procedure further thins out the bond population considerably.

Manager X will make one more short cut in order to make the task of optimizing the portfolio doable. After constructing the portfolio, Manager X will control the overall duration of the investment by installing a hedge using derivative instruments. Manager X will install an overlay of bond futures, one overlay per currency zone. Although keeping the futures matched with the portfolio holdings is a tedious exercise and is less precise than a real duration match via the bonds themselves, it has the advantage that it simplifies the portfolio optimization problem. This is because one of the two matching criteria is effectively removed. In this setting Manager X sets out to solve the core of the optimization problem. The task is then to select a limited number of issuers that concertedly reduce the carbon intensity while at the same time track the market index.

The bonds that have survived the various screens up to this point constitute an initial portfolio; it serves as a starting point for the local-search procedure that Manager X will apply next. But before being in a position to start the search, the sample structure must be defined. The samples should bring about the covariance structure underlying the bond price movements, as discussed earlier. Meanwhile it should agree with the philosophy of the investment strategy. For the strategy at hand the choice is straightforward. The notion of best-in-class it adheres to refers to economic sectors naturally; the intention is to purchase the assets of firms that have the most efficient production lines in terms of carbon emissions compared to their peers that operate in the same economic conditions, and thus in the same sector.

The sample choice is less obvious to make when designing a *quality* factor portfolio for example. Would it make sense to compare the creditworthiness of the issuing firms with peers in the same sector or rather with firms in the same credit rating category? The answer is not clear-cut. And besides, running pre-screens may not result in a pertinent *quality* factor portfolio either. Discarding the bottom third, the least creditworthy firms may wipe out the lowest rating category among the investment-grade bonds (i.e., the, BBB-rated bonds) entirely. In fact, the opposite may happen when trying to build a *value* factor. Screening on cheap-or-dearness would mechanically lead, if no care is taken, to discarding the highest rating categories (i.e., the AAA- or AA-rated bonds). Both such screens would introduce significant biases, which may lead to unintended tracking error.

Manager X decides to divide the bond world into three geographic zones: the United States plus Canada, Europe, and the rest of the world, and to divide each of them into 15 sectors. The third zone isn't actually very coherent and indeed turns out not to track very well; however, as long as the weight of this zone within the global bond index remains small, typically less than 15%, it does not weigh much on the overall performance. Hence, Manager X defines 3 × 15 samples and therefore has as many matching points for the portfolio to align in terms of DTS to the market index. The search procedure may then begin. The performance of the starting portfolio, obtained after the screening, can be quantified; its tracking capacity is measured by the scale of the mismatch in DTS summed over the matching points, and the tilt is measured in terms of relative carbon intensity.

Starting from the initial portfolio, issuer groups are eliminated in a way so as to move closer to the investment target. Manager X deploys an iterative selection procedure. The selection method relies on the same pairing principle that was used for replicating the issuer groups, namely that any two issuers, one having a low DTS and the other a high, can attain any DTS level together by adjusting their relative weights. The art is to find the pair among the many candidates that offers the best improvement, while siphoning weight from the one to the other.

Manager X chases up the winning pair, executes the optimal weight adjustment, and while doing so sees his portfolio improve step by step.

Pairs are sought within the sample groups of course. The improvement, or gain, a pair, x_1 and x_2, makes can be quantified as is done in equation (14) of Exhibit 52-1, where $D_j \cdot S_j$ is the target DTS of the sample j to which the pair belongs. At times, while executing a weight adjustment within a pair, the entire weight is siphoned away from one issuer. If that happens, the issuer is automatically eliminated from the portfolio. It may also happen that a small residual weight remains. Manager X decides to remove residual weights if they fall under a given threshold. The size of the threshold effectively controls how many portfolio holdings will eventually be retained.

This local-search procedure can be carried out by a computer algorithm. The advantage is that the search is exhaustive, as all combinations can be investigated in the space of a few microseconds. Also, nontrivial weight adjustments can be detected, which the eye does not spot, which do not necessarily lead to the elimination of an issuer but does sharpen up the portfolio. Moreover, the algorithm can be enhanced to deal with market liquidity as well. The liquidity scores can be inserted into the gain formula in a way as to give more chance to the most liquid bonds in a pair to survive. Or more importantly, if the optimization concerns a rebalancing of an already-invested portfolio, a penalty function can be introduced into the optimization objective that is geared to avoid excessive trading. Of course, to achieve that the gain formula must be calibrated carefully.

The optimization problem, which is the core of the sampling approach, is akin to the so-called knapsack problem.[10] This problem falls into the category of mixed-integer combinatorial optimization problems, which are NP-hard,[11] meaning that they are notoriously difficult to solve. Local-search computation algorithms are used habitually for solving this kind of problem, by which an initial solution is improved step by step until no more improvement is found.[12] The procedure that is described above can indeed be run by a computer algorithm programmed out. Interestingly, machine learning techniques appear to be effective for solving the bond portfolio optimization problem; in particular, the so-called genetic algorithms are successful.[13] In this method, not one but many solutions are tried simultaneously. They are locally improved, cross-fertilized

10. Tobias Dantzig, *Number: The Language of Science* (New York: MacMillan, 1930).

11. The CPU time needed for finding a solution grows exponentially with the problem size. See Norbert Jobst, Michael Horniman, Cormac Lucas, and Gautam Mitra, "Computational Aspects of Alternative Portfolio Selection Models in the Presence of Discrete Asset Choice Constraints," *Quantitative Finance* 1 (May 2001), pp. 489–501.

12. Stephen Satchell and Alan Scowcroft, *Advances in Portfolio Construction and Implementation* (Elsevier, 2003).

13. John Holland, "On Iterative Circuit Computers Constructed of Microelectronic Components and Systems." In *Proceedings of the 1960 Western Joint Computer Conference (WJCC)* – Session on the Design, Programming, and Sociological Implications of Microelectronics, National Joint Computer Committee, IEEE, 1960.

in a cunning way, and put into competition so that eventually the one with the strongest features survives.

The successes of such computer-powered solution techniques do not make the traditional bond manager redundant though. An important aspect of corporate bond investing is that the conditions keep changing, arguably more so than for other asset classes, and the problem setting should keep up with that. In particular, the market composition evolves relatively fast due to the continuous issuance and maturing of bonds, which can make the samples over- or undercrowded as a result. But also changes in the fund itself call for resets. While a fund grows, for example, more portfolio holdings can be afforded and with that a more granular sample setting, which eventually leads to better-optimized portfolios. Clearly, for dealing with such matters the versatile manager outdoes the subservient machine.

The bond management profession is facing a dilemma in this respect. It could be envisaged, going to one extreme, to develop powerful catch-all computer algorithms that are geared to solving the portfolio optimization problem in its most generic format. In that way, large quantities and a wide range of investment cases can be dealt with rapidly, albeit with little room for flexibility and customization. Or, going to the other extreme, the portfolio construction processes can remain ad hoc and largely manual, tailored to specific situations. This option may win based on quality but certainly loses out on quantity. It is not evident where the profession is going today, and the finance literature remains remarkably silent on this question. But overall, it is fair to say that automated algorithmic portfolio construction is gaining steam.

One market innovation that has stimulated the use of automated portfolio construction procedures over the last few years is the trading of what are referred to as "baskets in kind." These baskets are fictive stylized portfolios meant to represent the corresponding investment funds, which serve as reference points for handling the regular inflows and outflows of funds. Every morning for each fund, two baskets are produced and posted online, one for the subscriptions and one for the redemptions that may come in that day. The baskets facilitate the negotiations. In many cases, they are purchased or sold entirely; sometimes they are partly renegotiated. Considering that an average bond manager takes around 40 minutes to produce one in-kind basket manually, the interest of automating their construction is easy to understand.

KEY POINTS

- A unique aspect of corporate bonds is that they give access to a multiple of market exposures, all of which can be adjusted isolated and hedged out individually so as to fit precise investment purposes. Corporate bonds make it possible for investors to take a position on interest rate movements and on currency exchange rates, on top of firm-specific corporate credit risks.

- Corporate bonds are in effect utilized for a large spectrum of investment purposes, ranging from income-oriented strategies, such as liability-driven investing and long-term savings, to more price-driven strategies including pure alpha strategies.
- The risk of a corporate-bond portfolio is usually measured by means of directly observable characteristics; in particular, the duration measures the exposure to interest-rate risk and it is more and more popular to use the duration-times-spread for measuring the exposure to credit risk.
- There are basically two approaches to building corporate bond portfolios in use: the traditional mean-variance optimization method and the stratified sampling technique.
- As the daily management of corporate bond portfolios is becoming increasingly complex, especially since the handling of fund redemptions and subscriptions are taking place over baskets-in-kind, bond managers rely more on computer-powered portfolio-optimization algorithms.

CHAPTER
FIFTY-THREE

MANAGING THE SPREAD RISK OF CREDIT PORTFOLIOS USING THE DURATION TIMES SPREAD MEASURE

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The standard presentation of the asset allocation in a portfolio or a benchmark is in terms of percentage of market value. It is widely recognized that this is not sufficient for fixed income portfolios, where differences in duration can cause two portfolios with the same allocation of market weights to have extremely different exposures to macro-level risks. As a result, fixed income portfolio managers have become accustomed to expressing their allocations in terms of contributions to duration—the product of the percentage of portfolio market value represented by a given market cell and the average duration of securities comprising that cell. This represents the sensitivity of the portfolio to a parallel shift in yields across all securities within this market cell. For credit portfolios, the corresponding measure would be contributions to spread duration, measuring the sensitivity to a parallel shift in spreads. Determining the set of active spread duration bets (the differences between the exposures of the portfolio and the benchmark) from various market cells and/or issuers is one of the primary decisions taken by credit portfolio managers.

Yet all spread durations were not created equal. Just as one could create a portfolio that matches the benchmark exactly by market weights, but clearly takes more credit risk (e.g., by investing in the longest duration credits within each cell), one could match the benchmark exactly by spread duration contributions and still take more credit risk—by choosing the credits with the widest spreads within each cell. These credits presumably trade wider than their peer groups for a reason—that is, the market consensus has determined that they are more risky—and are often referred to as "high-beta" credits, because their spreads tend to react more strongly than the rest of the market to any systematic shock.

Based on this idea, and following an extensive analysis of corporate bonds' spread behavior, we have advocated since 2005 a new measure of risk sensitivity that utilizes spreads as a fundamental part of the credit portfolio management process. To reflect the view that higher spread credits represent greater exposures to sector-specific risks, we represent sector exposures by contributions to *Duration Times Spread* (DTS), computed as the product of market weight, spread duration, and spread. The shift from spread duration exposures to DTS exposures as the measure of market risk embraces a different paradigm for credit spread movement—in the form of relative spread changes rather than parallel shifts in spread.

The paradigm shift resulting from the DTS concept has many implications for portfolio managers, both in terms of the way they manage exposures to industry and quality factors (systematic risk) and in terms of their approach to issuer exposures (nonsystematic risk). First, modeling spread changes in relative rather than absolute terms generates improved forward-looking estimates of excess return volatility. Second, for computing the hedge ratios needed to form market-neutral credit trades, DTS is superior to "empirical betas" as a measure of market sensitivity. Third, for index replication, matching sector-quality allocations of a credit index in terms of contributions to DTS leads to improved tracking compared with matching the contributions to spread duration. This same way of viewing macro exposures can help to more accurately express active portfolio weights as well. Fourth, DTS-based issuer limits can be considered as an alternative to more standard caps on issuer market weight when imposing portfolio diversification constraints. Finally, the incorporation of the DTS approach into the design of multifactor risk models can help make such models more robust, more compact, and more accurate. In this chapter, we will explore each of these applications in turn, after a brief overview of the large body of evidence supporting the DTS concept.

THE NEED FOR A NEW MEASURE OF CREDIT SPREAD EXPOSURE

Two examples of market conditions when spread duration contributions do not suffice are shown in Exhibit 53-1. During the dot-com crisis, a relief rally in January 2001 led to a temporary tightening of spreads throughout the communications sector. However, that rally was not characterized by a purely parallel shift; rather, issuers with wider spreads tightened by more. Panel A displays the changes in spreads experienced in that month by the key issuers that made up the communications sector of the Bloomberg Barclays Corporate Index.[1] Panel

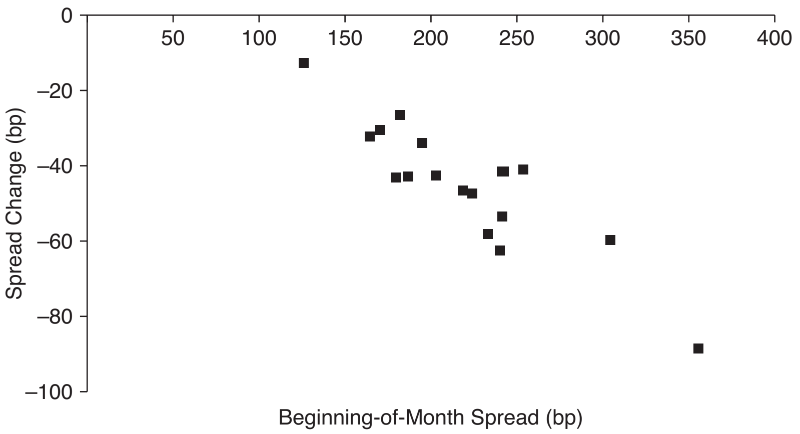
1. "Key issuers" refers to issuers that had outstanding issues with market value in excess of 1% of the sector aggregate market value. Panel A shows seventeen issuers that represented 216 outstanding issues; Panel B includes 19 issuers and 420 bonds.

B shows the spread tightening in the key issuers in the banking sector during the month of December 2010; a similar effect is seen in this industrywide rally.

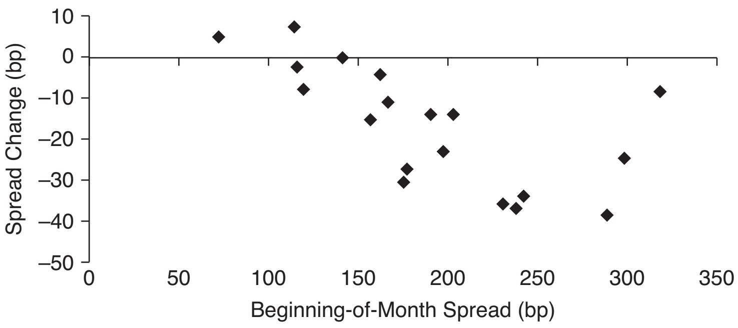
EXHIBIT 53-1

Spread Changes of Key Issuers in the Communications and Banking Sectors

Panel A. Communications Sector, January 2001



Panel B. Banking Sector, December 2010



Source: Barclays

Confronted with this reality, we conducted an extensive analysis of corporate bonds' spread behavior and developed a new measure of spread risk sensitivity. As higher spread credits have greater exposures to sector-specific risks, we represent sector exposures by contributions to DTS, computed as the product of market weight, spread duration, and spread. An overweight of 5% to a market cell implemented by purchasing bonds with a spread of 80 bps and spread duration of three years will be considered to be equivalent to an overweight of 3% using bonds with an average spread of 50 bps and spread duration of eight years ($0.05 \times 0.80 \times 3 = 0.03 \times 0.50 \times 8 = 0.12$).

How does this make sense? As mentioned above, a portfolio's contribution to spread duration within a given market cell is its sensitivity to a parallel shift in spreads across all bonds in that cell. What is the intuition behind this new measure?

In fact, the intuition is very simple. Let us look at a simple expression for the return of a given bond due strictly to change in spread R_{spread}. Let D denote the spread duration of the bond and s its spread; the spread change return is then given by

$$R_{spread} = -D \cdot \Delta s \tag{53-1}$$

It is quite easy to see that this equation is equivalent to

$$R_{spread} = -(D \cdot s) \cdot \frac{\Delta s}{s} \tag{53-2}$$

That is, just as spread duration is the sensitivity to an absolute change in spread (e.g., spreads widen by 5 bps), DTS is the sensitivity to a relative change in spread (e.g., spreads increase by 5% of their current levels). Note that this notion of relative spread change provides for a formal expression of the rough idea discussed above—that credits with wider spreads are riskier since they tend to experience greater spread changes in absolute terms.

Based on the absolute spread change approach (Equation 53-1), the volatility of excess returns can be approximated by

$$\sigma_{return} \cong D \cdot \sigma_{spread}^{absolute} \tag{53-3}$$

while in the relative spread change approach (Equation 53-2), excess return volatility follows

$$\sigma_{return} \cong D \cdot s \cdot \sigma_{spread}^{relative} \tag{53-4}$$

Given that the two representations above are equivalent, why should one of them be preferable to another? The key advantage of the DTS approach of Equation 53-4 is that relative spread volatilities are much more stable than absolute spread volatilities. We found extensive empirical evidence that the volatility of absolute spread changes of U.S. corporate bonds (both systematic and idiosyncratic) is linearly proportional to spread level, irrespective of sector, maturity, credit quality or time period.[2] This implies that the second approach, based on relative spread changes, should generate more accurate projections of spread volatility.

2. Arik Ben Dor, Lev Dynkin, Patrick Houweling, Jay Hyman, Erik van Leeuwen, and Olaf Penninga, "DTS (Duration Times Spread): A New Measure of Spread Exposure in Credit Portfolios," *Journal of Portfolio Management*, 33(Winter 2007), pp. 77–100.

SPREAD VOLATILITY AND DTS

The relation between the volatility of systematic spread changes and the average beginning-of-month spread level is plotted in Exhibit 53-2. The analysis was carried out using a large sample with over 560,000 monthly observations on all constituents of the Bloomberg Barclays Corporate and High Yield Indices rated B or higher between September 1989 and January 2005.[3] Bonds in each of the three main sectors (financials, industrials, and utilities) were divided into three equally populated duration buckets (short, medium, and long). Bonds in each duration bucket were then partitioned into pre-specified cells based on spread. Spread cell breakpoints varied across sector and duration to ensure that each spread cell was well populated monthly.[4] This procedure resulted in 66 distinct time series data sets; each consisted of a fairly homogeneous set of bonds with monthly data for their spreads and spread changes. The systematic spread change in a given cell each month was represented simply as the average spread change across all bonds that comprised that cell. We then calculated the time series volatility of these systematic spread changes and the average spread over time for each cell.

The results indicate an almost perfect linear relationship between spread volatility and the level of spread that can formally be expressed as

$$\sigma_{spread}^{absolute}(s) \cong \theta \cdot s \tag{53-5}$$

Estimating a simple regression based on Equation 53-5 provides an excellent fit to the data (R^2 in excess of 90%) with the slope coefficient θ equal to 9.1% using all observations and 9.4% if the three circled outliers are excluded.[5] Furthermore, for a given level of spread, the differences across sectors and maturity buckets are fairly small. Hence, the historical volatility of systematic spread movements can be expressed quite compactly, with only minor dependence on sector or maturity, in terms of a relative spread change volatility of about 9–10% per month. That is, spread volatility for a market segment trading at 50 bps should be about 4.5–5.0 bps/month, whereas that of a market segment at 200 bps should be about 18–20 bps/month.

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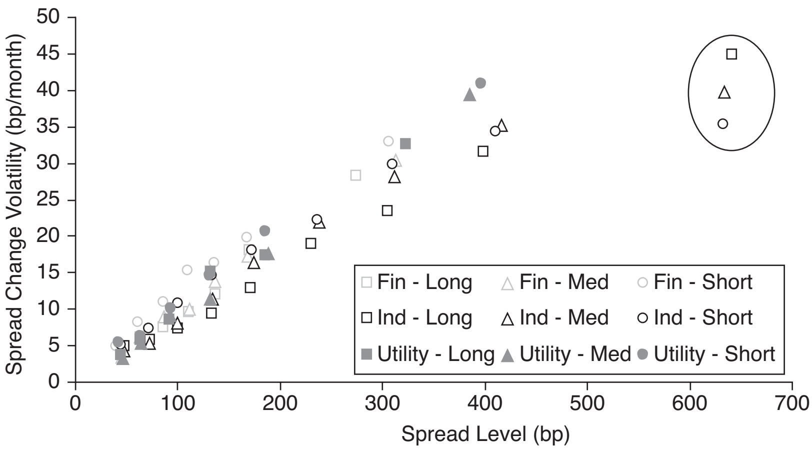
3. See Ben Dor, Dynkin, Houweling, Hyman, van Leeuwen, and Penninga, "DTS (Duration Times Spread): A New Measure of Spread Exposure in Credit Portfolios" for further detail regarding the analyses shown in Exhibits 53-2 and 53-3. In this section, we report our original results using data through 2005. In what follows, we use market data after this date as an extreme out-of-sample test of these relationships.
4. Bonds were assigned to one of 66 cells with breakpoints ranging from 100 bps to over 500 bps (the financial, industrial, and utility sectors had seven, nine, and six spread cells for each maturity bucket, respectively). To eliminate idiosyncratic effects, months in which a cell was populated by fewer than 20 bonds were excluded. Employing a weighted volatility estimate instead (where the number of observations in each month was used as the weighing factor) produced very similar results.
5. The population of the three highest spread cells (bonds trading at spreads above 500 bps) was very scarce for most of the study period. Consequently, most of their monthly spread realizations were excluded (due to the minimum bond population requirement). The statistical relevance of these most extreme data points is therefore questionable.

We also studied whether idiosyncratic spread volatility is similarly related to the level of spreads. We computed the standard deviation of the differences between all individual bonds' spread changes and the average spread change of their respective cell, pooled across all bonds and months. This pooled measure of idiosyncratic spread volatility per market cell was then plotted against the median spread of the cell. We again found a very strong linear relationship between spread and idiosyncratic spread volatility, with a slope similar to that estimated for systematic volatility.

EXHIBIT 53-2

Time Series Volatility of Systematic Spread Changes vs. Spread Level



Based on monthly observations for all constituents of the Bloomberg Barclays Corporate and High Yield Indices rated B or better, September 1989–January 2005.

Source: Barclays

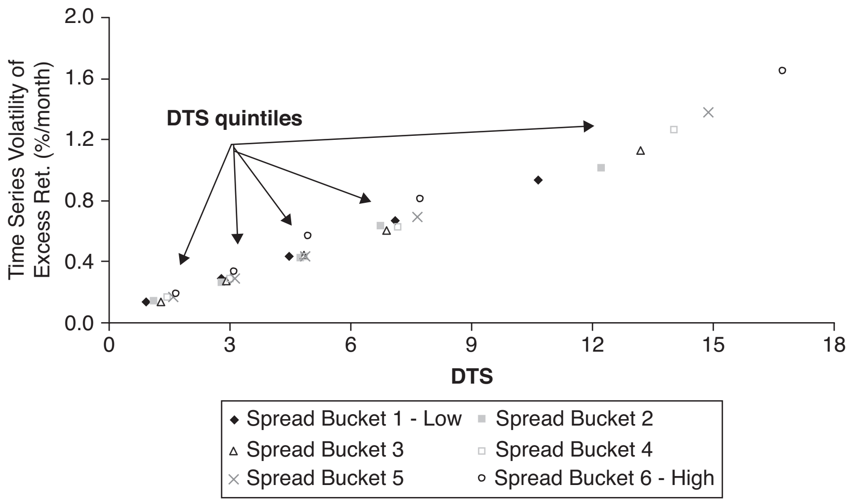
To corroborate these findings, we also investigated the relation between excess return volatility and DTS. If the volatility of systematic spread changes is proportional to the level of spread, then Equation 53-4 implies that a portfolio's excess return volatility should increase linearly with its DTS, with the slope equal to the volatility of relative spread changes. In addition, excess return volatility for portfolios with similar DTS should be approximately equal even if their spreads or spread durations differ.

To examine these predictions, bonds were assigned into DTS quintiles, which in turn were further subdivided into six equally populated buckets based on spread. The average excess returns and median DTS were calculated monthly for each bucket separately. These statistics were then used to compute the excess return volatility and average DTS for all time series.

The results of this analysis are presented in Exhibit 53-3, which plots the time series volatility of excess returns for each of the quintile-bucket combinations against its average DTS. First, it is clear that excess return volatility increases with the level of DTS and that a straight line through the origin provides an excellent fit. This is indeed confirmed by a regression of the excess return volatility against the average DTS, which finds a fit of 98% and an insignificant intercept. Furthermore, the estimate of the slope coefficient (8.8%) is in line with the volatility of relative spread changes found in Exhibit 53-2, as expected. Second, observations representing the same DTS quintile exhibit very similar excess return volatilities despite large difference in their spreads and durations.[6]

EXHIBIT 53-3

Excess Return Volatility vs. DTS



Based on monthly observations for all constituents of the Bloomberg Barclays Corporate Index, September 1989 to January 2005.

Source: Barclays

In 2009, we re-examined whether the key findings underlying the DTS concept remained valid through the credit crisis of 2007–2009.[7] We showed that the fundamental relationship between the level of spread and subsequent volatility persisted in a linear fashion across all sectors and credit ratings, although the proportionality factor increased from 10% to about 15%. While this implies that a long-term calibrated DTS model would not have fully captured spread risk during the crisis months, we demonstrated that it was far more effective than any other

6. The one exception to this is in the highest DTS quintile, where the subdivision by spread causes wide variations in DTS as well. As a result, the observations no longer form a tight cluster, but they continue to follow the same general relationship between DTS and excess return volatility.

7. Madhur Ambastha and Arik Ben Dor, "DTS (Duration Times Spread) in the Credit Crunch: Did It Live Up to Expectations?" *Barclays Research* (April 2009).

spread duration-based measure. The explicit use of spread in the DTS framework as a barometer of risk proved to be of paramount importance in managing credit portfolios during that volatile period.

The concept of spread proportionality and DTS are not limited only to U.S. corporate bonds. From a theoretical standpoint, we showed that structural credit risk models such as the Merton model imply a near-linear relationship between spread level and volatility.[8] Subsequent empirical studies indeed found that the applicability of DTS extends to other spread asset classes with a significant default risk. For example, we investigated the dynamics of CDS spreads[9] in both the U.S. dollar and euro markets using a different estimation approach, sample period and data frequency than those used in the original study of U.S. corporate bonds. Despite these differences in data and technique, we found clear evidence of a linear relation between spread volatility and spread level with a very similar slope.[10] Similar results were documented for European corporate and sovereign bonds and emerging market sovereign debt denominated in U.S. dollars.[11]

RISK PROJECTION: PREDICTING SPREAD VOLATILITY

Perhaps the most important requirement for managing a credit portfolio successfully is the ability to measure its risk accurately. A key benefit of DTS in the context of generating volatility forecasts is its use of current spread levels to quickly adapt to changing market conditions. In contrast, estimates based on past realized spread volatility can take longer to adapt, depending on the time window used for calibration. The selected time period is inherently subjective and may not perfectly reflect the current state of the market.

The credit crisis of 2007–2009 provides an excellent opportunity to examine the differences between forecasts based on DTS and traditional measures relying on historical realized spread changes for at least two reasons. First, the magnitude of the crisis was unprecedented. Spreads of U.S. investment-grade bonds widened to an all-time high of more than 6%, from lows of around 1% in the benign 2003–2006 period. Similarly, spreads of high-yield bonds rose to more

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8. Arik Ben Dor, Lev Dynkin, and Jay Hyman, "A Theoretical Basis for DTS (Duration Times Spread)," *Lehman Brothers* (December 2007). Robert C. Merton, "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance* 29 (May 1974).

9. Arik Ben Dor, Simon Polbennikov, and Jeremy Rosten, "DTS (Duration Times Spread) for CDS: A New Measure of Spread Sensitivity," *Journal of Fixed Income* 16 (Spring 2007), pp. 32–44.

10. Ben Dor, Polbennikov, and Rosten (2007) used maximum likelihood to estimate the relation between spread volatility and spread level of individual U.S. and European default swaps, based on weekly data over the period July 2004 and May 2006.

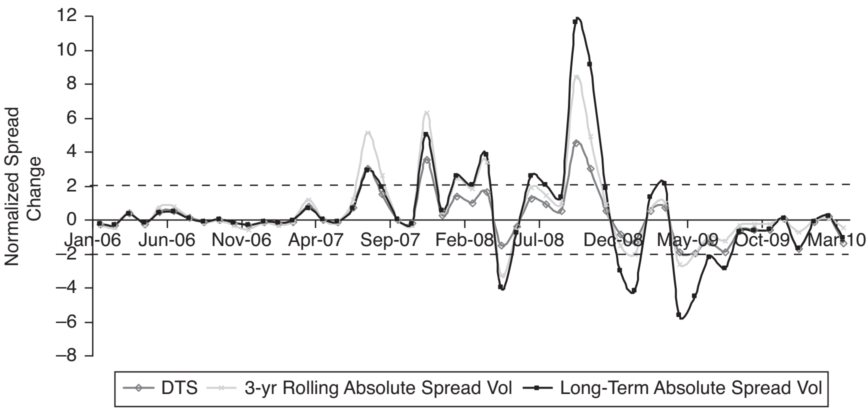
11. See Arik Ben Dor, Lev Dynkin and Jay Hyman, "DTS—Further Insights and Applicability," *Lehman Brothers* (August 2005). Arik Ben Dor, Albert Desclée, Jay Hyman, and Simon Polbennikov, "Managing European Sovereign Spread Risk," *Barclays Research* (August 2010). Madhur Ambastha, Arik Ben Dor and Lev Dynkin, "DTS (Duration Times Spread) for Emerging Market Securities—A New Measure of Spread Exposure," *Lehman Brothers* (February 2007).

than 18% and credit default index swap (CDX) spreads increased by a factor of five. Not only the magnitude, but also the extraordinary speed at which spreads widened, caught many investors off guard, with risk estimates calibrated to the sustained "volatility drought" of the previous few years severely underestimating the spread risk of corporate bonds. Second, since the concept of DTS was first introduced in 2005, the crisis period presented a true out-of-sample test of its effectiveness.

Exhibit 53-4 shows the monthly spread changes of the Bloomberg Barclays U.S. Corporate Index normalized by several projections of spread volatility from January 2006, well before the first signs of the crisis were observed, through March 2010, when markets were already in recovery mode. The first forecast of volatility, based on DTS, is the product of the spread level at the beginning of the month and the (approximate) relative spread volatility (10%/month) estimated in our original study, based on the analysis shown in Exhibit 53-2. The plot also includes two estimates using the realized volatility over a trailing 36-month window or during the entire history (since September 1989) available as of the start of each month.

EXHIBIT 53-4

Comparison of Volatility Forecasts Based on DTS and Historical Absolute Spread Changes



Normalized spread changes are monthly changes in spreads divided by the forecast volatility based on DTS with a 10% slope, absolute spread volatility computed over the trailing 36 months or the entire available history since September 1989. The results are reported monthly between January 2006 and March 2010.

Source: Barclays

The exhibit illustrates that the forecast based on the trailing 36 months would have fit the low volatility level during the pre-crisis period quite well, but was susceptible to large sudden shocks such as in July 2007 and November 2007, which resulted in 5.1 and 6.3 standard deviation realizations, respectively.

Although the estimator gradually adjusted to the change in market conditions, it continued to understate the level of risk more than a year after the crisis began, with an 8.4 standard deviation realization in September 2008.

In contrast, the "long-term" forecast was better prepared at the beginning of the crisis since it incorporated information from previous extreme market events such as the 1998 and 2002 crisis periods. While its forecast of volatility for July 2007, for example, was higher than that of the "short-term" estimator, it generated grossly underestimated risk projections toward the end of 2008. Because adjustment to changing market conditions is slow, using the forecast generated by the long-term volatility measure the spread change in September 2008 would have corresponded to an 11.6-standard-deviation event! Similarly, the estimator underestimated the magnitude of the spread tightening beginning in early 2009 as market conditions started to improve.

The DTS volatility estimates over the period were consistently superior to both forecasts using realized volatilities. The DTS-based forecasts quickly (albeit not perfectly) reflected both the increased level of risk since the crisis erupted and the reversal in market conditions in 2009, with most spread change realizations corresponding to less than two standard deviations. A notable exception was September 2008. Despite the already heightened level of spreads, the combined effect of Lehman Brothers' and Washington Mutual's defaults and the bailout of AIG in that month resulted in a 4.5-standard-deviation event. However, as discussed above, the forecasts using realized absolute spread volatility underestimated the risk by a factor of between two and three times more than the DTS-based forecast.

The credit crisis that began in 2007 affected not only corporate but also sovereign issuers. The deteriorating economic conditions in several of the euro area economies with high deficits and/or debt ratios subsequently raised solvency concerns among many investors. As a result, spreads of countries such as Portugal, Ireland, Italy, Greece, and Spain widened significantly in 2010 relative to German treasuries, to the point where the risk contribution of sovereign spreads in investment grade bond indices grew larger than that of corporate bonds.[12] Many market participants had to suddenly re-evaluate their risk management practices. It was apparent that past volatilities of absolute spread changes could no longer serve as a basis for forward-looking risk projections in this market, as sovereign spreads had mostly been very tight and stable since the inception of the Euro in 1999. The DTS paradigm, keying on rising spread levels, does not require a long period of increased spread volatility to warrant an increase in forward-looking risk estimates. Furthermore, as we already mentioned earlier, theory suggests that DTS should apply to all securities with a credit component irrespective of the issuing entity, and earlier results indeed confirmed it is applicable to emerging market

12. See Jay Hyman, Antonio Baldaque da Silva, Yael Eisenthal-Berkovitz, Amine El Khanjar, Anando Maitra, and Simon Polbennikov, "Sovereign Risk Spillover into Euro Corporate Spreads," *Journal of Fixed Income* 24(1), 2014, pp. 51–74

countries. It is therefore interesting to see to what extent using the DTS paradigm to project the spread risk of Euro sovereign issuers could have helped investors in this asset class.

Exhibit 53-5 compares the daily spread volatility of several Euro countries over two distinct periods, which roughly span the time period of the crisis. Volatility between August 2008 and July 2009 is represented on the horizontal axis, whereas the vertical axis reflects the volatility in the period from August 2009 to July 2010. The time partition was selected such that both periods have about the same length but correspond to different stages of the sovereign debt crisis. Each observation represents either the absolute or relative spread volatility of a particular country. Observations along the diagonal line indicate that the volatilities are the same over the two time periods.

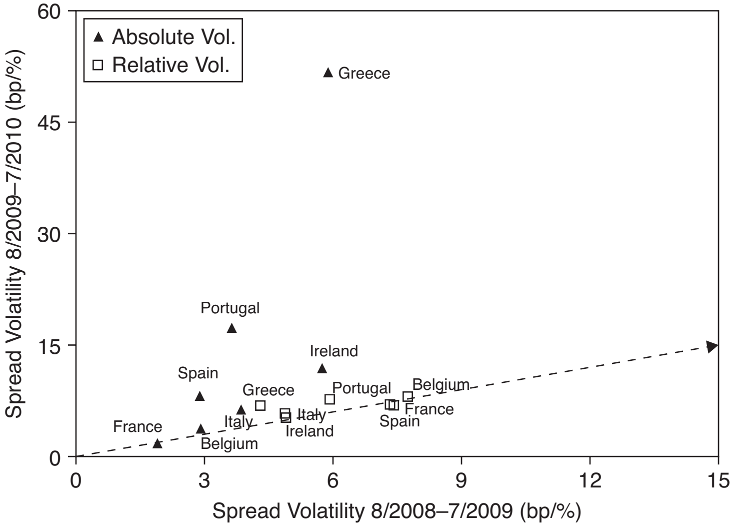
Two clear patterns can be observed in the plot. First, most of the observations representing absolute spread volatilities are located quite far above the line, pointing to a marked increase in volatility in the second period of the sample. In contrast, relative spread volatilities are quite stable, with almost all observations located near the straight line crossing the origin, which represents equal volatilities (absolute or proportional) in both periods. This is because the pick-up in volatility in the second period was accompanied by a similar increase in spreads. In particular, the daily volatility of absolute spread changes for Greece increased by a factor of almost 10 (from 5.9 bps to 51.6 bps), whereas in relative terms it only increased from 4.3% to 6.8%.

Second, the daily volatilities[13] of relative spread changes in various countries are quite tightly clustered, ranging from 4.5% to a bit over 8%, whereas the range of absolute volatilities is much wider, ranging from 1.6 bps to more than 17 bps for Portugal and even higher for Greece. Furthermore, spread proportionality seems to capture well not only the spread dynamics of the countries that were in the center of the crisis (Portugal, Greece, Spain, Ireland, and Italy), but also countries that were less affected such as Belgium and France. While the exhibit suggests that absolute spread volatility also remained essentially unchanged for these two countries, using relative spreads offers the advantage of similar volatilities across all sovereign issuers.

13. The results in this section are based on daily data due to the fairly short time period of relevance. The relative spread volatilities reported here thus seem to be much higher than those reported earlier for credit markets. Assuming that all daily spread changes are independent, and that a month contains about 20 business days, a 6% daily volatility would correspond to a monthly relative spread change volatility that is greater by a factor of $\sqrt{20}$, or over 26%. This apparent discrepancy reflects in part the fact that the analysis in this section directly examines the spread volatilities of individual issuers, without any attempt to separate systematic from issuer-specific effects. If we compute the total spread volatility for an issuer using our estimates of systematic and idiosyncratic spread volatility updated through the 2007–2008 credit crisis (15%/month), the implied *total* spread volatility of about 21%/month is not so different from the daily results (converted to a monthly frequency) shown here for euro sovereigns. It also underscores the approximate nature of this square root rule and the difficulty of comparing daily and monthly volatilities.

EXHIBIT 53-5

Absolute and Relative Volatility of Daily Spread Changes for Selected Sovereign European Issuers



Both absolute and relative spread volatilities are expressed in units with similar magnitudes. However, the interpretation is different: an absolute spread change of 10 represents a 10 bps widening in a country spread, while a relative spread change of 10 means that spreads changed by 10% of their current values (e.g., from 50 to 55, from 200 to 220).

Source: Barclays

Exhibits 53-4 and 53-5 provide an illustration of the advantage of the DTS approach compared with the risk estimated based on absolute spread changes. The DTS approach does not require a subjective selection of a historical calibration period, and allows for a rapid incorporation of market conditions as reflected in the level of spreads. This feature can be especially valuable in situations where market volatilities exceed any historical precedent, as illustrated in these two exhibits for the credit and sovereign crises of 2007–2010. It is also important to note that DTS-based risk forecasts can immediately adapt to changing conditions. Whereas models based on realized monthly volatility will only be updated at the end of a month, DTS estimates can be updated as soon as spread changes are marked—intra-month or even intra-day.

HEDGING: PREDICTING SENSITIVITIES TO MARKET SPREAD CHANGES

Another natural application of DTS is hedging. Consider an investor whose basic goal is to express a view favoring one issuer over another while taking as little directional market risk as possible. The primary driver of the performance of such a strategy should be the investor's skill at forming views on issuers, while any systematic risk is to be minimized. The success or failure in isolating issuer-specific risk lies in his ability to forecast the market beta of each security over the return horizon.

Suppose we are considering a trade as of the end of December, and plan to hold it in position for three months. The betas we would like to use for this hedge are the as-yet unknown ones that we will find ex post as we later review the returns realized from January through March. What is the best forecast we can make given the data that we have at our disposal? An obvious approach would be to use DTS. Since the DTS contribution of a position measures its systematic spread exposure, DTS neutrality should be the best way to hedge the market exposure of an issuer-specific trade that goes long one issuer and short another.

To examine this question, we conducted a study that compared two different methods for forecasting the market betas of individual CDS over a given period using only data available at the beginning of the period.[14] The first relied on the ratio of the DTS (in this case, risky PV01 times spread) of the individual CDS to that of the market as of the beginning of the period. The second approach was one commonly used by investors, based on the empirical beta of the individual CDS to the market from the prior period. We divided the data set, which contained roughly three years of weekly data, into nonoverlapping periods of equal length, either 26 weeks or 52 weeks each. For each period but the first, the beta of each security was estimated using the two methods: either by using the spread as of the start of the period or by using the security's beta from the prior period. We then regressed the realized beta during the period on each of these two candidate predictors. Since there were 84 issuers in each period, the regressions had 5×84 observations when a 26-week estimation period was used and 2×84 observations when a 52-week estimation period was used. The results of these regressions are shown in Exhibit 53-6.

Several things are apparent from Exhibit 53-6. First, we see that the DTS ratio provides a better prediction of next-period beta, with R-squared values approximately twice as high as those using the prior-period empirical betas. Second, the regression results tell a very different story for the two models. When using the DTS ratio, the intercept is not statistically significant, and the coefficient is very close to one; that is, the DTS ratio as of the start of the period is the best estimate of market beta in the coming period. For the empirical betas, this is not the case. The intercept plays nearly an equal role as the prior period beta, both in terms of the coefficients and the t-statistics. This means that if we want to forecast the next-period beta based on the empirical beta observed in the prior period, the best forecast would be to assume that the beta will be halfway between the prior observation and 1. That is, betas are mean-reverting. This observation dovetails nicely with the established literature on empirical betas in equity markets. For example, Grinold and Kahn make the following observations regarding equity betas:

14. Arik Ben Dor, Jay Hyman, Simon Polbennikov and Jeremy Rosten, "Hedging Pairwise CDS Trades Using DTS," *Lehman Brothers Global Relative Value* (April 16, 2007).

EXHIBIT 53-6

Predictors of Market-Beta Based on Start-of-Period DTS Ratios or Prior-Period Empirical Betas

Explanatory Variable for Predicting Beta	Time Period for Beta Estimation	R - Squared	Variable	*Regression Results* Coefficients	t Stat
Prior-Period Empirical Beta	26 weeks	0.19	Intercept	0.56	9.83
			Prior-Period Beta	0.44	9.85
Prior-Period Empirical Beta	52 weeks	0.23	Intercept	0.49	5.63
			Prior-Period Beta	0.51	6.97
DTS Ratio	26 weeks	0.36	Intercept	–0.09	–1.1
			DTS Ratio	1.09	15.31
DTS Ratio	52 weeks	0.5	Intercept	–0.04	–0.5
			DTS Ratio	1.05	12.86

Source: Barclays

> A stock with a high historical beta in one period will most likely have a lower (but still higher than 1.0) beta in the subsequent period. Similarly, a stock with a low beta in one period will most likely have a higher (but less than 1.0) beta in the following period. In addition, forecasts of betas based on the fundamental attributes of the company, rather than its returns over the past, say, 60 months, turn out to be much better forecasts of future betas.[15]

Rosenberg provides empirical evidence supporting this statement and shows how the predicted betas from Barra's E1 risk model do a much better job of forecasting next-period betas than just using historical betas.[16] His results indicate that a simple regression of the beta in one period on the historical beta from the prior period yield a coefficient of 0.58.

These results can perhaps help add another perspective to the DTS concept in general. Upon their first exposure to the DTS approach, some investors have noticed a striking similarity to the more familiar concept of beta-adjusted spread durations. Both of these approaches recognize that a systematic change in spreads throughout an industry does not tend to result in a parallel shift, but that some

15. Richard C. Grinold and Ronald N. Kahn, *Active Portfolio Management*, 2nd Edition, (New York: McGraw-Hill, 2000), p. 14.
16. Barr Rosenberg, "Prediction of Common Stock Betas," *Journal of Portfolio Management* (Winter 1985), pp. 5–14.

issuers will move by more than others. The difference between the two methods is that in one approach, the forward-looking market beta is estimated based on its past market beta, while in the other it is estimated based on its current spread level. Based on the head-on comparison of the two estimation methods shown in Exhibit 53-6, we can bring the two approaches into agreement. A portfolio's DTS exposure to a sector can now be seen to be equivalent to its beta-adjusted spread duration exposure, with the estimation of the betas provided by the market in the form of spreads.

After exploring the use of DTS to estimate hedge ratios of individual issuers relative to the market, we applied this approach to hedging paired long/short trades in CDS of two issuers from the same industry.[17] Selecting a pair of issuers *x* and *y* from a given industry at random, we would go long one unit of *x* (by selling protection) and hedge the systematic sector exposure by going short some amount of issuer *y* (by buying protection). A hedging strategy that used DTS ratios to determine the amount of issuer *y* to use was compared with one based on empirical betas. The details of this analysis are somewhat involved, and beyond the scope of this chapter, but they once again established the superiority of DTS-based hedge ratios over those based on empirical betas. The DTS-hedged trades were found to have lower P&L volatilities, more stable hedge ratios, and a smaller percentage of variance from systematic changes in sector spreads. Empirical betas proved to be more difficult to estimate, and prone to instability.

The DTS approach to hedge formation has several clear advantages. First, the calculation of the hedge ratio is simple and unambiguous and spares the investor some difficult decisions about how beta should be estimated (what frequency data? how long a window? Should recent data count more than older data?). Second, the DTS ratio has shown itself to be both a good predictor of market beta at the individual issuer level and a reliable mechanism for neutralizing the market exposure of long/short trades. Finally, when dealing with long/short trades in swaps of matched maturities, the DTS-neutral trade will be carry-neutral as well,[18] neatly avoiding the possibility of forming a portfolio with negative carry.

Although we restricted our investigation to the hedging of individual issuers and paired long/short trades in CDS, the results are applicable to a much broader portfolio context. Even portfolio managers who are able to take long/short positions in CDS do not necessarily hedge each trade on its own. Rather, long and short positions are established according to the manager's views, and the aggregate exposures of the portfolio are hedged to achieve the desired systematic exposures, either passive to the index or to actively reflect the manager's macro

17. For details, see Ben Dor, Hyman, Polbennikov, and Rosten, "Hedging Pairwise CDS Trades Using DTS."

18. If the duration is the same on both sides of the trade, then matching duration *x* notional *x* spread will be the same as matching notional *x* spread, which is exactly the way the monthly premium payments on the CDS are calculated. This means that the monthly premium flows on the two legs of the trade will exactly cancel each other out, and the total return of the trade will be entirely based on spread change.

views. We believe that the right way to manage spread risk, consistent with the hedging mechanism used here, is to measure industry exposures in terms of net DTS contributions. To maintain a neutral exposure, one would attempt to zero out the exposures in each industry. If a portfolio incorporates active industry exposures, the calculation of the overall risk should include correlations among relative spread movements in each sector. This approach is illustrated in the last section, which discusses how a risk model for spread asset classes can be constructed around the notion of DTS.

REPLICATION: CREATING INDEX TRACKING PORTFOLIOS

Portfolio managers often need to build portfolios that closely track the returns of the selected benchmark. Constructing a portfolio of cash instruments to replicate a target index can be accomplished using various methods, but the most commonly used approach is based on stratified sampling. It relies on partitioning the index into cells, which represent the manager's view of common risk factors affecting a given market (e.g., for credit, these might be sector and rating). Bonds are then selected from each "cell" based on certain criteria and weighted such that they match various characteristics of the cell, for example contribution to spread duration. The advantage of this approach is its simplicity and flexibility; its disadvantage is that it ignores the correlations among cells.[19]

In this section, we provide an illustration of the stratified sampling method using the Bloomberg Barclays U.S. Corporate Index, and matching only a single characteristic at a time: DTS or spread duration. Our intention is not to design the "optimal" replicating portfolio, but rather to focus on the relative efficacy of one characteristic relative to the other.

To construct the two replicating portfolios, we first partition the index into 24 cells (eight sectors × three credit ratings).[20] We then select 10 bonds to represent each cell in the portfolio.[21] This same set of 10 bonds is used in both variants of the replicating portfolio, to reduce noise from issuer selection and focus attention on the differences in systematic risk exposures. The key difference is in how we weight the bonds within each cell: in the DTS-based portfolio, we match the DTS exposure of the index in each cell, while in the spread-duration-based portfolio

19. A stratified sampling approach is "blind" to the relationships among cells. This can be remedied by complimenting a stratified sampling approach with the use of an optimizer that accounts for the correlations among cells.

20. The sector breakdown is as follows: Banking, Finance, Basic Industry, Consumer Cyclical, Consumer Non-Cyclical, Communications, Energy, and Utility.

21. The number of bonds selected from each cell is set to 10 since it strikes a good balance between having a realistic size for the replicating portfolio (240 bonds) and reducing idiosyncratic risk. If fewer bonds are used to represent each cell, the variation in tracking errors may reflect not only the difference between the two systematic risk measures (DTS and spread duration), but also the idiosyncratic performance of the set of bonds selected.

we match the index spread duration exposure.[22] For example, Exhibit 53-7 shows a market structure report of the Bloomberg Barclays U.S. Corporate Index along the sector/quality partition used for this replication exercise. For each cell of the partition, the report characterizes the exposure of the index to that market segment in three different ways: by market weight, contribution to option-adjusted spread duration (OASD), and contribution to DTS. The spread-duration-based replicating portfolio is constructed such that it matches the contributions to OASD in each of the index sectors (the second column from the right); the DTS-based replication matches the DTS contributions in the rightmost column.

EXHIBIT 53-7

Sector/Quality Profile of Bloomberg Barclays U.S. Corporate Bond Index, as of 12/31/2010

	Market Value [%]	OASD	OAS	DTS	OASD [cntr]	DTS [cntr]
Total	**100.00**	**6.30**	**155.7**	**10.26**	**6.30**	**10.26**
Aaa-Aa	17.74	5.65	103.0	6.26	1.00	1.11
A	45.53	6.30	144.2	9.46	2.87	4.31
Baa	36.72	6.63	195.5	13.18	2.43	4.84
Banking	**24.57**	**5.05**	**190.3**	**9.94**	**1.24**	**2.44**
Aaa-Aa	7.28	4.51	123.5	5.77	0.33	0.42
A	15.40	5.25	203.4	10.98	0.81	1.69
Baa	1.88	5.46	342.2	17.54	0.10	0.33
Finance	**11.21**	**5.92**	**191.2**	**11.74**	**0.66**	**1.32**
Aaa-Aa	3.49	5.32	117.8	7.40	0.19	0.26
A	3.78	6.40	176.8	11.49	0.24	0.43
Baa	3.95	5.99	269.9	15.83	0.24	0.62
Basic Industry	**10.30**	**6.26**	**140.6**	**9.30**	**0.64**	**0.96**
Aaa-Aa	0.68	5.11	89.1	4.67	0.03	0.03
A	4.57	6.04	91.4	6.04	0.28	0.28
Baa	5.05	6.61	192.1	12.87	0.33	0.65

(Continued)

22. The scheme used to weight the 10 bonds within each cell is fairly complex, involving a further subdivision of each cell into four quadrants, to ensure that we can match both market weight and the desired additional characteristic by a rule-based algorithm that always results in positive weights to all selected bonds. Details may be found in Ambastha and Ben Dor, "DTS (Duration Times Spread) in the Credit Crunch: Did It Live Up to Expectations?"

EXHIBIT 53-7

Sector/Quality Profile of Bloomberg Barclays U.S. Corporate Bond Index, as of 12/31/2010 (*Continued*)

	Market Value [%]	OASD	OAS	DTS	OASD [cntr]	DTS [cntr]
Consumer Cyclical	**5.32**	**7.15**	**121.8**	**9.39**	**0.38**	**0.50**
Aaa-Aa	1.18	8.17	75.9	7.97	0.10	0.09
A	1.57	6.78	86.6	7.13	0.11	0.11
Baa	2.57	6.92	164.3	11.41	0.18	0.29
Consumer Noncyclical	**12.82**	**6.49**	**106.7**	**7.59**	**0.83**	**0.97**
Aaa-Aa	2.80	6.86	71.2	5.85	0.19	0.16
A	5.42	6.61	86.0	6.34	0.36	0.34
Baa	4.59	6.12	152.9	10.14	0.28	0.47
Communications	**15.38**	**6.69**	**152.1**	**11.18**	**1.03**	**1.72**
Aaa-Aa	0.30	6.85	49.4	3.97	0.02	0.01
A	8.00	6.78	126.6	9.92	0.54	0.79
Baa	7.08	6.59	185.4	12.90	0.47	0.91
Energy	**9.10**	**7.32**	**141.6**	**11.30**	**0.67**	**1.03**
Aaa-Aa	1.68	6.38	72.4	5.28	0.11	0.09
A	2.38	7.09	105.4	8.24	0.17	0.20
Baa	5.04	7.74	181.8	14.76	0.39	0.74
Utility	**11.31**	**7.50**	**146.9**	**11.69**	**0.85**	**1.32**
Aaa-Aa	0.33	11.23	95.3	12.90	0.04	0.04
A	4.41	8.30	109.0	10.44	0.37	0.46
Baa	6.57	6.77	175.0	12.47	0.44	0.82
Energy	**9.10**	**7.32**	**141.6**	**11.30**	**0.67**	**1.03**
Aaa-Aa	1.68	6.38	72.4	5.28	0.11	0.09
A	2.38	7.09	105.4	8.24	0.17	0.20
Baa	5.04	7.74	181.8	14.76	0.39	0.74
Utility	**11.31**	**7.50**	**146.9**	**11.69**	**0.85**	**1.32**
Aaa-Aa	0.33	11.23	95.3	12.90	0.04	0.04
A	4.41	8.30	109.0	10.44	0.37	0.46
Baa	6.57	6.77	175.0	12.47	0.44	0.82

Source: Bloomberg, Barclays

A key part of any index replication attempt is selecting the bonds that form the replicating portfolio. In a real-life portfolio management setting, security selection plays an important role in determining performance and several different criteria can be employed in the security selection process, depending on the portfolio setting. If minimizing tracking error is the primary goal, then the security weights within each cell should focus on the primary issuer exposures of the benchmark. Additionally, managers may aim to maximize liquidity, or to add value by choosing securities that they believe will outperform. Ideally, though, as long as the portfolio has matched the benchmark allocations on the macro level, it should track well in the event of any major industry rally or decline. The key is to match the right set of macro exposures.

For the purposes of this study, our interest is not in the issuer selection mechanism, but in checking which set of macro exposures is most important to match. The selection mechanism therefore does not need to be optimal in any sense (e.g., minimizing tracking error volatility or maximizing performance). Rather, we would like to test our replication methods using several different issuer selection mechanisms, to ensure that differences between the two replicating portfolios (DTS matched and spread duration matched) are independent of the specific bonds that were selected. One approach is simulation, where bonds in each cell would be randomly selected, the replication results recorded and the analysis repeated multiple times. Another approach, which we use instead, is to specify explicit selection criteria based on bond characteristics. While this approach leads to a single replicating portfolio (per criterion), it more closely mimics a realistic process of constructing replicating portfolios for index tracking purposes.

We analyze five potential bond selection criteria. The first criterion, based on market value, selects 10 of the largest bonds in each cell. Hence, it results in the most investible and liquid portfolios (as larger size is generally associated with increased liquidity). The remaining four criteria are designed primarily to maximize the ability of our study to distinguish between the two replication strategies. The second and third criteria rely on spread and select the bonds with the highest (lowest) level of spread. This represents a replication strategy that tries to maximize carry (minimize risk). The last two criteria use an algorithm designed to maximize the dispersion in either spread duration or DTS among the bonds selected within each cell. Selecting bonds with the maximum potential dispersion in the characteristics used to match the index should magnify the mismatch between the portfolio and the benchmark in terms of the exposures not being forced to match. This in turn would facilitate the comparison between the replication results of the two sensitivity measures.

Exhibit 53-8 presents the tracking error volatilities (TEV) of the replicating portfolios during the 24-month period beginning in January 2007, for the various bond selection criteria. Irrespective of the selection criteria, matching each cell's DTS achieves lower tracking error volatility than matching its spread duration, although the improvement varies widely, from 1.2 bps/month to almost 15 bps/

month. Looking at the difference in weight given to each bond under the two matching schemes (reported in the third column) suggests that the reduction in TEV is generally more meaningful as the weight differential increases (i.e., as the replicating portfolios are less similar to each other).[23]

For example, if the selection criterion is market value, the average (absolute) difference in the weight of each selected bond under the two replication schemes (in proportion to the total index market value) is 0.46%, and the TEV declines from 22.9 bps/month for matching spread-duration exposures to 21.4 bps/month when matching DTS exposures. If the maximum-spread criterion is used instead, the weight differential rises to 0.72%, and the decline in TEV when matching DTS rather than spread duration exposures is 14.7 bps/month.

It is important to mention that the superior tracking achieved by matching the index DTS does not come at the expense of performance. The last two columns in Exhibit 53-8 display the average tracking errors of the replicating portfolios. The results indicate that while our simple replication exercise tends to underperform the index for any bond selection criteria, the DTS-based approach gives better average tracking errors (with one exception) than the spread duration-based one.

EXHIBIT 53-8

Index Replication Using Stratified Sampling

Selection Criteria	*Tracking Error Vol. (bp/month)* SD Match	DTS Match	Weight Differential per Bond (as % of Total Index MV)	*Average Tracking Error (bp/month)* SD Match	DTS Match
Market Value (largest)	22.9	21.4	0.46%	–11.5	–8.0
Spread (lowest)	20.7	15.6	0.89%	–10.6	–14.0
Spread (highest)	33.0	18.3	0.72%	–11.7	–4.4
Spread Duration Dispersion	17.0	15.8	0.47%	1.9	5.8
DTS Dispersion	28.2	24.7	0.59%	–6.1	–1.5

Replication of the Bloomberg Barclays U.S. Corporate Index is performed through matching the spread duration (SD) or DTS characteristic of each of the 24 cells in the partition (8 sectors × 3 credit ratings). Based on monthly observations (January 2007 to December 2008).

Source: Barclays

23. For each selected bond, we calculate the difference in the weight (as a proportion of the index aggregate market value) it is assigned under the DTS and spread duration matching. The weight differential per bond in Exhibit 53-8 is computed as the average of the absolute value of the weight difference for all the bonds selected.

The use of DTS exposures to replicate an index by stratified sampling is far from a theoretical exercise. This approach has been used to form a highly liquid portfolio of bonds to track the Bloomberg Barclays U.S. Investment-Grade Credit Index.[24] A purely rules-driven sampling methodology ensures transparency. The replication methodology uses a partition of five sectors by five duration categories, with each cell represented by two bonds. The bonds are selected based on a proprietary measure of liquidity and are weighted such that the index DTS exposure in each cell is matched. Historical backtesting of this strategy indicates that it tracks the index much more closely than an alternative strategy based on liquid derivatives including Treasury futures, swaps, and CDX.

EXPRESSING MACRO VIEWS IN ACTIVE PORTFOLIOS

Attention to the DTS exposures of a portfolio is essential for active portfolio managers as well as passive ones. In many financial institutions, the management of a portfolio is a team effort with distinct tasks for different players. Often, one group forms a set of macro views and expresses them as a set of overweights and underweights to various market segments that the portfolio should adopt relative to the benchmark. A second group may be charged with the implementation of this plan in terms of individual securities, often following the issuer selection advice of yet a third group. Yet, in order to achieve the most accurate implementation of the macro views, they must be expressed in terms of the type of exposures that best reflect the way the market moves. Referring back to the index profile shown in Exhibit 53-7, we saw that the passive credit investor will most effectively replicate the macro exposures of the index by matching the DTS contributions in the far right column, not the market value weights or the contributions to OASD. Similarly, the active investor should express the desired overweights and underweights relative to the benchmark in terms of contributions to DTS.

PORTFOLIO CONSTRUCTION: OPTIMAL DIVERSIFICATION OF ISSUER RISK

In the management of all but the most passive credit portfolios, the sizing of credit exposures must find the right balance between two opposing needs. To control risk, it is important to avoid taking a position in any given issuer that is overly concentrated. Conversely, to generate alpha based on analyst recommendations, it is important that the recommended names have sufficient weight in the portfolio to drive outperformance; over-emphasis on diversification can dilute the value of issuer selection. As a result, investors often seek guidance on what the "correct" level of diversification should be for a given portfolio.

24. Ariel Edelstein, Siddhartha Dastidar, and Bruce Phelps, "Tradable Credit Portfolio (TCX) to Track the USD IG Credit Index," *Barclays Research* (April 2010).

In the traditional approach to portfolio diversification, a plan sponsor imposes constraints on the portfolio that specify the maximum percentage of the portfolio, by market weight, that may be invested in any single issuer. This issuer limit may be dependent on credit quality, allowing larger concentrations in higher-rated issuers. In the past, we have formulated an approach to optimally determine these quality-dependent limits, based on an empirical study of the performance impact of downgrades.[25] This analysis determined that the ratio of allowed position sizes should be based on the relative risks in different quality groups. If the sole concern is downgrade risk, then the ratio indicated based on credit market data gathered from 1988 through 2001 was approximately 9:4:1. This means that if we take the allowed portfolio weight in a Baa-rated issuer as our unit size, a position in a security rated A may be four times as large and positions in Aa–Aaa issuers may be nine times as large. If "natural" spread volatility, which occurs in the absence of a ratings transition, is included in the risk measure as well, the discrepancy between the different ratings categories is lessened, and the ratio becomes 4:3:1. A more recent update of this model found that the experience during the 2007–2009 crisis was not supportive of large concentrations even in higher-rated issuers. The same model, updated to include data through the end of 2010, found that the optimal position size ratios were 2.8:1.6:1 based purely on downgrade risk and 2.6:1.6:1 when including the effect of all nonsystematic risk, both from downgrades and from natural spread volatility.

How can we apply the DTS model to this problem? A first step to this end would be to retain the framework of ratings-dependent caps on issuer market weight, but compute the position size ratios based on the ratios of average DTS levels in each credit quality group. This approach gives ratios that change over time as spreads widen and tighten, responding quickly to changing market conditions rather than needing to wait for an ex post analysis of realized losses. For example, as of December 2001, the position size ratio from the DTS method was 4.3:1.7:1, similar to the result from the empirical approach including the risk of both downgrades and natural spread volatility. As market volatility (and spread) ground lower in the following years, these ratios increased, peaking in March 2005 at 6.6: 3.0:1. However, when spreads skyrocketed in 2008, the ratio of position sizes in September 2008 for example, declined to as low as 1.4:1:1 as all credit qualities were deemed highly risky. As of December 2010, the DTS-based ratio of 2.1:1.4:1 agreed well with that from the updated empirical study.[26]

However, the DTS paradigm shift suggests a completely different approach to controlling portfolio concentrations, not just a simple recalibration. Rather than imposing a limit on the portfolio market weight in a given issuer (with the size possibly dependent on quality), a limit on the DTS contribution of any

25. Lev Dynkin, Jay Hyman and Vadim Konstantinovsky, "Sufficient Diversification in Credit Portfolios," *Journal of Portfolio Management* (Fall 2002), pp. 61–75.

26. Lev Dynkin, Jay Hyman, and Vadim Konstantinovsky, "Sufficient Diversification in Credit Portfolios: Balancing Two Approaches," *Barclays Research* (January 2011).

issuer should be imposed regardless of credit quality. This would have the effect of allowing a portfolio to have large concentrations in low-spread issuers while enforcing stricter diversification constraints on high-spread issuers. While this idea is attractive in principle, its implementation encounters several practical problems, as we shall discuss.

This DTS-based approach is in some ways quite similar to the traditional approach, in which issuer caps are specified in terms of market weights that differ based on credit quality; yet there are some crucial differences. In both schemes, the fundamental principle is to allow greater concentrations to issuers perceived to be less risky, and require more diversification where risk is greater. The fundamental difference between the two methods is the source of the risk assessment: the quality assigned by the ratings agencies or the spread assigned by the market. There are advantages to each.

Market weight limits based on credit ratings are very well suited for specifying the investment policy for a particular mandate. A permitted position is easy to identify and not subject to debate. Furthermore, as ratings change rather slowly, the guidelines are stable, and the manager is not forced to churn the portfolio as markets move.

Conversely, spreads can react more quickly to market events. As a particular issuer deteriorates in credit quality, the spread-based indicator will typically register that risk has increased much faster than the ratings-based indicator. Nevertheless, while this may be a clear advantage as far as measuring risk, it is not so clear that it is desirable to require managers to transact on price gyrations; the cost of such a policy could be prohibitive. A strict cap on DTS exposure would have the disadvantage of making the limits dependent on pricing, and could lead to inefficient forced selling.

Consider, for example, a strict implementation of a policy that limits DTS contributions. Suppose we restrict the maximum DTS contribution to any issuer to be 3.0, and that the manager establishes a 0.5% position in issuer XYZ with a spread of 100 bps and a duration of five years, for a DTS contribution of $100 \times 5 \times 0.5\% = 2.5$. If the spread widens out to above 120 bps, the manager would then be required to sell off some of the position to stay within the limits. This simple example highlights a number of difficulties with this arrangement. First, pricing uncertainty can make it unclear whether a given position is within the guidelines or not. Second, the need to adjust positions as spreads change represents both an undue hardship for managers and an increase in transaction costs for investors.

Another difficulty with a policy based exclusively on DTS contributions is that it can potentially allow very large exposures to short-dated corporates. While the risk of such a position may not be large in terms of spread volatility or excess return volatility, it is clearly undesirable from a tail-risk point of view. A prudent approach to tail risk is to limit the overall portfolio exposure to any single event.

Nevertheless, it is hard to ignore the evidence that credit ratings do not always present the full picture. The broad-brush treatment that allows the same position size for all A-rated issuers, even while large differences in spreads exist across this peer group, clearly leaves room for improvement. There is no question that incorporating information on issuer DTS contributions gives an improvement in our ability to estimate issuer risk. The difficulty is in setting up rules or guidelines that can incorporate this information without requiring unreasonably high turnover. With some ingenuity, it might be possible to reap the benefits of DTS-based risk controls without imposing too much of an operational burden. For example, one could establish a two-tiered constraint with different thresholds for new and existing positions. For instance, in the above example, if the DTS contribution limits were set at 3.0 for new purchases and 4.0 for existing positions, the XYZ position would remain within the guidelines unless the spread widened out from 100 to beyond 160. Presumably, the requirement to reevaluate the exposure to an issuer after a spread move of this magnitude would not be perceived as overly intrusive.

A more difficult challenge for a system of limits on issuer DTS contributions would be a generic rise in corporate spreads as was seen in 2008. In this crisis environment, it is likely that virtually every issuer in the credit portfolio would exceed the previously established caps on issuer exposures. Would we want to force managers to massively rebalance the portfolio into a market with no liquidity?

In general, forced selling is undesirable, and should be avoided whenever possible. We have conducted empirical studies of the performance impact on corporate bond indices of the forced selling of bonds downgraded to below investment grade.[27] These studies show that investors would be better served by holding on to "fallen angels" well beyond the downgrade, as on average they tend to eventually recoup the overly large losses that they experience as IG managers are forced to sell all at once. How might these results apply to a policy of selling upon a spread widening, even without any change in ratings? This is not at all clear. One might argue that this could help reduce the losses from eventual downgrades, or, conversely, that this would just serve to lock in losses in many bonds that will recover immediately and never suffer a downgrade. Generally, a momentum strategy like this one will do well in trending markets and poorly in choppy markets.

Even when DTS limits are in place, one would probably want to include a hard limit on market value weights, to make sure that no truly large concentrations exist in the portfolio, even in very short-dated or low-spread securities.

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27. Kwok Yuen Ng and Bruce Phelps, "Capturing Credit Spread Premium: Alternative Benchmarks for Credit Investors," *Barclays Research* (June 2010). This article traces the effect on credit index excess returns of rules that drop bonds immediately after downgrades to high yield. Indices and other forced sellers incur significant losses on such bonds but never enjoy the benefits of a subsequent recovery. Also see Arik Ben Dor and Zhe Xu, "Fallen Angels: Characteristics, Performance and Implications for Investors," *Journal of Fixed Income*, Spring 2011. This article studies the price dynamics of fallen angels over a three-year period around the downgrade date.

In short, we would recommend that for specifying hard limits on issuer exposures within a portfolio mandate, plan sponsors should retain the time-honored tradition of market-weight limits. However, we also believe that managers should track and control the DTS exposures to issuers, and ensure that no single exposure grows too large. Rather than implementing this rule via a hard cutoff beyond which sales would be mandated, managers should have a roughly defined upper limit for issuer DTS exposures and use their judgment in managing these exposures according to market conditions.

MODELING: CALIBRATING CREDIT RISK FACTORS

Many portfolio managers rely on multifactor risk models to help them measure and control portfolio risk, either in absolute terms or relative to a benchmark. The DTS approach is ideally suited to estimate spread risk in such models. For example, a risk model might contain modules for measuring exposures to three different types of adverse credit events: systematic changes in spreads, either market-wide or across a particular sector; issuer-specific spread changes; and defaults. The use of DTS can improve the modeling of the first two of these three types of credit risk.

Exposures to systematic changes in credit spreads in a particular market segment can be measured as the sum of the DTS contributions of all portfolio investments within that segment. The risk factor that relates to these exposures is a relative shift in spreads across the sector—for example, that all financial spreads increase by 10% of their current levels. The alternative to this, in a model not based on DTS, would be to assume that the risk factor is a parallel shift in spreads across a sector (e.g., all financials widen by 10 bps)—and that the exposures are therefore contributions to spread duration. Thus, in the DTS-based model, the key risk factor volatility for a particular sector would be its estimated volatility of relative spread changes, as shown in Equation 53-4 earlier in this chapter, while the alternative model would estimate the volatility of absolute spread changes as per Equation 53-3.

The DTS-based approach offers three distinct advantages. First, it offers a better assessment of the relative risks of different portfolios. If two portfolios have the same market weight and average spread duration in a given sector, but portfolio A implements this allocation with higher-spread assets than portfolio B, only the DTS-based model will correctly show that portfolio A has a greater exposure to a widening across this sector than does portfolio B. Second, the DTS-based approach improves the accuracy of the risk projection by reducing the uncertainty in the estimation of risk factor volatilities. As we have seen, relative spread volatilities are much more stable than absolute spread volatilities. Therefore, even if we do continually update our estimates of relative spread volatilities within each sector, we find that they change much more slowly than the corresponding estimates of absolute spread volatility and that they are less sensitive to the choice of the time window used in this estimation process.

The third advantage offered by DTS is perhaps more subtle, but it opens the door to the most profound change in the structure of the model. Up to this point, we have discussed the exposure to "a given segment of the market" in the abstract, without specifying exactly how the market is to be partitioned. However, choosing the partition along which to measure systematic exposures is one of the most critical elements of risk model design, involving careful trade-offs among various goals. It is desirable to limit the model to a small number of intuitive factors, both to maximize the clarity and practical applicability of the risk reports produced and to ensure that a sufficient number of bonds is available to accurately calibrate each risk factor. Conversely, it is important to include enough factors to achieve sufficient explanatory power. For example, a single risk factor that measures portfolio exposure to U.S. corporates would measure the effect on the portfolio of a potential rally or decline across the corporate bond universe, but not the effect of a relative widening of financials versus industrials. We would like to partition the universe finely enough to capture all major sector rotation effects.

When constructing a model of systematic spread risk for U.S. corporates prior to the introduction of the DTS model, we partitioned this universe into a sector/quality grid, using nine industry groups and three levels of credit ratings for a total of 27 risk factors.[28] The partitioning by quality was made absolutely necessary by the assumption that the systematic spread movement in a given market cell tends to take the form of a parallel shift in spreads. When we calibrated such a model to market data, we found that the volatility of absolute spread changes for Baa financials was much greater than that of Aa financials. Although the risk factors representing these two cells might be highly correlated, the substantial difference in volatilities precluded us from combining these cells.

If we instead assume that the spread change across an industry is a relative shift, we find that we no longer need to segregate our model by credit quality. The fact that Baa financials tend to have greater risk than Aa financials is reflected in the higher spreads; this will show up in the risk model as a larger exposure to the same risk factor based on relative spread volatility, rather than as an exposure to a different risk factor with greater (absolute spread) volatility. This puts the risk model designer at a great advantage with regard to the tradeoff between compactness and explanatory power. The model can be designed with roughly the same explanatory power as before using a much smaller number of risk factors, or we can use a finer industry breakdown to create a model with a similar number of factors but greater explanatory power. We have chosen the latter approach in our modeling efforts, increasing the level of sector detail to recognize 27 distinct industry groups.[29]

28. "The Global Risk Model: A Portfolio Manager's Guide," chapter 26 in Lev Dynkin, Anthony Gould, Jay Hyman, Vadim Konstantinovsky, and Bruce Phelps, *Quantitative Management of Bond Portfolios* (Princeton, NJ: Princeton University Press, 2007).

29. A detailed exposition of a multifactor risk model in which credit is modeled using the DTS approach may be found in Chapter 50 of this volume.

THE TERM STRUCTURE OF RELATIVE SPREAD VOLATILITY

We have shown conclusively that DTS is the best single metric available for measuring the overall exposure of a portfolio (or sector allocation) to systematic changes in credit spreads. We have further demonstrated that the success of the DTS paradigm is rooted in the stability of relative spread volatility compared to absolute spread volatility. However, mathematical models do not strictly govern the behavior of financial markets; they merely aim to establish a framework for guiding portfolio managers through whatever turbulence the next market swing may bring. Hence, if we directly measure the relative spread volatility of different segments of the corporate bond market over different time periods, we find that it varies—over time, across industries, and by maturity.

In a study focused on the dependence of relative spread volatility on bond maturity,[30] we found that relative spread volatility tends to be higher for shorter-maturity corporate bonds and lower for longer-maturity bonds. This effect was confirmed independently using data from both corporate bonds and from CDS in both U.S. and European markets. For example, using monthly data from 2006 through 2012, we found that compared with the relative spread volatilities of 5-year CDS, those of 10-year CDS are 20% lower, on average, and those of 3-year contracts are about 20% higher, on average. In bond markets, where a coarser approach to maturity partitioning is appropriate, we similarly find that relative spread volatilities in longer maturities (5–10 years) are about 20% lower than in shorter maturities (1–5 years).

One possible explanation that could be consistent with these observations is that the concept of relative spread shift applies more precisely in the cross-sectional dimension than along the term structure. A perception of increased risk in a sector is accompanied by a widening of spreads across the sector, with issuers at wider spreads widening by more. However, the issuer curve of any given issuer may move in a manner closer to a parallel shift. Thus, if issuer A trades at twice the spread of issuer B (at the same maturity), we should expect it to have twice the spread volatility as well; however, if the 10-year spread is double that of the 2-year spread within a single issuer curve, the implications for volatility may be different.

In a portfolio context, these conclusions are highly relevant for managers who take large active positions along the credit curve. In particular, if one seeks to match the sector exposures of a broad index by using only short-maturity bonds, leveraging the position to match the DTS contributions of the index, the resulting portfolio will tend to be over-hedged. For such a manager, a refinement of the DTS approach may help produce a more accurate hedge. We suggested several approaches to this problem, offering differing levels of accuracy and complexity.

30. Jay Hyman, Anando Maitra and Simon Polbennikov, "Term Structure Effects in Relative Credit Spread Volatility," *Barclays Research* (October 2012).

However, for managers who do not actively impose a maturity bias of this nature in their portfolios, we presented evidence that it should be sufficient to manage the net DTS contributions to each sector as long as the overall maturity profile of the portfolio remains in line with that of the index.

KEY POINTS

- Spread volatilities—both systematic and nonsystematic—tend to be proportional to spreads. This empirical observation, with theoretical backing, has many applications to credit portfolio management.
- Forecasts of spread volatility that combine long-term historical estimates of relative spread volatility with current spread levels are more accurate than historical estimates of absolute spread volatility, and quicker to adapt to changing market conditions.
- Estimates of market beta based on DTS ratios form better projections of future market beta than those based on past observations of empirical market beta.
- Matching index exposures to DTS is a better way to form index-replicating portfolios than matching exposures to market weight or contributions to spread duration. For active managers, credit sector overweights and underweights should be specified and implemented in terms of DTS exposures.
- Measuring and controlling DTS exposures to individual issuers can be viewed as an alternative or a supplement to issuer limits based on market weights and credit qualities.
- Portfolio risk models for fixed income can improve model accuracy and robustness by incorporating the DTS approach to project the risk entailed in both systematic sector overweights and in portfolio concentrations in individual issuers.
- DTS provides an excellent first-order risk estimate. However, direct measurement of relative spread volatilities reveals that these are somewhat higher for shorter maturities than for longer ones. This should represent a second-order effect in most portfolios, but must be considered when leverage is used to magnify term structure exposures.

CHAPTER
FIFTY-FOUR

CONSTRUCTING AND MANAGING HIGH-YIELD BOND PORTFOLIOS

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High-yield portfolio management involves the art and science of matching a portfolio's investments to its underlying objectives and overall risk profile. The focus is to balance risk against performance with the goal of achieving superior risk-adjusted returns over an entire credit cycle. From a portfolio management perspective, the high-yield market is a unique asset class due to the fact that high-yield securities exhibit the characteristics of both debt instruments and equities. Given the greater risk associated with highly levered companies, changes in the underlying fundamental credit profile are the primary driver of return over time as default loss is a key concern. However, as part of the fixed income asset class, debt attributes of the security, such as coupon, maturity, covenants, and ratings, also affect prices and performance.

High-yield bonds offer significant incremental return and income as compared to most other fixed income investments. However, it is essential to keep in mind their asymmetrical risk profile. That is, a bond's upside is generally limited to its face value at maturity or early redemption premium, while the downside could include an entire loss of principal in a default. In order to capture the attractive incremental returns and spreads offered by investing in high-yield bonds, minimizing default and credit loss are critical components to achieving this goal.

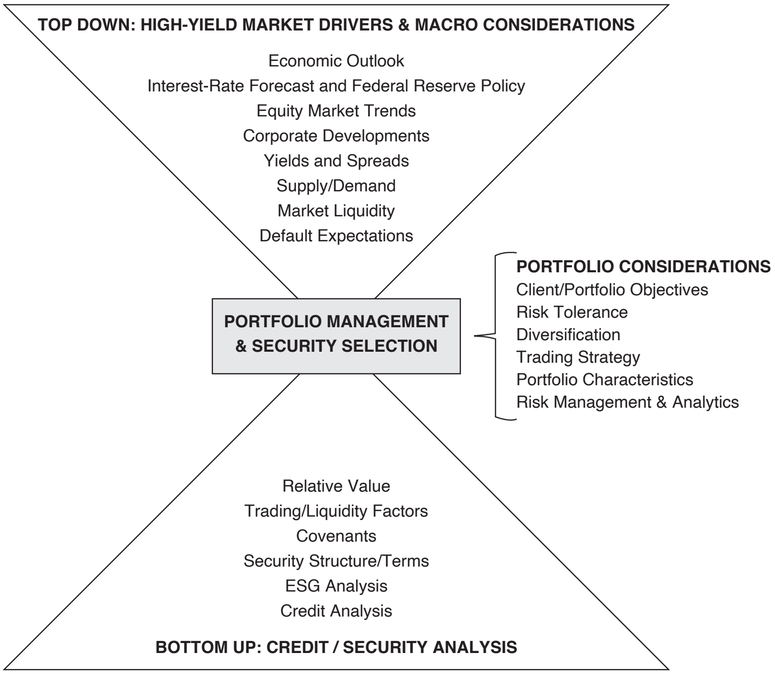
Properly assessing and managing risk is a critical element of managing a high-yield portfolio. Risk controls require developing insightful, comprehensive procedures to identify and control risk across the following three key areas:

1. Bottom-up credit/security analysis
2. Top-down high-yield market drivers and macro considerations
3. Portfolio considerations

Exhibit 54-1 identifies these three areas and highlights the elements to consider. The most successful portfolio managers have the ability to assimilate all three areas as the intersection point is the nexus of the portfolio decision-making process. Each of these areas and their elements are discussed in further detail below.

EXHIBIT 54-1

Constructing and Managing High-Yield Bond Portfolios



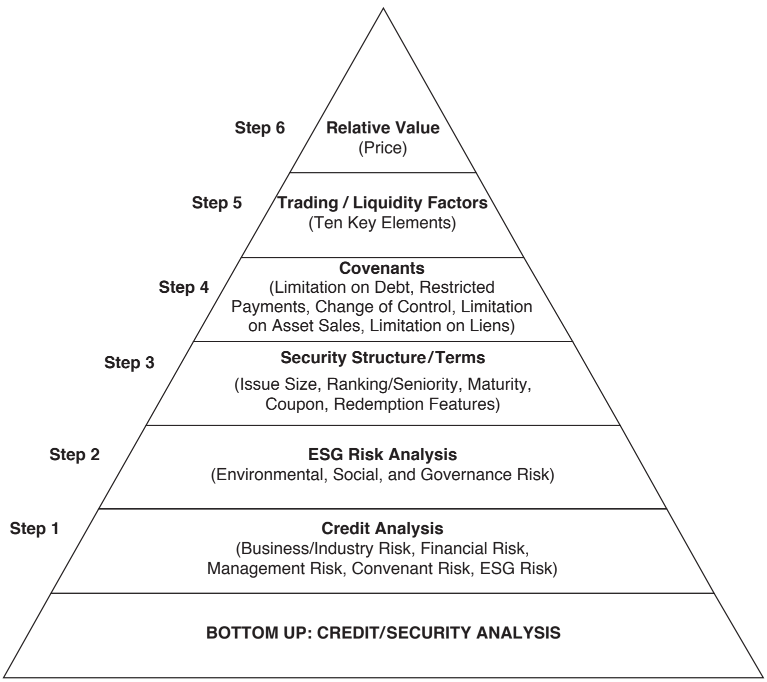
Over the long term (and through various economic cycles), portfolio managers who have avoided defaults and major trading losses have typically outperformed various high-yield benchmarks.

BOTTOM-UP CREDIT/SECURITY ANALYSIS[1]

While credit analysis is arguably the most important component of a bottom-up investment process, security structure/terms, covenants, trading liquidity factors, and relative value ultimately determine if a "good credit" will make a "good investment." Poor relative value or overpaying for a good credit could lead to underperformance. Weak trading liquidity factors can magnify the downside and disrupt the value equation in a negative surprise scenario. In executing a buy/sell decision, a step-by-step process is required to ensure consistent and disciplined decision-making. Exhibit 54-2 highlights the six steps in analyzing a high-yield credit. A checklist of positive and negative attributes should be utilized at each step. It is also important to emphasize that all of the bottom-up steps are significant in their own right. A favorable assessment on many of the steps may not necessarily outweigh an individual risk component that is identified in the process.

EXHIBIT 54-2

Six Steps in Bottom-Up Credit/Security Analysis



1. This section is adapted from Nicholas Sarchese and Amy Levine, "Credit Analysis and Analyzing a High-Yield Issuance," chapter 7 in William F. Maxwell and Mark R. Shenkman (eds.), *Leveraged Financial Markets: A Comprehensive Guide to High-Yield Bonds, Loans, and Other Instruments* (New York: McGraw-Hill, Inc., 2010).

Step One: Credit Analysis

Thorough credit analysis is ultimately the foundation for a successful high-yield investment. A greater investment risk is getting the credit analysis wrong as opposed to potentially overpaying for a sound credit. It is important to keep in perspective that the high-yield asset class involves highly levered companies that have disproportionately less margin for error. The asymmetrical upside/downside return profile of bonds also highlights the importance of avoiding meaningful downside credit risk. In practice, the underperformance related to overpaying for a good credit pales in comparison to the ultimate downside in holding the bonds of a credit that defaults. Remember that a bond's upside is limited to par (plus perhaps an early takeout premium), while the downside is theoretically zero. If a bond drops from par to 50, it would take 10 bonds to advance five points each in order to recoup the 50-point decline in just one credit! Equity portfolios do not have this similar dynamic because one investment can soar by 500%, thereby offsetting the losses in numerous other transactions. However, the number of bonds in a portfolio that can jump five points or more may be limited.

Credit analysis can be simply defined as determining the borrower's ability to meet its interest and principal obligations when due. It is often identified with financial ratio analysis. However, true credit analysis is much more comprehensive and encompasses greater in-depth review. For example, two credits with identical financial ratios may not represent the same credit risk. As outlined in Exhibit 54-3, credit analysis can be divided into five key areas: business risk; financial risk; management/ownership risk; covenant risk; and environmental, social, and governance (ESG) risk.

Thorough credit analysis is not complete without a detailed examination of all five risk factors. Weakness in any one of the five areas could offset the strength in the remaining four and result in high credit risk for a particular issuer (see Exhibit 54-4).

EXHIBIT 54-3

The Five Key Components of Credit Analysis

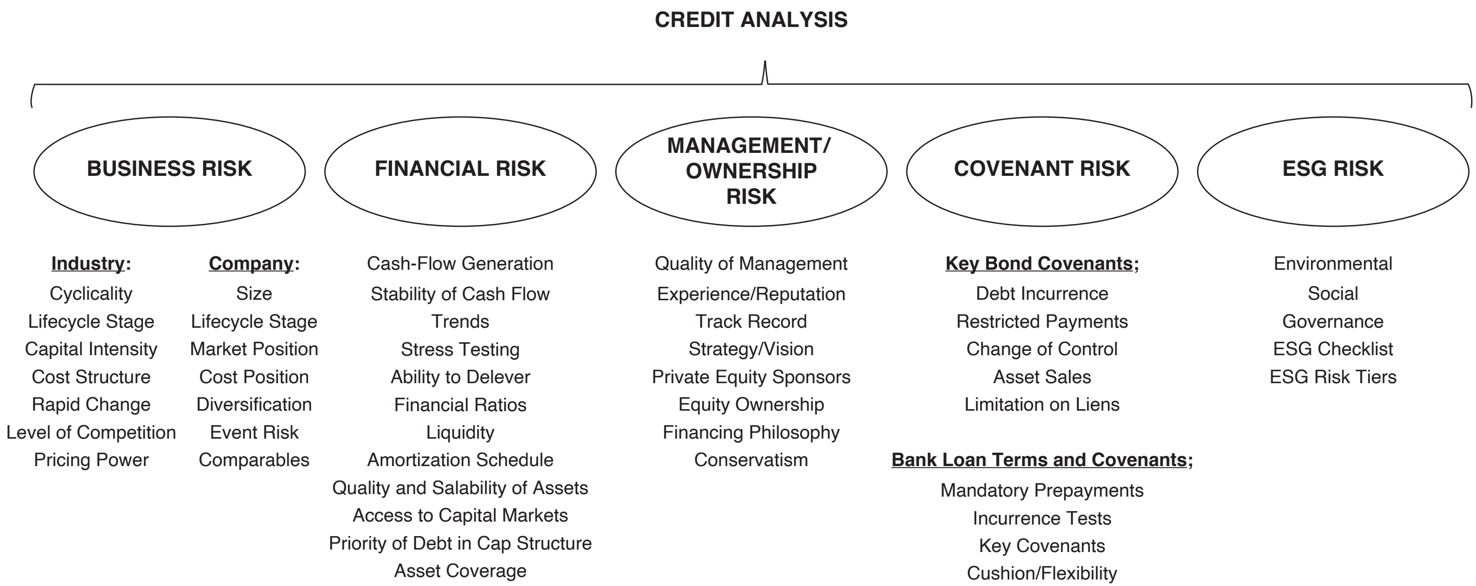


EXHIBIT 54-4

Credit Analysis Examples

Examples include:

Strong Financial Profile + Strong Management + Strong Covenant Protection + Strong ESG Profile

The issuer may not be able to offset a high business risk where the industry structure is unfavorable and the company is weakly positioned

Strong Business / Industry Fundamentals + Strong Financial Profile + Reasonable Covenant Protection + Strong ESG Profile

The strengths may not be able to offset the negative impacts of a weak management team with aggressive financial policy – OR – Bondholder unfriendly private equity sponsor

Strong Business / Industry Fundamentals + Strong Financial Profile + Strong Management + Strong ESG Profile

The strengths may not be able to offset the negative impact of a weak covenant package

Strong Business / Industry Fundamentals + Strong Management + Strong Covenant Protection + Strong ESG Profile

The strengths may not be able to offset the financial risk of a company that is overlevered

Strong Business / Industry Fundamentals + Strong Financial Profile + Strong Management + Strong Covenant Protection

The strengths may not be able to offset the ESG risk of a company with pollution concerns and potential for significant related liabilities and backlash.

Investors must focus their analysis on a "forward looking" view of all five risk areas. While historical results are important for perspective, ultimately it is the future credit trend that may dictate performance.

Business Risk

Analyzing the business risk of a particular credit involves an assessment of both the (1) industry risk and (2) company-specific risk from more of a strategic perspective. This analysis should involve not only determining whether the industry structure and fundamentals are favorable, but what is the company's strategic position within its industry. Even the best company in a given industry may not be able to withstand major structural or technological changes.

Industry Analysis. High levels of debt can be manageable and appropriate for certain industries but not others. Some industries are more conducive to leverage because their high operating margins, solid growth rates, and consistency of earnings enable the companies within the sector to service a higher degree of indebtedness. Factors used to assess an industry include stability of cash flows, stage in industry lifecycle, capital intensity, cost structure/operating leverage, degree of technical or demographic changes, competitive forces, regulation, and pricing power. In addition to providing an enhanced credit profile, industries that possess more favorable outlooks also tend to trade better because of positive macro considerations and investor support.

Company Analysis. In assessing an industry, it is imperative to dissect a company's specific strengths and weaknesses and determine how it fits into its industry. For example, a company can operate in a growing industry but possess obsolete technology. Conversely, a company can compete in a declining industry but have a leading market position and generate significant cash flow. There are several factors to consider:

- Size of the company
- Stage in company lifecycle
- Market position
- Diversification
- Potential for event risk

All of these factors can impact the creditworthiness of the borrower.

Financial Risk

After assessing an industry and company's business risk, the next step is to consider the overall financial risk and credit profile of the borrower. This consideration should take into account the company's capitalization and degree of leverage. The fundamental operating outlook and credit profile of a company are critical variables that should drive bond performance. Moreover, a thorough analysis must evaluate the past financial results to understand the drivers of the business.

Key variables to financial risk include:

- The stability of cash flows
- Recent and near-term projected performance trends
- Stress testing (how well a company's credit profile can withstand negative surprise)
- Analysis of free cash flow and the ability to de-lever
- Leverage and coverage statistics
- Cash and available liquidity
- Amortization/maturity schedule
- Quality and salability of assets
- Access to capital markets
- Asset coverage

Management/Ownership Risk

While factors relating to credit analysis are crucial, the owners and senior management of the company are responsible for establishing goals, objectives, and strategic vision for the business. In the end, a great management team can make a significant difference in the performance of a security.

Direct Communications. Portfolio managers or research analysts should have direct contact with senior management (i.e., one-on-one meetings or calls, company visits, etc.). Direct access is the best way to understand and evaluate management and can provide greater insight into the risk parameters for a specific issuer. Moreover, analysts should maintain an ongoing dialogue with company managements. During times of duress, if management is inaccessible, investor confidence in the company could be shaken, and the bonds may underperform.

Quality of Management. The quality of the senior management team is significant in making a sound investment. While successful companies must pursue effective strategies, development and execution of those strategies hinge on the management team in control. Although management assessment is somewhat subjective, and improves with experience, the best qualities to look for in a management team include: low turnover, tenure and reputation within the industry, strong track record, timeliness in filing financial statements, forthrightness in responding to questions, strategic vision, a deep bench, and successful completion of stated goals. Great business leaders are able to effectively communicate the company's strategy and vision, articulate the opportunities and risks confronting the company, and act decisively and proactively in times of change.

Private Equity Sponsors/Ownership. Oftentimes, a highly levered company may be owned by a private equity sponsor. In these cases, the equity sponsor drives the company's strategic direction and financial policies, while the operating senior management (i.e., CEO, COO, CFO) usually have less influence in the overall direction and financial risk tolerance of the company. It is always important to keep in mind that the interests of the private equity sponsor in many cases may not align with bondholders. For example, sponsors may declare a large cash dividend as quickly as possible to enhance their equity returns, although this action may lead to deterioration in the company's credit quality. If the sponsors have little capital at risk, they could try for a "swing for the fences" type strategy since they have little downside (having taken their invested capital out) but significant upside if the strategy pays off. This "no capital at risk" strategy is not ideal for bond investors as the company may have little capital cushion, particularly in a faltering economy. The sponsor's investment track record, default history, and record in paying down debt should be carefully examined. Another factor is the percentage of equity owned by the management team. If equity ownership is spread throughout management, they are more likely to be deeply engaged in the success of the overall enterprise.

Financing Philosophy. Investors must consider both the ownership's and management team's intentions regarding the company's balance sheet. Is management comfortable operating with high levels of debt and leverage, or are they more conservative and prefer to have more financial flexibility and lower leverage? Is management comfortable with the current amount of debt, or is debt pay down a key priority? How committed is management to paying down debt? Is management opportunistic in that they would consider making an attractive acquisition even if it involved meaningfully increasing the financial risk profile of the company? If the management team is comfortable with the current level of debt, they might focus on using cash flow toward paying dividends, share buybacks, or funding additional acquisitions. If debt pay down is a key priority, and the company generates a large amount of free cash flow, the issuer's credit metrics are likely to improve. Knowing management's philosophy toward debt is of vital importance in forecasting the company's credit profile as it will serve as a guide toward the application of free cash flow. Knowing management's philosophy is vitally important in order to judge their success in achieving previously stated goals as well as their credibility. For example, if the management team has stated its intention to de-lever and then initiates a large stock buyback, the bonds are likely to underperform as the "credit story" has not met expectations, and investors may have diminished confidence in senior management.

Covenant Risk

A detailed examination of covenants should be a critical focus of credit analysis. Although each tranche of debt may contain its own specific debt covenants, collectively they impact the borrower's overall credit risk profile and financial flexibility. Evaluating the collective impact of all of the company's covenants (bank loan as well as bond covenants) is important in understanding the overall credit risk of a company. The presence of a strong covenant package may have significant influence on bond performance. In certain cases, limited covenant flexibility may improve the overall credit profile of the company because it could create the opportunity for early redemption at a premium or limit increases in financial risk. Conversely, there are cases where limited covenant flexibility may prove to be a significant risk to a borrower's credit profile as it could force a liquidity event at an inopportune time in the credit cycle. Covenants are covered in further detail as part of step three, below, as the analysis of an individual security.

Environmental, Social, and Governance (ESG) Risk

Incorporating environmental, social, and governance factors into a thorough analysis strengthens the ability to assess the downside risk of credit investments. These issues are increasingly relevant because a growing portion of a firm's enterprise value lies in intangible assets, and many ESG factors relate to intangibles that are often not reflected in traditional financial statements and disclosures. Investors are increasingly applying these nonfinancial factors as part of their analytical process to identify material risks and growth opportunities.

While elements of ESG risks are already captured in the other previously outlined credit analysis components, including business risk (industry and company) and management/ownership risk, an ESG lens provides an extra tool for analysis. As stakeholders increasingly focus on these issues, ESG risks are increasingly becoming a more significant influence within a company's overall risk profile. Credit analysis is essentially incomplete if it ignores material ESG factors. ESG analysis is covered in further detail as part of step two, Environmental, Social and Governance (ESG) Risk Analysis.

Step Two: Environmental, Social, and Governance Risk Analysis

While environmental, social, and governance factors have always existed and percolated as more prominent risk factors for select companies and industries over time, collectively these risks have increasingly become a more visible and influential consideration for all companies and their overall fundamental risk profile. Managers that ignore these factors do so at their own peril as increased disclosure is demanded and investors, society, governments, and financial markets across the world continue to place greater emphasis on other important factors beyond near-term financial profitability and earnings trends. As part of a sound investment process and credit analysis, managers need to consider all meaningful risks, including those related to ESG, that may have an impact on a company's future prospects, operating performance, or valuation.

Defining ESG

ESG stands for Environmental, Social, and Governance and refers to the three key factors when measuring the ethical impact, hidden costs, and sustainability of a business or company. These factors are commonly used to evaluate the behavior of companies, as well as to help influence their future financial performance or valuation.

Environmental. Environmental criteria consider how a company performs as a steward of our natural environment as well as how climate change could impact the company.

Examples of environmental issues that should be considered include:

- Waste management and pollution
- Compliance with environmental regulations
- Greenhouse gas emission
- Resource depletion
- Climate change impacts
- Renewable energy

Social. Social criteria examine how a company treats people and manages relationships with employees, suppliers, customers, and the communities and local areas where it operates.

Examples of social issues that should be considered include:

- Employee relations & diversity/discrimination
- Workplace health and safety
- Labor standards across the supply chain
- Relations with local communities and customers
- Activities in conflict zones
- Data security and privacy

Governance. Governance deals with the company's leadership, how it polices itself, and how it is governed.

Examples of governance issues that should be considered include:

- Board composition and independence
- Audits and internal controls
- Stakeholder/shareholder relations
- Executive compensation
- Political contributions and lobbying
- Corruption and bribery

ESG Risk Analysis Integration

Formulating a formal ESG Policy is helpful to ensure that the investment process considers whether ESG factors are relevant to an investment, how to thoroughly assess these risks, and in what way to consider whether the factors could ultimately have a financial impact. Certain ESG issues can have a more direct impact on profitability, cash flow, and an issuer's ability to pay back debt in a timely manner and should already be a critical part of any investment analysis or research process as opposed to a "stand-alone" evaluation.

Examples of existing fundamental credit analysis that should already consider ESG variables include:

- An assessment of company and industry specific risk factors
- Proprietary financial models and stress tests to quantify impact of risk factors
- An assessment of company leadership and management track record

For example, an assessment of company and industry specific risk factors could focus on proposed environmental regulations that would have a detrimental impact on operations and model its impact on a company's credit profile. This could include considerations such as a material loss of revenues, a meaningful increase in cost structure, a significant increase in capital expenditures to meet compliance, or a substantial need for additional funding. As another example, an assessment of company leadership and management track record could focus on the private equity sponsor's pattern of aggressive and unfavorable actions toward bondholders.

Developing an ESG checklist with more specific factors for companies can be an invaluable risk assessment tool. Such checklists would not only highlight the more immediate and pressing ESG concerns already identified in traditional analysis, but can also serve as a vital screening tool to systematically identify and inventory a more comprehensive list of potential ESG risks. A comprehensive checklist of ESG considerations can include many of the examples mentioned in the section above defining each of the ESG factors. While managers may select outside vendors to aid in their ESG analysis, most services are heavily focused on companies with public equity. As a result, there is still incomplete data with the leveraged finance market and its private companies. Some observers have also noted inconsistency among different vendor results for the same issuer.

For those investors that choose to develop a proprietary approach, the analytical process should include a thorough review of the issuer using public information; financial statements; meetings with senior management; access to sell-side research; and, in some cases, discussions with competitors, vendors, customers, and industry contacts. It is the responsibility of credit analysts to identify and monitor ESG factors that may be impactful to a potential or existing investment. As part of the regular due-diligence process, the analyst should populate an ESG checklist that forms the basis for further analysis on key risks or opportunities related to specific ESG issues. Aside from specific ESG concerns considered, the resulting overall ESG risk tier can be an additional datapoint in assessing the risk and relative value of an investment.

Socially Responsible Investing (SRI)

No discussion of ESG is complete without mentioning the related concept of SRI. While ESG investing focuses on how environmental, social, and governance factors might affect the fundamentals, performance, or valuation of a particular company, SRI investing involves avoiding a particular investment in a company because it does not meet one's standards for making positive social impact. An example might be avoiding investments in companies that produce or sell addictive substances (e.g., alcohol, gambling, and tobacco). SRI investing can be implemented in various ways but is generally most commonly seen via custom-tailored, separately managed accounts with specific client-determined restrictions or a specially focused fund or portfolio with a socially responsible objective and investment restrictions.

Step Three: Security Structure and Terms

A key consideration of a particular bond investment is its terms and structure. Most investors tend to favor bonds that possess terms and structure that are in line or better than market standard. However, as terms evolve and change with market conditions, portfolio managers must understand the implications and risks associated with alternative structures, and if acceptable, ensure that they are compensated appropriately.

The following factors must be carefully evaluated:

- Issue size
- Ranking/seniority
- Maturity
- Coupon type
- Early redemption features

Issue Size

The issue size of a bond will influence its liquidity and general attractiveness to other constituents in the market. For example, an issue size that is less than $300 million will most likely have a smaller investor base and therefore less trading liquidity. To the extent there is a seller of this security, the downside impact to the market may be greater given the lower trading liquidity and a narrower universe of investors willing to purchase a small, less liquid security. Conversely, much larger issues (greater than $1 billion issue size) may experience greater price volatility. As they tend to be liquid "benchmark" issues in the high-yield market, they may exhibit higher beta during aggressive movements in the overall market as exchange-traded funds (ETFs) and institutional investors are able to more easily execute trades and express their market sentiment.

Ranking/Seniority

The ranking and seniority of a bond are vital factors in assessing the risk and attractiveness of a security. Ranking and seniority refers to the location of the bond within the issuer's capital structure as well as the priority of claim in the event of bankruptcy. The ranking and seniority range from and include senior secured, senior secured second-lien, senior unsecured, senior subordinated, subordinated, and structurally subordinated. The more senior securities in the capital structure are generally accompanied by lower relative yields. Additionally, investors must ascertain the level of guarantees provided and where the tranches of debt sit relative to the assets of the company as well as the ranking within the capital structure. Portfolio managers should properly identify the risk associated with the ranking/seniority terms of the specific security so that they can determine the appropriate yield.

Maturity

A bond's maturity involves both technical and credit considerations. From a top-down perspective, an investor may be concerned with a significant rise in interest rates and, therefore, favor a shorter maturity option within a given capital structure. From a bottom-up perspective, an investor may be comfortable with the short-term prospects and liquidity for a given credit, but much less comfortable with the longer-term viability of the company and, therefore, favor a shorter maturity option within a capital structure with multiple maturities. Demand for shorter maturities (five years or less) has grown due to the proliferation of dedicated short duration high-yield strategies. The short duration market has also led to a growing trend in primary issuance of bonds with final maturities of five years. High-yield bonds have most commonly been structured with final maturities of between 7 and 10 years, with 8-year maturities more recently being the most popular tenor. On occasion, issuers have also come to market with longer maturities of between 12 and 15 years to take advantage of the low-interest-rate environment. While these bonds can provide greater upside for improving credits and periods of yield compression, these longer maturity terms may sometimes lead to greater price volatility given the potentially smaller investor base interested in a "nonstandard" bond.

Coupon Type

While the high-yield market consists primarily of cash-pay bonds, alternative structures also exist, including zero coupon, pay-in-kind (PIK), or PIK toggle. While the alternative structures tend to offer higher yields as a result of the less investor-friendly repayment terms, they also typically possess greater trading liquidity risk as they tend to appeal to a much smaller investor base within the high-yield universe. Such bonds are generally indicative of higher risk companies that may require the flexibility to grow into their capital structure. Bonds with coupon-steps triggered by credit rating changes are also an alternative structure that can sometimes be seen in the high-yield market and are generally a result of fallen angel issuers that were originally investment-grade rated and subsequently downgraded to high yield. These coupon steps are triggered by a downgrade in credit ratings from the time or original issuance, providing a specified incremental coupon (e.g., 0.25% per rating notch) to help compensate investors for the deterioration in credit quality. While this feature can be an attractive offset in certain situations where credit ratings are deteriorating, they must also be carefully evaluated as the coupon-step will also adjust coupons lower when ratings are being upgraded, limiting the return and potential appreciation in bond price.

Early Redemption Features

Early redemption features are common within the high-yield market. For example, the most typical bond structures are eight-year, noncall 3. This type of security is not callable for the first three years of its life, but then is callable at the company's option and according to a schedule that pays a premium to face value that declines as it nears final maturity. There has also been a growing trend in issuers coming to market with less call protection in exchange for little-to-no additional premium. Portfolio managers must be careful in evaluating early redemption features that may have a significant impact on returns as they can limit a bond's potential upside. Conversely, having additional insight as to when a bond is most likely to be called can also present upside yield opportunities for more savvy investors. This concept is further explored in step six, Relative Value: Short Duration Callable Bond Analysis.

Step Four: Covenants

Contained within the indenture of all high-yield bond offerings are certain covenants (or agreements) between the issuing company and bondholders. Covenants are essentially restrictions on the borrower/issuer imposed by the lender/bondholder that require the company to do, or refrain from doing, certain activities. Covenants are primarily designed to protect bondholders by limiting the ability of the company to take actions that could lead to credit deterioration that would hinder the company's ability to service the interest and repay the obligations on a timely basis.

Covenants are often referred to as "tight/strong" or "loose/weak" depending on the specific terms and ultimate financial flexibility they provide the issuer. A weak covenant package can significantly increase the risk of a high-yield bond investment, even though the borrower's business and financial risk profiles can be strong. As a result, the covenant package may not protect the bondholders by prohibiting enough actions by the issuer that could be detrimental to its ability to repay the bonds and service the interest.

Covenant analysis is a crucial part of any high-yield bond investment process. While a strong covenant package cannot offset the risk of a weak credit, it may provide significant financial protection to the investor. A weak covenant package may not necessarily preclude investment in a particular issue; however, it may increase the return an investor demands due to the higher level of risk.

From an investment standpoint, there are six key covenant elements to analyze, as follows: Limitation on Indebtedness, Restricted Payments, Change of Control, Asset Sales, Limitation on Liens, and EBITDA Add-Backs.

Limitation on Indebtedness

The limitation on indebtedness covenant restricts the amount of additional indebtedness that an issuer can incur. Unless it is kept in proportion to operating cash flow and assets, additional indebtedness can ultimately dilute the claims of the existing bondholders and weaken the credit profile of the company due to the increased debt service requirements.

Restricted Payments

The restricted payments covenant protects bondholders' interests in the assets of the company by restricting the company's ability to distribute money or assets outside the company, thereby preserving the company's ability to repay its indebtedness. Undesirable distributions and asset transfers that are limited by this covenant include dividends, repurchases of equity, investments in unrestricted third parties, and retiring debt that is subordinate to the bonds before retiring the bonds.

It is important to recognize that the restricted payments covenant does not limit acquisitions and capital expenditures, both of which should result in incremental cash flow and return on investment. The test is ultimately backward looking in that it determines whether the company has earned the right to make a payment to benefit the equity of the company as opposed to the debt.

Change of Control

The change of control covenant requires the issuer to offer to purchase the notes at 101% of principal if a change of control occurs. It is the bondholder's option to accept or decline the offer. In effect, this covenant gives a put option to the bondholder upon certain events. The rationale behind the change of control covenant is that it protects bondholders against a change in controlling interest by an owner who may have a different financial strategy for the issuer that could ultimately lead to deterioration in credit quality.

Limitation on Asset Sales

In contrast to its title, the asset sale covenant does not necessarily limit the ability of the issuer to sell assets. Its true purpose is to define the acceptable use of proceeds from asset sales. The proceeds must be used to permanently repay debt or to reinvest in replacement assets. The rationale is that the assets sold usually generate earnings and cash flow to service debt and should be replaced with similar assets.

Limitation on Liens

The limitation on liens covenant is intended to protect the bondholder's seniority position relative to income producing assets and restricts a company's ability to secure future debt with company assets. It protects a bond's place in the capital structure and can support recoveries in the event of default. It is important to analyze and understand the definitions and carve-outs for the liens test given the potential for unexpected, additional secured debt. Unless it is kept in proportion to operating cash flow and assets, additional indebtedness can ultimately dilute the claims of the existing bondholders in recoveries and weaken the credit profile of the company due to the increased debt service requirements.

Addbacks

Addbacks are meant to reflect defined adjustments that are permitted to be added back to reported EBITDA or earnings-based calculations for covenant ratio and test purposes. Although addbacks are not a covenant in and of themselves, they impact the underlying calculations that are a key component for many of the earnings-based ratios and tests, including some described above. In most cases, addbacks are buried within defined covenant terms with the intention of portraying a more normalized earnings figure, exclusive of unusual negative one-time events, or inclusive of the benefit of implemented or expected cost savings. While the intention is constructive, investors must be extra careful of abuses in aggressive addback calculations that can sometimes represent as much as 50% or more of adjusted earnings and provide issuers materially more flexibility than warranted or expected. These aggressive adjustments can be overly generous in their portrayal of one-time events that in practice are more recurring in nature, or exceedingly liberal in anticipating prospective cost savings for which the realization is subject to significant execution risk and uncertainty.

Step Five: Trading/Liquidity Risk

While credit analysis is focused on assessing the financial risk of a particular bond issue, the analysis of trading and liquidity risk evaluates the additional volatility that may be experienced by a bond issue. Trading liquidity can hamper the performance of a bond issue that may possess a favorable credit risk profile, but the far more significant risk is that a poor trading liquidity profile could dramatically magnify the downside risk of a weak credit. It may be already difficult to garner investment interest and new buyers in a weak or deteriorating credit; however, it is considerably more challenging to develop new demand in a weak credit that also possesses poor trading liquidity. For example, a disappointing earnings announcement could result in a 2-point drop in bond price if the issue possesses favorable trading liquidity, whereas the same announcement could result in a 5-point (or greater) drop in price if the bond possesses thin trading liquidity. Portfolio managers should have extremely high conviction level in credits with limited liquidity and require higher returns in those situations.

Liquidity Risk [2]

Liquidity risk involves measuring the ability to sell a particular credit on a timely basis. While equities often trade on an organized stock exchange or electronically where buyers and sellers are matched, high-yield bonds trade over-the-counter. Bond investors are dependent on broker-dealers to make a market. Also, unlike equities, the majority of high-yield bonds do not trade on any given day. An interesting analogy is to think of the high-yield market as being like a lake that is one-mile wide, but only inches deep. If a particular high-yield bond has limited liquidity, portfolio managers may be unable to execute their buy/sell decisions.

Portfolio managers should take into consideration the following key elements to assess the liquidity risk of a particular bond.

1. *Public or private company:* Private companies may possess less liquidity than public companies because there is either not enough information about the company in the market or the information is as easily available to prospective investors. For example, an unregistered

2. This section is adapted from Mark R. Shenkman, "Principles of Managing High-Yield Assets," chapter 12 in *Leveraged Financial Markets: A Comprehensive Guide to High-Yield Bonds, Loans, and Other Instruments.*

bond (e.g., Rule 144A) issued by a private company may require potential investors to undergo a certification process before accessing reported financials, or prohibit sell-side research coverage and prevent them from publishing reports.

2. *Number of market-makers and number of analysts following the issuer:* The fewer professionals on Wall Street who trade or actively "follow" a bond, the less available information on a company. Bond issues that have only one market-maker and no analyst coverage may be so illiquid that they "trade by appointment" (meaning that a seller has to give an order to a broker-dealer who then tries to sell the bond over a period of time).

3. *Number of tranches of debt in the capital structure:* The more tranches, or issues, of debt that a company has outstanding, the higher the probability that more traders and analysts will follow a given credit. A large number of tranches provides more activity in an issuer because there are paired-trade possibilities, such as shorting senior bonds and going long subordinated bonds. The ability to trade across the capital structure in one credit increases the universe of investors interested in the bonds.

4. *Accessibility of management:* Bonds issued by companies with inaccessible management typically inhibit trading activity because investors lack sufficient information to give them comfort or conviction, particularly in volatile markets. If a management team is unwilling to talk when times are good, they are even more unlikely to talk when times are bad!

5. *CDX-listed issuer:* The CDX is a widely traded index of 100 credit default swaps (CDS) that mirrors the broader high-yield market. The CDX, the underlying CDS, and the underlying bonds are all linked by the arbitrage that exists if the CDX becomes too cheap compared to the CDS or the actual bonds. Therefore, underlying bonds of CDS in the CDX tend to trade more frequently because investors may be executing arbitrage trades. Moreover, the price of CDX-listed issues tends to be more volatile because they are the most liquid credits.

6. *Issuer is a major company within its industry:* Bonds of companies that have a real "presence" in their respective industries tend to have more liquidity for two reasons. First, if the underlying company is a major part of its industry, it becomes a proxy for the industry and allows investors to obtain exposure to a sector. Second, high-yield traders typically like to own and trade the largest credits in an industry sector.

7. *Size of issue:* The universe of potential buyers of a bond typically increases with the dollar size of the issue. The larger pool of potential

purchasers increases the ability of a bondholder to sell a particular issuer.

8. *Ratings of issuer and issue:* Higher-rated credits within the high-yield universe tend to trade more frequently because they are perceived as being more stable and have greater demand. Triple-C rated issues generally require more work and conviction to purchase, causing traders to be less willing to hold a bond with higher risk and a smaller universe of eligible investors.
9. *Crossover credits:* Bonds that generate demand from both investment-grade and high-yield buyers, such as utilities, offer greater liquidity. High-yield bonds that are considered crossover companies typically generate a new class of investment-grade purchasers who from time to time dip down and buy the high-yield bond tranche. With a larger universe of such buyers and sellers, liquidity often improves.
10. *Volume of trading activity according to TRACE:* Broker-dealers are required to timely report all high-yield bond trades to a self-regulating organization making post-trade price and volume details publicly available for all market participants to observe. This system is called TRACE (Trade Reporting and Compliance Engine). Providing market participants with timely information about transaction prices and quantities has dramatically increased transparency and visibility on liquidity and transaction costs. A bond's activity levels on TRACE will oftentimes be the most accurate measuring tool of its liquidity given its historical patterns and data points can be easily obtained and measured.

Based on these 10 criteria, with the greatest emphasis on TRACE activity, each credit should be designated as "L1," "L2," or "L3." L1 credits are traded by multiple market-makers on a daily basis and will typically exhibit the strongest liquidity characteristics and most consistent and frequent TRACE activity; L2 names are typically traded by two or more market-makers on a weekly basis and will typically exhibit reasonable liquidity characteristics and TRACE activity; and L3 credits trade a few times per month by one or more market-makers with limited TRACE activity, which can result in an inability to execute on a timely basis. In many cases, an L3 bond can become an "orphan" credit if the original underwriter no longer covers or makes a market in the credit.

The percentage of the portfolio represented by L1, L2, or L3 liquidity ratings should be calculated and monitored to determine the appropriate weighting in each category.

Step Six: Relative Value

Relative value is the final step in the bottom-up security analysis process. Once the credit and liquidity risks of an issue have been determined and evaluated, then the overall expected risk premium for the security can be appropriately established. Spread and yield analysis are typically the most appropriate metrics in determining if the security's return is commensurate with its overall credit and investment risk.

Risk/Reward

Determining relative value in the high-yield market is more an art than a science. The age-old maxim "Buyer Beware" rings loudly in high-yield as all risk is not created equal! For example, it is much easier to compare and value the risk of financial leverage across two credits than it is to determine how much incremental return or yield is required to compensate for the potential risk presented by significant covenant flexibility that can be utilized to the detriment of bondholders. Some investors use ratings (usually assigned by Moody's, S&P, and Fitch) to determine their credit risk and then evaluate the spreads on that basis. For example, a single-B-rated issue yielding 500 basis points over riskless U.S. Treasuries may be considered attractive relative to another single-B–rated issue yielding 350 basis points, or versus the current high-yield single-B index average spread of 400 basis points. However, in order to make this assessment, investors must assume that the credit ratings themselves are accurate, and that they are a "leading" indicator of credit risk. More importantly, investors should realize that credit ratings do not contemplate many of the investment risks discussed above, such as bond covenants, size of issue, quality of underwriter(s), number of market-makers, Wall Street sponsorship, and information flow, to list a few factors. Relying on the credit rating alone to determine risk will not give a complete picture and can be a perilous exercise during certain stages of the credit cycle.

Comparables

The basic formula for assessing relative value is to compare the yield and spread of the bond being evaluated to industry peers and other credits of similar risk. When evaluating yields and spreads on high-yield bonds, it is important to appropriately consider final maturities, optional redemptions, and workout dates. Given that the majority of bonds in the high-yield universe are callable, analysis of spreads and yields must consider multiple potential outcomes, with an emphasis on their yield-to-worst, spread-to-worst, effective workout dates, and option-adjusted spread. Option-adjusted spread (OAS) is the measurement of the spread that takes into account embedded redemption options. However, as OAS is calculated using historical data and volatility modeling, it is highly dependent on the model being used. Exhibit 54-5 is a typical "comp sheet" a portfolio manager should evaluate to assess the relative value of one bond versus another.

Analyzing the credit comparable above, it becomes apparent that Company C is a weaker credit. As compared to the other two companies, Company C has higher leverage, weak interest coverage, negative cash flow, and significant near-term amortization for which it does not appear to have ample liquidity to address.

EXHIBIT 54-5

Sample Credit Comparable Analysis

LTM Period	Company A Current	Company B Current	Company C Current
Revenue	**6,000**	**800**	**3,500**
EBITDA	**1,000**	**140**	**395**
Margin	**16.7%**	**17.5%**	**11.3%**
Capital Expenditures (Capex)	350	11	180
Interest	207	51	196
Tax	50	0	30
Cash Flow	**393**	**78**	**(11)**
Working Capital Changes	50	(10)	0
Other (including acquistions/dividends)	0	0	0
Free Cash Flow (FCF)	**443**	**68**	**(11)**
Financial Statistics			
EBITDA/Interest	4.8	2.8	2.0
(EBITDA-Capex)/Interest	3.1	2.5	1.1
Bank Debt/EBITDA	**2.1×**	**3.8×**	**2.8×**
Sr. Notes/EBITDA	**3.6×**	**3.8×**	**6.5×**
Sub. Notes/EBITDA	**3.6×**	**6.3×**	**7.8×**
Total Debt/EBITDA	**3.6×**	**6.3×**	**7.9×**
Net Debt/EBITDA	**2.9×**	**5.9×**	**7.3×**
Free Cash Flow/Total Debt	12%	8%	0%
% Total Debt/TEV	46%	. . .	99%
TEV/EBITDA	**7.9×**	**. . .**	**8.0×**
Liquidity			
Cash	750	60	250
Availability	650	50	275
Total Liquidity	**1,400**	**110**	**525**
Year 1 Amortization	500	12	15
Year 2 Amortization	70	11	500
Year 3 Amortization	70	11	15
Year 4 Amortization	70	11	400
Year 5 Amortization	70	11	15
Year 6+ Amortization	2,820	824	2,185

(Continued)

EXHIBIT 54-5

Sample Credit Comparable Analysis (*Continued*)

LTM Period	Company A Current	Company B Current	Company C Current
Capitalization			
Bank Debt	2,080	530	1,120
Sr. Notes	1,520	0	1,460
Sub Notes	0	350	500
Other Debt	0	0	50
Total Debt	**3,600**	**880**	**3,130**
Preferred	250		
Number of Shares	150	. . .	75
Stock Price	$37.00	. . .	$7.00
Equity Market Cap	5,550	. . .	525
Total Enterprise Value (TEV)	8,650	. . .	3,405
LESS: Cash	(750)	(60)	(250)
LESS: Other Value		. . .	
Adjusted TEV	7,900	. . .	3,155
Bond Pricing			
Coupon	5.75%	6.25%	6.50%
Final Maturity/Yrs to Maturity	6 years	8 years	7 years
Moody's/S&P/Fitch Ratings	Ba2/BB–/BB–	B2/B/B+	Caa1/B–/B–
Price	**104.50**	**101.50**	**91.00**
Yield to Worst (YTW)	**4.54%**	**5.30%**	**8.22%**
YTW Workout Date	**4.1 years**	**6 years**	**7 years**
Yield to Maturity (YTM)	**4.88%**	**5.99%**	**8.23%**
Duration to Worst (DTW)	**3.6**	**4.6**	**5.4**
Option-Adjusted Duration (OAD)	**3.5**	**5.2**	**4.9**
Duration to Maturity (DTM)	**5.0**	**5.9**	**5.4**
Spread to Worst (STW)	**428**	**554**	**772**
Option-Adjusted Spread (OAS)	**408**	**536**	**776**
OAS per unit of Net Leverage	**143**	**92**	**106**

Given the higher-risk credit profile, the spread on Company C's subordinated notes is meaningfully wider than its comparables, as one would expect. In contrast, Company A's stronger credit profile has resulted in a meaningfully tighter spread than its comparables. Although it also has substantial debt amortization in the current year, it appears to have ample liquidity (as measured by its cash and availability) to absorb the amortization. Ideally, credit comparables should include a snapshot of the trailing 12-month operating results as well as a forward-looking credit profile for the next 12 months.

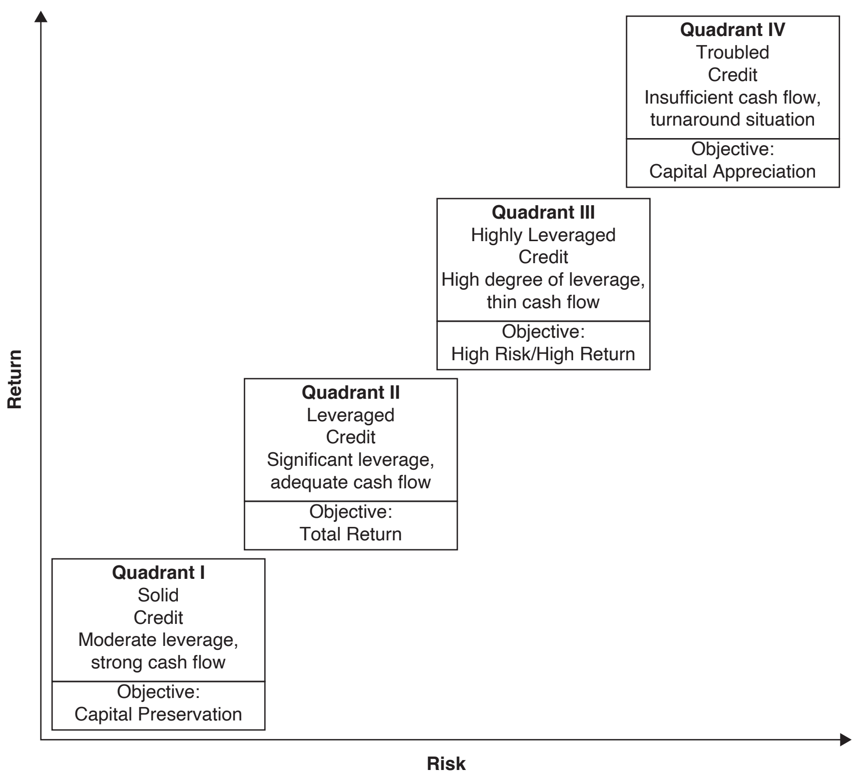
Quadrant Analysis

Many investors use credit ratings to determine risk and evaluate comparable spreads. Given the prevalence of ratings in the marketplace and their acceptance among market participants, portfolio managers cannot ignore these ratings but should not rely on them as a primary or ultimate assessment of creditworthiness. Rather, portfolio managers should construct a more comprehensive risk assessment that can be tailored to incorporate factors they deem appropriate.

Constructing a risk/return matrix can be helpful in determining a framework. Credits can be divided into quadrants as shown in Exhibit 54-6. A description of each of these quadrants is provided as follows:

EXHIBIT 54-6

Quadrant Matrix



Quadrant I: Solid credits with strong credit statistics, moderate leverage, and strong free cash flow. Typical characteristics would include companies with predictable and improving cash flows; deleveraging companies; and companies that have substantial assets well in excess of debt. Objective: capital preservation.

Quadrant II: Good credits with significant leverage that show stability and/or improvement in their credit profile via improved results and lower leverage. Quadrant II companies can appreciate or depreciate depending upon their ability to execute their business plans and ultimate credit trend. These companies typically possess above-average creditworthiness with adequate balance sheets and relatively weak asset value coverage of their total debt. Objective: capital preservation/total return.

Quadrant III: Weak credits with extremely high leverage and deteriorating or at-risk credit trends. These credits have a small margin for error and, therefore, require higher yields to compensate bondholders for the additional risk. Typical characteristics include minimal to negative free cash flow (best measured relative to total debt) and deteriorating credit statistics. They may also include start-up companies, companies with large capital requirements, and companies with aggressive capital structures that utilize zero coupon, PIK or PIK/toggle notes. Asset value coverage of total debt is typically weak. Objective: high risk/high return.

Quadrant IV: Troubled credits that are stressed or distressed and could be in actual or technical violation of covenants. Bonds are likely to be impaired and therefore should require much higher equity-like returns. Objective: capital appreciation.

When assigning quadrants to specific credits, they should be evaluated with an emphasis on the prospective, forward-looking view because the markets are more focused on where a credit is going rather than where it has been. Picking credits that may be transitioning from one quadrant to another can represent trading opportunities. Portfolio managers who are better able to correctly forecast credit trends should outperform their peers. Placing too much emphasis on past results could ultimately provide a myopic risk assessment and thereby limit the risk/reward equation and relative value analysis.

Within the quadrant concept, spreads can be analyzed relative to credits within the same quadrant. Given the potentially wide spectrum of credit quality within a specific quadrant, issuers may be further subdivided into lower and upper tiers for greater segmentation. Once quadrants have been assigned, portfolio managers should compare spreads of companies within the same quadrant that are most similar. When possible, comparisons should be to companies within the same industry and quadrant. Other relative considerations include trading history, stock, bank loan and CDS prices, and duration.

Scenario Analysis

Scenario analysis is another tool to better identify relative value and determine an appropriate investment recommendation. This analysis is particularly useful in circumstances with multiple outcomes or potential event risk.

In Exhibit 54-7, the subject company has just announced a significant acquisition, although financing has not yet been determined. After assessing the amount of flexibility provided by the company's existing covenants as well as taking into account current capital market conditions for debt and equity, the analyst can utilize a scenario analysis to determine a potential trading recommendation. Given management's prior comments and long-standing financial policy, the analyst has assigned a 75% probability to a debt-financed acquisition as opposed to a more balanced combination of debt and equity. Likely potential trading levels post the events are then assigned to each of the scenarios above based on relative value for the pro forma risk profile. This scenario analysis indicates that there are six points of potential downside on the higher probability outcome as opposed to one point of upside on the less likely outcome. Based on this analysis, the recommendation would likely be to sell or reduce the position if possible, or at least proceed with caution.

EXHIBIT 54-7

Scenario Analysis Example

	Probability	Bond Price	Yield	Spread	Leverage Ratio
Current Trading Level		97	6.8%	582 bps	5.0×
Scenario A	75%	92	7.6%	708 bps	6.3×
Scenario B	25%	99	6.4%	586 bps	4.7×

Assumptions:

Scenario A assumes 100% debt financed acquisition.

Scenario B assumes acquisition is financed with 60% equity and 40% debt.

Trading History

To the extent an issuer has had bonds outstanding for a period of time, portfolio managers should examine the trading history of those bonds. Exhibit 54-8 provides a list of some key trading history questions.

EXHIBIT 54-8

Key Trading History Questions

What is the issuer's bond price history? Has the bond been volatile in which case a higher risk premium may be more appropriate?

What is the issuer's bond spread history relative to the current spread? Is it at the tight end or wide end of its historical range? Is it aligned with credit profile?

What is the issuer's bond spread relative to its industry or the high-yield index? How has this relationship trended over time? Is it at the tight or wide end of its historical range? Where is the price relative to where the current credit profile warrants?

What is the current spread level relative to the spread at issuance? Has it widened or tightened dramatically? Were the moves associated with a change in credit profile as opposed to more technical factors?

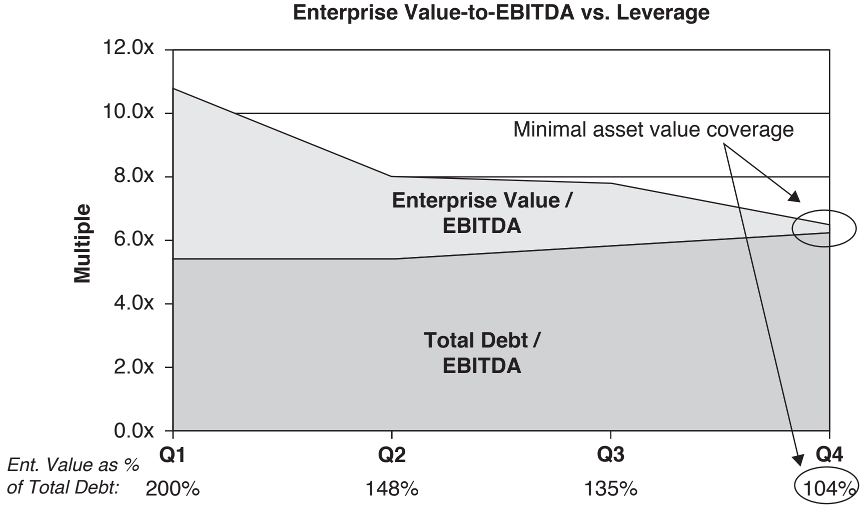
Stock Prices

Since many lower-rated companies are overlevered, their bond performance oftentimes is highly correlated to their stock prices. In some cases, equity prices may be a leading indicator and in other cases bond prices may lead the equity markets. In any event, equity prices (if it is public) of the specific credit, or its public peers and competitors, may have a significant impact on bond prices. As equity prices rise or fall, the equity valuation of the company changes, which essentially measures the degree of "equity cushion" on the specific credit. For example, a stock price that has declined 20% may signal that the implied asset value cushion relative to the bonds has also been dramatically reduced, thereby increasing the overall risk of the credit. If a portfolio manager is looking at two similar credits within the same industry and the same leverage ratios, they would rather own the company with the higher Enterprise Value-to-EBITDA valuation multiple because it ultimately implies greater asset value coverage and thereby less risk (all other things being equal). In Exhibit 54-9, a company's leverage has not changed dramatically over the last four quarters, but due to a severe decline in the stock price, the enterprise valuation of the company has fallen. As a result, the enterprise value coverage of total debt has declined dramatically, and the credit risk has increased. The equity cushion is the lightly shaded area in Exhibit 54-9.

Examples such as this illustration are an important reason why portfolio managers should not take comfort in high implied levels of asset coverage based on the stock price and enterprise value. If equity investors no longer have a favorable view on the company's growth prospects, multiples may contract. Thus, it is important for the credit analysis to include alternate independent methods of asset and enterprise valuation, while monitoring and considering movements in the current public equity value. Although credit metrics may not change dramatically in the near-term, a forward-looking viewpoint of the equity valuation may

EXHIBIT 54-9

Equity Cushion Example



be important in determining perceived enterprise value coverage and trading outlook. In Exhibit 54-9, the 104% enterprise value-to-total debt coverage in the fourth quarter (Q4) suggests that the bond requires equity-like returns as its implied asset coverage is weak.

Bank Loan Prices/CDS

Portfolio managers should monitor the price of the senior instruments in the capital structure as well as single-name CDS trends. Moreover, the lines between high-yield bonds and bank loans have blurred as the two markets and investor bases have converged with overlap. For example, if the yield on a company's term loan is too tight to the yield on its bonds, it may signify that one or both instruments are mispriced. In order to make an appropriate comparison, portfolio managers must evaluate both yields on an equivalent basis since the bank loan yield is a floating rate and based on LIBOR, SOFR, or an alternative benchmark, whereas the bonds are fixed-rate and based on comparable dated U.S. Treasuries. Monitoring CDS trends also provides a window into potential changes in market sentiment toward a particular issue. Depending on market conditions and trading in specific tranches, it can sometimes be easier for investors to express their credit opinion on a given issue by trading CDS as opposed to the underlying bond. As a result, market sentiment may sometimes be more quickly reflected in CDS price movement before it is evident in the bond. Evaluating and monitoring all securities within the capital structure is essential to good security selection.

Duration

Duration measures the price sensitivity to yield as well as the percentage change in price for a parallel shift in yield. The longer the duration, the more sensitive the price will be to interest rate fluctuations. Overall, bonds of equal maturity with higher yields will have shorter durations than lower-yielding issues.

Duration is an important consideration in assessing relative value apart from its sensitivity to changes in underlying Treasuries and determining the appropriate level of additional compensation for going further out on the curve. First, credit risk will naturally increase with longer-dated maturities as there are many factors that can change a company's credit profile over time and have a more profound impact on a levered issuer compared to an investment-grade issuer. Second, to the extent there is near-term potential for a negative surprise, a longer-duration bond should have more downside risk. As investors demand incremental yield to compensate for the risk, longer-duration bonds should generally experience more downside risk. Conversely, for issuers where the underlying credit profile is expected to improve meaningfully, longer-duration bonds will provide greater upside as credit spreads compress to reflect the lower risks, all other things being equal. Another important consideration in evaluating duration in high-yield bonds is adjusting analysis for callable bonds. As callable bonds are quoted at their yield-to-worst or most conservative yield outcome for a given price, the corresponding duration-to-worst metric may sometimes understate the duration of callable bond. As a result, it is important for managers to also consider the option-adjusted duration (OAD), final maturity, and the potential extension risk of duration being greater than expected should a bond's price drop below its call prices or par. The analysis of short duration callable bonds is further discussed below.

Short Duration Callable Bond Analysis

As the majority of bonds in the high-yield market are callable, it is important to consider the impact of their optional redemption features on a bond's potential return profile and duration. Before further exploring, it's important to note that market convention in pricing high-yield callable bonds is to quote the corresponding yield-to-worst and duration-to-worst for a given price. From a yield perspective, the resulting quoted yield will be the lower and more conservative outcome of the multiple redemption scenarios. This is to help investors ensure that specific income or yield requirements will still be met even in the worst scenarios. However, our experience has proven that yield-to-worst can oftentimes be an overly conservative metric, particularly when callable bonds are trading at premiums above their call prices. This is due to the fact that an issuer's decision to call its bonds is not soley based on refinance economics such as payback period and NPV, but more often driven by company specific motivations and circumstances. Some motivations beyond refinance economics can include the following:

- Issuer seeking to make a larger acquisition that may require additional debt financing and desiring to delay refinancing to occur in conjunction.

- Issuer is either in process or seeking to be acquired and not intending to refinance currently callable pre-payable debt with more onerous premiums or additional call protection.
- Issuer is intending to repay debt post filing an IPO, which can be an extended process.
- Issuer awaiting the benefit of improved operational trends over several quarters or expected/targeted credit rating improvement in anticipation of more favorable refinancing terms.
- Onerous covenant provisions that could incentivize issuers to redeem the bonds due to the additional financial flexibility advantages beyond the individual bond's payback economics.
- Issuer is awaiting conclusion of a strategic review that could result in sale, spinoff, or IPO of certain significant assets.
- An LBO sponsor is approaching its exit horizon and is unmotivated to call bonds as a refinancing would likely result in new call protection premiums that would be less appealing to potential suitors.
- Issuer seeking to coordinate redemption timing with other upcoming callable bonds or refinancing opportunities.

These are all just a few of the many company-specific circumstances that will ultimately drive the timing of refinancing and redemption decisions. As a result, yield-to-worst for bonds trading at a premium can oftentimes not be the best indicator of the likely yield, and investors may be able to capture greater yields and returns with more informed assumptions beyond the standard worst-case metric. Through in-depth research of catalysts driving the call and tender activity on each individual issue, a manager can add value and evaluate when bonds are most likely to be called to determine the yield to that more "likely" call date. Strong bottom-up fundamental research process can help a manager to understand issuers' financing needs and seize upon idiosyncrasies within the short duration high-yield universe. Exhibit 54-10 demonstrates a currently callable bond example. It highlights how quickly a bond's yield can ramp beyond the yield-to-worst if it remains outstanding as well as the meaningful incremental yield that can be captured when a manager's likely call date may differ with market expectations.

TOP-DOWN HIGH-YIELD MARKET DRIVERS AND MACRO CONSIDERATIONS

While the bottom-up component of portfolio management should be the primary driver of security selection, it is important to incorporate a view on key macro top-down factors that will influence the markets as well as individual industries and credits. Understanding these drivers is necessary in evaluating past performance

EXHIBIT 54-10

Short Duration Callable Bond Example

Bond Purchase Information

Coupon	**7.75%**		**First (Worst) Call**	**+30 days**	**+60 days**	**Likely Call* +90 days**	**Maturity**
Final Maturity	2/1/2024						
Purchase Date	1/1/2021	**Call Date**	2/1/2021	3/1/2021	4/1/2021	5/1/2021	2/1/2024
Purchase Price	104.3	**Call Price**	103.875	103.875	103.875	103.875	100
Yield-to-Worst	2.0%	**Annualized Yield**	2.0%	4.7%	5.6%	6.1%	6.2%
Duration-to-Worst	0.08						

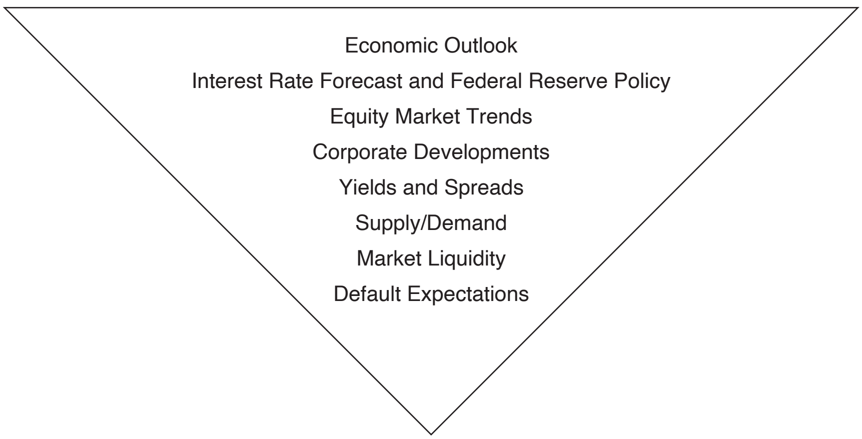
* Manager estimate.

and constructing individual portfolios. Furthermore, macro considerations are a key component to providing the proper context for individual industry and credit allocations. However, considerations must also be given to both global and local drivers and implications.

The high-yield market has eight primary drivers. The top-down (macro) component of the portfolio management process is further highlighted in Exhibit 54-11.

EXHIBIT 54-11

Top-Down High-Yield Market Drivers and Macro Considerations



Economic Outlook

All top-down macro views require some form of economic analysis. An assessment of current and expected future economic conditions is essential to portfolio management as the performance of the economy has a significant bearing on the performance and profitability of the companies that make up the high-yield market. All aspects of an economic analysis should consider both local and global drivers and implications. An analysis of the general economy usually begins with the business cycle. One determinant of industry allocation decisions is a forecast of whether the macro economy is improving or weakening. A forecast that differs from consensus can have a significant impact on strategy and performance. Economic indicators such as GDP, inflation, consumer sentiment, consumer spending, business investments, unemployment, housing, and ISM provide the necessary data to develop an informed viewpoint and forecast. Ideally, this data should be supplemented with primary research derived from direct management contact of portfolio holdings. Complementing economic data with primary research can provide a higher level of conviction in formulating an economic forecast. Furthermore, it may highlight risks in the consensus view and provide portfolio managers with an opportunity to add value and enhance returns. Once the economic outlook has been created, it is necessary to establish the impact of that forecast on specific industries as not all sectors are equally sensitive to the business cycle. For example, a negative economic outlook may warrant a higher weighting in defensive industries and credits. Conversely, a positive forecast would favor more economically sensitive industries and credits.

Interest-Rate Forecast and Federal Reserve Policy

Rising rates and tightening monetary policy tend to have a negative impact on fixed income investments. While high-yield bonds have historically shown a relatively low correlation to U.S. Treasuries as compared to many other fixed income asset classes such as investment-grade corporates, formulating an outlook on interest rates provides a framework for the construction of the portfolio. For example, if the interest-rate forecast calls for a significant increase in interest rates, it may be appropriate to reduce a portfolio's exposure to low coupon, longer maturities, and the most interest-sensitive lower-yielding credits. Additionally, from a credit perspective, certain industries that are highly sensitive to interest rates (such as financials) may face additional risk and technical pressure in a rising rate environment.

Equity Market Trends

Contrary to popular belief, the high-yield market has demonstrated a much higher correlation to the equity markets than to 10-year U.S. Treasuries. For the 20-year period ended May 2020, the high-yield market exhibited a –0.20 correlation to 10-year Treasuries versus a 0.69 correlation to large cap equity according to *eVestment*. Although high-yield is a fixed income vehicle, the meaningful risk premium over Treasuries absorbs much of the volatility in Treasuries to deliver more equity-like returns. As equity markets fluctuate, so does the ultimate equity cushion for debt investors. Stronger equity markets typically signify stronger outlooks and earnings momentum; however, they also signify stronger equity cushion and asset protection for bondholders. The opposite is true when equity markets are declining. These dynamics are amplified for highly levered companies. In the end, it is generally more difficult for high-yield bonds to perform well when the equity markets are declining. Portfolio managers should keep this dynamic in perspective when managing risk.

Corporate Developments

Just as corporate fundamentals drive returns on an individual issuer, broader trends in overall corporate developments influence the high-yield market as well.

To illustrate, a strong equity market may drive many private high-yield companies to go public and use the proceeds to pay down debt (a positive credit event). Conversely, an overabundance of available credit may incentivize private equity sponsors to raise debt in order to fund dividends to the equity holders at the expense of existing bondholders. To the extent corporate development trends are occurring on a broader scale, it may positively or negatively impact the high-yield market as investors anticipate other issuers that are likely to undertake similar positive or negative actions.

Market Yield and Spread: Relative to Historical Averages and Versus Other Asset Classes

In determining asset allocations for their larger, overall portfolio, investors will ultimately consider the relative yield and spread of high-yield bonds to historical averages as well as to other asset classes and investment alternatives. This consideration provides an important perspective for high-yield portfolio managers as it is a key influence that drives overall demand in the high-yield market as well as the market technicals. In developing a relative perspective, portfolio managers should consider the following reference points and how they compare to historical ranges and averages:

- High-yield market spread over Treasuries
- High-yield market absolute yield
- High-yield market spread vs. investment-grade corporates
- High-yield market spread vs. leveraged loans
- High-yield market yield vs. dividend yield on the S&P 500

For example, if high-yield spreads are at all-time wides, there should be strong technical pressure and ultimate demand to drive yields tighter as new buyers enter the market to take advantage of the opportunity. Additionally, if the incremental high-yield market spread over investment-grade corporates is at all-time historical tights, investors may decide that the incremental yield is insufficient, creating downside technical pressure.

High-Yield Market Supply/Demand

New issue supply and flow of funds play a meaningful role in the performance of the markets. While longer-term returns are more influenced by the overall corporate credit outlook and expected default rate, supply and demand characteristics may be difficult to forecast, but impossible to ignore. A record supply of new issuance can cause technical pressure on the secondary market in an otherwise fundamentally strong high-yield credit environment with low default expectations. Conversely, a lack of supply works to strengthen demand for existing issues in the secondary market and drive prices higher in a similar environment.

While new issue supply can easily be measured and monitored through multiple sources, demand is more difficult to ascertain. Although retail mutual fund flows are available on a daily basis, they provide only a limited picture of the overall high-yield market demand. High-yield retail mutual funds and ETFs account for less than 30% of the overall high-yield market. Additionally, these funds may not accurately represent the sentiment of the larger institutional investors, which account for a larger portion of the high-yield market. While retail fund flows provide a window into overall demand, the largest high-yield managers with significant institutional assets can better measure demand through their own level of marketing activity and internal subscriptions/redemptions. Demand can have a significant impact on market returns, particularly in periods where new issue supply is limited. Short-term demand considerations should also be evaluated. While retail mutual funds and ETFs represent a limited portion of the high-yield market, they can represent a significantly larger share of trading activity on given days where ETF activity is meaningful, causing them to have a greater technical impact on the market in certain circumstances.

Market Liquidity

Broker-dealers provide the liquidity needed to sustain active markets in high-yield securities. Over time, broader trends such as bank consolidation, increased regulations, and enhanced trade reporting have all had an impact on broker-dealers and market liquidity. Due to the consolidation among broker-dealers that was triggered by the financial crisis, smaller firms focused primarily on secondary trading entered the high-yield market to populate the void created in consolidation. Under global regulations known as Basel III, banks have had to use more capital to fund risky assets, while Dodd-Frank financial reform law in the United States imposed strict limits on how much of their own money banks are able to deploy across trading activities, adding pressure to market liquidity.

Additionally, TRACE reporting has required broker-dealers to report details of trades they execute within minutes. While the increased transparency has provided benefits to investors by reducing transaction costs, it has also impacted broker-dealer ability to take risk as a provider of liquidity and impacted their profitability. As a result, the broker-dealer's role has shifted from a vast majority of its trading volumes prior to the financial crisis being principal trades (involving their own inventory), to the majority being agency trades where it is simply linking up a buyer and seller. This has likely led to greater price volatility, particularly in downward markets, where levels must adjust lower until natural buyers are found. That said, overall liquidity has increased as trading volumes in high yield have grown meaningfully over the years to record levels and have largely kept pace with the robust growth in the size of the overall high-yield market. Additionally, growth in the popularity of ETFs, strong demand from foreign investors, and broader acceptance of the asset class have all had a positive impact on market liquidity. While electronic trading has captured a meaningful share of overall trading in investment-grade corporate bonds, its adoption in the high-yield market has remained more limited, as less than 12% of high-yield bonds were traded electronically on average in 2019, according to research by Greenwich Associates. Apart from the broader trends, the amount of capital provided to broker-dealer trading desks is a significant determinant of the ability to effectively trade in the high-yield market. For instance, a broker-dealer's senior management may decide (whether for macro concerns or company-specific circumstances) to "dial down" its risk exposure and hence limit the capital it allocates to its high-yield trading desk. As a result, investors may experience longer execution times, higher transaction costs, and greater price volatility before clearing levels are achieved. Market liquidity is also seasonal based on staffing and the new issue calendar. For example, late summer and periods surrounding holidays exhibit lower liquidity as broker-dealers operate skeleton crews and limit capital. Moreover, traders may be less willing to risk capital as they approach their fiscal year-end and thereby impact their year-to-date profit and loss. It is important for portfolio managers to understand both the secular and shorter-term trends that influence the ability to execute trades in the market.

Default Expectations

Since inception, the high-yield market's most important driver is default rates. In periods where default rate expectations are low, the high-yield market tends to perform well as the lower default expectations influence two important components of high-yield returns: risk premiums and default loss.

$$\text{Expected high-yield return} = \text{Risk-free rate} + \text{Risk premium} - \text{Default loss}$$

Many investors have become more tolerant of defaults and acceptance of losses due to defaults built into their performance expectations. In an environment of lower default expectations, risk premiums as measured through credit spreads should decline as investors are less concerned with default risk and willing to accept less yield, thereby driving bond prices up. Additionally, the lower expected default risk lowers the expected default loss, hence increasing the overall expected high-yield return. Portfolio managers can temper their portfolio risk tolerance based on their overall default expectations. For example, portfolio managers may be willing to assume more risk when the outlook for default rates are trending lower, whereas increasing default rates may warrant a more defensive posture.

PORTFOLIO CONSIDERATIONS

Portfolio considerations are the framework applied by the investment managers to ultimately decide which securities are most appropriate for inclusion in a given portfolio. They act as the filter to screen the potential investment universe utilizing the bottom-up and top-down considerations discussed in this chapter. These portfolio considerations include:

- Client/portfolio objectives
- Risk tolerance
- Diversification
- Trading strategy
- Portfolio characteristics
- Risk management and analytics

Client/Portfolio Objectives

Portfolio objectives are essential to providing the overall direction for portfolio construction and day-to-day investment decisions. A quote from poet Ella Wheeler Wilcox serves as a good analogy for the importance of these objectives: “One ship drives east and another drives west / With the selfsame winds that blow; / ‘Tis the set of sails / And not the gales / That tell us the way to go.”[3] With respect to portfolio management, investment objectives serve as the sails to guide the portfolio in the proper direction. The most vital portfolio objectives are return target and risk tolerance. The client or portfolio manager must decide what the primary investment objective is (i.e., income generation, total return, benchmark “hugger,” absolute return, or preservation of capital). Most portfolio managers have one primary objective and a secondary goal—for example, absolute total return as the primary objective and high current income as a secondary goal. The more clearly defined the objectives, the more likely the strategy will be effective and successful.

Risk Tolerance

In the universe of high-yield bonds, preserving capital, and controlling risks are paramount factors in generating superior returns over a full credit and economic cycle. Calibrating the portfolio’s risk tolerance goes hand in hand with the portfolio’s investment objective.

For example, a total return strategy will necessitate a higher-risk tolerance as managers must buy higher yielding issues with greater risk premiums or deeper discount paper in order to achieve the high return objective. However, these greater returns and higher risk premiums will likely result in greater volatility of returns as well a higher probability of default loss. Ultimately, portfolio managers must clearly define whether their core risk tolerance is conservative or aggressive and maintain an unwavering style in the face of changing markets.

3. Wilcox, Ella Wheeler, “The Winds of Fate,” in *World Voices* (New York: Hearst’s International Library Co., 1916).

Although it is feasible to beat the benchmark with a conservative strategy in a down market, or with an aggressive style in an up market, the combination of aggressive/conservative style outperforming in both bull and bear markets is extremely challenging and flawed. The lack of trading and the unavailability of many issues in the high-yield market inhibits the ability of portfolio managers to shift between styles in a short time frame. While a portfolio manager's core strategy and risk tolerance must remain intact in order to succeed over an entire market or credit cycle, this should not preclude portfolio managers from increasing or decreasing their risk tolerance within their core conservative or aggressive strategy as market conditions change. However, these changes in risk tolerance must remain incremental as opposed to radical. Success is measured by achieving the highest risk-adjusted returns over an entire market or credit cycle.

Diversification

A key factor in reducing risk and achieving return objectives is diversification. Diversification should not simply be measured by the number of investments held in a portfolio but must be evaluated on many critical levels in order to appropriately manage and lower the overall risk. One of the most common mistakes portfolio managers make is that they "fall in love" with an industry and/or a credit and fail to properly diversify their high-yield holdings.

Several key factors should be taken into account in assessing a portfolio's diversification. These include:

- Issuer concentration
- Industry concentration
- Credit and fundamental risk
- Liquidity
- Duration

Issuer Concentration

Diversification by issuer should be measured on several levels. Number of holdings and average position size are two of the most important diversification measures. Some investors may believe that a more concentrated "best ideas" approach to portfolio management (e.g., <35 issuers) will achieve the highest returns; however, it may do so at a much higher level of risk given that the most severe credit losses tend to be the unexpected ones. Conversely, some portfolio managers may believe that a large number of holdings (>400 issuers) provides greater protection against individual loss as well as smaller tracking error versus a given benchmark; however, this is typically more of an index fund approach and it is difficult to argue that a portfolio manager is adding much value in this scenario. Ultimately, a properly diversified portfolio should target position sizes of 1% to 1.5% on average per name in order to balance the benefits of diversification with the opportunity for greater value added. It is important to remember that larger portfolios will, by necessity, be forced to hold many more issues as their size limits the desired amount of a given issuer that can be held. Individual issuer weightings should also be managed with overall portfolio risk tolerance in mind. For example, higher-risk credits should at a minimum have lower average weightings in a conservative portfolio where higher-quality credits should be emphasized. In addition to the number of holdings and average position size, individual issuer limits, and top 10 concentrations should also be considered. In a properly diversified portfolio, most portfolio managers should maintain diversification percentages with limits of generally no more than 3% per issuer, and the portfolio's top 10 holdings should not exceed 25–30% of the portfolio. Portfolio managers must also make certain that their top 10 positions generate solid returns. If the top positions are underperforming, it is extremely difficult to achieve superior results.

Industry Concentration

Industry concentration levels should be held to no more than 15–20% and should be reserved for those industries with the strongest fundamental and technical characteristics. Additionally, the portfolio's five largest industry weightings should represent less than 50% of the total assets. Proper diversification should not only reduce a portfolio's volatility, but these weightings should help mitigate the effect of unexpected announcements by issuer or events that affect an industry in general. Industry allocations should also consider weightings based on more macro characteristics such as cyclicality and commodity exposure. While individual industry weightings may be diversified, there may be a higher concentration in cyclical exposure that could elevate portfolio risk if broader classification and monitoring is not also considered.

Credit and Fundamental Risk

Managing risk is a critical function for a high-yield portfolio manager. Most investors look to evaluate the ratings (e.g., Moody's/S&P/Fitch) distribution of the portfolio and monitor concentrations across ratings categories. However, portfolio managers should maintain their own proprietary framework and tools for evaluating and monitoring credit risk exposure and concentration. Managers who are able to utilize their own independent research and rankings have an advantage in capitalizing on inconsistencies or inefficiencies inherent in the agency credit ratings that are relied upon by the broader market. Geographic risk factors must also be considered, on the basis of country of domicile as well as source of profitability, demand, or supply. For example, in order to position a portfolio appropriately against potential trade concerns with a major economy such as China, a portfolio manager must be able to identify and manage their portfolio exposure to companies with meaningful supply/demand drivers tied to the country. Another important risk factor is to identify and monitor the percentage of holdings by the lead underwriter, senior lender, and private equity sponsor. Lead underwriters and senior lenders are important because not all underwriters and lenders are equally committed to the asset class. Some underwriter-brokers are active in high yield when there is a bull market and abandon their efforts when the market declines, leaving the purchaser holding an orphaned bond. Moreover, broker-dealers possess varying degrees of capital on their trading desks. Private equity sponsors, meanwhile, have track records that cannot be ignored. Some private sponsors are known for frequently taking major dividends out of their LBO companies, thus leaving the entities more leveraged with no benefit to the debt holders. ESG risk tiers are another important consideration in evaluating the potential downside risk to an overall portfolio. Overconcentration in any of these factors on a portfolio level could jeopardize performance over the long term.

Liquidity

Liquidity risk involves measuring the ability to sell a particular credit on a timely basis. If a particular high-yield bond has poor liquidity, a portfolio manager may be unable to execute a buy/sell decision. The percentage of the portfolio represented by L1, L2, or L3 liquidity ratings should be calculated and monitored. Concentration in L3 credits that trade sporadically should be a key focus and require strong conviction as the downside risk to these holdings is amplified by their illiquidity.

Duration

For the reasons discussed above, a bond's duration is an important driver of its volatility. Portfolio managers must consider their overall exposure to both longer and shorter duration bonds. Concentrations in either category can position the portfolio either more defensively (short-duration) or more offensively (long-duration). Barbell strategies where managers may emphasize shorter and longer duration extremes while avoiding mid-duration options may display a reasonable portfolio average duration, but ultimately exhibit greater risks given the longer concentration. Additionally, given the prevalence of callable bonds in the high-yield market, managing duration risk is more involved as it requires considering multiple redemption scenarios and metrics as opposed to a single duration measure. Duration-to-worst, option-adjusted duration, spread duration, duration-to-maturity, and average final maturity are all metrics to be managed and considered on both security and portfolio levels. Stress tests and scenario analysis are also helpful in quantifying variability and risk. It is important to evaluate exposures and concentrations across multiple measures to ensure that they are aligned with the portfolio manager's overall market outlook and portfolio objective.

Trading Strategy

Portfolio managers generally have trading styles that capture their bias toward generating short-term trading profits versus focusing on longer-term outperformance over an entire credit cycle. Given the significant transaction costs and liquidity limitations of the high-yield market, short-term trading can be costly.

Furthermore, it incorporates a greater degree of risk associated with attempting to time the market that can impact long-term performance. Regardless of the type of trading strategy, portfolio managers must develop and adhere to a buy and sell discipline that reflects their style and philosophy.

Buy Discipline

In executing a buy decision, a step-by-step process is required to ensure consistency and disciplined decision-making. It is critical for portfolio managers to employ a rigorous bottom-up credit/security selection process complemented by top-down macro considerations. Portfolio managers should not sacrifice this process in the name of expediency or believe they might miss a "hot" opportunity. If there is not sufficient time to complete adequate diligence on a particular issue, the investment should not be made. The optimal investment should exhibit positive characteristics across all six of the key security analysis steps discussed above and align with the overall investment objectives and risk tolerance of the portfolio. For example, portfolio managers should bifurcate the decision of whether the company is a sound credit from whether the credit's bonds are attractive on a relative value basis.

Sell Discipline

Having a disciplined sell process is crucial for high-yield investing. Knowing when to sell is many times more important than knowing what to buy because losses are typically greater than gains due to the call constrained feature inherent in most high-yield bonds. The ability to execute a sell decision can separate an average portfolio manager from an extraordinary one. The three primary reasons to sell a bond are:

- Credit deterioration
- Relative value (risk/reward imbalance)
- Management drift

Strong analysis and continuous in-depth monitoring are essential components of managing credit risk as the security analysis process does not end once a security is purchased.

Credit Deterioration. If a credit is undergoing (or forecasted to undergo) a decline in its fundamentals that may significantly increase the risk of default, the security should be sold. The more proactive a portfolio manager, the higher the overall portfolio return as default loss is minimized.

Relative Value. While fundamental reasons should always be the most significant sale criteria, relative value and managing the risk/reward balance are vital factors in driving long-term returns. For example, an issuer may not necessarily be at near-term risk for default, but if its risk profile has increased (or is forecasted to increase) materially, there may be a sale opportunity if yields have not yet reflected this concern. Conversely, if a credit's yield has increased well beyond the assessed risk, the bond should also be considered for sale. Lastly, credits that have shown significant improvement in their credit risk profile may no longer offer attractive yields. Although the credit profile may now be much stronger, an investment-grade credit profile may not be appropriate for a high-yield portfolio objective.

Management Drift. As discussed above, the quality of the management team is a significant factor in analyzing a company. The leadership and veracity of management is paramount in making this assessment. To that end, bonds of a company where the management team deviates from its previously stated goal(s) or misleads investors must be sold. These management teams present a higher level of risk that is difficult to assess or quantify.

Red Flags. An important complement to a strong sell discipline is to also have a process for uncovering potential risks that may not have been uncovered through traditional monitoring. Price drift and credit drift are two key elements to monitor. Bond prices should be monitored for declines and necessitate automatic reviews for declines of 10%. While ongoing credit analysis may not have uncovered a significant change in risk to justify the price movement, it is important discipline for the manager to appreciate and understand the reason for the movement. Credit drift is also an important element to monitor. For this purpose, the credit drift to monitor should be based on a systematically updated proprietary method by the portfolio manager as discussed above. Reacting to changes in the major rating agencies (e.g., Moody's, S&P, and Fitch) will invariably be a lagging indicator as the market is readily focused on these published credit ratings.

Portfolio Characteristics

A key element of portfolio management is monitoring and evaluating all of the portfolio's holdings and its resulting characteristics. Some of the characteristics to monitor include valuation metrics, risk metrics, and diversification/concentration metrics. A more comprehensive sample list is provided in Exhibit 54-12.

Each of the metrics should be evaluated both on an average portfolio level, but also further detailed in relevant buckets for deeper attention and analysis. For example, a portfolio's overall average yield may be in line with expectations and target, but a further analysis may uncover that the percentage weighting to bonds yielding above 10% is high and indicative of greater risk in the portfolio. Monitoring a portfolio's characteristics and its changes is an indispensable tool in portfolio management as it helps ensure a portfolio's holdings are in line with macro considerations and portfolio objectives as opposed to solely a result of bottom-up selection. Daily real-time review is necessary so that portfolio managers can make informed decisions based on actual facts that reflect changes in the market rather than "seat-of-the-pants" intuition. Organized, customized, and

EXHIBIT 54-12

Portfolio Characteristics

VALUATION	
Coupon	coupon
Price	price
Yield	current yield, yield-to-worst, yield-to-maturity, yield-to-custom
Spread	spread-to-worst, option adjusted spread, spread-to-custom, spread-to-maturity
Duration	duration-to-worst, option adjustd duration, spread duration, duration-to-maturity
Final Maturity	years-to-maturity
RISK	
Credit Ratings	Moody's, S&P, Fitch issue credit ratings
Proprietary Credit Rating	manager's custom independent rating/score to measure credit risk
ESG Risk Tier	manager's custom metric to measure ESG risk
Liquidity Risk Tiers	manager's custom metric to measure liquidity risk
DIVERSIFICATION/CONCENTRATION	
# of issuers	total number of issuers
% issuer weighting	individual issuer weightings
% top 10 issuers	% weighting to top 10 issuers
# of industries	total number of industries
% industry weighting	individual industry weightings
% top 5 industries	% weighting to top 5 industries
% cyclical	% weighting to cyclical industries
% heavy cyclical	% weighting to heavy cyclical industries
% energy	% weighting to energy
% non-U.S.	% weighting to non-U.S. domicile issuers

detailed analysis and reporting showing percentages and variance calculations are essential for critical decision-making.

Risk Management and Analytics

Risk management should be an integral part of the portfolio management process. This function is commonly performed by a group separate from the portfolio managers, although its members have frequent interactions with portfolio managers. Risk management typically involves portfolio monitoring, applying risk controls, performance attribution, and developing analytics.

Portfolio Monitoring

Both risk managers and portfolio managers are charged with monitoring a portfolio's characteristics and exposures on a more detailed and comprehensive level. This important function helps ensure a portfolio's holdings are aligned with portfolio objectives as well as consistent across multiple portfolios of similar strategy. Daily real-time review and analytics are vital to managing exposures and risk so that informed trade decisions are aligned with portfolio strategy and objectives. Interactive tools and analysis detailing exposures, weightings, and variance are important for decision-making and managing consistency.

Risk Controls

Risk controls should be present in the investment process, in pre-trade compliance, and in post-trade risk measurement and analysis. One of the keys to avoiding significant losses is to establish firmwide risk control procedures and to develop and maintain a formal credit review process that examines the key risk factors covered in this chapter, namely credit risk, liquidity risk, and portfolio/diversification risk. Implementing a pre-trade compliance system to monitor key parameters is a critical tool for controlling risk and helping to guide a portfolio's alignment with its objectives. A pre-trade compliance system typically involves an integrated portfolio management and trading system in which portfolio constraints and limitations are categorized and monitored in real time. As a result, a portfolio manager is unable to enter a trade order that does not comply with the portfolio's guidelines or risk tolerances. Post-trade risk measurement and analysis are useful for such things as monitoring portfolio concentrations and diversification as markets change. The analytics used for post-trade risk measurement can also be applied during portfolio construction exercises. For example, if a portfolio manager plans to increase duration and convexity in their portfolio, the post-trade risk measures can be used to forecast the impact of potential trades.

Performance Attribution

Performance attribution is another important tool that provides a feedback mechanism to portfolio and risk managers, serving as a helpful reference to better understand the results of investment decision as well as to guide future adjustments to the portfolio. The objective is to breakdown the variance between a portfolio's active returns and the returns of the passive market into various segmented detail for further analysis. This analysis serves to illuminate the portfolio manager's decision-making process and reveal factors that benefited or detracted from performance for a given period. It is important to identify the many flaws inherent in utilizing passive market indices as the benchmark, particularly in the high-yield market where the relative illiquidity of its underlying constituents makes an index very difficult to replicate in practice.

Analytics and Data Science

A successful risk management team can build and develop analytical tools that not only support the risk management process but also assist with portfolio construction. Common analytics include bond level valuation statistics such as yield-to-worst, option-adjusted spread, as well as other risk measures for both a portfolio and its associated index. The analytics could be available in reports or through business intelligence tools. Business intelligence tools have the added benefit of being dynamic, and thus are useful for scenario analysis. For example, a portfolio manager could examine the impact of spread widening or tightening across industries that are more or less sensitive to economic cycles. With good data and systems, analytics and data science can provide active tools to improve portfolio construction and understand where the risks exist relative to the potential rewards.

KEY POINTS

- High-yield bonds are a unique and dynamic asset class that combines the characteristics of both fixed income securities and equities. As such, the overall approach to managing a high-yield portfolio must involve an inherent underlying focus of the three key risks: credit, liquidity, and portfolio risks.
- High-yield portfolio management incorporates three key focus areas: (1) bottom-up credit/security analysis (2) top-down high-yield market drivers and macro considerations, and (3) portfolio considerations. All three elements are critical to effective portfolio management and the individual security selections occur at the intersection of these focus areas.
- The bottom-up credit/security analysis serves as the foundation for the investment decision. While credit analysis is arguably the most important component of the investment process, security structure/terms, covenants, trading liquidity factors, and relative value ultimately determine if a “good credit” will make for a “good investment.” It is important to emphasize that all of the bottom-up steps are significant in their own right, and that a favorable assessment on many of the steps may not necessarily outweigh an individual risk component that is identified in the process.
- Understanding and evaluating the top-down high-yield market drivers and macro considerations are another critical component of high-yield portfolio management. While the bottom-up component of portfolio management should be the primary driver of security selection, it is

important to incorporate a view on key macro top-down factors that will ultimately drive/influence the high-yield market as well as individual industries and credits.

- Portfolio considerations are the framework applied by the portfolio manager to ultimately decide which securities are most appropriate for inclusion in a given portfolio. They create the filter that is used to sceen the potential investment universe utilizing the bottom-up and top-down considerations.
- The high-yield market offers favorable return opportunities, but investors must also remember the old adage "The greater the return, the greater the risks!"

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CHAPTER
FIFTY-FIVE

CORPORATE BONDS AND ESG

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Corporate bond managers have enormous power in implementing Environmental, Social, Governance (ESG) criteria in their funds. The main source of influence they have might be transformed into strict engagement policy to pursue positive environmental and climate change policies. This chapter focuses on several topics and discusses the investment process of corporate bond managers and the possibility to invest in green bonds as promising tool to influence corporate management and achieve positive climate impact beneficial for future generations. It is important to note that corporate bond managers might be alpha seekers or environmentally motivated and provide examples of their investment processes.

Some economists believe that it is in the debt market that investors can have a greater impact on not only corporations but governments at all levels. The fixed income market represents one of the largest asset classes, with strong demand from pension funds, institutional investors, retail investors, and most importantly, dedicated ESG investors ranging from alpha seekers to environmental activists as noted by Branch, Goldberg, and Hand.[1] A way in which bond investors can have a greater impact than equity investors is by investing in green bonds and imposing carbon emission targets on corporations and governments.

Bonds do not have shareholder rights as equities; however, bond investors have indirect contact to companies that allows investors to exercise influence and attract management attention. "Engagement" reflects the specific type of involvement. An example of active engagement would be the influence of bond managers might make on senior management when issuing debt securities. More

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The views expressed are those of the authors and do not necessarily reflect those of LBBW Asset Management.

1. Michael Branch, Lisa R. Goldberg, and Pete Hand, "A Guide to ESG Portfolio Construction," *Journal of Portfolio Management* 45(4), 2019, pp. 61–66.

precisely, commitment to participate in a new issuance if certain ESG criteria, or low-carbon norms, are met.

In Australia's mining sector, companies raise funds via bond issuance. Actions taken by investors in the debt market affect funding costs directly. For example, when companies approach the bond market with new issues, investors might have a big opportunity to scrutinize the issuer with respect to its carbon emission practices or critical ESG issues and charge an interest rate that penalizes issuers who have pursued adverse climate change practices. This reflects the traditionally polarized discussion between academics and practitioners regarding the cost-of-capital, which is observable at the market as noted by Blitz and Swinkels.[2]

Whereas Heinkel, Kraus, and Zechner, and Hong and Kasperczyk argued that the cost of capital should increase if corporate investors refrain from investing in socially irresponsible corporate bond issuers, Fabozzi, Lamba, Nishikawa, Rao, and Ma found that they experience lower financing costs.[3] Practical research by Blitz and Fabozzi found even that a specific premium does not exist.[4] Eichholtz, Holtermans, Kok, and Yonder investigated commercial mortgages and real estate investment trusts (REITs) and found that these green bonds have lower spreads on the secondary market.[5]

Partridge and Medda extensively analyzed the green bond premium called "*greenium*" in the U.S. municipal bond market.[6] This issue however reflects the negative and positive screenings bond managers might employ to classify "sin" versus "nonsin" issuers. Whereas this difference is highly important and deserves further investigation, we focus on the positive effects of applying both positive and negative screenings. More precisely, we argue that corporate bond managers might use such screenings to filter their investment universe. Of course, as Blitz and Swinkels argued: "Full exclusion of a firm sends the most credible signal that one will not finance future growth of this firm by any means."[7] Whereas, complete refrain from investors might send unmistakable signals to the management, we argue that corporate bond managers might take an active role influencing and

2. David Blitz and Laurence Swinkels, "Is Exclusion Effective?" *Journal of Portfolio Management* 46(3), 2020, pp. 42–48.

3. Robert Heinkel, Alan Kraus, and Josef Zechner, "The Effect of Green Investment on Corporate Behavior," *Journal of Financial and Quantitative Analysis* 36(4), 2001, pp. 431–449; Hong, H., and M. Kacperczyk, "The Price of Sin: The Effect of Social Norms on Markets," *Journal of Financial Economics* 93(1), 2009, pp. 15–36; Frank J. Fabozzi, Asjeet S. Lamba, Takeshi Nishikawa, Ramesh P. Rao, and K. C. Ma, "Does the Corporate Bond Market Overvalue Bonds of Sin Companies?" *Finance Research Letters* 28 (March 2019), pp. 165–170.

4. David Blitz and Frank J. Fabozzi, "Sin Stocks Revisited: Resolving the Sin Stock Anomaly," *Journal of Portfolio Management* 44(1), 2017, pp. 105–111.

5. Piet Eichholtz, Rogier Holtermans, Nils Kok, and Erkan Yönder, "Environmental Performance and the Cost of Debt: Evidence from Commercial Mortgages and REIT Bonds," *Journal of Banking and Finance* 102 (2019), pp. 19–32.

6. Candace Partridge and Francesca Romana Medda, "Green Bond Pricing: The Search for Greenium," *Journal of Alternative Investments* 23(1), 2020, pp.4 9–56.

7. Blitz and Swinkels, "Is Exclusion Effective?"

engaging corporate management in terms to improving the ESG utility for the public, investors, and future generations.

Dimson, Karakas, and Li[8] and Focardi and Fabozzi[9] argued that corporate bond managers might exercise even more powerful impact and to accomplish greater changes with companies than traditional equity methods. Madhavan and Sobczyk showed, however, that bond funds and equity funds diverge substantially in terms of investment process and approach to ESG.[10] Engagement might be the right policy to influence and change its practices. Furthermore, engagement might mitigate the impact of "greenwashing," which arises when underlying projects initially announced as green are unable to deliver the desired and stated green objectives, as noted by Benabou and Tirole,[11] and Deng, Tang, and Zhang.[12] This serious challenge has been documented by Lyon and Maxwell and refers to the adverse selection of bond issuers who are misleading the market participants.[13] The adverse selection gives the issuer the advantage to enjoy benefits and even recognition for participating in environmental issues in the rapidly growing green bond sector. As Baker, Bergstresser, Serafeim, and Wurgler argued, green bonds represent a successful instrument to environmental change.[14] Therefore, bond managers become a specific and important role when participating in the green bond market. They must act and enforce the change with engagement in every stage of the Green Bond Principles (GBP)—at the use of proceeds, during project evaluation, the management of proceeds, and the reporting phase. The GBP has been established as voluntary guidelines for green bond investing.[15]

This chapter investigates the ESG issues a corporate bond manager might face from several different angles. Whereas we identify the major issues, strategies, and investment processes, we highlight the role and potential of green bonds to help bond managers to engage and push establishing better procedures and policies regarding environmental issues and to influence corporate management. Bond managers become increasingly important role in identifying greenness,

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8. Elroy Dimson, Oguzhan Karakas, and Xi Li "Active Ownership," *Review of Financial Studies* 28(12), 2015, pp. 3225–3268.

9. Sergio Focardi and Frank J. Fabozzi, "Climate Change and Asset Management," *Journal of Portfolio Management* 46(3), 2020, pp. 95–107.

10. Ananth Madhavan and Aleksander Sobczyk, "On the Factor Implications of Sustainable Investing in Fixed-Income Active Funds," *Journal of Portfolio Management* Vol. 46(3), 2020, pp. 141–152.

11. Roland Benabou and Jean Tirole, "Individual and Corporate Social Responsibility," Economica 77 (2010), pp. 1–19.

12. Zhiyao Deng, Dragon Yongjun Tang, and Yupu Zhang, "Is "Greenness" Priced in the Market? Evidence from Green Bond Issuance in China," *Journal of Alternative Investments* 23(1), 2020, pp. 57–70.

13. Lyon, T.P., and J.W. Maxwell "Greenwash: Corporate Environmental Disclosure under Threat of Audit," *Journal of Economics & Management Strategy* 20 (2011), pp. 3–11.

14. Malcolm Baker, Daniel Bergstresser, George Serafeim, and Jeffrey Wurgler, "Financing the Response to Climate Change: The Pricing and Ownership of U.S. Green Bonds," NBER Working Paper No. w25194, (2018).

15. International Capital Market Association (ICMA), "Green Bond Principles, 2016: Voluntary Process Guidelines for Issuing Green Bonds," GBP Resource Centre, 2016.

robust and transparent implementation and management of bond proceeds, and exercising management control and engagement for improving environmental issues. How corporate bond managers might act as alpha seekers but also much more emphasize their role as social and environmental activists has been shown by Branch, Goldberg, and Hand.[16] However, Jacobsen, Lee, and Ma stressed that corporate financial performance might diverge from the goals of successful investment manager—to achieve higher returns and lower portfolio risk.[17] A major issue is that it is better to engage rather to divest in the sense of Chambers, Dimson, and Quigley.[18]

Chia, Goldberg, Owyong, Shepard, and Stoyanov argued that there is a green factor relevant to the companies engaged in climate change operations that are unrelated to the risk factors used to explain performance and behavior. Specifically, this factor is common for companies of lower size, which experience higher volatility. Corporate bond managers for example might influence management and engage in companies, which in turn would reduce volatility. Furthermore, this factor might be part of a quantitative investment process as showed recently by Chen and Mussalli.[19]

THE BOND MANAGER ROLE

The International Energy Agency estimated that more than \$50 trillion in total must be invested by 2035 to achieve the goal of limiting temperature rise to no more than 2°C. In addition, the World Economic Forum estimated that \$5.7 trillion per year in funding from public and private capital will be required to meet the carbon emission target of that scenario. What type of instruments can provide such tremendous amounts of capital?

Gyura argued that investor sentiment and the new generation worldwide is changing, focusing much more on environmental solutions, renewable resources, climate change, and responsible investing.[20] Thus, there will be costs and opportunities as a result of the transition to a low-carbon-emission economy, which also reflect the demand for financial market products that reflect future-related issues. Therefore, some industrial sectors—like the fossil fuel energy sector and

16. Branch, Goldberg, and Hand, "A Guide to ESG Portfolio Construction."
17. Brian Jacobsen, Wai Lee, and Chao Ma, "The Alpha, Beta, and Sigma of ESG: Better Beta, Additional Alpha?" *Journal of Portfolio Management* 45(6), 2019, pp. 6–15.
18. Donald Chambers, Elroy Dimson, and Elen Quigley, "To Divest or to Engage? A Case Study of Investor Responses to Climate Activism." *Journal of Investing* 29(2), 2020, pp. 10–20.
19. Mike Chen and George Mussalli, "An Integrated Approach to Quantitative ESG Investing," *Journal of Portfolio Management* 46(3), 2020, pp. 65–74; Chin-Peng Chia, Lisa R. Goldberg, David T. Owyong, Peter Shepard, and Tsvetan Stoyanov, "Is There a Green Factor? *Journal of Portfolio Management* 35(3), 2009, pp. 34–40.
20. Gabor Gyura, "Green Bonds and Green Bond Funds: The Quest for the Real Impact," *Journal of Alternative Investments* 23(1), 2020, pp. 71–79.

pollution-intensive sectors and services—will be penalized, but new sectors will be created. Moreover, a transition would be necessary, and this shift reflects the growing financial support by companies engaging in environmental projects either as disruptive change or as a transitory shift. These changes reflect of course the cost of capital as argued by Blitz and Swinkels.[21]

However, Partridge and Medda argued that assessing performance, demand, and supply of green bonds is challenging. Specifically, the green premium is available in the secondary market, but it is not observed in the primary market. Challenges arise from the lack of data, pricing, liquidity, and the long-term holding period of green bonds and the fiduciary duties of bond managers, among other reasons.

Both academics and practitioners have documented that new types of bonds and bond structures are needed to attract and allocate capital to the necessary public and private investments. The debt market offers several opportunities to impact carbon emissions via bond covenants and special borrowing arrangements such as green bonds.

The major vehicle is green bonds. Mark Carney, governor of the Bank of England and chair of the Financial Stability Board, stated that the development of green bonds is an opportunity to advance a low-carbon future while raising global investment and increasing global growth.[22] In many aspects of modern financial markets, we see a transitory shift form the public into private sources of capital.

MANAGING RISKS AND TAKING OPPORTUNITIES

Institutional investors' responsibility to manage and protect their beneficiaries' assets must consider the impacts of climate change. In addition, if we are all to avoid dangerous climate change outcomes, investors will play a crucial part in contributing the trillions of dollars needed to support the transition to a lower-carbon economy. Many investors are already taking action to manage the risks and capture the opportunities that climate change presents:

- Reducing exposure to high-carbon assets
- Engaging with companies and policy makers[23]
- Integrating climate change into investment strategies[24]

21. Blitz and Swinkels "Is Exclusion Effective?"
22. Focardi and Fabozzi, "Climate Change and Asset Management."
23. See http://www.climateaction100.org.
24. Mercer, "Investing in a Time of Climate Change," 2015; https://www.mercer.com/our-thinking/wealth/climate-change-the-sequel.html; and https://www.mercer.com.au/content/dam/mercer/attachments/asia-pacific/australia/investment/sustainable-growth/mercer-climate-change-study-2015.pdf.

- Undertaking scenario analysis
- Improving disclosure and transparency
- Allocating capital to new, low-carbon, climate-resilient opportunities[25]

We investigate the possibilities to bond managers to influence and construct strategies to better cope with climate change. For bond portfolio managers, these strategies are based on negative and positive lists, avoiding specific investments, trading green bonds, and participating in the primary market by investing in green bonds or sustainability-linked bonds. First, we investigate the key strategies available for bond managers.

INTERNATIONAL NORM-BASED STRATEGIES

In the last 10 years several strategies have been established to reflect the growing "norm-based" strategies. For example, Fossil Fuel Free, UN SDGs, and UN Global Compact are the most important and widely accepted strategies. A brief explanation highlights the differences in these strategies. The UN Global Compact (Global Pact of United Nation) requires the consistent preservation of minimum social and ecological impact within organizations. Important principles referred to are human rights, diversity, child labor, bribery, and environmental protection.[26] However, as Amel-Zadeh and Serafeim argued, the lack of reporting standard makes the ESG criteria implementation a challenging task.[27]

What are green bonds, and why are green bonds a complementary tool to improve climate issues?

Green bonds are fixed income securities that have positive environmental and/or climate benefits. They are used to finance or refinance climate change undertakings. These bonds are issued via a special-purpose vehicles by supranational entities, central governments, government agencies, and corporations.[28] By definition, they follow the Green Bond Principles (GBP) stated by the International Capital Market Association (ICMA). The proceeds from the issuance are strictly used for pre-specified projects. The GBP are guidelines that recommend transparency and disclosure of information necessary to evaluate the environmental impact of a green bond.[29]

Under the *Green Use of Proceeds Bond*, the bond is full-recourse debt obligation. Under the *Green Use of Revenue Bond*, the bond is nonrecourse to the issuer and backed solely by the cash flow of the funded project. Fabozzi and

25. GIC, "Investors Got the Signal," 2016, http://globalinvestorcoalition.org/wp-content/uploads/2014/09/InvestorsGotTheSignal_FINAL.pdf.
26. http://www.unglobalcompact.org/.
27. Amir Amel-Zadeh and George Serafeim, "Why and How Investors Use ESG Information: Evidence from a Global Survey," *Financial Analysts Journal* 74(3), 2018, pp. 87–103.
28. Andreas Horsch and Sylvia Richer, "Climate Change Driving Financial Innovation: The Case of Green Bonds." *Journal of Structured Finance* 23(1), 2017, pp. 79–90.
29. https://www.icmagroup.org/green-social-and-sustainability-bonds/green-bond-principles-gbp/.

Nahlik stressed that under the third type, *Green Use of Proceeds Project Bond*, investors are fully exposed to the underlying project risk.[30] A further option is the *Green Use of Proceeds Securitized Bond*. This represent a structured product similar to plain vanilla covered bonds or asset-backed securities. There is a wide classification for green bond projects. In this respect, uniform guidelines are under development. Summarizing, we argue that the most green bonds have been issued for the purpose of financing or refinancing low-carbon-emission projects.

KEY STRATEGIES FOR MANAGING CLIMATE IMPACT OF BOND PORTFOLIOS

Amel-Zadeh and Serafeim stressed that performance, demand, and strategy and ethical considerations are highly important factors. More importantly, Branch argued that fund managers might act as alpha seekers or social activists with greater focus on their clients' needs and perceptions regarding environmental, social, and governance issues. There are several issues that reflect the engagement, decisions, and applications for corporate bond managers. And here an important distinction is necessary. Whereas companies dealing with renewable energies like solar, wind, and water are small newly founded enterprises dealing with environmental issues, large companies (blue chips) are focused on social and governance issues. The small and middle-size enterprises do not make new issues in large corporate debt. Moreover, the capital for such companies is provided by venture capitalists, private equity funds, and private placements. New corporate debt issues with a nominal size of $500 million is a privilege for large companies. Companies issuing debt in excess of $1 billion are primarily engaged in governance practices.

Alford argued that it is important to note that an ESG analysis does not differentiate between ESG and sustainability regarding equity or fixed income investing.[31] Moreover, the ultimate task is to assign a rating score based on the entire company structure. Therefore, conducting due diligence and research on companies includes analysis of the entire capital structure. However, the equity structure is much different than the debt capital. Whereas equity shareholders can directly participate and are involved in the long-term policy by their voting rights, debt owners have little influence on the company's activities. Corporate bond managers as debt holders can much less emphasize ESG factors unless they are dedicated to the principles and implement an active corporate bond strategy.

30. Frank J. Fabozzi and Carmel de Nahlik, *Project Financing, eighth edition* (London: Euromoney Institutional Investor, 2012).
31. Andrew W. Alford, "Some Considerations for Investors Exploring ESG Strategies," *Journal of Investing* 28(2), 2019, pp. 21–31.

Bond Covenants

An alternative way available to corporate bond investors to influence corporate carbon emission practices is through covenants, as argued by Focardi and Fabozzi.[32] Covenants can specify a target emission level that, if violated by the corporate borrower, would result in a covenant default (as opposed to a payment default). Carbon policy performance bonds, also called index-linked carbon bonds, are bonds that specify carbon emission reduction targets. These bonds, which have been issued by governments, have a periodic interest rate that is linked to the carbon emission reduction the issuing entity must satisfy. Failure to satisfy the specified carbon emission reduction target for a period results in the imposition of a penalty in the form of a higher interest rates. Appropriate benchmarks are inevitable for measuring carbon emissions and to meet standardized reporting issues, regulation, and transparency. These tasks remain challenging, as stressed recently by Gyura.[33] The reporting issues reflect also the disclosure policy of green bond funds on projects and even more importantly on individual, very often heterogeneous, green bond reports, which make aggregation and standardization even harder to achieve.

Corporate Governance

Governance issues refer to management quality, culture, risk profile, and other related issues. Corporate governance incorporates the senior management responsibility to meet long-term obligations regarding strategic goals and socially responsible targets. Engagement with corporate governance would translate in better and efficient reporting and, in fact, a transparent management process that eliminates corruption and requires explicit management commitment to climate and environmental issues. These issues also reflect further problematic practices like management compensation, lobbying, board membership, and so on.

Screening of Investments

Investing in green bonds requires a setup that refers to the specific preselection and more precisely to the screening of criteria directly relevant to long-term portfolio investment. The screening of investments refers to the *negative* or *exclusionary* screening. Specifically, it refers to the exclusion from a portfolio of certain sectors, companies, or practices based on specific ESG criteria. Alternatively, bond managers apply *positive* or *best-in-class* screening. Positive screening refers to the analysis of sectors, companies, or projects selected for positive ESG performance relative to industry peers. A very specific activity involves *norms-based screening*. The primary task here is the screening of investments against

32. Focardi and Fabozzi, "Climate Change and Asset Management."
33. Gyura, "Green Bonds and Green Bond Funds."

minimum business practices based on international norms. Norms-based screening is split into two different techniques:

- Defining the green bond investment universe based on a company' performance on international norms related to responsible investment/ESG issues.
- Exclusion of companies from portfolios after investment if they are found following research, and sometimes engagement, to contravene these norms. Such norms include but are not limited to, for example, the UN Global Compact Principles, the UN Universal Declaration of Human Rights, the UN International Labour Organization, and so on.

Positive screenings help to investigate the different sectors and to make investment decisions in the most successful companies. Primary market investments refer to the low-carbon transition process and will play a critical role in aligning bond portfolios to support and accelerate the transition to a lower-carbon economy. Opportunities are clean energy infrastructure (wind and solar projects), storage infrastructure, grid technology, low-emission vehicles in the transportation sector, and energy efficiency in the built environment and companies issuing green bonds to finance these undertakings. Portfolio managers could invest in securitized green bonds. In general, bond managers look at the new issues in the primary market and premiums in the secondary market.

Negative screening refers to avoiding or selling of debt securities of companies heavily exposed to fossil fuels or environmental pollution. However, not only primary producer companies are of particular interest, but companies involved in the entire business-cycle of environmentally problematic industries in general.

Active Involvement and Implementation of ESG Strategy by Corporate Bond Managers

Active engagement in ESG strategy requires a close interaction with executives, board members, and portfolio managers in order to push the ESG themes and their implementation in an organization. This immediately highlights a chain process, in which the entire life cycle of a product and investment is involved. Specifically, not only the asset management company purchasing a bond is involved, but also all other related parties. From a bond portfolio management point of view, the returns, portfolio and policy constraints, asset allocation, liquidity, holding period, and risk management are significant parts of the process. We highlight specific issues related to the activities related to implementation of an ESG strategy:

- Management
- Stakeholders and investors
- Portfolio managers

Under the management approach, collaboration with board members, executives, and related parties aims at aligning return targets, risk and return metrics, and philosophy of investing. The alignment targets the future performance measurement and benchmarking. Within this framework, benchmarks, peer group analysis, and factor models for evaluation can produce meaningful results.

Portfolio managers pursuing an ESG strategy must invest a lot of resources in communication. The communication refers to performance and development presentations, reports on progress, results, targets including engagement, investment, and avoiding an investment in a company. For example, portfolio managers might present the recent increase of factor models and their success to explain the variance of ESG portfolio returns.

Portfolio managers are in the forefront of implementing ESG strategies. This is the most heterogeneous and broad way to actively implement the ESG strategy. Both active and passive strategies face wide acceptance. The tactic asset allocation and strategic portfolio are common issues. For example, a bond manager might implement passively low-carbon investments. Alternatively, the long-term structure of a current bond portfolio might shift to an ESG strategy.

The role of the portfolio managers can be split into three main categories. The first refers to *engagement*—the extent of involvement with regulators, policymakers, and board members to implement the principles. The second channel to implement the ESG strategy is *investment*. Investing in fixed income securities can be done in an asset class or on sector level. It can affect a part of the asset allocation or the entire portfolio. For example, a portfolio manager could invest the whole corporate bond exposure of a portfolio in sustainable bonds, but leave the allocation of a portfolio to government bonds unaffected by the ESG strategy.

Review and Monitoring

To utilize ESG initiatives and principles, and capitalize their effects, portfolio managers have to constantly monitor and review the implementation of the principles and policies—implementing a PRI reporting framework for example. Disclosing portfolio holdings and exposure is an increasingly important step toward transparency and wide acceptance of ESG in the asset management industry. Specifically, bond managers might disclose their holdings in certain sectors as part of their active strategies. Gyura identified the transparency and the disclosure of portfolio holdings as a challenging issue, as global official green bond register does not exist.[34] The focus might be to achieve a higher educational level for both investors and potential clients. For example, reduction of the bond portfolio exposure to an industrial sector toward green energy might send positive signals to regulators, clients, and the public.

34. Gyura, "Green Bonds and Green Bond Funds."

THE GREEN BOND DILEMMA AND FUTURE OUTLOOK

Despite the fact that the spreads are low and the yield pick up limited, the diversification advantage of green bonds from a quantitative asset management point of view should not be neglected. Even more, despite the fact that green bonds do not deliver significant returns, the impact that green bonds might have in the economy and on future generations should be considered carefully. This issue has been raised recently by Meziani.[35] The author showed that green bonds reduce systematic risk. Adding green bond exposure to a government bond portfolio or diversified bond fund would reduce volatility not only through the lower beta coefficients but also due to a low liquidity risk. More specifically, previous research stressed that green bonds outperform during financial turmoil but underperform during normal conditions. As Madhavan, Sobczyk, and Ang (2020)[36] argued, managers would be able to generate value-added returns, on average, by adding time-varying factor exposure for example. Renneboog, Horst, and Zhang argue that investors embrace the initiative of pursuing socially responsible investments.[37] Therefore, corporate bond managers should consider them within an investment process, engaging with management to encourage them and achieve a positive environmental impact. Last but not least, the issue size remains a barrier for bond managers to participate in new issues. Although, relatively small companies make new bond issuance, a positive trade-off might be the result of intensive dialog between fund managers and company management. Increasing issue size, covenants, and regulatory change might bring desired results. Involvement of endowments, sovereign wealth funds, pension funds, and governments might significantly change the environmental landscape.

Canfin and Grandjean[38] and Gyura[39] highlighted that there is a dilemma with green bonds that stems from the fact that green bond issuance does not immediately translate into green projects. Shislov, Morel, and Cochran even argued that green projects might be undertaken without green bond issuance.[40] However, the authors argue, decreasing the cost of capital might be a positive catalyst for green project utilization. Again, we argue that the role of corporate bond

35. Seddik A. Meziani, "It Is Still Not Easy Being Green for Exchange-Traded Funds," *Journal of Index Investing* 10(4), 2020, pp. 6–23.

36. Ananth Madhavan, Aleksander Sobczyk and Andrew Ang, "Alpha vs. Alpha: Selection, Timing, and Factor Exposures from Different Factor Models," *Journal of Portfolio Management* 46(5), 2020, pp. 90–103.

37. Luc Renneboog, Jenke Ter Horst, and Chendi Zhang, "Socially Responsible Investments: Institutional Aspects, Performance, and Investor Behavior," *Journal of Banking and Finance* 32(9), 2008, pp. 1723–1742.

38. Pascal Canfin and Alain Grandjean, "Mobilizing Climate Finance: A Roadmap to Finance a Low-Carbon Economy," Report of the Canfin-Grandjean Commision, June 2015.

39. Gyura, "Green Bonds and Green Bond Funds."

40. Igor Shislov, Romain Morel, and Ian Cochran, "Beyond Transparency: Unlocking the Full Potential of Green Bonds," Institute for Climate Economics (I4CE), June 2016, https://www.researchgate.net/publication/320443734_Beyond_transparency_unlocking_the_full_potential_of_green_bonds.

managers in this case is important. Bond managers can exert influence in both the pre-issuance (as the use of bond proceeds are determined) and post-issuance (as the impact reporting is published). Further bond manager involvement would be the participation in scientific committees that would at least provide steps to translate target and desired tasks into investment procedures. A data-driven green bond investment process and the development of newest techniques in financial management might help managers with ratings, transparency, and evaluation issues. This important aspect has been recently addressed by Reed, Cort, and Yonavjak.[41]

The current stage of ETF development would be positive for bond trading and improving liquidity. Specifically, using electronic exchange, bond managers could enjoy higher liquidity in the market of green bonds for example. We remain confident that the future development in the industry, the rising worries highlighting the public interest on environmental issues, and the transition from small ESG-interested groups toward broader engagement of shareholders, regulators, investors, and asset managers will result in a positive overall impact. In our view, there should not be a discussion whether to divest or to engage. Moreover, the solution board members, institutional investors, regulators, and fund managers in particular should take is to engage.

In general, bond fund evaluation and asset class evaluation reveal that green bonds are still underdeveloped, do not automatically generate excess returns, and do not necessarily represent a *greenium* in the primary market, as argued by Zerbib.[42] Hachenberg and Schiereck[43] argued that green bonds do not even differ from normal bonds in terms of their spreads. However, a major issue remains that data on green bonds, green bond funds, and ESG in general is sparse. Zerbib argued that the entire primary market yield curve is slightly lower for green bonds than for plain vanilla bonds. However, Wulandari, Schäfer, Stephan, and Sun[44] found a significant premium in the secondary market. Rising bond prices in the secondary market might suggest higher liquidity, as most retail investors cannot approach the primary market and demand for exceeds the supply of green bonds. The influence the secondary market might have on the prime market that was initially suggested has not happened yet, thus it is up to bond managers to engage corporate management to improve the financial market for green bonds. Transparency, monitoring, and engagement would provide a better scope for

41. Patrick Reed, Todd Cort, and Logan Yonavjak, "Data-Driven Green Bond Ratings as a Market Catalyst," *Journal of Investing* 28(2), 2019, pp. 66–76.

42. Olivier D. Zerbib, "The Green Bond Premium," SSRN, 2016, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2889690; Olivier D. Zerbib, "The Effect of Pro-environmental Preferences on Bond Prices: Evidence from Green Bonds," *Journal of Banking and Finance* 98 (2019), pp. 39–60.

43. Britta Hachenberg and Dirk Schiereck, "Are Green Bonds Priced Differently from Conventional Bonds?" *Journal of Asset Management* 19(6), 2018, pp. 371–383.

44. Febia Wulandari, Dorothea Schäfer, Andreas Stephan, and Chen Sun, "The Impact of Liquidity Risk on the Yield Spread of Green Bonds," *Finance Research Letters* Vol. 27, No. C (2018), pp. 53–59.

successful climate-related policy, which in turn would help not only investors but also society as a whole.

KEY POINTS

- We presented the challenges, current investment opportunities, and prospects for achieving positive environmental impact. Specifically, corporate bond managers should turn more attention to active engagement. We present both aspects of ESG management—alpha seeking fund managers and those who are environmentally and socially motivated to achieve returns and specific client goals.
- Green bonds offer several possibilities for influencing and achieving environmental benefits for future generations. Despite negative returns, they provide diversification, and, moreover, investors might be willing to opt for lower returns in order to achieve higher social and environmental objectives.
- The integration of the ESG and the principles of socially responsible investing on a broad level involving asset owners, corporate management, and fund managers might be beneficial for both current and future generations. Exercising control of the use of proceeds, higher transparency, and unified and standardized reporting are the promising fields on which investors and most of all portfolio managers might focus.
- Increasing issue size, covenants, and regulatory change might bring desired results. Involvement of endowments, sovereign wealth funds, pension funds, and governments might significantly change the environmental landscape.
- Portfolio managers are in the forefront in implementing ESG strategies. The most important role of the portfolio managers is to engage and not to divest.

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CHAPTER

FIFTY-SIX

GLOBAL CREDIT BOND PORTFOLIO MANAGEMENT

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Global Capital Market Consultant

Corporate bonds are the most demanding and fascinating subset of the global debt capital markets. The label, *corporate,* understates the scope of this burgeoning asset class. As commonly traded and administered within the context of an overall debt portfolio, the "corporate asset class" actually encompasses much more than pure corporate entities. Instead of the title, *corporate asset class,* this segment of the global bond market really should be classified as the *credit asset class,* including non-agency mortgage-backed securities (MBS), commercial mortgage-backed securities (CMBS), and asset-backed securities (ABS). Sovereigns and government-controlled entities with foreign currency debt issues thought to have more credit risk than the national government also should be included. In keeping with conventional practice in the debt market, however, the application of the term *credit asset class* in this chapter will pertain only to taxable corporate bonds, sovereigns, and government-controlled entities. U.S. tax-exempt issuers and issues for the separate U.S. municipal debt asset class are not covered in this chapter.

From six continents, thousands of organizations (corporations, government agencies, projects, and structured pools of debt securities) with different credit "stories" have sold debt to sustain their operations and to finance their expansion. These borrowers use dozens of different types of debt instruments (first mortgage bonds, debentures, equipment trust certificates, subordinated debentures, medium-term notes, floating-rate notes, private placements, preferred stock) in multiple currencies (dollars, yen, euros, sterling, Swiss francs, reals, renminbi) from maturities ranging from one year to even a thousand years. Sometimes, these debt structures carry embedded options, which may allow for full or partial redemption prior to maturity at the option of either the borrower or the investor. Sometimes, the coupon payment floats with short-term interest rates or resets to a higher rate after a fixed interval or a credit-rating change.

Investors buy credit assets because of the presumption of higher long-term returns despite the assumption of credit risk. Except immediately prior and during recessions, credit products usually outperform local government bond benchmarks like U.S. Treasury securities and other higher-quality "spread sectors" such as U.S. agency securities, mortgage-backed securities, and asset-backed securities.

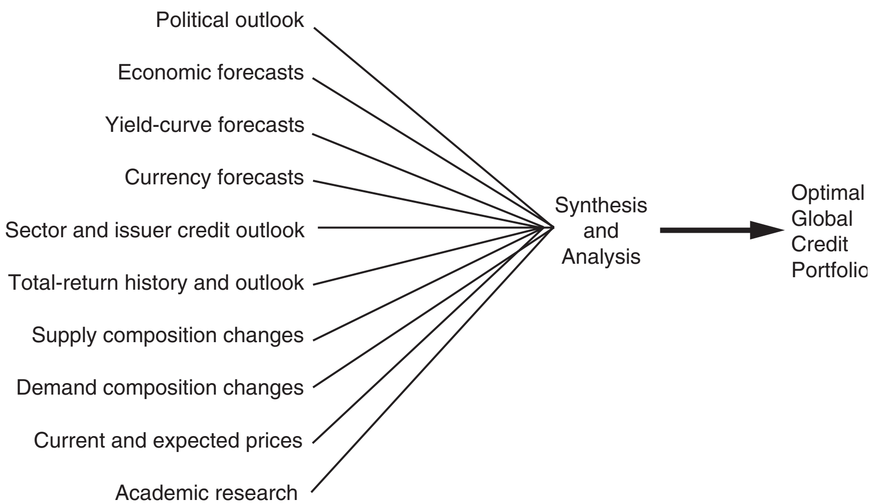
Global credit portfolio management presents a complex challenge. Each day hundreds of credit portfolio managers face thousands of choices in the primary (new issue) and secondary markets. In addition to tracking primary and secondary flows, investors have to keep tabs on ever-varying issuer fundamentals, creditworthiness, acquisitions, earnings, ratings, and prices cast in multiple gauges (bond price, nominal spread, interest-rate swap spread, and credit default swap spread). The task of global credit portfolio management is to process all this rapidly changing information about the credit markets (prices, issuers, issues, dealers, and competing managers) and construct the portfolio with the best return for a given risk tolerance. This discipline combines the qualitative tools of equity analysis with the quantitative precision of debt analysis.

Exhibit 56-1 illustrates the magnitude of this information-processing challenge. From a set of 5,000 different issuers, investors can assemble 4×10 (55) different combinations of 20-bond portfolios. The number of potential portfolio combinations of 20 bonds expands to the infinity neighborhood with the inclusion of additional variables such as rating (20 choices), issues (100,000), and currencies (at least 20). Incredibly, the number of potential combinations of this 20- bond credit portfolio exceeds the neutrons in the known universe. In turn, this begs the question of whether credit portfolio "optimization" is truly achievable given the current state of technology. Although perfect optimization may prove elusive, the optimization goal remains a worthy pursuit for asset managers.

Despite this apparent limitation on the perfection of credit portfolio optimization, broad demand exists for credit debt. Investors in credit debt consist of

EXHIBIT 56-1

Global Credit Sector Asset Allocation Methodology



individuals in the pursuit of incremental yields above government bonds, central banks aiming to extract a higher yield and return on their considerable holdings of fixed income assets, commercial banks arbitraging the difference between the greater yields on floating-rate notes and their lower cost of funding, mutual funds attempting to maximize both yield and total return, insurers and state pension funds seeking to fund their projected long-term liabilities, institutional total-return maximizers competing against each other on a monthly, quarterly, and annual basis to satisfy their clients (public or private pension fund plan sponsors) or risk their loss, and hedge funds staking out usually leveraged long or short positions in credits with short-term potential for major price movements. Portfolio investment choices are driven also by the existing security population of the credit market (sector, issuer, structure, and currency) and often the need to constrain tracking error deviations from broad corporate indices, by the psychology of portfolio managers (overall risk tolerance, shortfall risk aversion, and internal politics of the investment-management institution), and the state of market liquidity.

Borrowers and investors intersect mainly through dealers in both the classic telephone form and increasingly through "e-market techniques" such as electronic exchanges, websites, and emails. Each day a few dozen credit bond dealers convey information about secondary positions and new issue offerings from any of the thousands of credit borrowers to the hundreds of credit bond portfolio managers. Through their investment banking and syndicate operations, dealers also advise issuers on when and how to sell new debt. Through their debt research, sales, and trading arms, dealers relay investment recommendations to portfolio managers.

As shown in Exhibit 56-2, the task of global credit bond portfolio management is to process rapidly changing information about the credit bond market (cash and derivative prices, industry and issuers' fundamentals, ratings, issuance, demand, dealer market-making, and competing asset managers) and construct a portfolio with the best expected return for a given risk tolerance.

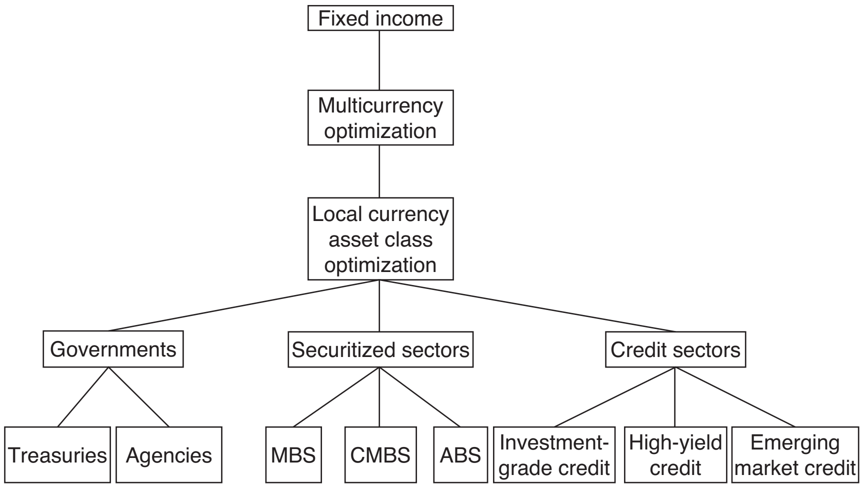
CREDIT RELATIVE-VALUE ANALYSIS

Credit portfolio management represents a major subset of the multi-asset global portfolio management process illustrated in Exhibit 56-2. After setting the currency allocation (in this case, dollars were selected for illustration convenience) and distribution among key debt asset classes (Treasuries, credit, agencies, asset-backed securities, commercial mortgage-backed securities, and mortgage-backed securities), bond managers are still left with a lengthy list of questions to construct an optimal credit portfolio. Some examples are:

- What stages are the global and local business cycles (peak, descending to recession, recession, ascending to peak)?
- How are overall capital market liquidity conditions and dealer receptiveness to trading?

EXHIBIT 56-2

Fixed Income Portfolio Management Process



- Will structural changes in broad market themes, geopolitical risk, regulation, rating agency philosophy, and portfolio management methodology affect valuations?
- Should U.S. investors add U.S. dollar–denominated bonds of non-U.S. issuers?
- Should central banks and sovereign wealth funds add high-quality euro-denominated corporate bonds or high-quality emerging market sovereigns to their reserve holdings?
- Should short-term money-market funded London-based portfolio managers buy fixed-rate U.S. industrial paper and swap into floating-rate notes?
- Should Japanese mutual funds own euro-denominated telecommunications debt swapped back into dollars or yen using currency swaps?
- Should U.S. insurers buy perpetual floaters (i.e., floaters without a maturity date) issued by British banks and swap back into fixed-rate coupons in dollars using a currency/interest rate swap?
- When should investors reduce their allocation to the credit sector and increase allocation to governments, pursue a "strategic upgrade trade" (sell Baa/BBB and buy higher-rated Aa/AA credit debt), rotate from industrials into utilities and/or financial institutions, switch from consumer cyclicals to noncyclicals, overweight airlines and underweight

telephones, or deploy a credit derivative (e.g., short the high-yield index or reduce a large exposure to a single issuer by selling an issuer-specific credit default swap) to hedge their portfolios?

To respond to such questions, managers need to begin with an analytical framework (relative-value analysis) and to develop a strategic outlook for the global credit markets.

Relative Value

Economists have long debated the concept and measurement of "value." But fixed income practitioners, perhaps because of the daily pragmatism enforced by the markets, have developed a consensus about the definition of value. In the bond market, *relative value* refers to the ranking of fixed income investments by geographic regions, sectors, structures (i.e., fixed versus floating rate), issuers, and issues in terms of their expected performance over some future period of time (horizon).

For a day trader, relative value may carry a maximum horizon of a few hours. For a dealer, relative value may extend from a few hours to a few months. For a total-return investor, the relative-value horizon typically runs from one to three months. For a large insurer, plan sponsor, and sovereign wealth fund, relative value usually spans a multiyear horizon. Accordingly, *relative-value analysis* refers to the methodologies used to generate such rankings of expected returns.

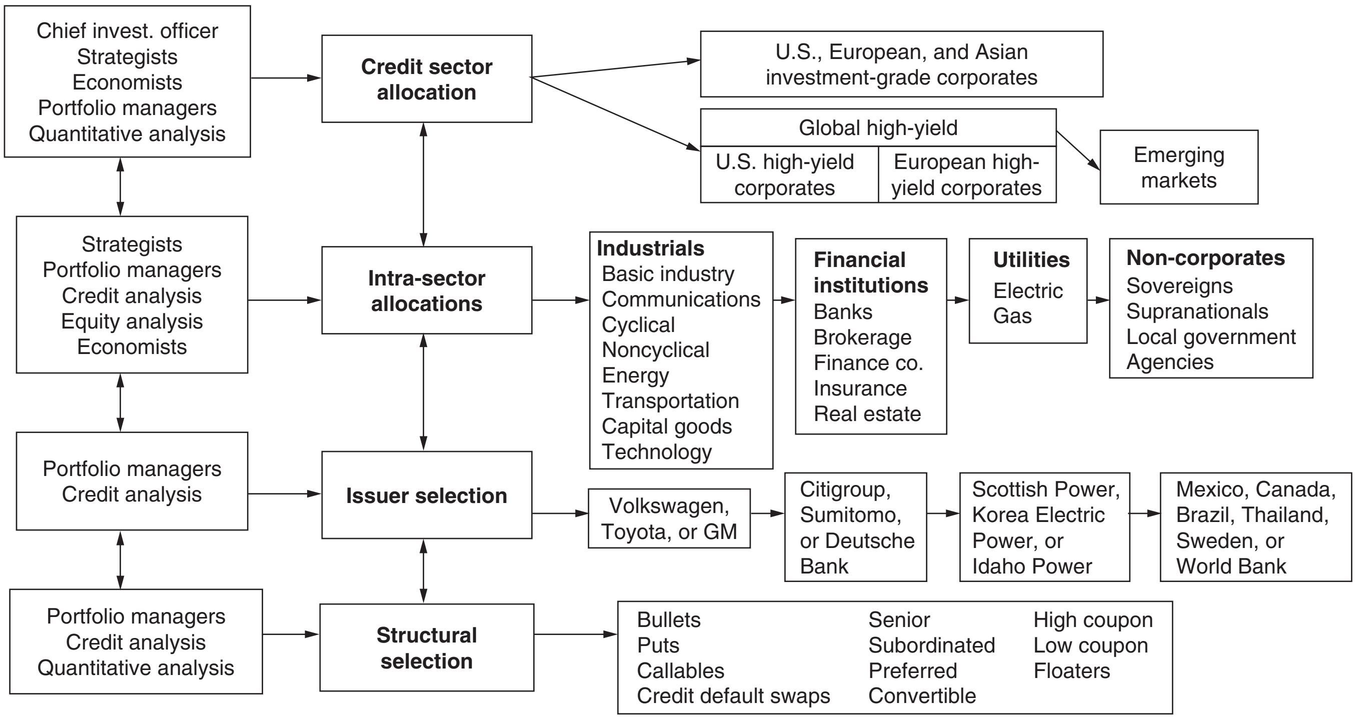
Classic Relative-Value Analysis

There are two basic approaches to global credit bond portfolio management—*top-down approach* and *bottom-up approach*. The top-down approach focuses on high-level allocations among broadly defined credit asset classes. The goal of top-down research is to form views on large-scale secular economic and industry developments like geopolitical risk, demographics, climate change, energy, global monetary and fiscal policies, global trade and capital flow imbalances, and plan sponsor investment philosophy. These views then drive asset allocation decisions (overweight certain sectors, underweight others). The bottom-up approach seeks to identify individual issuers and issues that will outperform their peer groups. Managers follow this approach hoping to outperform their benchmark owing to superior security selection while maintaining mainly neutral weightings to the sectors in the benchmark.

Classic relative-value analysis is a dialectic process combining the best of top-down and bottom-up approaches as shown in Exhibit 56-3. This process blends the macro input of chief investment officers, strategists, economists, and portfolio managers with the micro input of credit analysts, quantitative analysts, and portfolio managers. The goal of this methodology is to pick the sectors with the most potential upside, populate these favored sectors with the best

EXHIBIT 56-3

Credit-Sector Portfolio Management Process: Classic, Dialectic Relative-Value Analysis



representative issuers, and select the structures of the designated issuers at the yield-curve points that match the investor's overall portfolio duration target and perspective on the Treasury benchmark yield-curve.

For many credit investors, the use of classic relative-value analysis usually leads to portfolio management success. Although sector, issuer, and structural analyses remain the core of superior relative-value analysis, the increased availability of information and technology has transformed the analytical process into a complex discipline. Credit portfolio managers have far more data than ever on the total returns of sectors, issuers, and structures; quantity and composition of new-issue flows; investor product demand; aggregate credit-quality movements; multiple sources of fundamental and quantitative credit analyses on individual issuers; and yield-spread data to assist them in their relative-value analysis.

Relative-Value Methodologies

The main methodologies for credit relative-value maximization are

- Total-return analysis
- Primary market analysis
- Liquidity and trading analysis
- Secondary trading rationales and constraints analysis:
- Spread analysis
- Structure analysis
- Credit-curve analysis
- Green bonds, "ESG" compliant
- Credit analysis
- Asset allocation/sector analysis

In the sections that follow, we discuss each of these methodologies.

TOTAL-RETURN ANALYSIS

The goal of global credit portfolio management for most investors is to optimize the risk-adjusted total return of their credit portfolio. The best place to start is naturally total-return analysis. Accordingly, credit relative-value analysis begins with a detailed analysis of past returns and a projection of expected returns. For the entire asset class and major contributing subsectors (such as banks, utilities, natural gas pipelines, sovereigns, Baa/BBB, etc.), how have returns been generated? How much is attributed to credit-spread movements, changes in the fundamental fortunes of key issuers, and yield-curve dynamics? If there are macro determinants of credit returns (the total return of the credit asset class), then credit markets may display regular patterns. For instance, the macroeconomic cycle is the major driver of overall credit-spreads. With the approach of and during recessions, the escalation of default risk widens (raises) spreads (which are risk premiums over underlying, presumably default-free government securities—or swaps) and reduces credit returns relative to Treasuries. Conversely, economic prosperity reduces bankruptcies and enhances overall credit fundamentals of most issuers. Economic growth usually leads to tighter (lower) credit-spreads and boosts credit returns relative to Treasuries. For brief intervals, noncyclical technical factors can offset fundamentals.

Thanks to the development of total-return indexes for credit debt (databases of prices, spreads, issuer, and structure composition), analyses of monthly, annual, and multiyear total returns have uncovered numerous high-frequency patterns (i.e., large issue versus small issue performance variation, seasonality, election-cycle effects, and government benchmark auction effects) in the global credit market. Although they do not always recur, an awareness and understanding of these regular patterns is essential to optimizing portfolio performance.

PRIMARY MARKET ANALYSIS

The analysis of primary markets centers on new-issue supply and demand. Supply is often a misunderstood factor in tactical relative-value analysis. Prospective new supply induces many traders, analysts, and investors to advocate a defensive stance toward the overall credit market as well as toward individual sectors and issuers. Yet the premise, "supply will hurt spreads," which may apply to an individual issuer, does not generally hold up for the entire credit market. Credit spreads are governed by many factors; supply, although important, represents one of many determinants of spreads. During most years, increases in issuance (most notably during the first quarter of each year) are associated with market-spread contraction and strong relative returns for credit debt. In contrast, sharp supply declines are accompanied frequently by spread expansion and a major fall in both relative and absolute returns for credit securities. For example, this counterintuitive effect was most noticeable during August–October 1998. (Russian devaluation/default and Long-Term Capital Market implosion), August–December 2008 (fall of Lehman Brothers and onset of global financial panic), and March–May 2020 (initial peak of COVID-19 pandemic) when new issuance nearly disappeared temporarily in the face of a substantial increase in credit spreads.

In the investment-grade credit market, heavy supply is often associated with concurrent spread compression and boosts relative returns for credit assets as new primary valuations validate and enhance secondary valuations. When primary origination declines sharply, secondary traders lose reinforcement from the primary market and tend to reduce their bid. Contrary to the normal supply–price relationship, relative credit returns often perform best during periods of heavy supply.

The Effect of Market-Structure Dynamics

Given their immediate focus on the deals of the day and week, portfolio managers often overlook short- and long-term market-structure dynamics in making portfolio decisions. Because the pace of change in market structure is often gradual, market dynamics have less effect on short-term tactical investment decision making than on long-term strategy.

The composition of the global credit bond market shifted markedly over the last third of the twentieth century and continues in the twenty-first century. For example, medium-term notes (MTNs) dominated issuance in the front end of the credit yield-curve (1–7-year maturities) during the 1980s and 1990s. Structured notes and swap products heralded the introduction of derivative instruments into the mainstream of the credit market in the 1990s. The high-yield corporate sector became a widely accepted asset class in the 1980s, with emerging market debt following in the 1990s. Global origination became more popular since the early 1990s for U.S. government agencies, supranationals (e.g., World Bank), sovereigns, and large corporate borrowers.

Although the ascent of derivatives and high-yield instruments stood out during the 1990s, the quickening march toward full credit market globalization was the most important structural trend. The rapid development of the Eurobond market since 1975, the introduction of many non-U.S. issuers into the dollar markets during the 1990s, and the birth of the euro on January 1, 1999, led to the proliferation of truly transnational credit portfolios. The accelerating expansion of local-currency denominated debt origination, especially from Brazil, Russia, India, and China (the so-called BRICs), likely will be recalled as the most prominent evolutionary feature of early twenty-first-century global credit markets.

These long-term structural changes in the composition of the global credit asset class arise owing to the desire of issuers to minimize funding costs in different currencies, yield-curves, and yield spreads, as well as the needs of both active and asset/liability bond managers to satisfy their risk and return objectives. Portfolio managers will adapt their portfolios either in anticipation of or in reaction to these structural changes across the global credit markets.

The Effect of Product Structure

Partially offsetting the proliferation of issuers since the mid 1990s, the global credit market has become structurally more homogeneous. Specifically, bullet and intermediate-maturity structures have come to dominate the credit market. A *bullet maturity* means that the issue is not callable, putable, or sinkable prior to its scheduled final maturity. The trend toward bullet securities does not pertain to the high-yield market, in which callables remain the structure of choice. With the hope of credit-quality improvement, many high-yield issuers expect to refinance prior to maturity at lower rates.

There are three strategic portfolio implications for this structural evolution. First, the dominance of bullet structures translates into scarcity value for structures with embedded call and put features. That is, credit securities with embedded options have become rare and therefore demand a premium price. Typically, this premium (price) is not captured by option-valuation models. Yet, this "scarcity value" should be considered by managers in relative-value analysis of credit bonds.

Second, bonds with maturities beyond 20 years are a small share of outstanding credit debt. This shift reduced the effective duration of the credit asset class and cut aggregate sensitivity to interest-rate risk.

Third, the use of credit derivatives has skyrocketed since the early 1990s. The rapid maturation of the credit derivative market has led investors and issuers to develop new strategies to match desired exposures to credit sectors, issuers, and structures. In particular, many high-frequency traders (dealer desks, hedge funds, and active total return managers) prefer to execute their long and short credit positions in highly liquid portions of the credit derivative market rather than in conventional cash credit securities.

LIQUIDITY AND TRADING ANALYSIS

Short- and long-term liquidity needs influence portfolio management decisions. Citing lower expected liquidity, some investors are reluctant to purchase certain types of issues such as small-sized issues (less than $1 billion), private placements, MTNs, and nonlocal corporate issuers. Other investors gladly exchange a potential liquidity disadvantage for incremental yield. For investment-grade investors with even a medium-term horizon of more than six months, these liquidity concerns often are exaggerated.

The liquidity of credit debt changes over time. Specifically, liquidity varies with the economic cycle, credit cycle, shape of the yield-curve, supply, and the season. As in all markets, unknown shocks, such as a surprise wave of defaults or an eruption of geopolitical risk as in the immediate wake of 9/11, can reduce credit debt liquidity as investors become unwilling to purchase new issues at almost any spread and dealers become reluctant to position secondary issues except at very wide spreads. In reality, these transitory bouts of illiquidity mask an underlying trend toward heightened liquidity across the global credit asset class. With a gentle push from regulators, the global credit asset class is well along in converting from its historic "over-the-counter" domain to a fully transparent, equity/U.S. Treasury–style marketplace. In the late 1990s, new technology led to the creation of ECNs (electronic communication networks), essentially electronic trading exchanges. FINRA introduced the Trade Reporting and Compliance Engine (TRACE) to track publicly all institutional-sized trades of credit securities. In turn, credit bid/ask spreads generally have shifted lower for very large, well-known credit issues. This powerful combination of technological innovation and competition promises the rapid development of an even more liquid and efficient global credit market during the twenty-first century.

SECONDARY TRADE RATIONALES

Capital market expectations constantly change. Recessions may arrive sooner rather than later. The yield-curve may steepen rather than flatten in anticipation of monetary policy adjustments. Cyclical sectors, like auto and paper, may be moving down from their peaks. Higher oil and natural gas prices may enhance the credit quality of the energy sector. An industrial firm may have announced a large debt-financed acquisition, earning an immediate ratings rebuke from the rating agencies. A major firm may plan to repurchase 15% of its outstanding common stock (great for shareholders but leading to higher financial leverage for debt holders). In response to such daily information flows, portfolio managers amend their holdings. To understand trading flows and the real dynamics of the credit market, investors should consider the most common rationales of whether to trade and not to trade.

Popular Reasons for Trading

There are dozens of rationales to execute secondary trades when pursuing portfolio optimization. Several of the most popular are discussed below.

Yield-Spread Pickup Trades

Yield-spread pickup trades represent the most common secondary transactions across all sectors of the global credit market. Historically, at least half of all secondary swaps reflect investor intentions to add additional yield within the overall duration and credit-quality constraints of a portfolio.

This "yield-first psychology" reflects the institutional yield need of long-term asset/liability managers (plan sponsors and insurers). This investor bias toward yield maximization also may be a methodological relic left over from the era prior to the introduction and market acceptance of total-return indexes in the early 1970s.

Credit-Upside Trades

Credit-upside trades take place when the debt asset manager expects an upgrade in an issuer's credit quality that is not already reflected in the current market yield spread.

Credit-upside trades are particularly popular in the crossover sector—securities with ratings between Ba2/BB and Baa3/BBB– by two major rating agencies. In this case, the portfolio manager is expressing an expectation that an issue of the highest speculative-grade rating (Ba1/BB+) has sufficiently positive credit fundamentals to be upgraded to investment-grade (i.e., Baa3/BBB–). If this upgrade occurs, then not only would the issue's spread narrow based on the credit improvement (with an accompanying increase in total return, all else equal), but the issue also would benefit from improved liquidity because managers prohibited from buying high-yield bonds could then purchase that issue. Further, the manager would expect an improvement in the portfolio's overall risk profile.

Credit-Defense Trades

Credit-defense trades become more popular as geopolitical and economic uncertainty increase. Secular sector changes also often generate uncertainties and induce defensive positioning by investors. Unfortunately, because of yield-maximization needs and a general reluctance to realize losses by some institutions (i.e., insurers), many investors react more slowly to credit-defensive positioning. Ironically, once a credit is downgraded by the rating agencies, internal portfolio guidelines often dictate security liquidation immediately after the loss of single-A or investment-grade status. This is usually the worst possible time to sell a security and maximizes losses incurred by the portfolio.

New-Issue Swaps

New-issue swaps contribute to secondary turnover. Because of perceived superior liquidity, many portfolio managers prefer to rotate their portfolios gradually into more current and usually larger sized on-the-run issues. This disposition, reinforced by the usually superior market behavior of newer issues in the U.S. Treasury market (i.e., the on-the-run issues), has become a self-fulfilling prophecy for many credit issues. In addition, some managers use new-issue swaps to add exposure to a new issuer or a new issue structure.

Sector-Rotation Trades

Sector-rotation trades, within credit and among fixed income asset classes, have become more popular since the early 1990s. In this strategy, the manager shifts the portfolio from a sector or industry that is expected to underperform to a sector or industry that is believed will outperform on a total-return basis. With the general development of enhanced liquidity and lower trading transaction costs during non-crisis periods across the global bond market in the early twenty-first century, sector-rotation trades have become more prevalent in the credit asset class. Such intra-asset class trading has played a major role in differentiating performance among credit portfolio managers.

Curve-Adjustment Trades

Yield-curve-adjustment trades, or simply, *curve-adjustment trades,* are taken to reposition a portfolio's duration. For most credit investors striving for return maximization, their portfolio duration is typically within a range from 20% below to 20% above the duration of the benchmark index. Although most fixed income investors prefer to alter the duration of their aggregate portfolios in the more-liquid Treasury market, strategic portfolio duration tilts also can be implemented in the credit market. Such trades also are executed in anticipation of changes in the credit term structure or credit curve. For example, if portfolio managers believes that credit-spreads will tighten (either overall or in a particular sector), with rates in general remaining relatively stable, then they might shift the portfolio's exposure to longer-spread-duration credit issues in their preferred sectors.

Structure Trades

Within the set of investment-grade, fixed-rate credit securities, *structure trades* have become rarer as the global credit markets have become more homogeneous centered on intermediate bullets. Structure trades are swaps into structures (e.g., callable structures, bullet structures, and putable structures) that are expected to have better performance given expected movements in volatility and the shape of the underlying yield-curve. Structure trades also encompass swaps from less stringent issue indentures into stricter indentures that may afford bond investors greater protection should the issuer encounter financial difficulties. By expanding the choice set from fixed credit-only debt to include floating rate, preferred, preference, and even convertible securities, structural trades have become very common.

Basis Trades

Traders and asset managers regularly prowl the global credit asset class for discrepancies, even slight, among bond, nominal spread, Option-Adjusted Spread (OAS), interest-rate swap spread, and credit default swap spread values for the same and similar issues. These discrepancies may give rise to advantageous *basis trade* swaps.

Cash-Flow Reinvestment

Cash-flow reinvestment needs force credit investors into the market on a frequent basis. In some years, the sum of all cash flows from coupon, maturity, and partial redemptions (via tenders, sinking funds, and other issuer prepayments) can equal or exceed approximately 100% of all new gross issuance across the dollar bond market. Before the allocation of any net new investment in the bond market, investors have sufficient cash-flow reinvestment to absorb nearly all new bond supply. Some portfolio cash inflows occur during interludes in the primary market, or the composition of recent primary supply may not be compatible with portfolio objectives. In these periods, credit portfolio managers must shop the secondary market for investment opportunities to remain fully invested or temporarily replicate the corporate index by using ETFs, CDS, and financial futures. Portfolio managers who incorporate analysis of cash-flow reinvestment into their valuation of the credit market can position their portfolios to take advantage of the cash-flow reinvestment effect on spreads.

Trading Constraints

Portfolio managers also should review their main rationales for not trading. Some of the best investment decisions are not to trade. Conversely, some of the worst investment decisions emanate from stale views based on dated and anachronistic constraints (e.g., avoid investing in bonds rated below Aa/AA). The best portfolio managers retain very open minds, constantly self-critiquing both their successful and unsuccessful methodologies.

Portfolio Constraints

Collectively, portfolio constraints are the single biggest contributor to the persistence of market inefficiency across the global credit market. Here are some examples:

- Because many asset managers are limited to holding securities with investment-grade ratings, they are forced to sell immediately the debt of issuers who are downgraded to speculative ratings (Ba1/BB+ and below). In turn, this selling at the time of downgrade provides an opportunity for investors with more flexible constraints to buy such newly downgraded securities at a temporary discount (provided, of course, that the issuer's creditworthiness stabilizes after downgrade).
- Some sovereign wealth funds and U.S. state employee pension funds cannot purchase credit securities with ratings below A3/A– owing to administrative and legislative guidelines.
- Some U.S. pension funds also have limitations on their ownership of MTNs and non-U.S. corporate issues.
- Regulators have limited U.S. insurance companies' investment in high-yield corporates.
- Some European investors are restricted to issues rated at least single-A and sometimes Aa3/AA– and above, created originally in annual-pay Eurobond form.
- Some investors are confined to their local currency market—yen, sterling, euro, U.S. dollar. Often the same issuer will trade at different spreads in diverse local markets.

- Globally, many commercial banks must operate primarily in the floating-rate realm; this limits their use of all fixed-rate securities, unless converted into floating-rate cash-flows via an interest-rate swap.

"Story" Disagreement

"Story" disagreement can work to the advantage or disadvantage of a portfolio manager. Traders, salespersons, sell-side analysts and strategists, and buy-side credit researchers have dozens of potential trade rationales that supposedly will enhance portfolio performance. The proponents of a secondary trade may make a persuasive argument, but the portfolio manager may be unwilling to accept the "shortfall risk" if the investment recommendation does not provide its expected return. For example, in early 1998, analysts and investors alike were divided on short-term prospects for better valuations of Asian sovereign debt. After a very disappointing 1997 for Asian debt performance, Asia enthusiasts had little chance to persuade pessimists to buy Asian debt at the beginning of 1998. Technically, such lack of consensus in the credit market often signals an investment with great outperformance potential. Indeed, most Asian debt issues recorded exceptional outperformance over the full course of 1998 and 1999. After a difficult 2002, the same "rebound effect" was observed in U.S. electric utilities during 2003. Of course, "story" disagreement also can work in the other direction. For example, Enron and Lehman Brothers were long viewed as very solid credits before their sudden bankruptcies in late 2001 and September 2008, respectively. An asset manager wedded to this long-term view might have been reluctant to act on the emergence of less favorable information about Enron in the summer of 2001 and about Lehman during early 2008.

Buy-and-Hold

Although many long-term asset/liability managers claim to have become more absolute total-return-focused in the 1990s, accounting constraints (cannot sell positions at a loss compared with book cost or take too extravagant a gain compared with book cost) often limit the ability of these investors to trade. Effectively, these investors (mainly insurers) remain traditional buy-and-hold investors. Some active bond managers have converged to quasi-buy-and-hold investment programs at the behest of consultants to curb portfolio turnover. In the aftermath of the "Asian Contagion" in 1997–1998 and the Great Recession–induced financial panic of September 2008–March 2009, this disposition toward lower trading turnover was reinforced by the temporary reduction in market liquidity provided by wary bond dealers. At the first signs of a system-wide credit event (systemic risk) or credit trouble for an issuer (idiosyncratic risk), many credit portfolios would have improved returns by reducing their exposure to the overall credit asset class or to a deteriorating credit. And in the case of systemic-risk events, subsequent relative portfolio performance would have been greatly aided by adding solid issues temporarily caught up in the credit market's transitory general dislocation.

Seasonality

Lower-quality credits (Baa/BBB) tend to be more susceptible to underperformance during August–October as dealers and investors become more defensive with the approach of year-end. Conversely, lower-quality credits frequently outperform during the first quarter on optimistic hopes for strong economic, industry, issuer fundamentals for the full calendar year. Secondary trading slows at month end, more so at quarter end, and the most at the conclusion of calendar years. Dealers often prefer to reduce their balance sheets at fiscal year-end (December 31 or March 31 [Japan]). Also, portfolio managers take time to mark their portfolios, prepare reports for their clients, and chart strategy for the next investment period. During these intervals, even the most compelling secondary offerings can languish.

SPREAD ANALYSIS

By custom, some segments of the high-yield and emerging (EM) debt markets still prefer to measure value by bond price or bond yield rather than spread. But for the rest of the global credit market, nominal spread (the yield difference between corporate and government bonds of similar maturities) has been the basic unit of both price and relative-value analysis for more than two centuries.

Alternative Spread Measures

Many U.S. practitioners prefer to value investment-grade credit securities in terms of option-adjusted spreads (OAS) so that they can be compared more easily to the volatility ("vol") sectors (mortgage-backed securities and U.S. agencies).[1] But given the rapid reduction of credit structures with embedded options since 1990 (see structural discussion above), the use of OAS in primary and secondary pricing has diminished within the investment-grade credit asset class. Moreover, the standard one-factor binomial models[2] do not account for credit-spread volatility. And given the exclusion of default risk in OAS option-valuation models, OAS

1. These sectors are referred to as "vol" sectors because the value of the securities depends on expected interest rate volatility. These "vol" securities have embedded call options and the value of the options, and hence the value of the securities, depends on expected interest rate volatility.
2. The model is referred to as a "one-factor model" because only the short-term rate is the factor used to construct the tree.

valuation has seen only limited extension into the higher-risk markets of the quasi-equity, high-yield corporate, and EM-debt asset classes.

Starting in Europe during the early 1990s and gaining momentum during the late 1990s, interest-rate swap spreads emerged as the common denominator to measure relative value across fixed- and floating-rate note credit structures. The U.S. investment-grade and high-yield markets eventually may rely more heavily on such swap spreads to be consistent with Europe and Asia. But with the exponential growth of the credit-default swap (CDS) market since approximately 2000, CDS spreads have emerged as the standard gauge of relative pricing for large credit issuers.

The swaps framework allows managers (as well as issuers) to more easily compare securities across fixed-rate and floating-rate markets. The extension of the swap-spread framework may be less relevant for speculative-grade securities, in which default risk becomes more important. In contrast to professional money managers, individual investors are not comfortable using bond valuation couched in terms of swap spreads. The traditional nominal spread framework is well understood by individual investors, has the advantages of long-term market convention, and works across the entire credit-quality spectrum from Aaa to B. However, the nominal spread framework does not work very well for investors and issuers when comparing the relative attractiveness between the fixed-rate and floating-rate markets.

Spread Tools

Investors also should understand how best to evaluate spread levels in their decision making. Spread valuation includes mean-reversion analysis, quality-spread analysis, and percent yield-spread analysis.

Mean-Reversion Analysis

The most common technique for analyzing spreads among individual securities and across industry sectors is *mean-reversion analysis*. The *mean* is the average value of some variable over a defined interval (usually one economic cycle for the credit market). The term *mean reversion* refers to the tendency for some variables's value to revert (i.e., move toward) its average value. Mean-reversion analysis is a form of relative-value analysis based on the assumption that the spread between two sectors or two issuers will revert back to its historical average. This would lead investors to buy a sector or issuer identified as "cheap" because historically the spread has been tighter and will eventually revert back to that tighter spread. Also, this would lead investors to sell a sector or issuer identified as "rich" because the spread has been wider and is expected to widen in the future.

Mean-reversion analysis involves the use of statistical analysis to assess whether the current deviation from the mean spread is significant. For example, suppose that the mean spread for an issuer is 80 basis points over the past six months and the standard deviation is 12 basis points. Suppose that the current spread of the issuer is 98 basis points. The spread is 18 basis points over the mean spread or, equivalently, 1.5 standard deviations above the mean spread. The manager can use that information to determine whether or not the spread deviation is sufficient to purchase the issue. The same type of analysis can be used to rank a group of issuers in a sector.

Mean-reversion analysis can be instructive as well as misleading. The mean is highly dependent on the interval selected. There is no market consensus on the appropriate interval, and persistence frequents the credit market meaning that cheap securities, mainly a function of credit quality uncertainty, can remain cheap or become cheaper still.

Quality-Spread Analysis

Quality-spread analysis examines the spread differentials between low- and high-quality credits. For example, portfolio managers would be well advised to consider the "credit upgrade trade" when quality spreads collapse to cyclical troughs. The incremental yield advantage of lower-quality products may not compensate investors for lower-quality spread expansion under deteriorating economic conditions. Alternatively, credit portfolio managers have long profited from overweighting lower-quality debt at the outset of an upward turn in the economic cycle.

Percent Yield-Spread Analysis

Dating from the early twentieth century, *percent yield-spread analysis* (the ratio of credit yields to government yields for similar-duration securities) was another popular technical tool used by some investors. This methodology has serious drawbacks that undermine its usefulness. Percent yield spread is more a derivative than an explanatory or predictive variable. The usual expansion of credit percent yield spreads during low-rate periods overstates the risk as well as the comparative attractiveness of credit debt. And the typical contraction of credit percent yield-spreads during upward shifts of the benchmark yield-curve does not necessarily signal an imminent bout of underperformance for the credit asset class. Effectively, the absolute level of the underlying benchmark yield is merely a single factor among many factors (demand, supply, profitability, defaults, etc.) that determine the relative value of the credit asset class. These other factors can offset or reinforce any insights derived from percent yield-spread analysis.

STRUCTURAL ANALYSIS

As explained earlier in this chapter, there are bullet, callable, putable, and sinking fund structures. *Structural analysis* is simply analyzing the performance of the different structures discussed throughout this chapter. While evaluating bond structures was extremely important in the 1980s, it has become less influential in the credit bond market since the mid 1990s for several reasons. First, the European credit bond market almost exclusively features intermediate bullets. Second, the U.S. credit and the global bond markets have moved to embrace this structurally homogeneous European bullet standard. Plenty of structural diversity still resides within the U.S. high-yield and EM debt markets, but portfolio decisions in these speculative-grade sectors understandably hinge more on credit differentiation than the structural diversity of the issue-choice set.

Still, structural analysis can enhance risk-adjusted returns of credit portfolios. Leaving credit aside, issue-structure analysis and structural allocation decisions usually hinge on yield-curve and volatility forecasts, as well as interpretation of option-valuation model outputs (see the discussion below). This is also a key tool in making relative-value decisions among structured credit issues, mortgage-backed securities, and asset-backed securities. In the short run and assuming no change in the perceived creditworthiness of the issuer, yield-curve and volatility movements largely will influence structural performance. Investors also should take into account long-run market dynamics that affect the composition of the market and, in turn, credit index benchmarks.

Specifically, callable structures have become rarer in the U.S. investment-grade credit bond market. This is due to an almost continuously positively sloped U.S. term structure since 1990 and the yield-curve's intermittent declines to approximately multi-decade lows in 1993, 1997, 1998, 2002, 2008–2010, and 2020. As a result, the composition of the public U.S. corporate bond market converged toward the intermediate-bullet Eurobond and euro-denominated bond market. Sinking-fund structures, once the structural mainstay of U.S. natural-gas pipelines and many industrial sectors, are on the "structural extinct species list."

Callables

Typically after a 5- or 10-year wait (longer for some rare issues), credit structures are callable at the option of the issuer at any time. Call prices usually are set at a premium above par (par + the initial coupon) and decline linearly on an annual basis to par by 5 to 10 years prior to final scheduled maturity. The ability to refinance debt in a potentially lower-interest-rate environment is extremely valuable to issuers. Conversely, the risk of earlier-than-expected retirement of an above-current market coupon is bothersome to investors.

In issuing callables, issuers pay investors an annual spread premium (about 20–40 basis points for high-quality issuers) for being long (from an issuer's perspective) the call option. Like all security valuations, this call premium varies through time with capital market conditions. Given the higher chance of exercise, this call option becomes much more expensive during low-rate and high-volatility periods. Since 1990, this call premium has ranged from approximately 15–50 basis points for investment-grade issuers. Callables significantly underperform bullets when interest rates decline because of their negative convexity. When the bond market rallies, callable structures do not fully participate given the upper boundary imposed by call prices. Conversely, callable structures outperform bullets in bear bond markets as the probability of early call diminishes.

Sinking Funds

A sinking-fund structure allows an issuer to execute a series of partial calls (annually or semiannually) prior to maturity. Issuers also usually have an option to retire an additional portion of the issue on the sinking-fund date, typically ranging from one to two times the mandatory sinking-fund obligation. Historically, especially during the early 1980s, total-return investors favored the collection of sinking-fund structures at subpar prices. These discounted sinking funds retained price upside during interest-rate rallies (provided the indicated bond price remained below par), and given the issuers' requirement to retire at least annually some portion of the issue at par, the price of these sinking-fund structures did not fall as much compared with callables and bullets when interest rates rose. It should be noted that astute issuers with strong liability management skills sometimes can satisfy such annual sinking-fund obligations in whole or in part through prior open-market purchases at prices below par. Nonetheless, this annual sinking-fund purchase obligation by issuers limits bond price depreciation during periods of rising rates.

Putables

Conventional put structures are simpler than callables. Yet, in trading circles, put bond valuations often are the subject of debate. American-option callables grant issuers the right to call an issue at any time at the designated call price after expiration of the noncallable or nonredemption period. Put bonds typically provide investors with a onetime, one-date put option (European option) to demand full repayment at par. Less frequently, put bonds include a second or third put option date. A very limited number of put issues afford investors the privilege to put such structures back to the issuers at par in the case of rating downgrades (typically to below investment-grade status).

Thanks to falling interest rates, issuers shied away from new put structures as the 1990s progressed. Rather than incur the risk of refunding the put bond in 5 or 10 years at a higher cost, many issuers would prefer to pay an extra 10 to 20 basis points in order to issue a longer-term liability.

Put structures provide investors with a partial defense against sharp increases in interest rates. Assuming that the issuer still has the capability to meet its sudden obligation, put structures triggered by a credit event enable investors to escape from a deteriorating credit. Perhaps because of its comparative scarcity, the performance and valuation of put structures have been a challenge for many portfolio managers. Unlike callable structures, put prices have not conformed to expectations formed in a general volatility–valuation framework. Specifically, the implied yield volatility of an option can be computed from the option's price and a valuation model. In the case of a putable bond, the implied volatility can be obtained using a valuation model such as the binomial model. The implied volatility should be the same for both puts and calls, all factors constant. Yet, for putable structures, implied volatility ranged from 4% to 9% in the 1990s, well below the 10% to 20% volatility range associated with callable structures for the same time period. This divergence in implied volatility between callables (high) and putables (low) suggests that asset managers, often driven by a desire to boost portfolio yield, underpay issuers for the right to put a debt security back to the issuer under specified circumstances. In other words, the typical put bond should trade at a lower yield in the market than commonly the case.

Unless put origination increases sharply, allowing for greater liquidity and the creation of more standardized trading conventions for this rarer structural issue, this asymmetry in implied volatility between putable and corporate structures will persist. Meanwhile, this structure should be favored as an outperformance vehicle only by investors with a decidedly bearish outlook for interest rates.

CREDIT-CURVE ANALYSIS

The rapid growth of credit derivatives since the mid 1990s has inspired a groundswell of academic and practitioner interest in the development of more rigorous techniques to analyze the term structure (1–100 years) and credit structure (Aaa/AAA through B2/B) of credit-spread curves (higher-risk, higher-yield securities trade on a price rather than a spread basis).

Credit curves, both term structure and credit structure, are almost always positively sloped. In an effort to moderate portfolio risk, many portfolio managers take credit risk in short and intermediate maturities and substitute less-risky government securities in long-duration portfolio buckets. This strategy is called a *credit barbell strategy*. Accordingly, the application of this strategy diminishes demand for longer-dated credit risk debt instruments by many total-return, mutual fund, and bank portfolio bond managers. Fortunately for credit issuers who desire to issue long maturities, insurers and pension plan sponsors often meet long-term liability needs through the purchase of credit debt with maturities that range beyond 20 years.

Default risk increases nonlinearly as creditworthiness declines. The absolute risk of issuer default in any one year remains quite low through the investment-grade rating categories (Aaa/AAA to Baa3/BBB−). But investors constrained to high-quality investments often treat downgrades like quasi-defaults. In some cases, such as a downgrade from single-A to the Baa/BBB category, investors may be forced to sell securities under rigid portfolio guidelines. In turn, investors justifiably demand a spread premium for the increased likelihood of potential credit difficulty as rating quality descends through the investment-grade categories.

Credit-spreads increase sharply in the high-yield rating categories (Ba1/BB+ through D). Default, especially for weak single-B and CCC, becomes a major possibility. The credit market naturally assigns higher and higher risk premia (spreads) as credit and rating risk escalate.

In particular, the investment-grade credit market has a fascination with the slope of issuer credit curves between 10- and 30-year maturities. Like the underlying Treasury benchmark curve, credit-spread curves change shape over the course of economic cycles. Typically, spread curves steepen when the bond market becomes more wary of interest-rate and general credit risk. Spread curves also have displayed a minor propensity to steepen when the underlying benchmark curve flattens or inverts. This loose spread-curve/yield-curve linkage reflects the diminished appetite for investors to assume both curve and credit risk at the long end of the yield-curve when higher total yields may be available in short and intermediate-credit products.

CREDIT ANALYSIS

In the continuous quest to seek credit upgrades and contraction in issuer/issue spread resulting from possible upgrades and, more important, to avoid credit downgrades resulting in an increase in issuer/issue spread, superior credit analysis has been and will remain the most important determinant of credit bond portfolio relative performance. Credit screening tools tied to equity valuations, relative spread movements, and the Internet (information available tracking all related news on portfolio holdings) can provide helpful supplements to classic credit research and rating agency opinions. But self-characterized credit models, relying exclusively on variables such as interest-rate volatility and binomial processes imported from option-valuation techniques, are not especially helpful in ranking the expected credit performance of individual credits.

Credit analysis is both nonglamorous and arduous for many top-down portfolio managers and strategists, who focus primarily on macro variables. Genuine credit analysis encompasses actually studying issuers' financial statements and accounting techniques, interviewing issuers' managements, evaluating industry issues, reading indentures and charters, and developing an awareness of (not necessarily concurrence with) the views of the rating agencies about various industries and issuers.

GREEN BONDS/ESG COMPLIANT

The notion of "green bonds" began in the 1970s when some investors began to avoid buying the debt of electric utilities constructing nuclear power plants, especially after the accident at Three Mile Island in 1979. Through time, this reticence to invest in firms that were less rigorous in their adherence to pristine environmental, social, and governance (ESG) practices became more common and was often formally enshrined in investment guidelines. In response, green equity and debt indices were devised. A slew of green/ESG investment vehicles (particularly ETFs)were created by many mutual funds and institutional money managers. As a result, even in-house asset managers were obligated to consider the green/ESG status of existing and potential investments. At root, this well-intentioned practice created another rationale to either buy, hold, or sell a credit debt investment.

ASSET ALLOCATION/SECTOR ROTATION

Sector rotation strategies have long played a key role in equity portfolio management. In the credit bond market, "macro" sector rotations among industrials, utilities, financial institutions, sovereigns, and supranationals also have a long history. During the last quarter of the twentieth century, there were major variations in investor sentiment toward certain credit sectors like utilities, industrials, and financial institutions.

Beginning in the mid 1990s, "micro" sector rotation strategies in the credit asset class have become much more influential as portfolio managers gain a greater understanding of the relationships among intracredit sectors from these index statistics.

Exhibit 56-4 illustrates the main factors bearing on sector rotation and issuer selection strategies. For example, an actual or perceived change in rating agency philosophy toward a sector and a revision in profitability expectations for a particular industry represent just two of many factors that can influence relative sectoral performance.

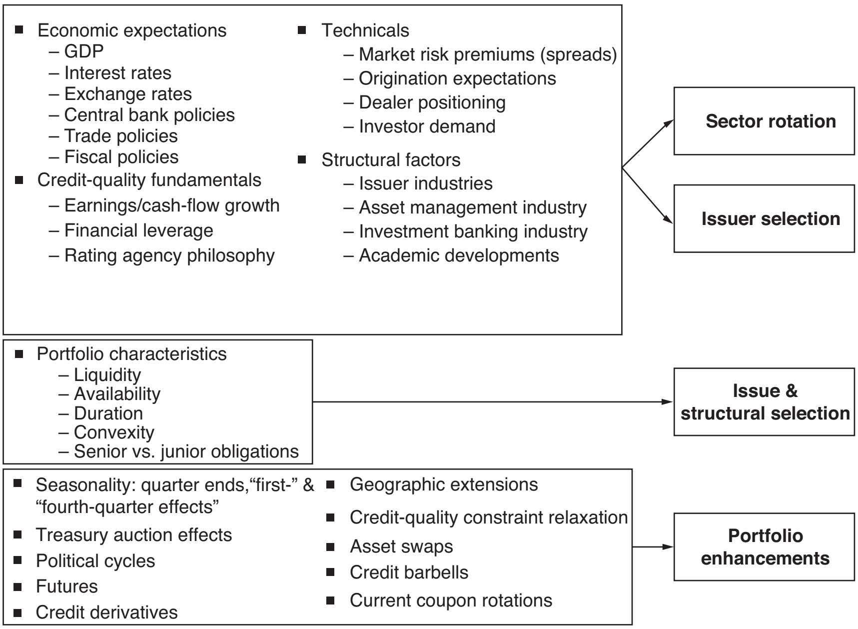
Common tactics to hopefully enhance credit portfolio performance are also highlighted in Exhibit 56-4. In particular, seasonality again warrants comment. The annual rotation toward risk aversion in the bond market during the second half of most years contributes to a "fourth-quarter effect;" that is, there is underperformance of lower-rated credits, B in high-yield and Baa in investment-grade, compared with higher-rated credits. A fresh spurt of market optimism greets nearly every new year. Lower-rated credit tends to outperform higher-quality credit. This is referred to as the "first-quarter effect." This pattern suggests a very simple and popular portfolio strategy: underweight low-quality credits and possibly even credit products altogether until the mid-third quarter of most years and then move to overweight lower-quality credits and all credit products in the fourth quarter of most years.

KEY POINTS

- As prescribed in capital market theory, investors should be rewarded for the assumption of incremental risk. Reality conforms to theory in the global credit market. Over the long run, credit products provide higher long-term returns than presumably risk-free government securities.

EXHIBIT 56-4

Some Outperformance Methodologies



- Credit returns and risk are viewed as "asymmetric." On occasion, asset managers may suffer large, transitory relative underperformance to Treasuries with the onset of systemic risk event. And the price of individual credit securities may tumble from the par vicinity to zero in the event of default.
- Credit bond portfolio management requires more work and asset management firm infrastructure than other debt asset classes. There are thousands of credit choices, dozens of security forms, and multiple structures, and the size of the global credit asset class will accelerate during the twenty-first century thanks to the entrance of new emerging market based issuers.
- Global bond management philosophy has evolved rapidly over the past two decades. Major portfolio-duration bets (more than 10% above or below the duration of an index benchmark) have become less common by asset managers because of frequent duration-timing disappointments. The use of CDS has expanded. New quantitative tools to assist in relative-value rankings and asset allocation (i.e., risk budgeting) have proliferated. And particularly at large asset management firms, credit portfolios have truly become globalized.

- In conjunction with the demonstrably higher long-term returns of corporates and an ongoing migration from “government-only index benchmarks” to “government plus corporate and securitized index benchmarks,” this reduction in currency and curve timing has propelled investor interest in global credit portfolio optimization as a path to more consistent overall portfolio outperformance in an increasingly competitive asset management industry.

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CHAPTER
FIFTY-SEVEN

INTERNATIONAL BOND PORTFOLIO MANAGEMENT

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International bond portfolios invest in heterogeneous fixed income securities. Their focus is global, and compared to traditional bond funds, global bond funds try to gain different market premiums. Specifically, international bond funds focus on generating alpha investment in currencies and government bonds as liquid instruments and have exposure to corporate bonds, high-yield bonds, and financials both in local and hard currency. International unconstrained bond funds—that is, funds without restriction on which type of securities they have to invest in—use derivative instruments to generate excess returns.

Interest rates have been decreasing in the last 20 years, generating enormous bond market returns. However, the interest rates in different countries exhibit different dynamics in normal market environments and sometimes converge during times of financial distress. There are two main types of markets in which global bond funds invest: emerging markets and developed markets. In general, aggressively allocating bond funds prefer liquid instruments, countries with less political risk, and the major global currencies and asset classes, and use futures, options, and other derivatives. These funds invest in futures on interest rates, currencies, foreign exchange options, government bonds, and corporate bonds. They often undertake currency hedging, but in general implement active currency bets using options, forwards, and other derivatives.

Alternatively, some conservative bond funds prefer to invest in a large number of securities and to gain the liquidity premium—for example, investing in less liquid government and corporate bonds in both hard and local currencies—and have large numbers of portfolio holdings. However, these funds have less portfolio turnover.

In general, there are two currency universes that institutional investors prefer to invest in. The G10 currencies are the most liquid developed market currencies. The G10 include U.S. Dollar (USD), Euro (EUR), Canadian Dollar (CAD), British Pound (GBP), Swiss Franc (CHF), Japanese Yen (JPY), Swedish Krone (SEK), Norwegian Krone (NOK), Australian Dollar (AUD), and New Zealand Dollar (NZD).

The emerging markets (EM) group comprises the currencies of heterogeneous countries with different levels of liquidity. EM currencies include Mexican Peso (MXN), Brazilian Real (BRL), Chili Peso (CLP), Columbian Peso (COP), South African Rand (ZAR), Polish Zloty (PLN), Russian Rubble (RUB), Turkish Lira (TRY), Hungarian Forint (HUF), Thai Baht (THB), Malaysian Ringgit (MYR), Philippine Peso (PHP), and Indonesian Rupiah (IDR), among others.[1]

A third group is the *frontier markets* group, consisting of Nigeria, Romania, Bangladesh, Jordan, Oman, Argentina, Bulgaria, Kazakhstan, and Sri Lanka, among others, which offer high yields but suffer from extremely low liquidity and are beyond the primary focus of international bond portfolio managers.

It is important to note that international bond funds are classified according to their emerging market exposure. Funds with large weights in EM are considered by database providers to be EM funds. This distinction is less important from a management perspective unless the manager desires explicitly to change its category in a specific category. Database providers for global bond funds include Mercer Insight, Morningstar, and Lipper, among others.

The objective of the chapter is to provide a detailed analysis of a yield curve–based quantitative approach to management of international bond portfolios. A central issue is how to deal with risks associated with international bond portfolios, to derive expected bond returns for multiple currencies, and to optimize portfolio allocation and fixed income security selection in a multiple-stage procedure. Finally, the monitoring and the performance attribution using multiple spot curves that is an integral part of the management process is described.

RISKS AND RETURNS IN INTERNATIONAL BOND PORTFOLIOS

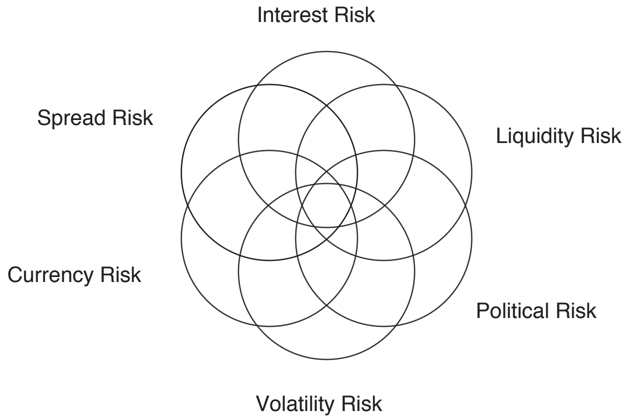
International bond portfolios involve a complex number of risks. Some of these risks are common for traditional fixed income portfolios. However, these risks interact, and their interconnectedness increases with time. Exhibit 57-1 summarizes six main risks of international bond portfolios.[2]

For globally invested portfolios there is a specific, heavy risk factor, which is the currency risk. Anson argued that currencies have an expected return of zero, and thus investments in local currency fixed income securities expose the

1. The classification changes with time. The current classification refers to FTSE, MSCI, S&P, and Russell: https://en.wikipedia.org/wiki/Frontier_markets.
2. See Chapter 2 in this book.

EXHIBIT 57-1

Interacting Common Risks for International Bond Portfolios



portfolio to a certain amount of volatility.[3] This underlines the short-term necessity of actively managing international bond portfolios. Controlling for the currency volatility and exposure becomes a central part of international fixed income portfolios. Currency risk, interest rate risk, and spread risk are directly related to liquidity and political risks. The latter become increasingly relevant for EM and less capitalized financial markets—e.g., Sub-Sahara, Asia, and LatAm.

In addition, the liquidity risk is in the normal market environment contradictory to the currency and interest rate risk, as liquidity premium requires a long-term holding period. Bond portfolios with short-term views focus on interest rate risk, currency risk, and spread risk. A major issue is the weekly currency and rate volatilities, which had a correlation of 0.69 in the period from 2005 to 2019. The monthly correlation coefficient is 0.62. The high correlation between rates and currencies requires approaches and tools that deal with the dynamic of the two asset classes.

Thus, the main focus turns to international bond portfolios dealing with currency, interest rate, and spread risk, as managers apply multiple approaches to asset allocation and securities selection. We show that volatility risk is a primary risk in international bond portfolios.

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3. Mark J. P. Anson, "The Currency Conundrum: Regret versus Optimal Hedging," in Momtchil Pojarliev and Richard M. Levich, *The Role of Currency in International Portfolios* (Risk Books, London UK, 2014).

A YIELD CURVE–BASED APPROACH FOR INTERNATIONAL BOND PORTFOLIOS

Decomposing the price of a fixed income security provides valuable information for portfolio managers. Considering the discrete price change of a fixed income security in a small change in time-to-maturity shows the relationship clearly. It is easy to decompose the total return of a bond into a price change due to the passage of time and a change of bond price due to a change in yield:

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} = \frac{\Delta P(t,y)}{P} = \frac{\partial P}{\partial t}\frac{1}{P}\Delta t + \frac{\partial P}{\partial y}\frac{1}{P}\Delta y$$

To derive expected returns, the focus remains on the passage of time component. Building the total differential shows the effects on the expected returns:

$$\begin{aligned}\left[\frac{\partial P}{\partial t}\frac{1}{P}\Delta t\right] &= \sum\nolimits_{i=1}^{n} CFe^{-yt}\left(-t\frac{\partial y}{\partial t} - y\frac{\partial t}{\partial t}\right)\frac{1}{P}\Delta t \\ &= -t\sum\nolimits_{i=1}^{n} CFe^{-yt}\,\frac{1}{P}\frac{\partial y}{\partial t}\Delta t - \sum\nolimits_{i=1}^{n} CFe^{-yt}\,\frac{1}{P}y\Delta t = MD\frac{\partial y}{\partial t}\Delta t - P\frac{1}{P}y\Delta t\end{aligned}$$

If we assume that there are small changes in time $\frac{\partial y}{\partial t} \approx \frac{\Delta y}{\Delta t}$, and a bond is approaching time-to-maturity as Δy rolls down or up the yield curve, then the passage of time, or roll down, is a sum of a vertical component attracting yield-curve volatility as measured by the modified duration, ($MD\Delta y$), and an initial yield adjusted by the change in time $(y\Delta t)$:

$$\left[\frac{\partial P}{\partial t}\frac{1}{P}\Delta t\right] = MD\frac{\partial y}{\partial t}\Delta t - P\frac{1}{P}y\Delta t = MD\frac{\Delta y}{\Delta t}\Delta t - P\frac{1}{P}y\Delta t = MD\,\Delta y - y\Delta t$$

Modified duration (MD) is a measure of the interest sensitivity of a bond price to interest rate changes multiplied by the yield changes Δy.

Finally, extending the MD to the spread duration incorporates the spread factor. However, interest rate dynamics are related to currency movements. Thus, bond yield changes ultimately reflect currency dynamics, since the uncovered interest parity (UIP) does not hold in the short term. This is consistent with the short holding periods applied for the roll downs. The UIP states that the interest rate differential between two countries should be equal to the projected change in exchange rate between the respective currencies. If the UIP holds, the interest rate movements would offset currency movements, and vice versa. Put differently, in an unhedged Australian dollar (AUD) bet against the U.S. dollar (USD) with positive pay-off, fixed income instruments would generate loss. The rising yield on an Australian government bond would neutralize the appreciation, and thus the gain, of the AUD–USD position. Again, the fact that the UIP does not hold in the short term allows for the modeling of currency investing and fixed income investing in international bond portfolios with short-term rebalancing.

In an international bond portfolio, to integrate the entire yield curve, we move from discrete to continuous bond pricing. Consequently, parsimonious yield-curve models apply to bond pricing. The theoretical price of a bond $T(t,s)$ at time *t* using the spot curve *s* is

$$T(t,s)=\sum_{t=1}^{n}\frac{CF}{\left(1+s_t\right)^t}=\sum_{t=1}^{n}\frac{CF}{\left(1+\frac{s_t}{n}\right)^{n.t}}=\sum_{t=1}^{n}\frac{CF}{\left(e^{s_t}\right)^t}=\sum_{t=1}^{n}CF.e^{-t.s_t}\text{, with}\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n=e$$

Now, we can use the spot rates instead of yields and apply the roll downs derived by the corresponding yield curve.

There are two models to fit a yield curve from the observed bond prices. These are the parsimonious Nelson-Siegel and the Svensson approaches.[4] Parsimonious means that a handful number of parameters explain the interest rate dynamics. The Nelson-Siegel polynomial is expressed as follows:

$$s_t\left(\beta_i,m,\tau\right)=\beta_0+\beta_1\left[\frac{1-e^{-\frac{m}{\tau}}}{\frac{m}{\tau}}\right]+\beta_2\left[\frac{1-e^{-\frac{m}{\tau}}}{\frac{m}{\tau}}-e^{-\frac{m}{\tau}}\right]$$

The Nelson-Siegel approach is suitable for sectors, countries, and asset classes with a lower number of fixed income securities available for regression. The local currency spot curves derived from government bonds in Hungary, Poland, the Czech Republic, New Zealand, Norway, Sweden, South Africa, and Mexico are good examples of the suitability of this parsimonious approach.

Formally, the Svensson model is similar to the Nelson-Siegel. The difference is in the additional curvature component β_3 and a decay parameter τ_2 suitable for explaining short-term bond yields. This model is preferred for countries, industry segments, or general sectors with a large number of bonds. The Svensson approach is widely applied to some European government bonds, U.S. Treasury bonds, and Japanese bonds.

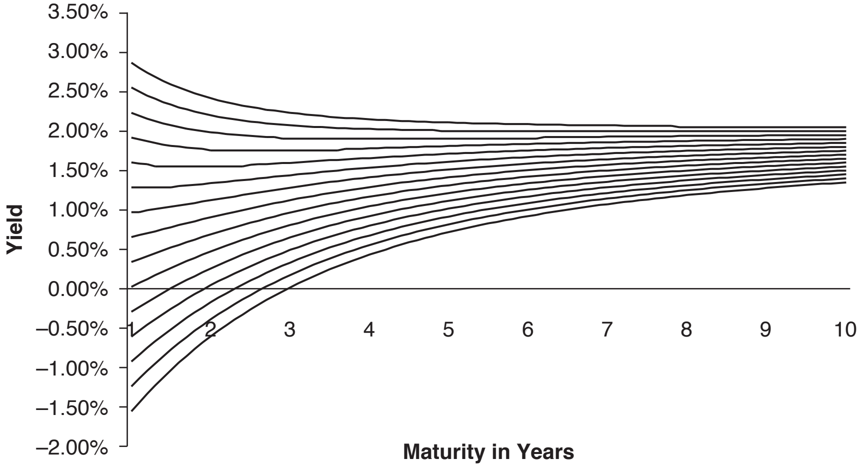
$$s_t\left(\beta_i,m,\tau_1,\tau_2\right)=\beta_0+\beta_1\left[\frac{1-e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}}\right]+\beta_2\left[\frac{1-e^{-\frac{m}{\tau_1}}}{\frac{m}{\tau_1}}-e^{-\frac{m}{\tau_1}}\right]+\beta_3\left[\frac{1-e^{-\frac{m}{\tau_2}}}{\frac{m}{\tau_2}}-e^{-\frac{m}{\tau_2}}\right]$$

The shape of local currency spot curves varies substantially between countries. Nelson-Siegel and Svensson polynomials are a good choice for modeling local currency spot curves that behave like real curves and are also a good choice to use for attribution analysis. Exhibit 57-2 contains possible spot curves.

4. Charles R. Nelson and Andrew F. Siegel, "Parsimonious Modeling of Yield Curves," *Journal of Business* 60(4), pp. 473–489, and Lars E.O. Svensson, "Estimating and Interpreting Forward Interest Rates: Sweden 1992–1994," 1994. IMF Working Paper No. 94/114.

EXHIBIT 57-2

Nelson-Siegel Polynomial for Various Beta-Parameters in a Low-Interest-Level Environment—Simulation



Having fitted the spot curves, a quantitative bond management approach focuses on expected returns. The price (P) of a fixed income security at time *t* is equal to the theoretical price (T) using the underlying spot curve and the option-adjusted spread (OAS):[5]

$$P(t) = T(t, s_t + OAS_t) = \sum_{t=1}^{n} CF.e^{-t(s_t + OAS_t)}$$

The OAS is the spread of a fixed income security that is added to the underlying spot curve in order to estimate the theoretical price of a bond. The OAS is a sum of the z-spread, or zero-volatility spread, or the spread to the spot-rate curve (ZS) and the option component (OC) of a bond with embedded option. Thus, for fixed income securities without embedded options, the OAS is equal to the ZS, which is true for most government bonds, for example.

$$OAS_t = ZS_t + OC_t$$

Thus, the roll-down return of a fixed income security, and thus its expected return, is estimated using the yield curve at the beginning of the period:

$$E(R)_t = T(t_1, s_0 + OAS_0) - T(t_0, s_0 + OAS_0)$$

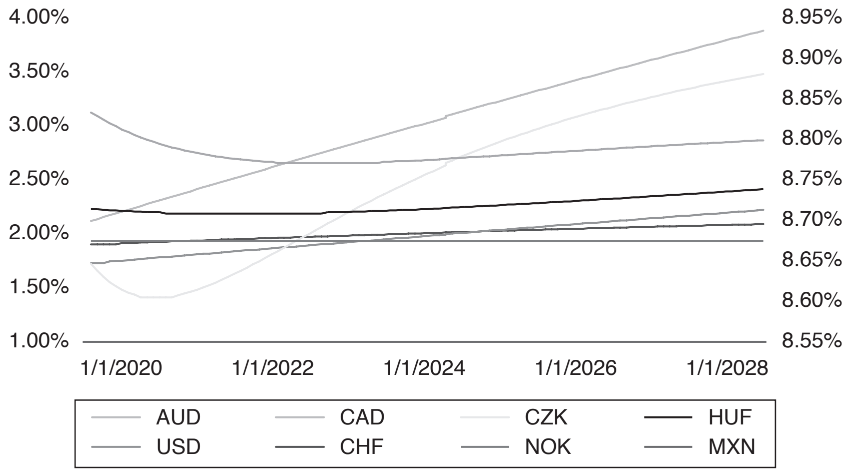
5. William Burns and Wensong Chu, “An OAS Framework for Portfolio Attribution Analysis,” *Journal of Performance Measurement* (Summer 2005), pp. 8–20, and Phil Galdi, “Bond Index, Rules and Definition: General Calculation Methodology & Classification Scheme,” Merrill Lynch Bond Indices, October 12, 2000, and ICE “Bond Index Methodologies,” July 31, 2018.

Furthermore, the assumption holds that the option-adjusted spread is constant. As spreads and interest rates change with time, choosing an appropriate holding period is an important issue. Otherwise explained, a holding period of three months and estimating roll downs under the assumptions of constant yield curve and constant spread bear significant risk, magnified by the natural strong volatility of currencies. As already noted, foreign exchange volatility impacts the roll downs. Thus, long holding periods are simply unrealistic to lead to robust and trustworthy investment processes.

The expected roll down applies to all fixed income securities in an international bond portfolio and is the building block for the portfolio construction and optimization, and then for spot curve–based performance attribution. In Exhibit 57-3, we apply the analysis to a sample portfolio using fitted spot curves:

EXHIBIT 57-3

Example Spot Curves Used to Derive Roll Down Returns



Source: Constructed by the author from data obtained from Bloomberg, LLC.

Exhibit 57-4 shows an example of expected returns (roll downs) of a sample of fixed income securities computed with the corresponding spot curves, bond description, and foreign exchange (FX).

EXHIBIT 57-4

Expected Returns: 30-Day Roll Downs for Various Fixed Income Securities

Bond Description	Sector	FX	*P*(*t*)	*T*(*t*,*s*)	Roll Down	OAS
ACGB 2 3/4 04/21/24	Government	AUD	104.56	103.27	0.19%	–0.26%
ACGB 3 1/4 04/21/25	Government	AUD	107.71	106.60	0.21%	–0.19%
ACGB 4 1/4 04/21/26	Government	AUD	115.13	114.14	0.23%	–0.14%
CAN 1 09/01/22	Government	CAD	97.24	97.00	0.16%	–0.07%
CAN 1 3/4 03/01/23	Government	CAD	100.09	99.76	0.18%	–0.09%
CAN 2 09/01/23	Government	CAD	101.25	100.81	0.17%	–0.10%
CAN 2 3/4 06/01/22	Government	CAD	103.16	102.90	0.17%	–0.08%
CAN 1 1/2 06/01/23	Government	CAD	98.58	98.18	0.16%	–0.10%
CZGB 2.4 09/17/25	Government	CZK	105.25	103.09	0.19%	–0.34%
CZGB 1 06/26/26	Government	CZK	95.66	93.23	0.18%	–0.37%
CZGB 0.45 10/25/23	Government	CZK	94.62	93.38	0.17%	–0.29%
HGB 2 1/2 10/24/24	Government	HUF	102.57	100.17	0.33%	–0.45%
HGB 5 1/2 06/24/25	Government	HUF	121.37	119.41	0.37%	–0.31%
HGB 3 06/26/24	Government	HUF	106.12	104.30	0.33%	–0.36%
MBONO 8 12/07/23	Government	MXN	98.99	97.55	0.71%	–0.38%
MBONO 10 12/05/24	Government	MXN	107.96	106.26	0.77%	–0.36%
MBONO 5 3/4 03/05/26	Government	MXN	87.24	85.78	0.67%	–0.31%

Source: Data obtained from Bloomberg, LLC.

CURRENCY ALLOCATION AND BOND SELECTION: PORTFOLIO CONSTRUCTION

Absolute Return Bond Portfolios

Within this setup, the optimization would produce reasonable weights for a portfolio: an allocation to U.S. dollar (USD) might be 25%, an exposure to the Mexican peso (MXN) 10%, to the Australian dollar (AUD) with 5%, and a 15% weight in the New Zealand dollar (NZD), and so on. A long/short portfolio allocation is possible and often desired. Size and side models for allocation are usually in place. Bond managers with currency management skills prefer short currencies with low interest rates and build long positions in currencies with high interest rates. This approach, simply categorized as a carry strategy adapted to bond portfolios, requires strong risk management.

Benchmark Portfolios

Absolute return bond portfolios are the exception. According to Morningstar, most of the international bond portfolios have a benchmark. The following are widely used benchmarks for international bond portfolios focused on government bonds:

- ICE BofA World Sovereign Bond Index
- ICE BofA Global Government Index
- J. P. Morgan GBI Broad Unhedged Index

The country/currency allocation in these indices is similar, with the largest weight in U.S. dollar and U.S. Treasuries of roughly 35%. The second and third largest weights are European government bonds in euro (EUR), with roughly 27%, and Japanese government bonds in Japanese yen (JPY), with roughly 25%. Thus, the three major currencies/countries comprise roughly 75% of the index.

Widely used indices for international bond portfolios that include corporate, quasi-sovereign, and government bonds are the following indices:

- Bloomberg Barclays Global Aggregate Total Return Index Value Unhedged
- Bloomberg Barclays Multiverse Total Return Index Value Unhedged
- ICE BofA Global Fixed Income Markets Index
- ICE BofA Global Broad Market Index

Benchmark portfolios require additional constraints in the allocation process. However, active managers are tempted to allocate aggressively in order to outperform the benchmark. High active share—as a measure of the difference of the absolute sum of weights relative to benchmark—is an integral part of the optimization. However, tracking error can increase substantially. Therefore, currency allocation should take this into account. Additional risk of increasing tracking error results from the number of single fixed income securities in a portfolio. A large number of securities reduces the tracking error. Whereas global government bond indexes comprise roughly 2,000 bonds, global aggregate benchmarks comprise more than 20,000 single issues. In the case of liquid government bonds, a large number of portfolio holdings allows for frequent turnover. However, a large number of less liquid bonds reduces the possibility of frequent turnover, thus decreasing the short-term gains of a currency premium but increasing the liquidity premium in a portfolio. In general, for benchmark portfolios there is a much higher trade-off between the currency risk, liquidity risk, interest rate and spread risk than for absolute return portfolios.

A General Framework for Currencies and Countries

As the complexity of multicurrency international bond portfolios grows, a separation between portfolio allocation and selection is a natural consequence. Considering the newest developments in finance, Marcos López de Prado showed that integrated models dealing with buying or selling fixed income instruments (the *side* decision), and decisions degrading the size of particular exposure (the *size* decision, or risk management decision), present problems for fund managers.[6]

This issue is present and represents a serious concern in international bond portfolios. The reason lies in the different setups for deriving expected returns and considering risks of currencies and fixed income instruments. Whereas currencies have an expected return of zero, the local currency yield curves in different sectors—government, corporate, financial, high-yield, and so on—help to derive expected returns of fixed income securities.

In practice, it is better to build two models, one to allocate in currencies and another to allocate and/or select in bonds. Currency decisions (size) and fixed income decisions (side), or vice versa, of international bond portfolios require different techniques. Let us consider the currency exposure decision as a risk management decision and the bond exposure as a buying or selling decision.

Since currencies represent risk for fixed income portfolios, the minimum variance optimization (MVO) suggested by Nobel prize–winning economist Harry Markowitz (1952) suits the purpose very well to minimize the risks associated with foreign exchange (FX).[7] In this line of thought, currency exposure is an allocation decision. However, following different setups is possible, and a convenient choice between them determines the risk of an international bond portfolio. Nevertheless, multiple decisions may employ two-step MVO optimization:

- Country-Country Allocation
- Country-Currency Allocation
- Currency-Country Allocation

6. Marcos López de Prado, "The 10 Reasons Most Machine Learning Funds Fail," *Journal of Portfolio Management* 44(6), 2018, pp. 120–133.
7. Harry Markowitz, "Portfolio Selection," *Journal of Finance* 7(1), 1952, pp. 77–91.

- Currency-Currency Allocation

Within the *Country-Currency* setup, the manager allocates to the country (e.g., 30% in Japan) and then allocates to different currencies (e.g., JPY-denominated bonds, EUR-denominated bonds, or even USD-denominated bonds). Within this setup, the portfolio asset allocation is not determined by a single factor (e.g., the U.S. dollar). Thus, the analysis is focused on country-specific economic drivers and valuations.

In a *Currency-Country* setup, the portfolio construction has the primary task of determining the currency exposure risk as portfolio allocation and then of making a country decision; for example, an MVO optimization allocated 30% to the Japanese yen (JPY) as a consequence of a risk-off scenario or expectation of market turmoil, and after further optimization, allocates to different countries of risk—European government bonds in JPY of 10% and 20% of U.S. bonds in JPY.

In a *Country-Country* setup, the decision is much more driven by two types of currency debt issuance: hard currency and local currency debt. Within this rare situation, a management decision is spread between a small number of countries issuing debt in hard and in local currencies. An MVO optimization to track the benchmark exposure of the ICE BofA Emerging Markets External Sovereign Index (EMGB Index) is a good example. Specifically, the allocation would be to invest in Bulgarian EUR- or USD-denominated debt.

The *Currency-Currency* allocation is widely applied in international bond portfolios, due to its suitability to reflect the benchmark exposure, both the currency and country allocation, and the liquidity risk in a single step. Specifically, one of the most widely used international bond portfolio benchmarks is the ICE BofA World Sovereign Bond Index, which comprises roughly 35% in USD-, 23% in JPY-, and 30% roughly in EUR-denominated government bonds. Funds that compare their performance against this benchmark in fact manage two of the risks associated with international bond portfolios—interest rate risk and currency risk. Applying currency-currency allocation is the same as country-country allocation, since both risks are identical.

The next natural step in a top-down portfolio management process is to derive portfolio selection. To remain consistent with the previous step, the selection deals with expected risks and returns within the portfolio allocation. Put differently, an allocation of 15% in the British pound requires selection and optimization of weights to the fixed income instruments to fit within this allocation.

OPTIMIZATION TECHNIQUE FOR MULTICURRENCY BOND PORTFOLIOS

Optimizing the Portfolio Allocation

Regarding portfolio allocation, the focus is on optimal currency allocation. The variance of currency movements in a portfolio accounts for a large proportion of portfolio risk, and long time series in all currencies are available for this purpose.

A successful optimization technique for FX risk in a portfolio is the minimum variance optimization (MVO), and a good example is the currency-currency optimization. However, a necessary adjustment to the currency time series is inevitable in order to properly run the optimization and to derive allocation.

A currency pair is given in the notation EUR-USD for example. The first part of the notation means the currency in which the pair is long and the second refers to the short position. Some currency pairs are expressed in unit notations and not in price notations. Put differently, it is essential to convert all unit notations into prices in order to derive returns. In the above example, this notation differs from the base currency of the fund or the currency in which the fund's net asset value (NAV) is denominated. Specifically, the EUR-USD notation and the time series suits a USD-based fund. However, an international bond fund with a euro base currency has to convert the unit notation into a price notation. A similar technique applies to all currencies:

$$\frac{\text{EUR}}{\text{USD}} = 1.083 \rightarrow \text{USDEUR} = 0.9233$$

The EUR-USD notation of 1.083 corresponds to the price notation for a European investor of 0.9233. As a rule of thumb, the base currency should always take the second part of the notation. For funds with base currency in USD, the currency pairs might be: EUR-USD, CAD-USD, AUD-USD, NZD-USD, JPY-USD, CHF-USD, GBP-USD, PLN-USD, HUF-USD, and so on.

This makes clear that the currency allocation of an international bond portfolio depends on a proper formulation of currency risk. Specifically, from the above notation, it is clear that the foreign exchange risk depends on the base currency of a portfolio. Computing the global foreign exchange volatility shows the different volatility magnitude for USD-, EUR-, JPY-, and GBP-based investors. The observant reader can recognize the different magnitude of foreign exchange volatility from different investors' perspectives. As shown in Exhibit 57-5, the currency volatility for JPY-based investors is higher compared with that of EUR-based investors.

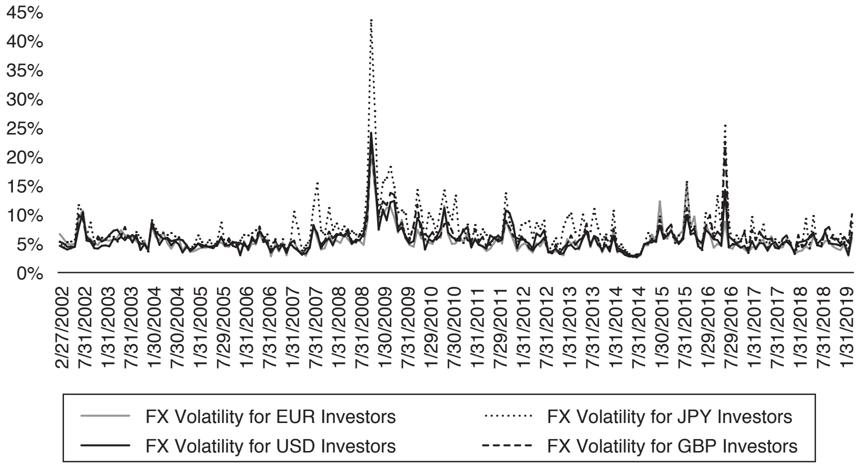
Formally, the MVO optimization under consideration of the variance-covariance matrix of currency returns has the following form:

$$\sigma_{PF}^2 = \left(w_1^{FX}, \ldots, w_k^{FX}\right) \begin{pmatrix} \sigma_1^2 & \cdots & \rho_{1k}\sigma_1\sigma_k \\ \vdots & \ddots & \vdots \\ \rho_{k1}\sigma_k\sigma_1 & \cdots & \sigma_k^2 \end{pmatrix} \begin{pmatrix} w_1^{FX} \\ \vdots \\ w_k^{FX} \end{pmatrix}$$

Of course, country weights $w_1^{Country}$ can replace the currency weights w_i^{FX} depending on the management approach, preferences, and constraints.

EXHIBIT 57-5

Global Foreign Exchange Volatility for USD, EUR, JPY, and GBP Investors



Source: Constructed by the author from data obtained from Bloomberg, LLC.

Optimizing the Portfolio Selection

The complexity of international multicurrency bond portfolios requires appropriate optimization techniques. An appropriate technique should be capable of incorporating a possibly extremely high number of restrictions, for example. However, specific needs might expand the list and thus the matrix equation:

- Multiple modified durations—the portfolio MD as the sum of segment MD
- Maturity buckets—for example, 1–3 years, 3–5 years, 5–7 years, 7–10 years, and more than 10 years in every single currency/country in the portfolio
- Single bond min/max weights—for example, constraints on single fixed income securities in a portfolio
- Sectors and countries—for example, Germany, South Africa, Mexico, Chile, Thailand, Poland
- Currency exposure—for example, USD, GBP, HUF, NZD, EUR, and so on
- Spreads—threshold spread levels as rich/cheap indicators—for example, a maximum of 0.2% spread on U.S. Treasuries above the spot curve is acceptable

- Specific factor sensitivity—specific curve factor exposure
- Interactive exposure—for example, USD- and EUR-denominated corporate bonds, but no GBP-denominated corporates. Alternatively, Australian covered bonds in EUR, but not in local currency.

Linear equations help to model the complex constraints and exposure of an international bond portfolio. A simple estimation would include the desired portfolio allocation expressed as a vector of the portfolio weights. However, fund managers often desire to see the differences between the current portfolio and the new portfolio allocation and selection and thus to estimate the differences as vectors of sell and buy orders. Thus, a more holistic model incorporates the current portfolio in the optimization. The additional add-in allows adjustments for transaction costs (*tc*) and a specific threshold level for the overall portfolio turnover, for example.

Formally, the optimization problem is expressed as follows:

$$Arg \max_{w} w'r = \left(w_1, \ldots, w_n, b_1, \ldots, b_n, s_1, \ldots, s_n\right) \begin{pmatrix} r_1 \\ \vdots \\ r_n \\ tc \\ \vdots \\ tc \end{pmatrix}$$

where w' is the transposed vector of portfolio weights including the buy and sell securities, and r is the vector of expected returns, including a uniform transaction cost penalty parameter tc. Transaction costs can be split into two categories: explicit (such as bid-ask spreads, brokerage fees, and trade and custodian commotions) and implicit (such as market impact and price movement costs). Market impact costs result during the execution of trades and as markets are volatile. In general, large international bond funds have an advantage on the explicit costs; however, too-large bond funds have a strong market impact and might move markets if engaged in specific currencies or fixed income securities. For example, the relatively low spot liquidity and daily average turnover volume of 5,017 million U.S. dollars of the Polish zloty (PLN) against the U.S. dollar might be challenging for a multibillion international bond fund taking a spot 10% bet of its volume in USD-PLN.[8] Additionally, uniform tc is problematic for heterogeneous bond portfolios, since the transaction costs in the different currencies, sectors, sub-asset-classes, and so on, cannot be uniform. For example, the transaction costs for U.S. Treasuries cannot be the same as for trading Indonesian government bonds in Indonesian rupiah (IDR), or Turkish sovereign bonds in EUR, Turkish

8. Bank of International Settlements, "Triennial Central Bank Survey: Global Foreign Exchange Market Turnover in 2019," Monetary and Economic Department, 2019.

lira (TRY), or even in U.S. dollars (USD), for example. However, the purpose of *tc* is to act as a penalty function in an optimization process.

In general, a matrix enhanced by slack variables helps to model the portfolio constraints.[9] The slack variables are necessary to capture possible restrictions in a portfolio. Every bond is assigned 1 if it is denominated in U.S. dollars and 0 otherwise. For example, if a desired restriction to the MD of a bond in Hungarian forints (HUF) is not to exceed 6%, the slack variable takes a value of 1, and zero otherwise. Modeling these restrictions is central in international bond portfolio management due to the lack of liquidity in specific markets. For example, U.K. gilts or U.S. Treasuries have very different liquidity than emerging market bonds. This issue becomes relevant in times of financial stress, as liquidity dries out, typically emerging market currencies depreciate heavily, interest rates soar due to bond sell-offs, and low-yielding currencies appreciate as investors seek to shelter their capital in large economies and liquid markets. Examples of such markets are U.S. Treasuries and U.S. dollar, Japanese yen (JPY) and Japanese government bonds, and Swiss franc (CHF) and Swiss government bonds.

Within matrix $\acute{A}^*$, a manager can capture all possible exposures in the portfolio: modified duration, currency, sector, asset class—covered bond, government bond, financial, corporates, high-yield bonds, and so on—in addition to the yield-curve factor exposures, country of issuance, country of risk, maturity buckets, and so on. The portfolio constraints matrix can be expanded according to a vast set of quantified criteria. Let us explain the complexity of this technique in matrix solution form.

Specifically, the upper left matrix comprises the four constraints on currencies (FX), maturity buckets (M), sectors (S), and countries (C). Of particular interest are the matrixes in the middle. They control for the portfolio holdings and the buying and selling of securities. The lower part of the portfolio constraints matrix refers to the turnover constraints. In general, the matrix increases in dimension as more constraints or variables and parameters are added. This is a major advantage of portfolio optimization in heterogeneous bond funds.

$$
\left(\begin{array}{cccc|cccc|cccc}
FX_1 & S_1 & M_1 & C_1 & 0 & & \cdots & 0 & 0 & & \cdots & 0 \\
 & & & & & 0 & & \vdots & & 0 & & \vdots \\
\vdots & \vdots & \vdots & \vdots & \vdots & & \ddots & & \vdots & & \ddots & \\
FX_n & S_n & M_n & C_i & 0 & \cdots & & 0 & 0 & \cdots & & 0 \\
\hline
1 & & \cdots & 0 & -1 & & \cdots & 0 & 1 & & \cdots & 0 \\
 & 1 & & \vdots & & -1 & & \vdots & & 1 & & \vdots \\
\vdots & & \ddots & & \vdots & & \ddots & & \vdots & & \ddots & \\
0 & \cdots & & 1 & 0 & \cdots & & -1 & 0 & \cdots & & 1 \\
\hline
0 & 0 & \cdots & 0 & 1 & 1 & \cdots & 1 & 0 & 0 & \cdots & 0
\end{array}\right)
\begin{array}{c}
\geq\leq \\ \geq\leq \\ \geq\leq \\ \geq\leq \\ = \\ = \\ = \\ = \\ \leq
\end{array}
\left(\begin{array}{c}
\text{Currency Exposure (FX)} \\ \text{Sectors (S)} \\ \text{Maturity Buckets (M)} \\ \text{Countries(C)} \\
\hline
\text{Portfolio Holding}_1 \\ \text{Portfolio Holding}_2 \\ \vdots \\ \text{Portfolio Holding}_n \\
\hline
\text{Turnover Constraint}
\end{array}\right),
$$

$$
\text{with } 0 < w_1, \ldots, w_n \leq w_{\text{MAX}},\ b_1, \ldots, b_n \geq 0,\ s_1, \ldots, s_n \geq 0
$$

9. Dessislava A. Pachamanova and Frank J. Fabozzi, *Simulation and Optimization in Finance: Modeling with MATLAB, @Risk, or VBA.* (Wiley, 2010), p.157 discuss the inclusion of slack variables.

In fact, the upper-left matrix is a $m \times n$ country-maturity-allocation matrix (alternatively, currency-maturity-allocation matrix, sector-maturity-allocation matrix, etc.) that captures a very large amount of information. This matrix provides fund managers of international bond portfolios with unique opportunities to manage their funds. Specifically, they can adjust for multiple duration constraints and manage both the overall allocation and selection toward sectors and maturity buckets in particular. For example, the matrix view allows for a bullet maturity allocation in Hungarian government bonds, but at the same time to allocate using a barbell strategy in European debt, or alternatively using a ladder strategy in U.S. Treasuries. Furthermore, short modified duration in South Africa and long duration in U.K. gilts are possible solutions as subtargets in the optimization. However, managers must be vigilant, as the dimension of the matrix can cause serious estimation problems if the constraints and input information increase. To summarize, a fund manager can increase the degree of flexibility of the portfolio selection and allocate in global corporate bonds, covered bonds, government bonds, countries, maturity buckets, or durations, and above all adjust for interactions according to certain constraints. Exhibit 57-6 illustrates a sample portfolio with its currency and maturity allocation as a result of an allocation and selection optimization.

RISK MANAGEMENT AND ADDITIONAL TOOLS

Risk management for international bond portfolios is a challenging and sophisticated task, which involves the risk management division and front office. Specifically, fund managers employ complex techniques to monitor and analyze the exposure to risk. This is the main idea of this section.

To this end, risk management refers to duration management and stop-loss discipline, carrying out stress-test scenarios of curve shifts, currency simulations, and calculating break-even rates for the roll down returns, and so on. We highlight some important topics:

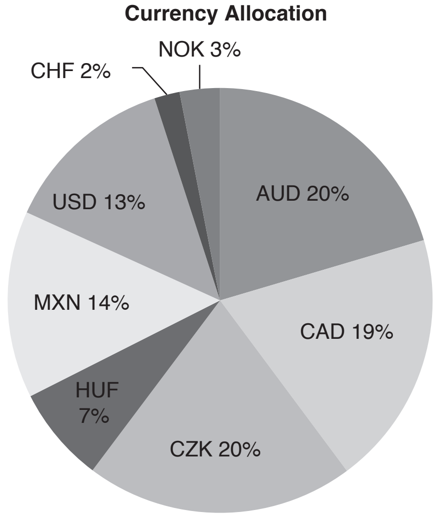
- Duration management
- Factor models
- Currency hedge and overlay management
- Simulations

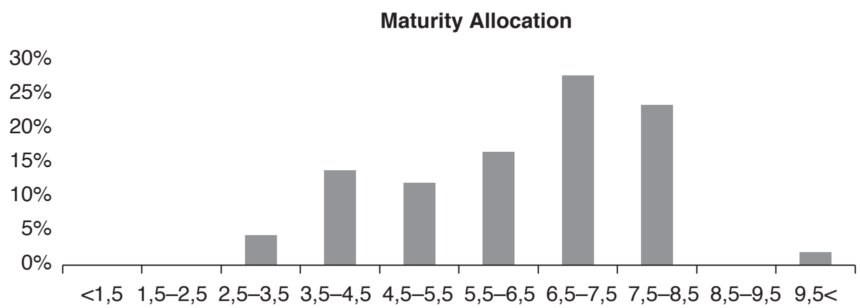
Duration Management

Duration management as a risk management tool for managing interest rate risk has a much more complex role for international portfolios than for traditional portfolios. Specifically, the systematic risks of international portfolios comprising multiple currencies and fixed income securities in multiple currencies mean a heterogeneous duration metric. More precisely, in an international portfolio

EXHIBIT 57-6

Currency, Country, and Maturity Allocation of an International Bond Portfolio





exposure to 10 currencies, the manager faces 10 different duration measurements. This would be the natural step of the allocation and selection process to different yield curves. In this example, a manager allocates to U.S. dollars and considers the U.S. Treasury curve. International bond portfolios allow tremendous possibilities for duration management. A helpful approach is to show the durations using country-maturity matrices or currency-maturity matrices.

Factor Models

A further enhancement to the risk management tool is the incorporation of risk factor models. Factor investing has gained great momentum in recent decades.

The portfolio systematic risk can be decomposed into factors and managers can monitor their risk factor exposure. A serious advantage for factor models is that they are suitable to evaluate both benchmark and absolute return portfolios.

Further enhancements consist of incorporating active monitoring of factor bets and actively managing a bond portfolio according to the factor exposure. This represents an important technique applied to more passively managed products. A novel risk approach is to actively monitor the risk factor bets of other fund managers. The terms "crowded trades" and "factor crowdedness" measure the exposure of other fund managers to the same underlying factors. Specifically, within the optimization process, exposure to the factors shift, slope, and butterfly is a reasonable and desirable solution, and applying a factor model as a risk management tool and measuring the factor crowdedness allows for constant monitoring of herding behavior. It is an important source of information, since it would reveal, for example, strong bets on decreasing interest rates globally. Furthermore, factor models allow for the control of currency risk exposure.

Specifically, style factors capturing the main currency strategies—carry, value, and trend—allow an explanation of which style reflects the current management approach. A general factor model can have the following form:

$$R_{i,t} = \alpha_i + \sum_{i=1} \beta_i F_{j,t} + \varepsilon_t$$

where $R_{i,t}$ is the total return generated by the fund, α is the intercept, β is a coefficient that measures the sensitivity of a fund's return to the factor, F is the beta factor that requires a systematic risk premium in the market, and ε is the random error term.

Possible factors to include in a factor model for international bond portfolios are:[10]

- Level factor, or bond carry factor
- Structure factor, or bond value factor
- Curvature factor
- Currency carry
- Currency value
- Currency momentum

10. For extensive analysis on factors for international bond portfolios, see Gueorgui Konstantinov, "On the Dynamics of EMU Bond Portfolios: From Diversification of Risk Factors to Convergence of Fund Exposure," *Journal of Investing* 27(2), 2017, pp. 91–101 (the author provides information on constructing curve-based factors); Gueorgui Konstantinov, "Capturing Short-Term and Long-Term Alpha of Global Bond Portfolios: Evidence from EUR-Investors' Perspective," *Financial Markets and Portfolio Management* 30(3), 2016, pp. 33–365; Clifford S. Asness, Tobias Moskowitz, and Lasse. H. Pedersen, "Value and Momentum Everywhere," *Journal of Finance* 68(3), 2013, pp. 929–985; Jean Michel Maeso, Lionel. Martellini, and Riccardo Rebonato, "Factor Investing in U.S. Sovereign Bond Markets: A New Generation of Conditional Carry Strategies with Applications in Asset-Only and Asset-Liability Management," *Journal of Portfolio Management* 46(2), 2020, pp. 121–140.

- Default risk premium
- Fama-French-Carhart global equity factors
- Currency and rate volatility

An overview of the factors provides information on their relevance for international portfolios:

The *level factor*, comprising international bond level as denoted by the long-term bond yields of liquid bonds: corporate, government, covered, financials. The factor can be modeled as the change of the long-term bond yield level: $\left(\Delta 10Y\right)$.

The *structure factor* refers to a factor capturing the slope of international fixed income securities as measured by the rate of change of the differences in the corresponding long-term and short-term bond yields $\left(\Delta 10Y - 2Y\right)$.

The *curvature factor* might capture the bond dynamics to residual curve movements.

The currency *carry* represents the borrowing in low-yielding currencies and investing in high-yielding ones. The index consists of long positions in the top high-yielding currencies and short positions in the low-yielding ones. Deutsche Bank Currency Harvest Index represents a currency carry factor.

The *currency value* factor represents the under- or overvalued currencies that an investor may consider—this factor is typical for currency investors and was established to explain the fundamental currency valuation. A systematic process considers the ranking of the three currencies with the highest average spot market return adjusted for the purchase power parity exchange rate, published by the OECD. Thus, the index consists of the long position in the three undervalued and short positions in the three overvalued currencies. An example is the Deutsche Bank Currency Value Index.

The *currency momentum* describes the short-term or some of the mid-term tendencies in the price movements. This factor captures the often-used technical analysis in the markets. The Deutsche Bank Trend Index is an example of such a factor.

The *default risk premium* is the spread of Baa bond yield minus the 10-year U.S. Treasury yield and is a widely accepted measure for corporate bond risk premium.

The *Fama-French-Carhart factors* for global equities are suitable for international bond portfolios. Recent research found that the Fama-French equity factors explain a large percentage of corporate bond returns. Specifically, these factors are relevant for fixed income instruments with more equity-like properties—for example, high-yield securities and corporate bonds with lower ratings. These factors are the equity premium (Mkt-Rf), value (HML), size (SMB), profitability (RMW), investment (CMA), and the momentum factor (MOM).

The *currency and rate volatility* are important factors in international bond portfolios both from management and risk management perspectives. Investment banks provide data on the currency and rate volatilities. Implied volatility time series are inputs for option prices, thus monitoring them allows an impression of risk to be gained in both asset classes. Furthermore, volatility simulations can provide valuable information of possible tail risks for a portfolio.

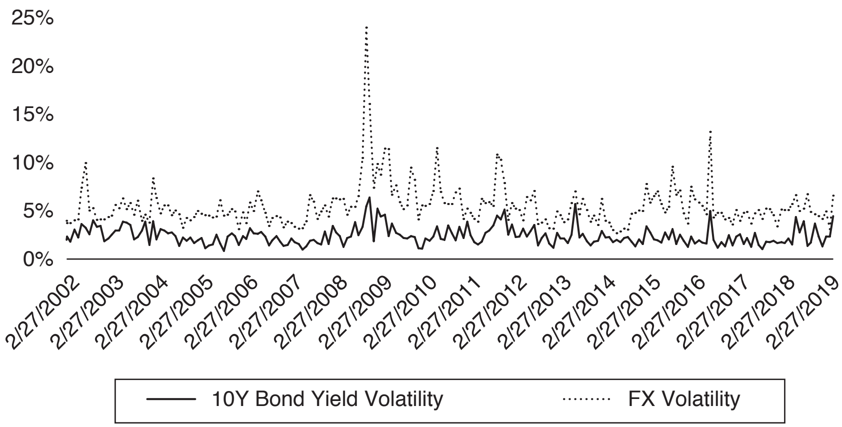
We measure the daily absolute changes q for a set of currencies (EUR, CAD, CHF, JPY, GBP, AUD, NZD, SEK, NOK, PLN, HUF, ZAR, MXN, THB, MYR, IDR, PHP, CLP, BRL) on each day τ in our sample. We then average over all currency return available on any given day, and average daily values up to the weekly frequency. Thus, our foreign exchange and global 10-year (10Y) bond volatility proxy in month t is given by[11]

$$\sigma^{FX} = \frac{1}{T_t}\sum_{\tau\in T_t}\left[\sum_{n\in N_\tau}\left(\frac{\left|\Delta FX_\tau^q\right|}{N_\tau}\right)\right] \text{and}\, \sigma^{10Y} = \frac{1}{T_t}\sum_{\tau\in T_t}\left[\sum_{n\in N_\tau}\left(\frac{\left|\Delta 10Y_\tau^q\right|}{N_\tau}\right)\right]$$

Thus, we can compute the 10-year bond volatility and the foreign exchange volatility and compare them. These factors, contained in Exhibit 57-7, can be used in both the management optimization approach and as explanatory variables in a factor model.

EXHIBIT 57-7

Monthly 10Y Government Bond and Global Foreign Exchange Volatility



Source: Constructed by the author from data obtained from Bloomberg, LLC.

Computing historical volatilities reveals information regarding foreign exchange and bond risks. Appropriate models for predicting volatilities exist and are widely accepted for both fixed income and foreign exchange investments.

11. Lukas Menkhoff, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, "Carry Trades and Global Foreign Exchange Volatility," *Journal of Finance* 67(2), 2012, pp. 681–718.

For example, one of the most widely used models is the General Autoregressive Conditional Heteroscedasticity model (GARCH).

Currency Hedge and Currency Overlay Management

Currency depreciations during financial market turmoil cause a rise in correlations of multiple assets. In particular, emerging markets are vulnerable to capital outflows and rising bond yields and thus currency depreciation. Although the exact mechanism flows through different channels, abrupt spikes harm bond investments. Investors prefer currency-hedged international investments; however, the nature of the benchmark and the underlying exposure is one of the variables to consider. The next component refers to the amount of base currency exposure in the benchmark—that is, the amount of U.S. dollar exposure of a U.S.-based investor, or the EUR-bond-exposure for a Euro-based investor. A further, perhaps the most important, component of currency hedge is the cost of hedging, which depends on the level of short-term or money market yields.

Currency overlay management techniques serve as an add-on to the existing fixed income portfolio. This topic has attracted a great deal of attention, since currency risk poses a serious threat to fixed income portfolios. Currency overlay strategies consider the actual weights, and thus the current currency exposure, of a bond portfolio and apply momentum strategies to hedge the exposure to risk.[12] Other techniques refer to the base currency risk of a fixed income portfolio. Gueorgui Konstantinov and Frank J. Fabozzi showed the direct relationship between currency strategies and fixed income investments.[13]

Simulations

These are convenient tools to model complex relationships and to compute different scenarios of the underlying variables. Simulations in international bond portfolios allow for the following:

- Computation of probability of different scenarios—for example, positive (upward) shift in U.S. Treasuries, negative parallel movement of the spot curve in Emerging Markets Asia (Thailand, Indonesia, Philippines, Malaysia, China, for example) following a risk-off scenario and financial turmoil in this region
- Interaction-based scenario analysis—combined-stress-test-based or correlation-based scenarios with multiple effects on portfolio—for example, a global shift in the bond yields and combined effects with

12. Momthchil T. Pojarliev, "Some Like It Hedged," CFA Research Foundation, 2018 provides a comprehensive overview and arguments of currency hedging, how it is created, and what the important differences are between Canadian, European, U.S., and Japanese investors.
13. Gueorgui Konstantinov and Frank J. Fabozzi, "Carry Strategies and the U.S. Dollar Risk of U.S. and Global Bonds," *Journal of Fixed Income* 30(3), 2021, pp. 26–46.

the U.S. dollar, and possible effects on the option-adjusted spreads as a consequence of rising interest volatility

- A cheap and efficient method of scenario analysis for portfolio managers

PERFORMANCE MEASUREMENT AND ATTRIBUTION

Within this section, we refer to the performance evaluation and attribution of international bond portfolios, which defer to a large extent compared to the overall performance measurement. The main difference, and thus the most important source of management information, is yield-curve management.

Performance Measurement

The Sharpe ratio is widely applied in performance measurement. The ratio is a sample statistic calculated using the sample mean and the standard deviation of a manager's returns over a period of time. The Sharpe ratio has a significant advantage, measuring the reward of a unit of taken risk, and is expressed in the following way:

$$SR = \frac{E\left(R_{PF}\right) - R_f}{\sigma_{PF}}$$

However, the simple Sharpe ratio considers only the first and the second moments of the return distribution and fails to account for non-normal returns of international bond portfolios caused in particular by currency exposure. The Adjusted Sharpe Ratio (ASR) suggested by Jacques Pezier and Anthony White (2008) considers the skewness (s) and the kurtosis (k) of the original Sharpe Ratio:[14]

$$ASR = SR\left[1 + \frac{s}{6}SR - \frac{(k-3)}{24}SR^2\right]$$

Yield Curve–Based Attribution

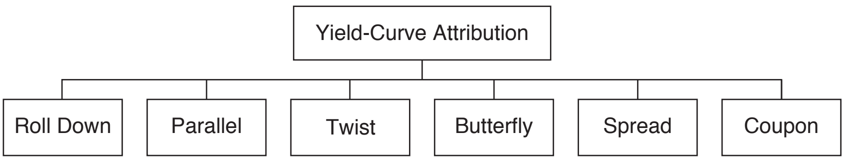
Decomposing the drivers of portfolio return ex post is inevitable for multicurrency bond portfolios. As a natural consequence of a multi-curve-based management approach, the performance attribution should properly reflect portfolio results. A yield curve–based attribution model allows information to be gained regarding

14. Jacques Pezier and Anthony White, "The Relative Merits of Alternative Investments in Passive Portfolios," *Journal of Alternative Investments* 10(4) 2008, pp. 37–39.

the different curve dynamics in the underlying currency exposure and different interest rate regimes. Specifically, the curve dynamics of the U.S. Treasuries differs from the yield-curve changes in Hungary, for example. The specific business cycle causes these changes to differ substantially, as well. In general, the factors level, slope, and curvature explain roughly 95% of the volatility of interest rates.[15] As a natural consequence, the changes of these factors explain the curve dynamics. At a portfolio level, quantifying the factors in the different currency exposures reveals the underlying complex dynamic of both currency and fixed income securities.[16] The return attribution of a portfolio can be decomposed by the following five factors in addition to the local currency returns shown in Exhibit 57-8:[17]

EXHIBIT 57-8

Yield-Curve Attribution Factors



Whereas the roll down and the coupon factors are return effects resulting from the passage of time, the remaining three factors—parallel, twist and butterfly, and spread—are yield curve–based. Measuring the effects in local currency in every sector, country, or asset class allows identification of the source of return by taking different bets on the yield curves. The currency effects reveal the magnitude of currency depreciation or appreciation as a result of the curve management. The price change from t_0 to t_1 is decomposed in separate steps using the underlying spot curve to evaluate the impact of the five factors—shown formally as follows:

$$R_t = \frac{T\left(t_1, s_1 + OAS_1\right) - T\left(t_0, s_0 + OAS_0\right)}{T\left(t_0, s_0 + OAS_0\right)}$$

The spot curve–based attribution model then needs to estimate the following factors and put them in relation to the dirty prices—that is, including the accrued interest on the clean price at $t_0\left(P_0 + AI_0\right)$.

A necessary step is to estimate the spot curves at the beginning and at the end of the desired period.

For simplicity, the curve dynamics are explained only by the shift component. The difference in the β_0 parameter of the Nelson-Siegel or the Svensson curve gives the shift of a particular spot curve:

$$shift = \beta_0\left(t_1\right) - \beta_0\left(t_0\right)$$

The *roll down* is the pure effect of the passage of time and results from the difference of a bond price discounted with the same spot curve and option-adjusted spread OAS_0 at time t_1 and t_0:

$$\text{Roll down} = \frac{T\left(t_1, s_0 + OAS_0\right) - T\left(t_0, s_0 + OAS_0\right)}{P_0 + AI_0}$$

The *parallel* effect results as a consequence of a sole shift in the initial spot curve at time t_1. More precisely, the bond price at t_1 is discounted using the spot curve at s_0 with the option-adjusted spread OAS_0. The shift is added to the bond price at t_1, using the spot curve s_0, and the OAS_0:

$$\text{Parallel} = \frac{T\left(t_1, s_0 + OAS_0 + shift\right) - T\left(t_1, s_0 + OAS_0\right)}{P_0 + AI_0}$$

The *twist* and butterfly effects add up to a structure effect, which reflects the change in the yield curve shape. The structure effect is shown as

$$\text{Structure} = \frac{T\left(t_1, s_1 + OAS_0\right) - T\left(t_1, s_0 + OAS_0 + shift\right)}{P_0 + AI_0}$$

However, a split of the structure effect is necessary to evaluate the returns from changes in steepness (twist) and curvature (butterfly). Within this framework, we start where we stopped with the parallel effect. Specifically, after adding a shift to the old spot curve at t_0, we now measure the effect on bond prices between that price and the completely new price resulting from the spot curve at t_1:

$$\text{Twist} = \frac{T\left(t_1, s_1 + OAS_0 + shift\right) - T\left(t_1, s_0 + OAS_0 + shift\right)}{P_0 + AI_0}$$

The *butterfly* can be shown as a residual effect of the entire curve movement. Perhaps in an intuitive manner, the butterfly captures the residual effect in excess curve shift between s_0 and s_1 spot curves:

$$\text{Butterfly} = \frac{T\left(t_1, s_1 + OAS_0\right) - T\left(t_1, s_1 + OAS_0 + shift\right)}{P_0 + AI_0}$$

Mathematically, adding the twist and the butterfly effects, the term $T\left(t_1, s_1 + OAS_0 + shift\right)$ cancels out, to result in a structure effect. An alternative way to show the twist and butterfly effects is to gage them by the spot curve parameters.

The *spread* attribution effect is simply the bond price change at t_1 using the spot curve s_1 due to a change in the option-adjusted spread between OAS_0 and OAS_1.

$$\text{Spread} = \frac{T\left(t_1, s_1 + OAS_1\right) - T\left(t_1, s_1 + OAS_0\right)}{P_0 + AI_0}$$

The *coupon* effect measures the amount of accrued interest during the holding period.

$$\text{Coupon} = \frac{AI(t_1) - AI(t_0)}{P_0 + AI_0}$$

This sum of these effects shows the local curve return effect. Yield-curve attribution is essential in international bond portfolios. The advantage lies in the possibility of using different types of spot curves—local currency, country, sector and asset classes—corporates, financials, covered, etc., with different ratings fitted from the bulk of fixed income securities available in the investment universe.

Exhibit 57-9 shows the spot curve–based attribution for an international bond portfolio. One of the biggest advantages of the separation of local currency bond returns and the foreign exchange impact is that the vector of FX returns always reflects the base currency. In general, this attribution approach explains on average 97% of local currency bond returns.

To compute the contribution to portfolio return in that month, it is necessary to multiply the portfolio weights w_i with the corresponding return components—roll down, parallel, and so on:

$$R_t^{C_k} = \sum_{i=1}^{n} r_n^c w_n$$

The total portfolio return of 1.77% is the sum of the local currency bond returns of 0.63%—estimated using the underlying spot curves and the foreign exchange impact of 1.14%. The local currency bond returns (0.63%) are mainly driven by positive contribution of roll-down returns of 0.25%, and a twist effect of 0.21%. The spread effect contributed 0.17%. The residual effect shows how much performance is not explained by the model. Exhibit 57-10 contains the cumulative results for the yield-curve factor attribution.

EXHIBIT 57-9

Spot Curve–Based Attribution for an International Bond Portfolio

Bond	Weight	Roll Down	Coupon	Parallel	Twist	Butterfly	Spread	Return (LC)	FX	Total
ACGB 2 3/4 04/21/24	2%	0.16%	0.00%	0.01%	–0.01%	0.56%	–0.20%	0.56%	1.83%	2.40%
ACGB 3 1/4 04/21/25	8%	0.17%	0.00%	0.01%	–0.01%	0.59%	–0.17%	0.60%	1.83%	2.44%
ACGB 4 1/4 04/21/26	10%	0.18%	0.01%	0.01%	–0.01%	0.59%	–0.19%	0.57%	1.83%	2.41%
CAN 1 09/01/22	4%	0.15%	0.00%	0.00%	0.00%	–0.09%	0.28%	0.33%	1.94%	2.27%
CAN 1 3/4 03/01/23	3%	0.16%	0.00%	0.00%	0.00%	–0.10%	0.24%	0.30%	1.94%	2.25%
CAN 2 09/01/23	4%	0.15%	0.00%	0.00%	0.00%	–0.11%	0.26%	0.30%	1.94%	2.24%
CAN 2 3/4 06/01/22	4%	0.15%	0.00%	0.00%	0.00%	–0.08%	0.23%	0.28%	1.94%	2.22%
CAN 1 1/2 06/01/23	4%	0.15%	0.00%	0.00%	0.00%	–0.10%	0.25%	0.28%	1.94%	2.22%
CZGB 2.4 09/17/25	8%	0.15%	0.00%	0.02%	–0.02%	0.17%	0.25%	0.56%	–0.51%	0.05%
CZGB 1 06/26/26	10%	0.16%	0.00%	0.02%	–0.02%	0.22%	0.14%	0.51%	–0.51%	–0.01%
CZGB 0.45 10/25/23	2%	0.15%	0.00%	0.01%	–0.01%	0.09%	0.38%	0.64%	–0.51%	0.13%
HGB 2 1/2 10/24/24	4%	0.29%	0.00%	–0.06%	0.06%	0.13%	0.48%	0.90%	1.12%	2.04%
HGB 5 1/2 06/24/25	2%	0.28%	0.00%	–0.06%	0.06%	0.31%	0.49%	1.12%	1.12%	2.26%
HGB 3 06/26/24	1%	0.28%	0.00%	–0.06%	0.06%	0.01%	0.60%	0.88%	1.12%	2.01%

(Continued)

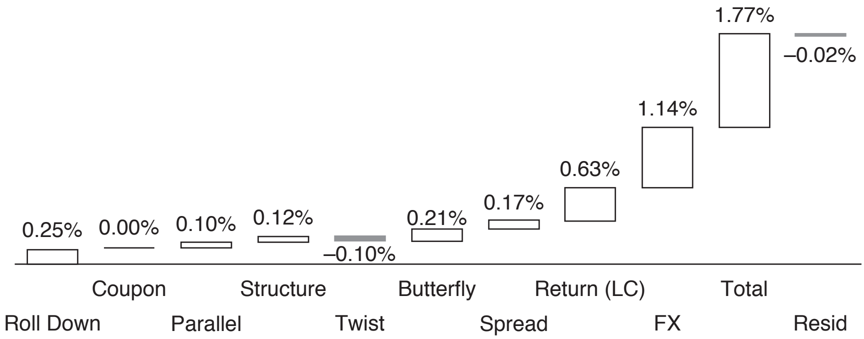
EXHIBIT 57-9

Spot Curve–Based Attribution for an International Bond Portfolio (*Continued*)

Bond	Weight	Roll Down	Coupon	Parallel	Twist	Butterfly	Spread	Return (LC)	FX	Total
MBONO 8 12/07/23	3%	0.67%	0.01%	0.80%	–0.78%	0.70%	0.32%	1.70%	2.44%	4.19%
MBONO 10 12/05/24	4%	0.68%	0.01%	0.89%	–0.87%	0.74%	0.36%	1.73%	2.44%	4.22%
MBONO 5 3/4 03/05/26	7%	0.73%	0.01%	1.11%	–1.08%	0.83%	0.33%	1.79%	2.44%	4.28%
T 1 1/2 08/15/26	10%	0.23%	0.00%	0.00%	0.00%	–0.42%	0.42%	0.25%	0.60%	0.85%
T 2 11/15/26	3%	0.23%	0.00%	0.00%	0.00%	–0.42%	0.43%	0.27%	0.60%	0.86%
SWISS 0 1/2 06/27/32	2%	0.03%	0.00%	–1.83%	1.85%	0.33%	0.00%	0.37%	–1.43%	–1.06%
NGB 2 05/24/23	3%	0.10%	0.00%	0.00%	0.00%	0.15%	–0.58%	–0.34%	1.18%	0.84%

EXHIBIT 57-10

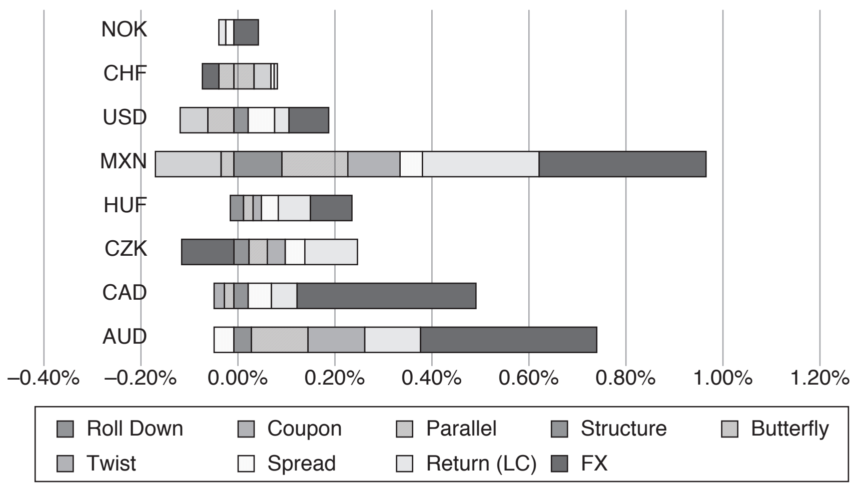
Total Contribution of Portfolio



The results in Exhibit 57-11 show the contribution of every single curve component to the specific currencies in a portfolio.

EXHIBIT 57-11

Currency Spot Curve–Based Effects



The same procedure applies to a benchmark. In this case, the active decisions are the differences between portfolio and benchmark components, both in currency and factor exposure.

Backtest Evaluation

Portfolio managers are always interested in improving their strategies, models, and tools. Therefore, over the years, backtesting of portfolio strategies has been an integral part of fund managers' activities. In this line of thought, multiple tests using the Svensson instead of the Nelson-Siegel polynomial, or cubic spline models, or the Vasicek approach for yield-curve fitting, are examples of different tests. International bond portfolios have the unique advantage that they can be expanded or shrunk in respect of the number of currencies, countries, sectors, and types of fixed income securities. Further examples are modification to the optimization techniques, the inclusion of machine-learning approaches, factor models, and so on. Simple comparison of the tests with corresponding performance metrics, such as the Sharpe ratio, the Treynor ratio, the information ratio, and so on, would produce a biased estimation. Put differently, a strategy might be profitable in backtest but would produce undesirable results in real conditions. Given the complexity of international multicurrency bond portfolios, adjusting for multiple testing is the cornerstone of modern finance, the finance of the twenty-first century.

KEY POINTS

- Expected returns can be decomposed into two components—horizon and vertical effects. These effects show that fixed income securities absorb currency and interest rate movements.
- Estimating the specific spot curves allows currency allocation, bond selection, and performance yield curve–based attribution.
- Currency risks can be minimized using minimum variance optimization, since currencies are financial assets but not real assets, and thus have zero expected return.
- Bond portfolio optimization, or portfolio selection, can be easily modeled using local currency yield curves and modeling the entire portfolio, incorporating portfolio constraints—for example, duration, factor exposure, currency exposure, spreads, turnover, and specific portfolio holdings constraints.
- Spot curve–based attribution provides insightful information for past performance. However, the yield curve–based factor exposure is a valuable input for portfolio construction.
- Developing new models and techniques is inevitable for modern bond portfolio management. Adjusting the results for multiple tests, transparency in result presentation and successful implementation of a new strategy are issues both investors and regulators should focus on in the future.

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CHAPTER
FIFTY-EIGHT

FACTOR INVESTING IN SOVEREIGN BOND MARKETS

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The abundance of theoretical and empirical research on factor investing in the equity universe stands in sharp contrast to the relative scarcity of research on risk premia in bond markets. From the investment practice standpoint, a similar contrast exists between factor investing in the equity space, which is a relatively mature subject, and factor investing in bond markets, which still is in its infancy. That relatively little is known about the out-of-sample performance of factor investing in fixed income is perhaps surprising, given the importance of bond holdings in investors' portfolios, and given that a number of concerns have been expressed about the shortcomings of traditional sovereign bond benchmarks.

This chapter describes the theoretical, empirical, and implementation challenges related to factor investing in a credit-risk-free issuer universe. In such a universe, neither time-series nor cross-sectional differences in risk and performance can be explained by differences in creditworthiness, as they could be in the case of a multi-issuer universe. The key message is that it is possible to identify economically justifiable strategies that, after accounting for transaction costs and other forms of trading frictions, generate excess returns from investing in a relatively homogenous set of highly correlated securities. The profitability of these strategies can be due to a reward from factor exposure, systematic predictability resulting from market inefficiencies, behavioral biases, or a combination of the above.

PROBLEMS WITH EXISTING BOND BENCHMARKS

One of the major problems with bond benchmarks that simply weight the debt issues by their market value has been referred to by Laurence Siegel as the "bums' problem."[1] Given the large share of the total debt market accounted for by issuers with large amounts of outstanding debt, market-value-weighted corporate bond indices will have a tendency to overweight bonds with large amounts of outstanding debt. It is often argued that such indices will thus give too much weight to riskier assets. It is debatable whether debt weighting really leads to the riskiest securities being overweighted.[2] However, it is clear that market-value debt weighting leads to concentrated, and hence poorly diversified, portfolios. A similar problem has been documented for cap-weighted equity benchmarks.[3]

In addition to the problem of concentration, fluctuations in risk exposures (such as duration or credit risk in existing indices) are another source of concern.[4] Such uncontrolled time variation in risk exposures is incompatible with the requirements of investors that these risk exposures be relatively stable so that allocation decisions are not compromised by implicit choices made by an unstable index. For example, an asset–liability mismatch would be generated by changes in the duration of the bond index if the latter were used as a benchmark for a pension fund bond portfolio.

BENEFITS AND PITFALLS OF FACTOR INVESTING IN FIXED-INCOME MARKETS

The modern approach to factor investing first requires the identification of robust and economically motivated sources of risk in fixed income markets.[5] An economic motivation is not just an academic nice-to-have. Understanding the reason for the cross-section differential returns matters a lot from the point of view of a robust benchmark creation. If the excess returns are due to a behavioral "irrationality," it

1. Laurence B. Siegel, *Benchmarks and Investment Management,* technical report, the Research Foundation of the Association for Investment Management and Research (Charlottesville, Virginia, 2003).

2. A higher weight for an issuer with a high market value of debt does not necessarily mean that the index is overweighting issuers with a high face value of debt. An issuer with a high amount of par value debt outstanding will only get a high weight if the market value is relatively close to par value, which implies that the issuer is not perceived to be very risky. It is therefore not clear why the market-value-weighted index should become riskier. In addition, loading onto riskier issuers should not be a problem if this risk is rewarded by higher expected returns.

3. See, for example, Noel Amenc, Felix Goltz, and Véronique Le Sourd, "Assessing the Quality of Stock Market Indices." EDHEC Publication, 2006.

4. For more details, see Carlos Heitor Campani and Felix Goltz, "A Review of Corporate Bond Indices: Construction Principles, Return Heterogeneity, and Fluctuations in Risk Exposures," EDHEC-Risk Institute Publication, 2011.

5. See, for example, Lionel Martellini and Vincent Milhau, "Factor Investing: A Welfare-Improving New Investment Paradigm or Yet Another Marketing Fad," EDHEC-Risk Institute Publication, 2015.

could in principle be arbitraged away by rational investors. Revealing the behavioral anomaly could therefore be the first step toward its disappearance. However, its persistence or otherwise may be linked to the availability or scarcity of "arbitrage capital."[6] Finally, if the excess returns are due to institutional frictions, they can be an easy source of profitability for investors who are not affected by the regulatory or institutional constraints. However, they can disappear at the stroke of a regulatory pen. And if the excess returns are truly due to an anomaly, then they are likely to disappear after its discovery as it becomes exploited.

Matters are different if the origin of the excess returns can be traced to a source of rewarded systematic risk. In this case, the attending compensation (the corresponding "market price of risk") will not disappear by discovering it, as it is just a compensation for being paid well or poorly in good and bad states of the world, respectively. This compensation may well decrease or increase in size over time with the investors' risk aversion, but, at any point in time, it simply reflects "fair pricing."

For the sake of brevity, we refer in what follows to all types and sources of differential cross-sectional returns as "generalized factors," but it should be kept in mind that, from the perspective of the creation and long-term profitability of investable factor benchmarks, the underlying causes for the excess returns can be very important.

Unfortunately, the recent discovery that "traditional" equity factors such as value or momentum seem to be effective also in the fixed income area and other asset classes does create an embarrassing explanation problem. As Asness, Moskowitz, and Pedersen eloquently put it, "the strong correlation structure among value and momentum strategies across such diverse asset classes is difficult to reconcile under existing behavioral theories, while the high Sharpe ratio of a global across-asset-class diversified value and momentum portfolio presents an even more daunting hurdle for rational risk-based models."[7] So, we seem to find more and more factors and to observe that the "old" factors seem to work even where they were not expected (or even supposed) to; however, we are further and further away from a unified understanding of why they do. As argued above, unfortunately this imperfect understanding does matter when it comes to building robust and stable investable portfolios.

Modern "generalized factor discovery" in the fixed income area is also made more difficult by the problem of proxies. Very often a candidate factor (such as liquidity or value) is difficult to measure, or even to define, precisely. Furthermore, as recognized as early as 1993 by Fama and French, a straightforward transposition to the fixed income arena of the factors that are most popular

6. This clear distinction between "irrationality"-based and institutional-based source of differential cross-sectional returns can easily become blurred: the availability of the speculative capital that should arbitrage irrationalities away, for instance, may become greatly reduced because of regulatory initiatives such as the Volker rule in the United States or the Likanen proposal in the EUR area.
7. Clifford S. Asness, Tobias J. Moskowitz, and Lars H. Pedersen, "Value and Momentum Everywhere," *Journal of Finance* 68(3), 2013, 929–985.

in the equity space (such as value, momentum, or low volatility) is not straightforward.[8] This has led to the proliferation of proxies and, sometimes, to the creation of proxies of proxies. For instance, Asness, Moskowitz, and Pedersen investigate value and momentum in fixed income, and circumvent the problem of defining value for bonds (a concept that, according to Fama and French, "has no obvious meaning for . . . bonds")[9] by arguing that "individual stock portfolios formed from the negative of past 5-year returns are highly correlated with those formed on BE/ME ratios in our sample. . . . Hence, using past 5-year returns to measure value seems reasonable." The logic here is to use as proxy (the 5-year returns) to stand in for another proxy (value) for an unspecified latent factor. In itself, the choice may well be reasonable, but the link to the desired proxy (value), let alone to the latent factor, is neither transparent, nor unique: indeed, in the literature a number of additional measures of value for bonds have been proposed.

This concern is of relevance for the construction of robust benchmarks. After all, if a factor proxy is associated with a true risk premium, the attending "excess" return is simply a compensation for receiving good or bad payoffs in periods of high or low consumption, respectively. High or low consumption, in turn, can be parsed in terms of a relatively small number of (often highly correlated) economic configurations, such as low growth or high unemployment. A principled and parsimonious approach to proxy analysis is therefore essential, especially in the nascent field of fixed-income factor investing.

TAXONOMY OF FIXED INCOME FACTORS

All these qualifications should be clearly kept in mind as we review the generalized fixed-income cross-sectional factors that have been identified most consistently in the modern literature. Despite of the aforementioned difficulties, value[10] and momentum[11] remain among the best documented fixed income generalized factors.

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8. Eugene F. Fama and Kenneth R. French, "Common Risk Factors in the Returns on Stocks and Bonds," *Journal of Financial Economics* 33(1) 1993, 3–56.

9. Footnote 5 in Asness, Moskowitz, and Pedersen, "Value and Momentum Everywhere."

10. For U.S. Treasuries, see Asness, Moskowitz, and Pedersen, "Value and Momentum Everywhere." For corporate bonds, see Mathieu L'Hoir and Mustafa Boulhabel, "A Bond-Picking Model for Corporate Bond Allocation," *Journal of Portfolio Management* 36(3), 2010, 131–139.

11. For U.S. Treasuries, see Asness, Moskowitz, and Pedersen, "Value and Momentum Everywhere." For investment-grade bonds, see the following two studies that find a reversal: Kenneth Khang and Tao-Hsien King, "Return Reversals In The Bond Market: Evidence And Causes," *Journal of Banking & Finance* 28(3), 2004, 569–593 and William S. Gebhardt, Seren Hvidkjaer, and Bhaskaran Swaminathan, "Stock and Bond Market Interaction: Does Momentum Spill Over?" *Journal of Financial Economics* 75(3), 2005, 651–690. Gebhardt, Hvidkjaer, and Swaminathan also find reversal, while no momentum is found in the study by Gergana Jostova, Nikolova, Alexander Philipov, and Christo Stahel, "Momentum in Corporate Bond Returns," *Review of Financial Studies* 26(7), 2013, 1649–1693. Jostova, Nikolova, Philipov, and W. Stahel also find evidence of momentum in the corporate high-yield market, as did Libor Pospisil and Jing Zhang, "Momentum and Reversal Effects in Corporate Bond Prices and Credit Cycles," *Journal of Fixed Income* 20(2), 2010, 101–115.

Beyond value and momentum, liquidity has also been found to be a relevant factor. Rebonato and Sherwin focus on the establishment of a robust liquidity proxy for fixed income.[12] They show that this measure of liquidity is closely linked to measures such as "liquidity and noise"[13] and to funding liquidity. They also argue that a large part of the yield premium provided by TIPS over U.S. nominal Treasuries can be explained as a compensation for the liquidity risk factor. Using a variety of visible market proxies (but without trying to combine them as in Rebonato and Sherwin), Rebonato and Naik also document the impact of liquidity on the pricing of TIPS relative to nominal Treasury bonds.[14] Finally, low risk has been found relevant both in corporate bonds and in Treasuries.[15] Indeed, in the case of Treasuries, it is well known[16] from time-series studies that low-maturity bonds offer a higher Sharpe ratio in virtually every economic environment.[17]

These factors (in particular, value and momentum) have direct counterparts in the equity universe. In addition, one also needs to analyze the well-known factors that explain time-series changes in returns. Wherever there is a risk, and to the extent that this risk covaries positively with consumption, asset-pricing theory tells us to look for a possible reward. Ever since the 1990s, it has been well known that a principal component analysis of the returns on bonds with different maturity from a sovereign issuer suggests that three main factors, namely, changes in level, slope, and curvature of a yield curve,[18] explain a very large

12. Rebonato Riccardo and Hong Sherwin, "Robust and Interpretable Liquidity Proxies for Market and Funding Liquidity,"*Journal of Fixed Income* 30 (3), 2020, 67–82.

13. Grace Xing Hu, Jun Pan, and Jiang Wang, "Noise as Information for Illiquidity," *Journal of Finance* 68(6), 2013, 2341–2382.

14. Riccardo Rebonato and Vassant Naik, "Can Liquidity Explain the Recent Fall in Breakeven Inflation?" PIMCO Working Paper (March 2017).

15. For example, see the following: Raul Leote de Carvalho, Patrick Dugnolle, Lu Xiao, and Pierre Moulin, "Low-Risk Anomalies in Global Fixed Income: Evidence from Major Broad Markets," *Journal of Fixed Income* 23(4), 2014, 51–70; Antti Ilmanen, Rory Byrne , Heinz Gunasekera, and Robert Minikin, "Which Risks Have Been Best Rewarded," *Journal of Portfolio Management* 30(2) 2004, 53–57; Andrea Frazzini and Lars H. Pedersen, "Betting against Beta," *Journal of Financial Economics* 111(1), 2014, 1–25; and Patrick Houweling and Jean van Zundert, "Factor Investing In The Corporate Bond Market," *Financial Analysts Journal* 73(2) 2017, 100–115.

16. See, for example, Rebonato and Naik, "Can Liquidity Explain the Recent Fall in Breakeven Inflation?"

17. While these results are statistically very robust, their economic significance is not obvious in the presence of realistic implementation constraints: especially for Treasuries and high-yield corporate bonds, the recent very-low-yield environment has made equity-like returns only obtainable with unfeasibly high leverage. The following study documents a required leverage of 50 for the lowest-risk (and highest Sharpe ratios) bonds: De Carvalho, Dugnolle, Lu, and Moulin, "Low-Risk Anomalies in Global Fixed Income: Evidence from Major Broad Markets."

18. Crump and Gospodinov have recently challenged this received wisdom by arguing that only the first (level) factor has economic meaning, and that the slope and curvature features are artefacts of the orthogonalization of the eigenvectors. Whatever the merit of their observation, the traditional decomposition remains valid from a statistical point of view. For a discussion, see R.K. Crump and N. Gospodinov, "Deconstructing the Yield Curve," Federal Reserve Bank of New York Staff Reports, Staff Report No. 884, April 2019, revised May 2019.

portion of returns over time.[19] In this context, it is therefore natural to ask whether the risks associated with changes in interest rate levels, and also possible in slope and curvature, are rewarded.

In what follows, we focus on the level and slope factors, which explain the largest percentage of bond return variations, before turning our attention to value and momentum.

LEVEL AND SLOPE FACTORS IN SOVEREIGN BOND MARKETS

Excess return studies in Treasuries have concentrated to date on the profitability of "carry" strategies, that is, strategies where the investment on a N-maturity bond is held for a holding period (typically of one year) and is funded by the sale of a short bond expiring at the end of the investment period. The returns are given by

$$xret_{t\to t+1} = p_{t+1}^{N-1} - p_t^N - y_t^1 = \left(y_t^N - y_{t+1}^{N-1}\right)\left(N-1\right) + \left(y_t^N - y_t^1\right) \qquad (58\text{-}1)$$

where p_t^N denotes by time-t log price of a T-maturity bond, and y_t^N its yield.

These strategies have been unconditionally profitable, as Exhibit 58-1 shows for data spanning the 1971–2017 period. The most commonly adduced explanation for this profitability is the existence of a positive risk premium associated with bearing "duration" risk. These performance results become more interesting when analyzed during expansion and recession periods, as shown in Exhibit 58-2. When this business-cycle decomposition is made, it becomes apparent that the carry strategies have been profitable during recessions, unprofitable during expansions, and particularly unprofitable in the second half of the recorded expansions. If an explanation of the excess returns in terms of a risk premium is to be valid, the market price of risk must therefore change sign, and must do so with the expansionary/contraction phases of the business cycle. The same exhibit also shows that the unconditional profitability of the carry strategy strongly depends on the exact period under study: even for a period as long as 1955–1986 (over 30 years) the excess return from holding Treasuries has been at best indistinguishable from zero, and perhaps even negative.

19. See Robert B. Litterman and Jose Scheinkman, "Common Factors Affecting Bond Returns," *Journal of Fixed Income* 1(1) 1991, 54–61.

EXHIBIT 58-1

Zero-Coupon Carry Strategies Main Statistics

Maturity	2	3	4	5	6	7	8	9	10
Average	0.53%	0.96%	1.32%	1.63%	1.90%	2.13%	2.32%	2.48%	2.62%
Standard Deviation	1.73%	3.15%	4.38%	5.51%	6.58%	7.61%	8.61%	9.60%	10.58%
Sharpe Ratio	0.30	0.30	0.30	0.30	0.29	0.28	0.27	0.26	0.25

This exhibit reports the average returns, standard deviations and Sharpe ratios from the carry strategies (1-year investment period) in equation (1) for U.S. Treasuries from 1971 to 2017. Zero-coupon bond prices are from Refet S. Gürkaynak, Brian Sack, and Jonathan H. Wright, "The U.S. Treasury Yield Curve: 1961 to the Present," *Journal of Monetary Economics* 54 (8), 2007, 2291–2304.

EXHIBIT 58-2

Zero-Coupon Carry Strategies Sharpe Ratios Under Different Economic Periods

	2-Year	5-Year	10-Year
Full Sample	0.20	0.20	0.16
1955–1986	0.04	–0.01	–0.07
1987–2014	0.59	0.56	0.49
Recession	0.82	0.72	0.59
Expansion	0.01	0.06	0.05
First-Half Expansion	0.52	0.50	0.45
Second-Half Expansion	–0.61	–0.50	–0.48
Tightening Cycles			
1979:Q3–1981:Q2	–1.06	–1.13	–1.23
1993:Q3–1995:Q1	–0.79	–0.86	–0.86
2004:Q2–2006:Q2	–1.52	–0.90	–0.50

This exhibit gives the Sharpe ratios of the 2-, 5- and 10-year carry strategies during different time periods.

Overall these empirical facts show that (1) if the excess returns are due to risk premia, the market price of risk must be time-varying and depend on state variables linked to the business cycle and (2) even over extended periods of time, the profitability of the unconditional carry strategy stems from averaging the positive excess returns made during recessions and the negative excess returns incurred in expansionary periods.

These two findings suggest that additional performance can be generated from a time-varying exposure to the level factors, embedded within so-called *conditional* carry strategies, with suitably defined time-varying exposures to the level factor. The set of dynamic fixed income factor investing strategies also includes conditional flattener/steepener strategies, with suitably defined time-varying exposures to the slope factor.[20] Slope-based strategies ("flatteners" and "steepeners") require long/short positions. In a long-only mandate portfolio, they can therefore only be implemented as on overlay. Since the variability associated with the level mode of deformation is much higher than the volatility of slope or curvature, slope-based strategies require precise immunization against level (duration) risk. These slope-based strategies also have to be made self-funding. As they are built from long and short duration-neutral positions, they entail leverage, which must be controlled.

20. One can also mention curvature-based strategies are based on the exploitation of convexity and require level and slope immunization. For more details, see Riccardo Rebonato and Vladislav Putyatin, "The Value of Convexity: A Theoretical and Empirical Investigation," *Quantitative Finance* 18(1), 2017, 11–30.

Strategies Based on the Prediction of the Level

As Equation (58-1) shows, the success of level-based ("carry") strategies is totally predicated on the ability to predict the future *level* of rates. Curve steepening or flattening does not contribute to their profitability. In practice, level-based strategies are implemented by being longer or shorter duration than a given benchmark (with no leverage and after funding). As their profitability is linked to the first mode of deformation, which is by far the most volatile, in general they give rise to the largest potential profits. It must be stressed, however, that in the current market conditions of extremely low rates, long-only carry strategies have very limited potential upside. Indeed, if their profitability is to be explained in terms of risk premia, most estimate currently suggest zero or negative risk compensation.

The literature on the predictability of level-based returns is large and has witnessed a true blossoming after the 2005 paper by Cochrane and Piazzesi, who discovered the "tent" factor.[21] Ludvigson and Ng[22] have shown that non-yield-curve factors greatly improve the predictability of returns, and Cieslak and Povala[23] employ a mixed yield-curve/macro-financial set of variables to obtain even greater predictability of returns. Rebonato and Hatano[24] extend the Cieslak-Povala approach and show how to build a whole class of parsimonious return-predicting factors with similarly high out-of-sample predicting power.

Given a set of factors, in order to establish when an investor should be longer or shorter duration than a benchmark, the excess returns calculated using Equation (58-1) are first regressed against a vector, $\mathbf{x}_t$, of yield-curve or macro-financial variables, denoted by

$$\boldsymbol{x}_t = \left[1; x_t^1, \ldots, x_t^k\right] \; :$$

$$xret_t = (\gamma^{(n)})^T \quad \boldsymbol{x}_t + \varepsilon_t \tag{58-2}$$

The quantities $(\gamma^{(n)})^T \quad \boldsymbol{x}_t$ are referred to as the *return-predicting factors*. We mainly work in what follows with the factors identified in the studies by Cochrane and Piazzesi, Cieslak and Povala, Fama and Bliss (slope), and Campbell and Shiller factors. In all cases, the factors are built from yield-curve variables (with the addition of macrofinancial information for the Cieslak-Povala model). More precisely, for the slope the single regressor is taken to be the difference between the 10-year and the 2-year yield; in the case of the Cochrane-Piazzesi factor the

21. John H. Cochrane and Monika Piazzesi,"Bond Risk Premia, " *American Economic Review* 95(1), 2005, 138–160.

22. Sydney Ludvigson and Sereena Ng, "Macro Factors in Bond Risk Premia," *Review of Financial Studies* 22(12), 2009, 5027–5067.

23. Anna Cieslak and Pavol Povala, "Expected Returns in Treasury Bonds," *Review of Financial Studies* 28(10), 2015, 2859–2901.

24. Riccardo Rebonato and Taku Hatano, "The Economic Origin of Treasury Excess Returns: A Cycles and Trend Explanation," Working Paper, 2018. Available at http://dx.doi.org/10.2139.

regressors are five forward rates[25]; for the Cieslak-Povala model, the factors are given by cycles, which, in turn, are built by regressing yields against a slow-moving average of inflation, τ_t:

$$y_t^{(n)} = a + b\tau_t + \varepsilon_t \tag{58-3}$$

and then using the residual, ε_t, as the maturity-depedent cycle:

$$cycle_t^{(n)} = y_t^{(n)} - a - b\tau_t \tag{58-4}$$

As Rebonato and Hatano[26] discuss, the quantity $a - b\tau_t$ can be interpreted as "where the yield should be" given the inflation expectation (proxies by the estimated long-term inflation trend). These cycles then become the right-hand variables in regression (58-2).

The Sharpe ratios and descriptive statistics of the unconditional carry strategy have already been shown in Exhibit 58-1. Exhibit 58-3 details the substantial improvement in Sharpe Ratios when conditional strategies based on the Cieslak-Povala (*CiP*) or Cochrane-Piazzesi (*CP*) return-predicting factors are employed. All the returns were calculated using one-year investment periods, monthly overlapping.

Strategies Based on the Prediction of the Slope

Turning to slope-based strategies, one may define a *flattener* strategy as the trade consisting of buying one unit of a 10-year zero-coupon bond and selling *R* units of the 2-year zero-coupon bond, where *R* is chosen so as to duration-neutralize the portfolio. The whole portfolio is cash positive, and the cash is invested in a zero-duration discount bond maturing at the end of the investment horizon.[27] After duration hedging, an unconditional flattener strategy has a (positive) Sharpe ratio that is barely statistically different from zero. However, one can again create a return-predicting factor, $(\beta^{(n)})^T \boldsymbol{x}_t$, using the regression

$$xret_t^{flattener} = (\beta^{(n)})^T \boldsymbol{x}_t + \varepsilon_t \tag{58-5}$$

where $xret_t^{flattener}$ are now the excess return from the unconditional duration-hedged flattener strategy, and the vector $\boldsymbol{x}_t$ contains either the level or the slope of the yield curve, or both. Maeso, Martellini, and Rebonato find that both slope and

25. In the original paper by Cochrane and Piazzesi, yearly returns for maturities out to five years were analyzed, and therefore the five forward rates exactly covered the maturity spectrum. When more return maturities than factors are used, as in our case, we retain the same number of regressors, and the five forward rates are evenly spaced along the maturity spectrum. The following study shows that the precise location of the forward rates makes little difference: Riccardo Rebonato, "Are Non-Level Factors Rewarded in The Treasury Yield Curve? EDHEC-Risk Institute Working Paper.

26. For more details, see Jean-Michel Maeso, Lionel Martellini, and Riccardo Rebonato, "Factor Investing in U.S. Sovereign Bond Market: A New Generation of Conditional Carry Strategies with Applications in Asset-Only and Asset-Liability Management," *Journal of Portfolio Management* 46(2) 2020, 121–140.

27. See Rebonato, "Are Non-Level Factors Rewarded in The Treasury Yield Curve?"

EXHIBIT 58-3

Conditional Carry Strategies Sharpe Ratios

Maturity	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cielsak-Povala	0.522	0.533	0.544	0.554	0.561	0.566	0.569	0.571	0.571
Cochrane-Piazessi	0.408	0.427	0.441	0.45	0.457	0.461	0.464	0.466	0.467
Unconditional	0.359	0.357	0.354	0.348	0.34	0.331	0.32	0.308	0.297

This exhibit reports the Sharpe ratios of the conditional carry strategies with the notional proportional to the Cieslak-Povala (*CiP*) or Cochrane-Piazzesi (*CP*) return-predicting factors (first two rows), and of the unconditional carry strategy (third row) for maturities from 2 to 10 years.

level are statistically significant predictors of profitability for the flattener/steepener strategy.[28] They also find that the sign of the slope coefficient in Equation (58-5) for the slope factor is positive both in the univariate and the bivariate regression. When the slope is high, the investor should enter a flattener strategy; when the slope is low, or the yield curve inverted, investors should engage in a steepener strategy. Additionally, the sign of the level coefficient is negative in the univariate regression and positive in the bivariate regression. Also the slope and level regressors are strongly negatively correlated, and therefore the significant increase in R^2 achieved by adding an explanatory variable that, on a stand-alone basis, has a negligible stand-alone R^2 that can be explained in terms of cooperative suppression[29] or reciprocal suppression.[30,31]

In sum, conditional flattener/steepener strategies present attractive and simple strategies; investors should enter flatteners when the yield levels are high and the curve is steeply sloped, and steepeners when yields are low and the yield curve inverted.

VALUE FACTOR

Value has been recognized as one of the most important factors for equities at least since the pioneering work by Fama and McBeth.[32] In equities, the ratio of book to market value has traditionally been used as a proxy for the value factor. Natural as this choice is for this asset class, it is difficult to translate the concept of value to the fixed income domain, and, for this reason, Fama and French[33] have argued that value does not apply to fixed income instruments in general, and to Treasury bonds in particular.[34] This seems to be at odds with recent literature, which claims to have found value (and momentum) "everywhere."

The "problem with value in bonds" is rendered more acute by the rather ad hoc definitions of value used for fixed income instruments. As discussed earlier

28. Maeso, Martellini and Rebonato, "Factor Investing in US Sovereign Bond Market: A New Generation of Conditional Carry Strategies with Applications in Asset-Only and Asset-Liability Management."

29. Jacob Cohen, Patricia Cohen, Stephen G. West, and Leona S. Aiken, *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences: Third Edition* (Mahwah, N.J: Lawrence Erlbaum Associates, 2003).

30. Anthony J. Conger, "A Revised Definition for Suppressor Variables: A Guide to Their Identification and Interpretation," *Educational and Psychological Measurement* 34(1), 1974, 34–46.

31. Intuitively, the increase in explanatory power stems from the fact that, owing to the negative correlation, both independent variables achieve higher explanatory power than in stand-alone regressions because when used together each independent variable is adjusted for the other.

32. Eugene F. Fama and James D. MacBeth, "Risk, Return, and Equilibrium: Empirical Tests," *Journal of Political Economy* 81(3), 1973, 607–636.

33. Eugene F. Fama and Kenneth R. French, "Common Risk Factors in the Returns on Stocks and Bonds," *Journal of Financial Economics* 33(1), 1993, 3–56.

34. Fama and French note that "explanatory variables like size and book-to-market equity have no obvious meaning for government and corporate bonds."

in this chapter, Asness, Moskowitz, and Pedersen have defined value for bonds as the (negative of the) five-year bond returns—a choice motivated by the observation that, in equities, this difference in returns is found to be positively correlated with the book-to-market ratio.[35] The factor thus defined may well predict future bond returns, but its interpretation as "value" seems at least stretched, and one, if not two, steps removed from the true latent underlying factor. As a result, the labeling of the chosen measure as "value" becomes rather arbitrary.

An Economically Motivated Definition for Value

Rebonato, Maeso, and Martellini[36] provide an arguably more satisfactory definition of value in U.S. Treasury bonds and show that the value quantity thus defined has very strong predictive power of future cross-sectional Treasury returns. More precisely, they identify "cheap" ("valuable") and "expensive" bonds using a dynamic Gaussian term structure models, and show that a systematic, no-peek-ahead strategy of investing in the cheap and shorting the expensive bonds has a strongly positive Sharpe ratio.

The affine model Rebonato, Maeso, and Martellini employ is written under the physical P measure as

$$dr_t = \kappa_t^P \left(\theta_t^P - r_t\right) dt + \sigma_t dw_t \tag{58-6}$$

$$d\theta_t = \kappa_\theta^P \left(\theta_\theta^P - \theta_t\right) dt + \sigma_\theta dw_\theta \tag{58-7}$$

$$E\left[dw_t dw_\theta\right] = \rho dt \tag{58-8}$$

The model can be interpreted as describing the actions of the monetary authorities who respond to deviations of the inflation and/or output gap from their desired target levels by adjusting the Fed Funds rate (in our model, the "short rate") toward the long-term NAIRU-compatible[37] nominal rate (the ultimate reversion level θ_θ^P). They do so, however, with a degree of urgency (of "aggressiveness") that depends on the economic conditions of the moment; the adjustment is therefore achieved by letting the short rate revert to a time-dependent reversion level, which in turn reverts toward the unchanging NAIRU-compatible long-term nominal rate, θ_θ.[38]

After the calibration procedure has been carried out, for each bond one can generate a time series of pricing errors by comparing the model price to the

35. "Value and Momentum Everywhere." They show "that individual stock portfolios formed from the negative of past 5-year returns are highly correlated with those formed on BE/ME ratios in our sample. . . . Hence, using past 5-year returns to measure value seems reasonable."

36. Riccardo Rebonato, Jean Michel Maeso, and Lionel Martellini, "Defining and Exploiting Value in U.S. Treasury Bonds," *Journal of Fixed Income* 29(2), 2019, 6–25.

37. The NAIRU is defined as the nonaccelerating inflation rate of unemployment, i.e., the unemployment rate which produces neither inflationary nor deflationary pressures.

38. More details on the model formulation, on the connection between the real world and the pricing measure and on model calibration can be found in the study by Rebonato, Maeso, and Martellini.

market price. As for the signal, it can be formed for each bond by taking the difference between a slow-moving average and an adjusted fast-moving average of price errors. To establish a trading strategy, one may set the notional of the position in each bond to be proportional to the strength of the signal for that bond on that day.

Typical patterns for the two moving averages and the resulting signal are shown in Exhibit 58-4. As the exhibit shows, the trading signals tend to display a clear mean-reverting behavior, with reversion speeds implying half-lives of several weeks to a few months. This observation is important because it suggests that the signal is practically exploitable, in that it requires neither excessively long investment horizons nor overly frequent rebalancing.

On any given day, a trading strategy will consist of long positions in cheap bonds and short positions in expensive bonds. The resulting portfolio will not have a systematic long or short bias but, on any given day, it will not have exactly zero cost and will not be exactly duration neutral. To neutralize for the impact of systematically decreasing (or increasing) yields, one may control for a possible residual duration exposure in the portfolio by calculating the net portfolio duration, and by subtracting the hypothetical profit (or loss) that a portfolio with that residual duration would make given the change in average yield from one day to the next.

Profitability of the Strategy

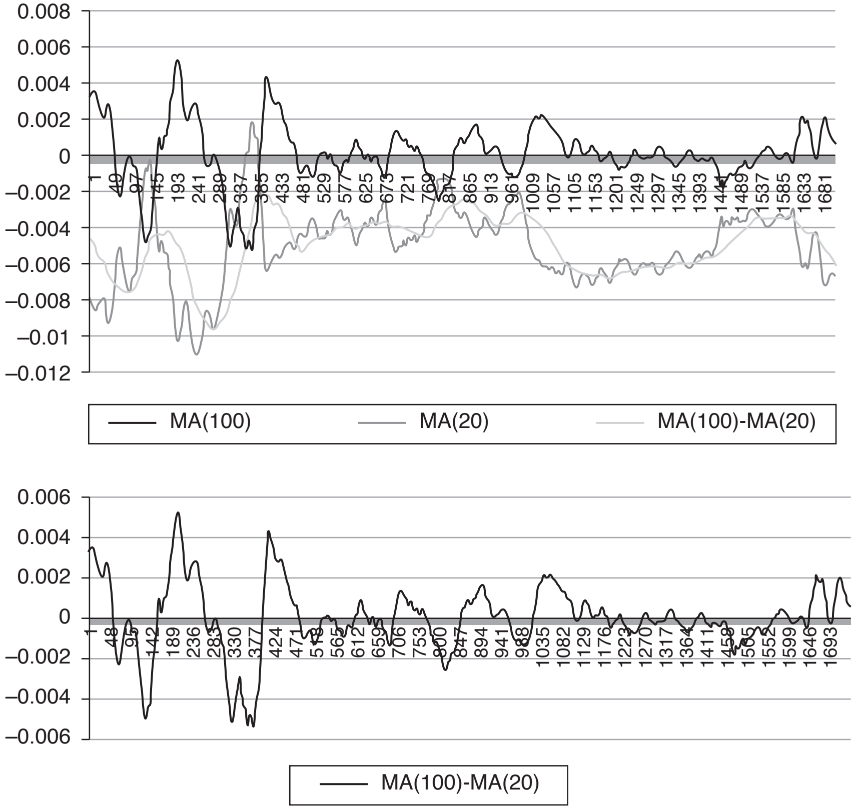
Implementing a version of this strategy, Rebonato, Maeso, and Martellini[39] obtain results shown in Exhibit 58-5, which displays the ratio of the strategy returns and volatility, that is, the Sharpe ratio of the funded, duration-neutralized strategy. They find that the Sharpe ratio is positive in 14 out of 15 of the three-year blocks under study, has tended to decline over time but is often very high, is never significantly negative, and is significantly greater than zero at the 99.9% confidence level in 12 out of 15 blocks.

They also note that the strategy tends to produce high returns (but not necessarily high Sharpe ratios!) when the market volatility is high: in these periods, the volatility of the strategy is also high, and therefore the Sharpe ratios do not display this link with the market volatility. This finding is significant because it suggests a clear indication of the origin of the profitability of the strategy. These results can, in fact, be reconciled with the findings by Hu, Pan, and Wang,[40] who establish a link between price errors ("noise" in their terminology [p. 2341]) for Treasury bonds and a general decrease in market liquidity. The explanation they offer is that the greater the decrease in liquidity, the greater the difficulty encountered by pseudo-arbitrageurs in carrying out the trades that should bring Treasury prices in line with fundamentals. To the extent that an increase in volatility can be

39. "Defining and Exploiting Value in U.S. Treasury Bonds."
40. "Noise as Information for Illiquidity."

EXHIBIT 58-4

20-Day and 5-Day Moving Averages for CUSIP 912810CU and Their Difference (Top Panel), and the Associated Trading Signal (Bottom Panel)



associated with a decrease in market liquidity, the findings of our study are consistent with the interpretation in Hu, Pan, and Wang and provide a rationale for the source of profitability of the strategy. And if, indeed, high returns are reaped in periods of high market volatility, it is not surprising that in these periods also the volatility of the strategy should be high, as the deviations from fundamentals may well increase (giving rise to temporary losses) before eventually reverting toward their reversion level.

Rebonato, Maeso, and Martellini also explore a long-only version of the strategy, which at any point in time only invests an equal amount in those bonds that, according to the model, are underpriced (cheap). They find that the long-only strategy outperforms, in terms of Sharpe ratio, the market portfolio in 14 out of the 15 three-year periods. These results are very important for the practical applicability of the strategy for many institutional investors, who often have long-only constraints.

EXHIBIT 58-5

Sharpe Ratios for the Strategy in the Three-Year Block in the Left Column for 2 and 20 Days in the Short and Long Moving Averages

Date	Sharpe Ratio
1975–1977	0.565
1978–1980	0.573
1981–1983	1.348
1984–1986	1.820
1987–1989	1.081
1990–1992	1.235
1993–1995	–0.014
1996–1998	0.110
1999–2001	1.282
2002–2004	0.691
2005–2007	0.326
2008–2010	2.716
2011–2013	0.876
2014–2016	1.812
2017–2018	1.121

MOMENTUM FACTOR

Momentum strategies have been found to be profitable in a wide number of asset classes. In equity markets, a well-known early example of academic research in this area is the study by Jegadeesh and Titman,[41] who find over the period 1965–1989 a statistically significant positive performance for dollar-neutral cross-sectional momentum strategies that purchase best performing U.S. stocks over the past 3 to 12 months, sell the losers, and hold the position for 3 to 12 months. Cross-sectional momentum strategies have also been studied in the U.S.

41. Narasimhan Jegadeesh and Sheridan Titman, "Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency," *Journal of Finance* 48(1), 1993, 65–91.

equity market by Moskowitz and Grinblatt,[42] and in European stock markets by Rouwenhorst.[43] Similar cross-sectional strategies have then been found profitable in currencies.[44] All these cross-sectional strategies consist of buying (selling) securities that recently outperformed (underperformed) their peers over the past 3 to 12 months.[45]

Rebonato, Maeso, and Martellini[46] complement this strand of the literature by presenting a systematic empirical investigation of the profitability of cross-sectional momentum and reversal strategies in U.S. Treasuries, using more than 40 years of daily data at the individual security level. Looking at the security level is very important, because studies that instead employ "synthetic" zero-coupon bonds can be vitiated by the well-known serial autocorrelation of pricing errors, which can masquerade as a momentum effect.[47]
Rebonato, Maeso, and Martellini apply the following empirical methodology[48] to build a zero-cost cross-sectional momentum strategy:

1. Fix a lookback period of L months and a holding (investment) period of H months; for example, take (L, H): (3, 3), (6, 6), (9, 9) and (12, 12).
2. At end of month date t, consider all the N_t bonds that (i) are in the universe at date t, (ii) were in the universe at date $t-L$, and (iii) that will be in the universe at date $t+H$.
3. At date t, compute for each bond i its relative L-month past excess return with respect to the market: $\left(r_{i,t}^{L} - r_{m,t}^{L}\right)$. $r_{i,t}^{L}$ is the bond i L-month past performance and $r_{m,t}^{L}$ is the market L-month past performance.
4. At date t, assign to each bond i the weight: $w_{i,t} = \frac{1}{\mathrm{N_t}}\left(r_{i,t} - r_{m,t}\right)$. Note that we have $\sum_{i=1}^{N_t} w_{i,t} = 0$.

42. Tobias Moskowitz and Mark Grinblatt, "Do Industries Explain Momentum?" *Journal of Finance* 54(4), 1999, 1249–1290.
43. Geert Rowenhorst, "International Momentum Strategies," *Journal of Finance*, 53 (1998), 267–284.
44. See, for example, Lukas Menkhoff, Lucio Sarno, Mark Schmeling, and Andreas Schrimpf, "Currency Momentum Strategies," *Journal of Financial Economics* 106(3), 2012, 660–684.
45. One can also define time-series momentum, namely, the strategy of looking at the past performance of each security over the last 3 to 12 months, and of buying (selling) those with positive (negative) past performance over a certain investment period.
46. Riccardo Rebonato, Jean Michel Maeso, and Lionel Martellini, "Factor Investing in Sovereign Bond Markets: Cross-Sectional and Time-Series Momentum in U.S. Sovereign Bond Market," EDHEC-Risk Institute Working Paper, 2019.
47. For instance, the widely used zero-coupon bond prices was used by Refet S. Gürkaynak, Brian Sack, and Jonathan H. Wright, "The U.S. Treasury Yield Curve: 1961 to the Present," *Journal of Monetary Economics* 54(8), 2007, 2291–2304. They are obtained by fitting the Nelson-Siegel model to the market prices of coupon-bearing bonds. (Charles R. Nelson and Andrew F. Siegel, "Parsimonious Modeling of Yield Curves," *Journal of Business* 60(4), 1987, 473–489.) As the authors recognize, these fitted prices suffer from serially correlated pricing errors.
48. This methodology was first suggested in Jonathan Lewellen, "Momentum and Autocorrelation in Stock Returns," *Review of Financial Studies* 15(2), 2002, 533–563.

5. Normalize the weights so as to have a cross-sectional zero-cost momentum portfolio, that is, to be 1$ long and 1$ short at the beginning of the investment period:

$$w_{i,t}^{norm} = \frac{w_{i,t}}{\sum_{i=1}^{N_t} w_{i,t}^{+}} \text{ where } w_{i,t}^{+} = w_{i,t} \text{ if } w_{i,t} > 0 \text{ and } w_{i,t}^{+} = 0 \text{ otherwise.}$$

Finally, applying a duration-adjustment to the notional of the short and long positions by dividing the returns of each bond by their duration, and the duration-adjusted market return is the cross-sectional average of the duration-adjusted bond returns. Duration adjustment, *which does not imply duration neutralization*, is performed so as to achieve an approximate risk parity (volatility parity) among the various constituent bonds.

When they do so, Rebonato, Maeso, and Martellini[49] find significant profitability for all the duration-adjusted *reversal* (as opposed to momentum) strategies, and significant results for three out of the four lookback/investment periods (6, 9, and 12 months). Exhibit 58-6 displays some of these results, which show that the annualized mean return of the 6-, 9-, and 12-month duration-adjusted reversal strategies are 0.9%, 1.1%, and 1.3%, respectively, over their sample period.

EXHIBIT 58-6

Descriptive Statistics of Duration-Adjusted Long-Short Cross-Sectional Momentum Strategies

Look-Back and Holding Periods (months)	**3M**	**6M**	**9M**	**12M**
Mean return (annualized)	–0.5%	–0.9%	–1.1%	–1.3%
Volatility (annualized)	3.8%	3.8%	3.9%	3.8%
Sharpe ratio	–0.14	–0.23	–0.29	–0.34
t-stat (Newey-West)	–1.16	–2.21	–3.13	–4.11

This exhibit reports the main descriptive statistics (annualized mean total return, annualized volatility and Sharpe ratio) of the long-short cross-sectional momentum strategies with duration-adjustment. The row labelled “t-stat (Newey-West)” reports the *t*-statistic for the rejection of the hypothesis that the mean in the first row is zero.

From the perspective of important classes of institutional investors with investment constraints, long-only portfolios are particularly relevant, and the strategy presented above can be implemented in such a way as to meet long-only constraints. More specifically, one can naturally compare the returns from giving each bond in the universe an equal duration-adjusted notional with the returns from the strategies of giving equal duration-adjusted weights to the previous

49. “Factor Investing in Sovereign Bond Markets: Cross-Sectional and Time-Series Momentum in U.S. Sovereign Bond Market.”

period winners and losers. The results obtained in a long-only context also suggest that the reversal ("losers") portfolio outperforms the momentum ("winners") portfolio and the market portfolio in term of mean return.

KEY POINTS

- Factor investing in equities has traditionally been focused on identifying securities with positive and negative exposure to rewarded factors and building long-short portfolios to exploit this difference in exposure via cross-sectional strategies.
- The prevailing academic approach for equity factor strategies has been to assume a constant premium.
- Return studies in the fixed income area have taken the complementary view of focusing on the state dependence of the factor, invariably assumed to be associated with the level ("duration") risk, and of constructing unleveraged, time-series strategies.
- Recent empirical evidence suggests that slope-based strategies are profitable, and that their profitability may arise from a residual degree of predictability in the mean-reversion properties of the yield-curve slope once business-cycle components have been accounted for.
- The empirical evidence suggests that value-based cross-sectional strategies are not only statistically significant but also economically profitable.
- Profitability of reversal (as opposed to momentum) strategies over a wide range of look-back and investment periods have been found to be profitable.
- Overall, empirical findings suggest that both time-series and cross-sectional factor investing in the fixed income market are a vibrant field of research and fruitful sources of practically implementable strategies.

CHAPTER
FIFTY-NINE

HEDGE FUND FIXED INCOME STRATEGIES

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In this chapter, we discuss several common hedge fund fixed income investment strategies, including macro, asset-backed credit, capital structure arbitrage, long/short credit, distressed, basis trading, volatility trading, and cross-currency arbitrage. We believe that a solid understanding of macro-economic conditions, the economic environment, and the influence of policymakers and participants is critical for any robust investment strategy, including fixed income hedge fund investment strategies. Therefore, we begin with a discussion of macro investing fixed income strategies, focused on interest rates and currencies, and then move into further discussion of other strategies that are relative value arbitrage ones, as well as long-biased ones. The performance of all of these strategies is dependent upon the portfolio manager's ability to take advantage of deviations in asset prices from their fair values. This process requires having analytical tools and a historical context within which to gauge asset price deviations and their potential for corrections. Relative value, asset-backed, and arbitrage strategies require more sophisticated valuation tools for the computation of the expected value of security cash flows.

MACRO INVESTING

All elements of fixed income investing require an understanding of the macroeconomic framework and the macro-political economic environment. The macro initial condition will dictate a growth and price stability bias. The macro policy bias will determine the set of policy choices appropriate to achieve the policy bias objective. The philosophical bias of policymakers influences the analytical framework within which initial conditions are diagnosed. The elements of macro economies include by country or region: political framework, economic biases, banking system management, central bank growth and political biases, government balance sheet conditions, initial macro credit conditions, political decision-making process, and currency management, among others.

The complex dynamics of the interaction of these considerations will result in a directional bias for many (if not all) of the risk parameters that concern portfolio managers. The interest-rate direction, yield-curve shape, volatility of interest rates, risk spreads, and currency valuation depicted in Exhibit 59-1, along with the corresponding second derivatives of each, are dominated by the dynamics of the macro system.

Many attributes define the macro-political economic environment. The institutional architecture is certainly very important. This is defined by political, banking, and legal systems. While these systems may be easily understood conceptually, they morph over time as the political/philosophical bias of the people in charge change as well as changes in the attitude of the general population occur, which can happen much more slowly.

Understanding the philosophical economic bias of each region is vital to anticipating policy and changes in policy. The primary objectives are simple and straightforward. In the United States, the stated objectives are a stable rate of inflation and full employment. The Europeans concern themselves most with price stability. The Chinese have traditionally seemed more concerned with internal industrial development via a mercantilist export policy. Each country will have a particular objective at any particular time, and over time the importance of any particular objective will change as conditions change. Moreover, the philosophical bias evolves as a country evolves. In his *Republic,* Plato describes a very plausible evolution of political rule. Among those considered include democracy, aristocracy, oligarchy, philosopher kings, monarchy, socialism, totalitarianism, and dictatorship. The implications of each are quite important to investment decisions, as are the migration of regime one to another.

In a 1968 article, Milton Friedman elaborates on public policy priorities, potential policy choices, and the difficulty of effective implementation:

> To state the general conclusion still differently, the monetary authority controls nominal quantities—directly, the quantity of its own liabilities. In principle, it can use this control to peg a nominal quantity—an exchange-rate, the price level, the nominal level of national income, the quantity of money by one or another definition—or to peg the rate of change in a nominal quantity—the rate of inflation or deflation, the rate of growth or decline in nominal national income, the rate of growth of the quantity of money. It cannot use its control over nominal quantities to peg a real quantity—the real rate of interest, the rate of unemployment, the level of real national income, the real quantity of money, the rate of growth of real national income, or the rate of growth of the real quantity of money.

EXHIBIT 59-1

Expected Changes in Market Variables Relative to Changes in Economic Growth

	Early Growth	Mid-Growth	Late Growth	Recession
Rates	Stable	Increasing	Increasing	Falling
Yield Curve	Positive	Flattening	Inverting	Steepening
Volatility	Low	Moderate	High	High
Risk Spreads	Narrowing	Narrowing	Narrowing	Widening
Currency	Appreciate	Appreciate	Appreciate	Depreciate

UNDERSTANDING THE COMPONENTS OF THE STATISTICS

With an eye to dissecting aggregated statistics, the investor should analyze key economic data such as debt-to-GDP ratio, exports and imports as a percentage of GDP, banking system leverage, aggregate bank assets, nominal government spending, personal savings rates, net national savings, expected changes in FX rates, inflation rates, GDP nominal and real rates, and unemployment rates, among others.

Understanding the trend of any particular statistic is insufficient. Understanding the distribution of components of the statistic is vital. In this regard, it is most important to distinguish between the distribution of debt formation, both public and private, directed to consumption and that associated with investments. It is important to understand the distribution of prices associated with inflation. It is important to understand the components of trade, both exports and imports, associated with consumption and investments. The implications of the distributions are vitally important to predictions of the future and to an inferential understanding of the motivations of policymakers and the public at large. Also vital to the process is an understanding of when policy end points are near and the implications thereof. A microscopic understanding of the data will enable the investor to decide what coefficients to assign to each statistic and to change the coefficients when appropriate.

Armed with data that may differ somewhat across sources, the portfolio manager's challenge is to forecast various risk parameters, knowing there is more to economic behavior than statistics. The portfolio manager must also account for regulatory changes, sociological conditions, political risk, and the psychology of the participants. One looks to the markets for inferential valuations that presumably synthesize all of these criteria. After all, money-making is a bet against forward prices. So, forward rates, yield curves, and currency values are all requisite inputs to the portfolio manager's decisions after an assessment of all of the statistics and after an evaluation of all of the political/economic/philosophical judgments.

BIG CHANGES ARE VERY IMPORTANT

The price of an asset is simply the intersection of supply and demand. Activist policy institutions such as the U.S. Federal Reserve Bank, the European Central Bank (ECB), the Bank of England, and the Bank of Japan have decided to change their status from referee to both player and referee and to engage directly in the markets in such a way that they become price setters. ZIRP (zero interest rate policy) and NIRP (negative interest rate policy) across much of the non-U.S. developed market have created significant changes in the pricing of all assets, and of course of the global bond markets. This is a most important fundamental change to capitalism. Direct government interference in capital markets means that prices are less subject to fundamental macro valuations described herein and more a function of the "social" desire of policymakers. This is a gigantic change and during such a change the portfolio manager must consider placing political, sociological, and philosophical forecasts ahead of the traditional economic forecasts associated with a "capitalist" system.

THE YIELD CURVE

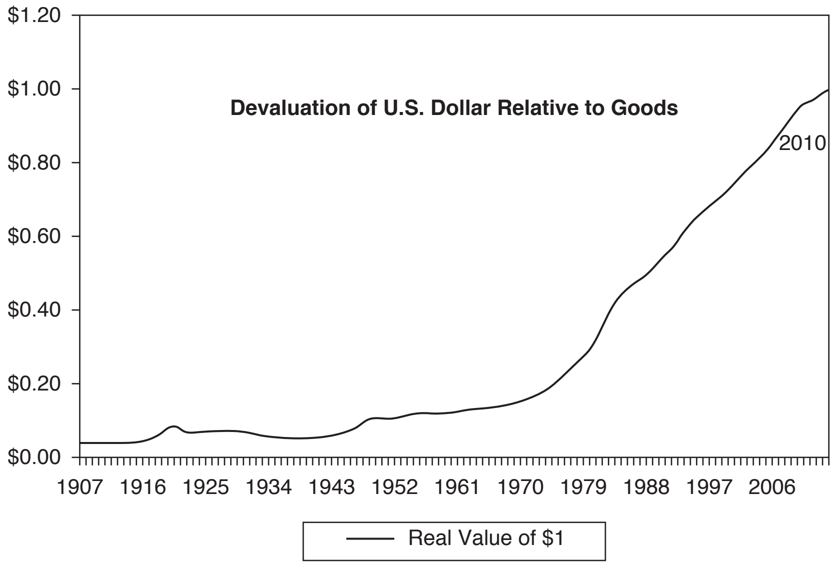
The yield curve is a mapping of interest rates for various lending periods for a particular issuer. The yield-curve shape can vary substantially, and changes in the shape of the yield curve can be an important source of return to the investor. Longer maturities typically yield more because there is more pro-inflation risk and credit risk embedded within them and they are less liquid than shorter maturities. Absent credit risk considerations, longer-maturity securities' yields are lowered because of their higher convexity, which takes on greater value when interest rates become more volatile. In addition, we observe an example of the pro-inflation tendency of policy in the United States from 1907 to 2011 in Exhibit 59-2.

Creditors generally cannot foreclose on a sovereign issuer. Defaults on sovereign issuers result in "restructuring," in which creditors receive a fraction of their principal back. So, in anticipation of a potential restructuring, rates increase on the sovereign to reflect increased credit risk. The increase in rates further impairs the sovereign's credit, thereby increasing default probabilities because the interest rate itself is higher than the rate of sovereign growth, growth that itself is reduced by the higher interest rate. Moreover, over very long periods, demographic trends become an increasingly important variable if there is a large outstanding debt. Reductions in population growth translate into fewer workers to contribute to debt servicing and increases in the forward population relieve the debt burden.

The sovereign credit default swap (CDS) market is yet another check on the creditworthiness of the sovereign and the change in credit status. The CDS market is one in which investors can buy and sell insurance on sovereign credit.

EXHIBIT 59-2

U.S. Inflation Policy



A policy is triggered, and the insurance collected if and only if a default occurs or a restructuring, if the CDS contract so specifies. The CDS spread is relative to a standardized LIBOR term and should map closely to the yield spread on that sovereign's bond to the same term rate. Technical contract specifications and potential for regulatory interference cause the two spreads to be unequal. However, the direction of the spreads should be consistent most of the time.

Economic inferences and dynamics, forecasts for interest rates and currencies are, as discussed, much more complex in a highly globalized world economy. Traditionally, currency forecasting was a function of interest-rate differentials, growth and inflation, trade and capital flows, differentials and purchasing-power parity. Post the 2008 financial crisis, there has been an increasing focus on the growth in relative factor productivity and net trade flows. The military strength of a nation is always a very important consideration.

Many financial economists and investors believe the output gap is an important determinant of inflation. The output gap and inflation are inversely related as the output gap measures the degree of abundance of resources in the economy. The output gap theory relies on empirical Phillips curve analysis, which measures the historical relationship between labor and inflation.

Currency debasement, inflation, and taxation are all substitute expropriating vehicles in addition to regulatory tools, such as capital controls, the sovereign has at its disposal. The selection of vehicles is made in consideration of prevailing conditions paramount to an investor in sovereign bonds and currencies relative to forward values. Exhibit 59-3 is a crude mapping of currency and bond strategy given a particular policy circumstance.

In regard to the valuation of currencies in the spot and forward markets, any differences between U.S. and another country's interest rates implied by forward over prevailing rates represents the speculative motive in that market or is indicative of high transaction costs.

EXHIBIT 59-3

Implications of Policy Choices

	Capital Controls	Increase Taxes	Reduce Taxes	Inflate	Deflate	Increase Spending	Decrease Spending
Bonds	–	+	–	–	+	–	+
Currency	–	Amb	Amb	–	+	Amb	Amb

+ Buy, – Sell, *Amb* ambiguous.

POLITICAL SELF-INTEREST VERSUS INTEREST OF THE SOVEREIGN

Politicians and policymakers can be predisposed to do what is in their best interest as opposed to the national interest. The national interest is, as discussed in the beginning of this chapter, a function of one's underlying political/philosophical/economic beliefs. To the extent that politicians get re-elected by providing benefits to the population through spending programs, we will observe an accumulation of debt and a generalized inflation over time. This has certainly been the case for the United States. Exhibit 59-4 provides inferential support for the thesis that politics in democratic nations are incentivized to increase debt for the purpose of providing greater benefits to its constituents with the hope of re-election.

Investors in bonds and currencies must consider the psychological impact on policymakers' behavior when legacies are in the making. The period from the 2008 financial crisis through 2011 is an example of a period when legacies are at risk and monumental global financial and social change is proceeding. It is a time for bond and currency investors to evaluate the efficiency and sustainability of policies, as well as realistic alternatives to prevailing policies and the implications thereof. Investors should heed the council of notable economists of the past. Specifically, Keynes' policy prescription to a financial crisis might result in "euthanasia of the rentier,"[1] as well as Robert Triffin's concern about the

1. Chapter 24 in John Maynard Keynes, *The General Theory of Employment, Interest, and Money* (Cambridge, MA: Harcourt, Brace and Company, 1936).

EXHIBIT 59-4

Sample Spot and Forward Currency Valuation

		One-Year		Three-Year		Five-Year	
	Spot	**Fwd**	**Implied**	**Fwd**	**Implied**	**Fwd**	**Implied**
USD			0.45%		1.33%		2.23%
Europe	1.3592	1.3518	0.98%	1.3405	1.80%	1.3561	2.34%
Australia	0.9912	0.9456	5.28%	0.8725	5.59%	0.8251	5.91%
China	6.585	6.4625	–1.35%	6.2577	–0.40%	6.0015	0.57%

responsibility of the custodians of the reserve currency: "We should be as averse as foreign countries—or more so—to incurring again the awesome political responsibilities and inflationary temptations inseparable from the exorbitant privilege of having our national currency used as the main international currency of the world."[2]

Macro fixed income hedge fund investment is one significant hedge fund style of investing. The rest of this chapter is devoted to other styles ,including asset-backed credit, capital structure arbitrage, long/short credit, distressed, basis and volatility trading, and cross-currency arbitrage.

ASSET-BACKED CREDIT STRATEGY

The asset-backed credit strategy is a long/short style of portfolio management that focuses on investing in securitized debt obligations, which may encompass a wide variety of types of debt from residential and commercial mortgages to leases and credit cards. The portfolio manager seeks to identify asset-backed securities that they believe are mispriced relative to the value of the supporting loan collateral for long or short investments. This strategy is focused, generally, on higher-yielding securities backed by loans to riskier borrowers, but not exclusively so.

The best opportunities to purchase mispriced asset-backed securities generally occur during significant dislocations in the credit markets. Practitioners of this strategy will often develop complex proprietary models to value collateral referencing a given security with the goal of ascertaining whether that security may or may not have a greater liquidation value and principal and interest payment stream than is built into the current pricing. These valuation models will include current information such as payment delinquencies as well as payment projections over the expected life of the security. These models will have the ability to analyze loan level data. Hedging or shorting in this strategy may tend to focus on hedging macro risk factors such as general market declines as well as use derivatives on specific vintage or year and seniority in the payment of a securitized obligation.

The types of asset-backed credit collateral considered as a potential investment set for the credit strategy includes agency and agency-issued residential mortgage securities, primarily, as well as consumer credit asset-backed securities, commercial mortgage securities, and commercial nonmortgage-asset-backed securities, among others. The largest asset-backed credit group, residential mortgages, consists of securities backed by the differing mortgage loan types.

These loans are not only securitized into pooled obligations but are further divided into tranches tiered by payment priority loss. The lower the payment priority, the higher the default risk, but also the higher the current yield. Part of this investment strategy is for the portfolio manager to not only identify misvalued

2. Robert Triffin, "The International Role and Fate of the Dollar," *Foreign Affairs* 57(2), 1978/79, Council on Foreign Relations.

securities but misvalued tranches. At times, the cheapest security may be the first loss and in other instances it may be the top of the structure. The portfolio manager may also choose to allow their impression of the market environment determine where they are most comfortable in the tranche structure with the view that defaults have a cyclical component.

A portfolio manager may also choose to purchase securities that are "seasoned," meaning that they are older. Borrowers that have been current on their payments, historically, tend to continue to pay. However, seasoned securities tend to be more fully priced and are less likely to be cheap. Short strategies tend to be hedges designed to protect from systematic risks such as against general deterioration in all asset prices. Less security specific, these hedges might include both stocks and bonds or their derivatives due to limited ability to short or borrow cash securities particular to the asset type of the long positions.

Some of the underlying collateral trends monitored by the portfolio manager include home and commercial property price appreciation, cumulative default rates, delinquency trends, cumulative loss rates, loss severity from sale, loan-to-value rates, loan modification levels, liquidation rates, geographic REO levels, commercial sector demand, and unemployment rates, among others. Because default rates are the primary risk factor in this asset class, the asset-backed credit portfolio manager will monitor the performance of the underlying loans behind the asset-backed securities held and the ones under consideration for possible inclusion in their portfolio. Some details include the number of reference loans that are delinquent, length of time delinquent, nonperforming, in foreclosure and liquidated, as well as restructured and re-performing.

Hedging techniques and possibilities have greatly expanded in scope and potential for this hedge fund strategy over time. At one time, one could only primarily think in terms of hedging systematic or cyclical risk. One would choose broad-based credit, interest-rate, or even equity indices to provide downside protection. However, during the beginning stages of the housing debt market crisis a proliferation of derivative products that referenced asset-backed securities and tranches of asset-backed securities by type were developed that offered ways to more directly hedge or short sell residential and, later, commercial asset-backed securities. These derivatives are tranched, allowing for a more specific type of asset-backed hedge or short sale instrument.

CAPITAL STRUCTURE ARBITRAGE

Capital structure arbitrage is an investment strategy that is typically focused on stressed or distressed companies. These are ones with high balance sheet leverage. A capital structure arbitrage portfolio manager considers all securities of a company (debt and equity) for possible mispricing or relative mispricing. They view the securities by payment priority against current cash and future earnings potential. They assess value by ascertaining probabilistic ability to pay debt obligations as well as potential realized equity valuation. Capital structure arbitrage is an investment strategy that is flexible and broad enough in scope to accommodate opportunities that arise throughout the credit cycle. For example, the portfolio manager may be more constructive on holding equity that appears cheap versus a senior debt short hedge during an economic recovery and shorting equity while holding senior secured debt during economic contraction. Other times, the financial merit of a company's outstanding securities may hold a case independent of economic times. The portfolio manager will likely identify a specific catalyst event that will correct the senior versus junior security relative value mispricing. This catalyst could be an upcoming refinancing or a business specific event. This strategy tends to use low levels of leverage as the companies invested in have high levels of balance sheet leverage.

The layers of securities within a company can be quite varied from senior secured bank debt with strong covenants to the most junior security or equity-based ones. Each of these securities can be expected to have unique volatility characteristics. The more junior a security, the more likely it will be relatively more volatile. The portfolio manager must consider this volatility when positioning long and short as this will affect the overall P&L volatility exposure to their portfolio.

The portfolio manager must evaluate the covenants of outstanding debt and ascertain payment priority, which can be complicated. The most difficult layer of complication comes from companies with multiple subsidiaries. Subsidiaries and holding companies may have cross-liabilities and not be entirely self-reliant. The portfolio manager must also factor in debt maturity schedules as an important element of valuation against their prediction of future ability to make interest and principal payments. Often the clarification of payment priority and asset rights are resolved in a court of law. The portfolio manager must have a thoughtful way of assessing the likely bankruptcy proceeding outcomes in regard to the various debt instruments outstanding. This process can be fairly long and the outcomes uncertain. However, these securities are usually ones that can be sold or traded long before final legal decisions are reached.

A capital structure arbitrage portfolio is likely to contain multiple positions in various securities within the capital structures of many companies. Each of these companies is likely to be or anticipated to be experiencing some form of structural change as a result of meaningful current or prospective corporate events. The events may not only include a changing capital structure specific to one company but may represent changing financial fortunes inflicted by the larger macroeconomic environment on many sectors of the economy. Often the capital structure arbitrage portfolio can be concentrated by sector as industry dynamics can affect multiple companies at once in a way that creates opportunity unique to that sector. The portfolio manager thinks in terms of various scenarios with probabilistic outcomes. The long and short security weightings will reflect their probabilistic assessments. Longs may hold a larger weight if stronger economic fortunes are expected ahead, for example. Events have varying time frames and the portfolio manager is also likely to assess the attractiveness of an opportunity based on the present value of the expected price change of the securities positioned.

Hedging in this strategy tends to be company specific, whether on a junior or senior security basis. However, it is usual to see industry-level hedges or even index-based ones in this strategy. Capital structure arbitrage portfolios can tend to be net long for the company specific positions. Other more generalized hedging techniques may often make sense to deploy in order to mitigate overall market beta exposures.

LONG/SHORT CREDIT STRATEGY

The long/short credit strategy is also referred to as a relative value strategy or a fixed income arbitrage strategy. Within any of these descriptions are multiple substrategies or investment approaches. Some of these substrategies may have very specific tightly hedged arbitrages while others have more systemic or generalized hedging approaches. Long/short credit strategies can include debt securities within the entire credit spectrum from investment-grade to high-yield and distressed. All approaches depend upon a bottom-up analysis of a given company's ability to pay its debt obligations based on its business model and its revenue prospects. Similarly, portfolio managers are focused on economic and leverage cycles, which affect companies' abilities to meet their debt obligations. A long/short credit portfolio can consist simply of diverse bond positions both long and short of companies that the portfolio manager feels are worthy of taking a positive or negative view based on current default probability versus current price. A portfolio manager can be expected to hold overall exposure ranging from net long to closer to market neutral. Practically speaking, it is unusual for a portfolio to be consistently net short.

Cash corporate debt (loans, bonds, and preferreds) and derivatives, both single company reference as well as index and tranches of indices, are the main instruments used, in addition to sovereign debt instruments. However, interest-rate and equity instruments are used to hedge or emphasize certain desired exposures. Specifically, cash corporate debt obligations are ones that have some claim or payment priority in the event of corporate default. Derivative instruments, credit default swaps, are generally bi-lateral payment agreements between two contractual parties based upon the financial fortunes of a referenced entity. These instruments represent no direct obligation of the referenced company in the event of default. These instruments will be assessed based on a given entities' prospective cash flows, asset quality, covenant protection, possible catalysts that may alter an entity's future earnings capabilities, industry trends, overall default rates, credit conditions, industry, and broad economic factors, among others.

The long/short credit portfolio manager may take several different approaches toward building their portfolio. They may construct a credit long book and a credit short book with the net and gross exposures reflecting some macro point of view regarding underlying market volatility and near-term direction. In general, the gross market value of the aggregated positions versus assets under management can be expected to be larger for higher-rated, lower-spread debt than lower-rated, wider-spread debt. Such construction reflects a risk attitude that the latter is likely more volatile in price.

Directional longs may include the debt or credit derivatives of out of favor, stressed, distressed companies; debt whose prices seem to be below their fair price as assessed by the portfolio manager or of companies undergoing positive changes. Directional shorts may include the debt of or credit derivatives of companies that are experiencing a cyclical decline, whose prices seem to be above their fair price given future earnings potential as assessed by the portfolio manager or provide opportunity to profit from the part of the leverage cycle in which all corporate bond spreads are widening. The portfolio manager can be expected to use leverage but hold some reasonable portion of unencumbered or excess cash over their margin requirements. The amount of unencumbered cash held will rise and fall depending on the overall conditions of the markets, both by cyclicality and opportunity. Depending on the risk appetite of the portfolio manager, their portfolio may be highly diversified with hundreds of positions or be more concentrated. Generally, over time the more concentrated a portfolio, the more volatile that portfolio's valuation can be expected to be. Concentration can refer to position size, ownership percentage of a particular debt issue, geography, industry, and credit quality, among others.

Of a given debt issue, the higher its investment rating, the lower the probability of its default; however, the return distribution of such a debt issue will be negatively asymmetrically skewed with more downside potential than upside. This is what makes hedging interesting in this strategy. Hedging can be company specific in such a way that overlaps with capital structure arbitrage and involve other debt in the same company as well as reference credit default swaps. Hedging or shorting can be used to express a negative view on a company or a sector as well as to maintain a net short position during times of market turmoil. Hedging can also be as broad in nature to include generalized equity, credit, and interest-rate hedges. The more tightly hedged, market neutral, or investment-grade focused a given portfolio is, the greater the likelihood leverage will be higher than otherwise. Concentrated or net long portfolios can be expected to be commensurately less leveraged, as this type of portfolio will be more volatile than a market neutral one.

DISTRESSED DEBT

The distressed investing strategy is one that focuses on investing in the securities of companies experiencing financial stress. They may or not be in default. The investment situations may be ones that are meant to focus on improving corporate balance sheets, others may be liquidation investments in which a company's securities may represent a claim on valuable assets, including cash, some liquidity investments in which refinancing will provide the necessary time for a company to recover, or litigation investments in which the portfolio manager may participate on creditor committees and the value of certain securities will be determined in a court of law. As well, some positions may be short ones in deteriorating companies that are losing market share or are cyclical in nature. All positions will generally be constructed with an identifiable catalyst or some event, usually corporate specific, that will unlock the value potential of securities held in the portfolio.

The securities held in the portfolio of a distressed strategy can include all parts of the capital structure of a company, holding company, or subsidiary as well as aggregated debt securities as described in the asset-backed security strategy section. Securities range from senior secured debt (such as bank loans) to subordinated debt (such as second lien debt) down to more junior secured securities (such as busted convertibles trading well below the convertible price and equities). Other types of debt securities exist only with companies experiencing financial distress, such as debtor in possession (DIP) or rescue financing. The lower the debt in the capital structure or payment priority, the lower the dollar price can expect to be.

The distressed portfolio manager may take several approaches to building their portfolio. This strategy is primarily long biased, and the characteristics of the securities held in a sensibly constructed portfolio will include ones that are the debt or equity of companies that are industry leaders or have strategic importance, ones that are cheap relative to not only current valuation but have a cushion to protect during a downturn or market volatility, and ones that are well-priced for the industry and region in which the company does business. The portfolio manager may use other companies' valuations in a similar industry to ascertain value of a target company as a way of affirming the total valuation of the securities they are holding. It is worth noting that one aspect of this strategy overlaps with the asset-backed credit strategy in that impaired structured credit such as collateralized debt obligations (CDOs) and collateralized loan obligations (CLOs), which are bundled multiple corporate debt obligations are often part of a distressed portfolio manager's investment set. These securities can be disaggregated to the loan or bond level and valued against current market pricing for the debt obligations of the underlying companies. The portfolio manager will value the sum of the collateralized obligation against the parts and attempt to profit if there is a suitable mismatch. Overall, the distressed portfolio will be likely constructed of multiple positions in multiple companies but can be concentrated, as when the securities of the top 10 companies represent a majority of the invested assets under management.

Hedging for this strategy will span from other parts of the capital structure in which strategic long positions exist to index or interest-rate hedges. Hedges may also include the debt and equity of other companies within the same or similar industries as strategic long positions. This strategy may also encompass short positions for companies whose fortunes are declining given industry trends and economic outlook. However, in this situation, which can be fairly cyclical by nature, portfolio managers may tend to restrict capital inflows, or even return money to investors if opportunities are scarce. Tactically, portfolio managers can move "up or down" in the capital structure, buying senior secured positions during the weaker part of the economic or industry cycle and taking more junior security positions, unsecured or equity, during growth phases of the cycle. While not necessarily a hedging technique, it is a risk mitigation one.

BASIS TRADING

Basis trading involves the simultaneous purchase and sale of two closely related securities to take advantage of relative mispricing.

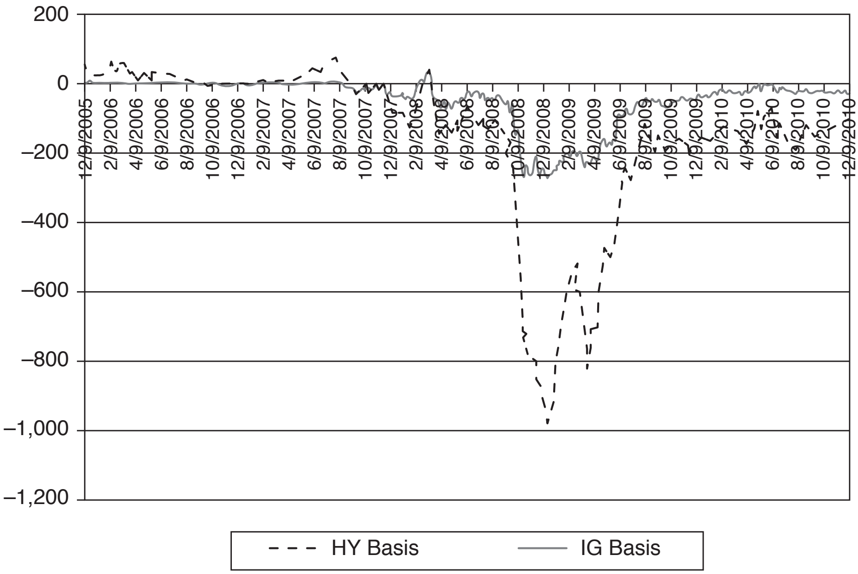
In the classic futures basis trade, an investor can buy a cash U.S. Treasury security and sell a futures contract. In a credit basis trade, an investor purchases or sells a cash corporate bond and hedges the credit risk by the purchase or sale of credit default swaps. Other versions, such as the LIBOR-fed funds or its longer-maturity counterpart, the swap-spread trade, as well as the cross-currency basis swap, which involves funding in one currency and swapping via the currency forward exchange-rate market, are also popular.

The hallmark of all basis trades is the isolation of a factor that is not present in one side of the trade but is present in the other side. In the futures basis trade, the important factor is the presence of a delivery option. The gross basis of each bond in the delivery basket is computed by computing the difference in its forward price versus the converted price of the futures contract (the delivery price, which equals the futures price times a conversion factor specified by the exchange). To obtain the net basis, the gross basis is adjusted by the net carry, which is the coupon income and re-investment income minus the funding cost or repo rate of the bond. When the net basis is positive, a long cash/short futures basis trade has a negative expected loss equal to the basis. For example, if the net basis is 2/32nds, the long-cash, short futures position is expected to lose 2/32nds if held to the futures expiration date. The reason for negative expected return is that the person who is short the futures contract has an option to deliver one of the bonds in the delivery basket, and the price of the option is equal to the value of the net basis. The short effectively pays the long futures holder for this option. Since all option values are positively correlated to a rise in volatility, the value of the option can rise if interest-rate volatility rises. In the case of the futures basis trade, the probability of another bond switching to become the cheapest to deliver rises as volatility rises. An investor with the short futures position will have the value of the delivery option rise in an environment of rising volatility. Futures basis trading is really an option trading enterprise.

In a cash-CDS basis trades, an investor prefers to purchase a cash corporate bond and buy protection against it using credit default swaps contracts. If cash bond yields are higher than the price of protection, then the investor can take out risk-free profits. Following the history of the cash-CDS trade (below depicted at an aggregate level), illustrates some important insights into the fundamental driving factors. Before the Global Financial Crisis (GFC) of 2008, the cash-CDS basis traded within a small range around zero. However, the GFC created a substantial widening of the spread, and the basis went negative; that is, cash bonds traded substantially wider than CDS. In other words, at the height of the GFC an investor who had cash could purchase a cash corporate bond and buy protection on the credit risk and still be ahead by hundreds of basis points from those who did not have the CDS and were forced to liquidate the cash bonds. In other words, the cash-CDS corporate basis trade is driven by the important risk-factor of liquidity. When liquidity is ample (as illustrated by the convergence of the basis trade after the infusion of liquidity from the Fed), the spread between cash and CDS quickly falls, as shown in Exhibit 59-5.

EXHIBIT 59-5

Sample Spreads Between Cash and CDS



VOLATILITY TRADING

Volatility trading focuses on the purchase and sale of implied volatility in the market. In its most direct form, volatility trading attempts to benefit from opportunities and perceived mispricing in the fixed income options markets. Since options prices are primarily determined by the implied volatility of the underlying reference security, a portfolio manager can analyze the opportunity from many different angles.

The first approach is to buy or sell options when the implied volatility is rich or cheap compared with some metric of long-term levels. To do so, portfolio managers use various estimation techniques to measure and forecast realized volatilities. If implied volatilities are higher than the forecast of realized volatilities, options are sold and the risk to the underlying is delta-hedged based on some model. Typically, option prices reflect a risk premium since sellers of options require compensation over and above the fair value of the options in order to sell them. Over long periods of time, the average return from selling fixed income options and holding them to maturity, in particular, has been positive since yields are naturally mean reverting (high rates slow the economy down and hence cause yields to fall). Many portfolio managers follow the ratio of implied to realized volatilities to wait to initiate these trades. For those who do not want to hedge the risk to the underlying by delta hedging, instruments such as variance and volatility swaps are available where a direct bet on the level of volatility levels can be made in relation to a volatility strike. Of course, this strategy is very directional in both the level of volatility and in the level of rates since the profit or loss is driven by both movements in the level of uncertainty as well as the demand for options from hedgers.

Another approach to trading volatility is to look at the volatility surface and find opportunities from mispricing of particular strikes, expiries, and maturities. The swaption volatility "cube" is specified in terms of swaption expirations, as well as the swap "tails" that these swaptions exercise into the different strikes given the option expirations and underlying forward swaps. For instance, with low rates and the short-end of the yield curve pegged to zero rates, a portfolio manager might take the view that the implied volatility for a payer swaptions (one that gives the right to pay fixed) at a higher strike than current forward is pricing in too much volatility. They can sell that swaption and pick both the volatility premium and the payer skew (currently, payer swaption volatilities are higher than receiver swaptions due to inflation hedging demand for high strike payer swaptions).

Many portfolio managers also look at implied optionality across various fixed income securities. For instance, a mortgage-backed agency pass-through is sensitive to the change in volatilities since rising volatilities increase prepayment probabilities. A mortgage pass-through buyer is naturally short the prepayment option to the homeowner and is compensated for the option in terms of extra spread. If the level of swaptions volatilities is low compared with the option volatility implicit in the mortgage security, a portfolio manager can position a volatility arbitrage by buying the MBS and buying the swaption.

A further extension of volatility trading is to execute the trades across markets. One might take the view that fixed income option volatility in the United States is higher than Europe and sell options in one market versus purchase in another. Or that the volatility expressed in the fixed income options market is higher or lower than the volatility expressed in the longer dated currency options markets. The two are related because currency forwards are driven by both the spot exchange–rate and interest-rate differentials, and for longer-dated forwards the volatility and correlation of the longer rates becomes a dominant relative value factor.

CROSS-CURRENCY ARBITRAGE

Cross-currency arbitrage is a strategy where bonds in one country are purchased and then hedged with cross-currency swaps to take out the currency risk. Typically, the currency hedging is done using shorter maturity currency hedging contracts than the maturity of the bonds. For instance, a USD-denominated fund might purchase Japanese government bonds (JGBs) or German bunds at close to or even below zero yields. Hedging out the currency risk using a one-month forward would require selling the Japanese yen forward and buying the USD forward for one month. As discussed in the macro section earlier, different global central banks are pursuing different monetary policies, so as of this writing, the short-term interest rates in Japan or in Europe are much lower than in the United States. If the interest rate differential between U.S. short-term rates and the foreign rates is large, this adds to the yield of the foreign bond purchased over the horizon of the currency hedge (note that there is no guarantee that the currency hedge can be "rolled" at its maturity, which is a risk of this strategy).

By buying low-yielding foreign bonds and leveraging up the positions and then overlaying a currency hedge, investors are then able to increase the yield on their portfolios, primarily as a function of short interest-rate differentials. The risk of this strategy can emanate from three areas: first, there is a significant duration risk of the underlying bonds with their long maturities; second, there is currency hedging risk if the forwards cannot be rolled; finally, there is the risk that the underlying bond has credit risk that can result in spread widening or perhaps even default. Foreign buyers have bought large quantities of peripheral European bonds such as Italian bonds on a currency-hedged basis and taken on the credit risk of Italy. One impact of the cross-currency strategy has been that even though foreign bonds have a much lower yield than U.S. bonds as of this writing, on a currency hedged basis their yield is higher than U.S. bond yields, so for a short-term investor, there is better carry in such foreign bonds than in U.S. bonds.

KEY POINTS

- All elements of fixed income investing require an understanding of the macroeconomic framework and the macro-political economic environment at any point in time, present and future, for any country or region within which the investment is derived. The complex dynamics of the interactions of these considerations result in a directional bias for many (if not all) of the risk parameters that concern portfolio managers. The interest-rate direction and volatility, yield-curve shape, risk spreads, and currency valuations as well as the second derivatives of each of these are all dominated by the dynamics of this macro system.

- The asset-based credit strategy is a long/short style of portfolio management that focuses on investing in securitized debt obligations, which may encompass a wide variety of types of debt from residential and commercial mortgages to leases and credit cards, among others.
- Capital structure arbitrage is an investment strategy that is typically focused on stressed or distressed companies, ones with high balance sheet leverage.
- The long/short credit strategy contains multiple substrategies or investment approaches. Some of these substrategies can have very specific, tightly hedged arbitrages, while others have more systemic or generalized hedging approaches. For example, such a portfolio could hold diverse bond positions, both long and short of companies that the portfolio manager feels are worthy of taking a positive or negative view on based on expected default probability versus current price. The hedges could be quite similar to the long positions or just an index hedge.
- The distressed investing strategy is one that focuses on investing in the securities of companies experiencing financial stress. They could be in default or close. The investment situations could be ones that are meant to focus on improving corporate balance sheets; others could be liquidation investments in which a company's securities may represent a claim on valuable assets including cash, some liquidity investments where refinancing will provide the necessary time for a company to recover, or litigations investments where the portfolio manager may participate on creditor committees and the value of certain securities will be determined in a court of law.
- Basis trading involves the simultaneous purchase and sale of two closely related securities to take advantage of relative mispricing. For example, in the classic futures basis trade, an investor buys a cash Treasury security and sells its futures contract.
- Volatility trading focuses on the purchase and sale of implied volatility in the market. In its most direct form, volatility trading attempts to benefit from opportunities and perceived mispricing in the fixed income options markets.
- Cross-currency arbitrage involves the purchase of bonds in one country that are then hedged with cross-currency swaps to remove currency risk. Typically, the currency hedging is done using shorter maturity currency hedging contracts than the maturity of the bonds. This strategy can add to the yield of the bonds.

CHAPTER
SIXTY

FINANCING POSITIONS IN THE BOND MARKET

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Leveraging strategies require that an investor borrow funds. There are several well-established arrangements in the bond market for borrowing funds. The most common practice is to use the securities as collateral for a loan. In such instances, the transaction is referred to as a *collateralized loan*. In this chapter we will look at the four types of collateralized loans in which the collateral is a bond: repurchase agreement, dollar roll, securities lending, and margin buying.

A collateralized loan is not the only mechanism available to an investor for creating leverage. Derivative contracts are instruments that allow an investor to synthetically create leverage. This is so because a derivative contract allows an investor to obtain greater exposure to a specific bond issuer per dollar invested than the same dollar amount invested in the cash-market instrument. For example, the initial futures margin that an investor must make to obtain a long position in a Treasury bond futures contract creates an exposure to Treasury bonds much greater than the exposure if that initial futures margin were used to purchase Treasury bonds. In the case of an interest-rate swap, consider the fixed-rate receiver's position. This party is effectively borrowing on a floating-rate basis to obtain exposure to a fixed-rate bond position where the par value of that bond position is equal to the swap's notional amount. Similarly, there are cash-market instruments that have embedded leverage. For example, an inverse floater position is equivalent to borrowing funds on a floating-rate basis in order to obtain a fixed rate.

REPURCHASE AGREEMENT

A *repurchase agreement*, or simply *repo agreement* or *repo*, is the sale of a security with a commitment by the seller to buy the same security back from the purchaser at a specified price at a designated future date. The price at which the seller subsequently must repurchase the security is called the *repurchase price*, and the date that the security must be repurchased is called the *repurchase date*. Basically, a repurchase agreement is a collateralized loan where the collateral is the security sold and subsequently repurchased. The difference between the purchase (repurchase) price and the sale price is the loan's dollar interest cost. The interest rate a borrower agrees to pay is called the *repo rate*. When the term of a repo is one day, it is called an *overnight repo*; a repo for more than one day is called a *term repo*.

To illustrate a repo, suppose that a portfolio manager owns a five-year Treasury note with a par value of \$10 million and a full value of \$10,015,455. Suppose further that the portfolio wants to borrow funds for 10 days using the Treasury note as collateral for a repo. Since the repo is for more than one day, it is a term repo. On the day the repo is initiated, the portfolio manager would agree to deliver ("sell") \$10,015,455 it is holding of the Treasury note to a third party, say a government dealer firm, and repurchase the same Treasury note from the government dealer firm 10 days later for an amount determined by the repo rate. Suppose that the repo rate in this transaction is 0.08%. Then, as will be explained below, the portfolio manager would agree to deliver the Treasury note for \$10,015,455 and repurchase the same securities for \$10,015,677.57 10 days later. The \$222.57 difference between the "sale" price of \$10,015,455 and the repurchase price of \$10,015,677.57 is the dollar interest on the financing.

The following formula is used to calculate the dollar interest on a repo transaction:

$$\text{Dollar interest} = (\text{dollar principal}) \times (\text{repo rate}) \times (\text{repo term}/360)$$

Notice that the interest is computed using a day-count convention of actual/360 like most money market instruments. In our illustration, using a repo rate of 0.08% and a repo term of 10 days, the dollar interest is \$222.57, as shown below:

$$\$10{,}015{,}455 \times 0.0008 \times (10/360) = \$222.57$$

The advantage to the dealer of using the repo market for borrowing on a short-term basis is that the borrowing rate (i.e., the repo rate) is less than the cost of bank financing. (The reason for this is explained below.) From the perspective of the entity lending the funds, the repo market offers an attractive yield on a short-term secured transaction that is highly liquid.

The repo market can be used not only to finance a position in the market but also to cover a short position. For example, suppose that a dealer shorted a bond issue two weeks ago and must now cover the position—that is, deliver the bond issue. The dealer can do a *reverse repo* (i.e., agree to buy the bond issue and sell it back). Of course, the dealer eventually would have to buy the bond issue in the market in order to cover its short position. In this case, the dealer is actually making a collateralized loan to the counterparty.

Any security can be used as collateral for a repo. When a Treasury security is used with an overnight maturity, the repo rate is referred to as the *Secured Overnight Funding Rate.*

Credit Risks

Repos should be structured carefully to reduce credit risk exposure. The amount lent should be less than the market value of the security used as collateral, thereby providing the lender with some cushion should the market value of the security decline. The amount by which the market value of the security used as collateral exceeds the value of the loan is called *repo margin* or, simply, *margin*. Margin is also referred to as the "haircut." Repo margin is generally between 1% and 3%. For borrowers of lower creditworthiness and/or when less liquid securities are used as collateral, the repo margin can be 10% or more.

To illustrate the role of a haircut in a repurchase agreement let us once again return to the portfolio manager who wants to use $10 million of the Treasury note as collateral for 10-day borrowing using a repo. Recall that the par value of the position is $10 million, and the note's full price is $10,015,455. When a haircut is included, the amount the customer is willing to lend is reduced by a given percentage of the security's market value. In this case, the collateral is 102% of the amount being lent. Accordingly, to determine the amount being lent, we divide the note's full price of $10,015,455 by 1.02 to obtain $9,819,073.53. Suppose that the repo rate in this transaction is 0.08%. Then the portfolio manager would agree to deliver the Treasury note for $9,819,073.53 and pay interest of $218.20 as shown below:

$$\$9{,}819{,}073.53 \times 0.0008 \times (10/360) = \$218.20$$

The repurchase price is then $9,819,291.73 (= $9,819,073.53 + $218.20).

Another practice to limit credit risk is to mark the collateral to market on a regular basis. (Marking a position to market means recording the value of a position at its market value.) When the market value changes by a certain percentage, the repo position is adjusted accordingly. The decline in market value below a specified amount will result in a margin deficit. The Master Repurchase Agreement (MRA)[1] gives the borrower the option to cure the margin deficit by either providing additional cash or by transferring additional securities that are reasonably acceptable to the lender. Suppose instead that the market value rises above the amount required for margin. This results in a margin excess. In such instances, the MRA grants the lender of funds the option to give the borrower cash equal to the amount of the margin excess or to transfer purchased securities to the borrower.

1. In the United States, the MRA is the standardized repo agreement used for repo transactions. The latest version of the MRA, published by Securities Industry and Financial Markets Association (SIFMA) can be found on its SIFMA website.

Since the MRA covers all transactions where a party is on one side of the transaction, the margin maintenance is not looked at from an individual transaction or security perspective but as all repo transactions with the same counterparty.

The price to be used to mark positions to market is defined in the agreement. The market value is defined as one "obtained from a generally recognized source agreed to by the parties or the most recent closing bid quotation from such a source."

One concern in structuring a repo is delivery of the collateral to the lender. The most obvious procedure is for the borrower to deliver the collateral to the lender or to the cash lender's clearing agent. In such instances, the collateral is said to be "delivered out." At the end of the repo term, the lender returns the collateral to the borrower in exchange for the principal and interest payment. This procedure may be too expensive, though, particularly for short-term repos, because of the costs associated with delivering the collateral. The cost of delivery would be factored into the transaction by a lower repo rate that the borrower would be willing to pay. The risk of the lender not taking possession of the collateral is that the borrower may sell the security or use the same security as collateral for a repo with another party.

As an alternative to delivering out the collateral, the lender may agree to allow the borrower to hold the security in a segregated customer account. Of course, the lender still faces the risk that the borrower may use the collateral fraudulently by offering it as collateral for another repo transaction. If the borrower of the cash does not deliver out the collateral but instead holds it, then the transaction is called a *hold-in-custody repo* (HIC repo). Despite the credit risk associated with an HIC repo, it is used in some transactions when the collateral is difficult to deliver (such as in whole loans) or the transaction amount is small and the lender of funds is comfortable with the reputation of the borrower of the cash.

Another method is for the borrower to deliver the collateral to the lender's custodial account at the borrower's clearing bank. The custodian then has possession of the collateral that it holds on behalf of the lender. This practice reduces the cost of delivery because it is merely a transfer within the borrower's clearing bank. If, for example, a dealer enters into an overnight repo with customer A, the next day the collateral is transferred back to the dealer. The dealer can then enter into a repo with customer B for, say, five days without having to redeliver the collateral. The clearing bank simply establishes a custodian account for customer B and holds the collateral in that account. This specialized type of repo arrangement is called a *triparty repo*. In fact, for some regulated institutions, for example, federally chartered credit unions, this is the only type of repo arrangement permitted.

The agreement covers the events that will trigger a default of one of the parties (i.e., "events of default") and the options available to the nondefaulting party. In the case of a bankruptcy by the borrower, the bankruptcy code in the United States affords the lender of funds in a qualified repo transaction a special status. It does so by exempting certain types of repos from the stay provisions of the bankruptcy law. This means that the lender of funds can liquidate the collateral immediately to obtain cash.

Determinants of the Repo Rate

Just as there is no single interest rate, there is no unique repo rate. Repo rates vary from transaction to transaction and across time due to a number of factors. These factors include the following: (1) quality of the collateral; (2) term of the repo; (3) delivery of the collateral; (4) availability of the collateral; and (5) the prevailing federal funds rate.

DOLLAR ROLLS

In the mortgage-backed securities (MBS) market, a special type of collateralized loan has developed because of the characteristics of these securities and the need of dealers to borrow these securities to cover short positions. This arrangement is called a *dollar roll*, so-called because the dealer is said to "roll in" securities borrowed and "roll out" securities when returning the securities to the investor.

As with a repo agreement, it is a collateralized loan that calls for the sale and repurchase of a security. Unlike a repo agreement, the dealer who borrows the securities need not return the identical securities. Specifically, the dealer need only return "substantially identical securities." This means that the security returned by the dealer that borrows the security must match the coupon rate and security type (i.e., issuer and mortgage collateral). This provides flexibility to the dealer. In exchange for this flexibility, the dealer provides 100% financing. That is, there is no overcollateralization or overmargin required. Moreover, the financing cost may be cheaper than in a repo because of this flexibility. Finally, unlike in a repo, the dealer keeps the coupon and any principal paid during the period of the loan.

Determination of the Financing Cost

Determination of the financing cost is not as simple as in a repo. The key elements in determining the financing cost, assuming that the dealer is borrowing securities/lending cash, are

1. The sale price and the repurchase price
2. The amount of the coupon payment
3. The amount of the principal payments due to scheduled principal payments
4. The projected prepayments of the security sold (i.e., rolled in to the dealer)
5. The attributes of the substantially identical security that is returned (i.e., rolled out by the dealer)
6. The amount of under- or overdelivery permitted

Let's look at these elements. In a repo agreement, the repurchase price is greater than the sale price; the difference represents interest and is called the *drop*. In the case of a dollar roll, the repurchase price need not be greater than the sale price. In fact, in a positively sloped yield-curve environment (i.e., long-term rates exceed short-term rates), the repurchase price will be less than the purchase price. The reason for this is the second element, the coupon payment. The dealer keeps the coupon payment.

The third and fourth elements involve principal repayments—scheduled principal and prepayments. As with the coupon payments, the dealer retains the principal payments during the period of the agreement. A gain will be realized by the dealer on any principal repayments if the security is purchased by the dealer at a discount and a loss if purchased at a premium. Because of prepayments, the principal that will be paid is unknown and represents a risk in determination of the financing cost.

The fifth element is another risk because the effective financing cost will depend on the attributes of the substantially identical security that the dealer will roll out (i.e., the security it will return to the lender of the securities) at the end of the agreement. Finally, delivery tolerances allowing for a small amount of under- or overdelivery are permitted.

MARGIN BUYING

Investors can borrow cash to buy securities and use the securities themselves as collateral in a standard margin agreement with a brokerage firm. The funds borrowed to buy the additional securities will be provided by the broker, and the broker gets the money from a bank. The interest rate that banks charge brokers for these transactions is known as the *call money rate* (also called the *broker loan rate*). The broker charges the investor the call money rate plus a service charge.

The broker is not free to lend as much as it wishes to the investor to buy securities. The Securities and Exchange Act of 1934 prohibits brokers from lending more than a specified percentage of the market value of the securities. The initial margin requirement is the proportion of the total market value of the securities that the investor must pay for in cash. The 1934 act gives the Board of Governors of the Federal Reserve the responsibility to *set initial margin requirements*, which it does under Regulations T and U. The initial margin requirement varies for stocks and nongovernment/nonagency bonds and is currently 50%, although it has been below 40%. There are no restrictions on government and government agency securities.

The Fed also establishes a *maintenance margin requirement*. This is the minimum amount of equity needed in the investor's margin account as compared with the total market value. If the investor's margin account falls below the minimum maintenance margin, the investor is required to put up additional cash. The investor receives a margin call from the broker specifying the additional cash to be put into the investor's margin account. If the investor fails to put up the additional cash, the securities are sold.

SECURITIES LENDING

A security lending transaction involves two parties. The first is the owner of a security who agrees to lend that security to another party. This party is called the *security lender* or the *beneficial owner*. The second party is the entity that agrees to borrow the security, called the *security borrower*. A *security lending transaction* is one in which the security lender loans the requested security to the security borrower at the outset, and the security borrower agrees to return the identical security to the security lender at some time in the future. The loan may be terminated by the security lender on notice to the security borrower, typically of not more than five business days.

To protect against credit risk, the security lender will require that the security borrower provide collateral. Collateral can take the form of (1) cash, (2) a letter of credit, or (3) a security whose value is at least equal in value to the securities loaned. In the United States, the most common form of collateral is cash. Outside the United States, all types of securities have been used as collateral, including common stock and convertible securities. Typically, if the collateral is a security, it is marked-to-market on a daily basis.

When cash is the collateral, the proceeds are reinvested by the security lender. The security lender faces the risks associated with reinvesting the cash. The income generated from reinvesting the cash is given to the security borrower less an amount retained by the security lender for loaning the security because the fee earned by the security lender is then the difference between the income earned from reinvesting the cash and the amount the security lender agrees to pay the security borrower. The security lender's fee is called an *embedded fee* when there is cash collateral. The agreed-on amount that the security lender pays to the security borrower is called a *rebate*. The security lender only earns a fee if the amount earned on reinvesting the cash collateral exceeds the rebate. In fact, if the amount earned is less than the rebate, the security lender incurs this cost.

When the collateral is a letter of credit or a security, the security borrower compensates the security lender by a predetermined fee. This fee is called a *borrow fee*, and it is based on the value of the security borrowed. Notice that while the security lender knows what the fee will be in the case of noncash collateral, this is not the case when there is cash collateral. The fee is a function of the performance of the portfolio or security in which the cash collateral is reinvested.

During the period in which the security is loaned to the borrower, there may be an interest payment (dividend payment in the case of stock). The security lender is entitled to a payment from the security borrower equal in amount to any such payment. The payment made by the security borrower to the security lender for this purpose is called a *substitute payment* or *in-lieu-of payment*.

A party with a portfolio of securities to lend can either (1) lend directly to counterparties that need securities, (2) use the services of an intermediary, or (3) employ a combination of the first two. If a party decides to lend directly, it must have the in-house capability of assessing counterparty risk. When an intermediary is engaged, the intermediary receives a fee for its services. The intermediary could be an agent (i.e., acts on behalf of a security lender but does not take a principal risk position) or a principal (i.e., takes a principal risk position). Possible agents include the current domestic/global custodian of the securities or a third-party specialist in securities lending.

When cash collateral must be reinvested, a securities lender must decide on whether it will reinvest the cash or use the services of an external money manager. As noted earlier, securities lenders may realize a return on the cash collateral that is less than the rebate.

Comparison to Repurchase Agreements

It is worthwhile to compare a security lending transaction in which the collateral is cash to a repurchase agreement because both transactions represent a secured borrowing. We will do this with an illustration. The parties are as follows:

- Manager X, who is the beneficial owner of security A
- Manager Y, who needs security A to cover a short position

Also suppose that security A is a debt instrument that pays coupon interest.

The following agreement is entered into by manager X and manager Y:

1. Manager X agrees to transfer security A to manager Y.
2. Manager Y agrees to give cash to manager X.
3. At some future date, manager Y agrees to return security A to manager X.
4. Manager X agrees to return the cash to manager Y when manager Y returns security A to manager X.

The economics of this transaction are simple: it is a secured loan of cash with the lender of cash being manager Y and the borrower of cash being manager X. The collateral for this loan is security A. This transaction can be structured as a security lending or a repurchase agreement. No matter what it is called, the economics are unchanged.

If this transaction is structured as a security lending agreement, then

1. Manager X is the security lender (beneficial owner).
2. Manager Y is the security borrower.
3. Manager X invests the cash received from manager Y and at the end of the transaction rebates part of the income earned to manager Y.
4. The amount earned by manager X from security lending is uncertain and, in fact, can be negative.
5. Manager Y pays manager X any interest income that manager X would have received from the issuer of the security.

6. At some future time, manager X requests the return of security A and returns the cash collateral to manager Y.

If this transaction is structured as a repurchase agreement, then

1. Manager X is the seller of collateral or, equivalently, the borrower of funds using security A as collateral.
2. Manager Y is the buyer of collateral or, equivalently, the lender of funds.
3. Manager X invests the cash received from manager Y and at the repurchase date pays interest to manager Y based on the repo rate.
4. The amount earned by manager X from the repurchase agreement is uncertain and, in fact, can be negative.
5. Manager Y pays manager X any interest income that manager X would have received from the issuer of the security.
6. At the repurchase date, manager X buys back security A from manager Y at the repurchase price (which includes interest).

Whether the transaction is a repo or reverse repo depends on the perspective of the parties, as discussed earlier in this chapter. Notice that unlike a repurchase agreement, which has a repurchase date—which can be rolled over—there is no repurchase price in a security lending transaction.

KEY POINTS

- A repurchase agreement is the sale of a security with a commitment by the seller to buy the security back from the purchaser at a specified price on a designated future date.
- Repo margin, or haircut, is the amount by which the security's value exceeds the loan amount.
- A dollar roll is a specialized type of collateralized loan particular to the MBS market.
- Investors can borrow cash to buy securities and use the securities themselves as collateral with a standard margin agreement with a brokerage firm.
- A securities lending transaction involves one party lending a security and accepting collateral while another party borrows a security and provides collateral.
- In order to induce the security borrower to provide cash as collateral as opposed to some other form (e.g., another security or letter of credit), the security lender pays the security borrower a prespecified fee called the rebate rate.

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PART

NINE

DERIVATIVE INSTRUMENTS AND THEIR APPLICATIONS

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CHAPTER

SIXTY-ONE

INTRODUCTION TO INTEREST-RATE FUTURES AND OPTIONS CONTRACTS

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Interest-rate derivatives give bond portfolio managers a vehicle for altering the interest-rate sensitivity of a fixed income portfolio economically and quickly. *Derivative contracts,* known as such because they derive their value from an underlying instrument, offer portfolio managers and traders risk and return profiles that are difficult to attain in their absence. Interest rate derivatives include futures, forwards, options, swaps, caps, and floors. Our focus in this chapter is on futures, forwards, and options. Swaps are covered in Chapter 64, and caps and floors in Chapter 67.

The purpose of this chapter is twofold. First, we explain the basic characteristics of futures, forward contracts, and options Second, we review the most actively traded and most representative over the counter (OTC) and listed contracts. We omit from our discussion the use of futures for controlling interest rate risk; this topic will be explained in more detail in Chapter 62.

BASIC CHARACTERISTICS OF FUTURES CONTRACTS

A *futures contract* is an agreement between a buyer (seller) and an established futures exchange or its clearinghouse in which the buyer (seller) agrees to take (make) delivery of a specific amount of a valued item such as a commodity, stock, or bond at a specified price during a designated time. For some futures contracts, settlement at expiration is in cash rather than actual delivery.

When an investor takes a position in the market by buying a futures contract, the investor is said to be *long the futures* or have a *long position in the futures*. If, instead, the investor's opening position is the sale of a futures contract, the investor is said to be *short the futures* or have a *short position in the futures.*

Futures contracts based on a financial instrument or a financial index are known as *financial futures.* Financial futures can be classified as interest-rate futures, stock index futures, or currency futures. This chapter focuses on interest-rate futures and includes a description of the most important interest-rate futures contracts currently traded.

To illustrate how financial futures work, suppose that X buys a futures contract and Y sells a futures contract on a 6% five-year Treasury note for settlement one year from now. Suppose also that the price at which X and Y agree to transact one year from now is $100. This is the futures price. This means that one year from now Y must deliver a 6% five-year Treasury note and will receive $100. X will take delivery of a 6% five-year Treasury note and will pay $100.

The profit or loss realized by the buyer or seller of a futures contract depends on the price and interest rate on the delivery date. For example, if the market price of a 6% five-year Treasury note at the settlement date is $110, because rates have declined, the buyer profits, paying $100 for a security that is worth $110. In contrast, the seller loses, because an instrument worth $110 must be delivered in exchange for $100. If interest rates rise on 6% five-year Treasury notes so that the market price is $90, the seller of the futures contract profits and the buyer loses.

When the investor first takes a position in a futures contract, he must deposit a minimum dollar amount per contract as specified by the exchange. As the price of the futures contract fluctuates, the value of the investor's equity in the position changes. At the close of each trading day, any market gain results in an increase in the investor's equity, whereas any market loss results in a decrease. This process is referred to as *marking to market.* Should an investor's equity position fall below an amount determined by the exchange, he must provide additional margin. On the other hand, if an investor's equity increases, he may withdraw funds. Consequently, a futures position may require substantial cash flows before the delivery date. Margin is described in more detail later in this chapter.

BASIC CHARACTERISTICS OF FORWARD CONTRACTS

A *forward contract* is much like a futures contract. A forward contract is an agreement for the future delivery of some amount of a valued item at a specified price at a designated time. Futures contracts are standardized agreements that define the delivery date (or month) and quality and quantity of the deliverable. Futures contracts are traded on organized exchanges. A forward contract is, in contrast, usually nonstandardized and is traded over the counter by direct contact between buyer and seller.

Although both futures and forward contracts set forth terms of delivery, futures contracts are not intended to be settled by delivery. In fact, generally only a small percentage of outstanding futures contracts are delivered or go to final settlement. However, forward contracts *are* intended to be held to final settlement. Many of the most popular forward contracts, however, settle in cash rather than actual delivery.

Forward contracts may or may not be marked to market. Consequently, there is no interim cash flow on forwards that are not marked to market.

Finally, both parties in a forward contract are exposed to credit risk because either party may default on its obligation. In contrast, credit risk for futures contracts is minimal because the clearing corporation associated with the exchange guarantees the other side of each transaction.

BASIC CHARACTERISTICS OF OPTION CONTRACTS

An *option* is a contract in which the seller of the option grants the buyer of the option the right to purchase from, or sell to, the contract seller a designated instrument at a specified price within a specified period of time. The seller (or *writer*) grants this right to the buyer in exchange for a certain sum of money, called the *option price* or *option premium.*

The price at which the instrument may be bought or sold is called the *exercise* or *strike price.* The date after which an option is void is called the *expiration date.* An *American option* may be exercised any time up to and including the expiration date. A *European option* may be exercised only on the expiration date. A *Bermudan option* can be exercise only on predetermined dates.

When an option writer grants the buyer the right to purchase the designated instrument, it is called a *call option.* When the option buyer has the right to sell the designated instrument to the writer, the option is called a *put option.* The buyer of an option is said to be *long the option;* the writer is said to be *short the option.*

Consider, for example, an option on a 6% five-year Treasury note with one year to expiration and an exercise price of \$100. Suppose that the option price is \$2 and the current price of the Treasury note is \$100 with a yield of 6%. If the option is a call option, then the buyer of the option has the right to purchase a 6% five-year Treasury note for \$100 within one year. The writer of the option must sell the Treasury note for \$100 to the buyer if he or she exercises the option. Suppose that the interest rate on the Treasury note declines and its price rises to \$110. By exercising the call option, the buyer realizes a profit, paying \$100 for a Treasury note that is worth \$110. After considering the cost of buying the option, \$2, the net profit is \$8. The writer of the option loses \$8. If, instead, the market interest rate rises and the price of the Treasury note falls below \$100, the call option buyer will not exercise the option, losing the option price of \$2. The writer will realize a profit of \$2. Therefore, the buyer of a call option benefits from a decline in interest rates (a rise in the price of the underlying fixed income instrument) and the writer loses.

If the option is a put rather than a call and the interest rate on Treasury notes declines and the price rises above $100, the option buyer will not exercise the option. The buyer will lose the entire option price. If, on the other hand, the interest rate on Treasury notes rises and the note's price falls below $100, the option buyer will benefit by exercising the put option. In the case of a put option, the option buyer benefits from a rise in interest rates (a decline in the price of the underlying fixed income instrument) and the option seller loses.

The maximum amount that an option buyer can lose is the option price. The maximum profit that the option writer (seller) can realize is the option price. The option buyer has substantial potential upside return, whereas the option writer has substantial downside risk. The risk/reward relationships for option positions are investigated in Chapter 66.

Options can be written on cash instruments or futures. The latter are called *futures options* and are traded only on exchanges. Options on cash instruments are also traded on exchanges but have been traded much more successfully over the counter. These *OTC,* or *dealer, options* are tailor-made options on specific Treasury issues, mortgage securities, or interest-rate indexes. Option contracts are reviewed later in this chapter.

DIFFERENCES BETWEEN OPTIONS AND FUTURES (FORWARD) CONTRACTS

Unlike a futures or forward contract, an option gives the buyer the *right* but not the *obligation* to perform. The option seller has the obligation to perform. In the case of a futures or forward contact, both the buyer and seller are obligated to perform. In addition, the buyer of a futures or forward contract does not pay the seller to accept the obligation, whereas in the case of an option, the buyer pays the seller an option premium.

Consequently, the risk/reward characteristics of the two contracts also differ. In a futures or forward contract, the long position realizes a dollar-for-dollar gain when the price of the futures or forward increases and suffers a dollar-for-dollar loss when the price of the futures or forward decreases. The opposite holds for a short position. Options do not provide such a symmetric risk/reward relationship. The most a long position may lose is the option premium, yet the long retains all the upside potential. However, the gain is always reduced by the price of the option. The maximum profit the short position may realize is the option price, but the short position has substantial downside risk.

REPRESENTATIVE EXCHANGE-TRADED INTEREST-RATE FUTURES CONTRACTS

Interest-rate futures contracts can be classified by the maturity of their underlying security. Short-term interest-rate futures contracts have an underlying security that matures in less than one year or a short-term reference interest rate. The maturity of the underlying security of long-term futures exceed one year. Exhibit 61-1 displays most interest-rate futures contracts traded in the United States. The contracts are arranged along the yield curve from short-term interest rates through the Ultra Long Bond contract. Notice that some of the contracts have physical settlement. Other contracts are cash settled. The success of cash-settled contracts depends on having the price or yield in the calculation not be subject to manipulation. Below we describe the specifications of the long-term futures contracts (Treasury bond futures and Treasury notes futures) and short-term futures contracts (Treasury bill futures, Eurodollar futures, interest-rate swap futures, and federal funds futures).

Treasury Bond Futures Contract

The Treasury bond (T-bond) futures contract is the most successful interest-rate (or commodity) futures contract. Prices and yields on the T-bond futures contract are quoted in terms of a (fictitious) 20-year 6% Treasury bond, but the exchange where the contract is traded, the Chicago Mercantile Exchange (CME), allows many different bonds to be delivered in satisfaction of a short position in the contract. Specifically, any Treasury bond with a remaining maturity of at least 15 years, but less than 25 years, from the first day of the delivery month is acceptable for delivery. There is an Ultra Long Treasury futures contract that differs only in that it is based on Treasury bonds with at least 25 years to maturity.

The T-bond futures contract calls for the short (i.e., the seller) to deliver \$100,000 face value of any one of the qualifying Treasury bonds. However, because the coupons and maturities vary widely, the price that the buyer pays the seller depends on which bond the seller chooses to deliver. The rule used by the CME is one that adjusts the futures price by a conversion factor that reflects the price the bond would sell for at the beginning of the delivery month if it were yielding 6%. Using such a rule, the conversion factor for a given bond and a given delivery month is constant through time and is not affected by changes in the price of the bond or the price of the futures contract.

The seller has the right to choose which qualifying bond to deliver and when during the delivery month delivery will take place. When the bond is delivered, the buyer is obligated to pay the seller the futures price multiplied by the appropriate conversion factor, plus accrued interest on the delivered bond. It is important to emphasize that while the underlying Treasury bond for this contract is a hypothetical issue and therefore cannot itself be delivered into the futures contract, the bond futures contract is not a cash settlement contract. To close out a Treasury bond futures contract, one can either initiate an offsetting futures position or deliver a qualifying issue.

Paradoxically, the success of the CME Treasury bond contract can in part be attributed to the fact that the delivery mechanism is not as simple as it may first appear. There are several options implicit in a position in bond futures. First, the seller chooses which bond to deliver. Thus, the seller has an option to swap between bonds. If the seller is holding bond A for delivery, but bond B becomes

EXHIBIT 61-1

Representative Exchange-Traded Interest-Rate Futures Contracts

Contract	Form	Contract Size	Contract Months	Settlement
Eurodollar 1-month	Futures	$3,000,000	First 12 consecutive calendar months	Cash
SOFR 1-month	Futures	$5,000,000	First 12 consecutive calendar months	Cash (average daily SOFR interest during contract delivery month)
Fed Funds 30-day	Futures	$5,000,000	First 24 calendar months	Cash
Eurodollar 3-month	Futures	$1,000,000	Mar/Jun/Sep/Dec 40 contracts = 10 years	Cash
SOFR 3-month	Futures	$1,000,000	Mar/Jun/Sep/Dec 40 contracts = 10 years	Cash (compounded daily SOFR interest during contract reference quarter)
Overnight Index Swap 3-months	Futures	$1,000,000	First eight months in the March quarterly cycle (i.e., White and Red expiry years)	Cash
Treasury 2-year	Futures	$200,000	First five consecutive contracts in the March, June, September, and December quarterly cycle	Physical
OTR 2-year	Futures	$100,000	Corresponds to 2-year Treasury notes auctions. Final Settlement Date is the morning of the following new Treasury note auction (in the named expiry month).	Cash

(Continued)

EXHIBIT 61-1

Representative Exchange-Traded Interest-Rate Futures Contracts (*Continued*)

Contract	Form	Contract Size	Contract Months	Settlement
Treasury 3-year	Futures	\$200,000	The first five consecutive contracts in the March, June, September, and December quarterly cycle	Physical
Treasury 5-year	Futures	\$100,000	The first five consecutive contracts in the March, June, September, and December quarterly cycle	Physical
OTR 5-year	Futures	\$100,000	Corresponds to 5-year Treasury notes auctions. Final Settlement Date is the morning of the following new Treasury note auction (in the named expiry month).	Cash
Swap 5-year	Futures	\$100,000	The first three consecutive contracts in the March, June, September, and December quarterly cycle	Cash
Swap 7-year	Futures	\$100,000	The first three consecutive contracts in the March, June, September, and December quarterly cycle	Cash
Treasury 10-year	Futures	\$100,000	The first five consecutive contracts in the March, June, September, and December quarterly cycle	Physical
OTR 10-year	Futures	\$100,000	Corresponds to 10-year Treasury notes auctions. Final Settlement Date is the morning of the following new Treasury note auction (in the named expiry month).	Cash

(*Continued*)

EXHIBIT 61-1

Representative Exchange-Traded Interest-Rate Futures Contracts (*Continued*)

Contract	Form	Contract Size	Contract Months	Settlement
Swap 10-year	Futures	$100,000	The first three consecutive contracts in the March, June, September, and December quarterly cycle	Cash
Treasury Bond	Futures	$100,000	The first five consecutive contracts in the March, June, September, and December quarterly cycle	Physical/Maturity at last 15 years from first day of delivery month, but less than 25 years, from first day of delivery month
Treasury Ultra Bond	Futures	$100,000	The first five consecutive contracts in the March, June, September, and December quarterly cycle	Physical/ Remaining maturity of not less that 25 years from the first day of delivery month
Swap 30-year	Futures	$100,000	The first three consecutive contracts in the March, June, September, and December quarterly cycle	Cash
Barclay's U.S. Index	Futures	$100 × Index Value of Barclays Capital Aggregate Bond Index	March, June, September, and December (March quarterly cycle)	Cash

cheaper to deliver, she can swap bond B for bond A and make a more profitable delivery. Second, within some guidelines set by the CME, the seller decides when during the delivery month delivery will take place. She thus has a timing option that can be used to her advantage. Finally, the short retains the possibility of making the wildcard play. This potentially profitable situation arises from the fact that the seller can give notice of intent to deliver for several hours after the exchange has closed and the futures settlement price has been fixed. In a falling market, the seller can use the wildcard option to profit from the fixed delivery price.

The seller's options tend to make a contract a bit more difficult to understand, but at the same time they make the contract more attractive to speculators, arbitrageurs, dealers, and anyone else who understands the contract better than other market participants. Thus, in the case of the Treasury bond futures contract, complexity has helped provide liquidity.

Treasury Note Futures

There are seven Treasury note futures contracts: 10-year on the run, 10-year, the Ultra 10-year, 5-year on-the-run, 5-year, 2-year on-the-run, and 2-year. Four of the seven contracts are modeled after the Treasury bond futures contract and are traded on the CME. The on-the-run contracts are also traded on the CME, but they are cash settled. The underlying instrument for the 10-year Treasury note futures contract is $100,000 par value of a hypothetical 10-year 6% Treasury note. There are several acceptable Treasury issues that may be delivered by the short. A note is acceptable if the maturity is not less than 6.5 years and not greater than 10 years from the first day of the delivery month. The delivery options granted to the short position are the same as for the Treasury bond futures contract.

For the five-year Treasury note futures contract, the underlying is $100,000 par value of a U.S. Treasury note that satisfies the following conditions: an original maturity of not more than five years and three months and a remaining maturity of not less than four years and two months as of the first day of the delivery month.

The underlying for the two-year Treasury note futures contract is $200,000 par value of a U.S. Treasury note with a remaining maturity of not more than two years and not less than one year and nine months. Moreover, the original maturity of the note delivered to satisfy the two-year futures cannot be more than five years and three months.

As mentioned earlier, there are several Treasury securities that are eligible for delivery by the seller of the futures contract. Consider the 10-year Treasury Note futures: the underlying security of 10-year Treasury Note with 6% coupon is a hypothetical security. In fact, the 6% coupon is very far from the yield levels after the Great Financial Crisis of 2008–2009; it was defined many years earlier, when a 6% coupon or yield was typical for a 10-year Treasury note. Over recent years, when 10-year Treasury yield has been in the range of 0.5% to 3.3%, the futures contract price has been inflated due to this high 6% hypothetical coupon relative to the much lower yield levels. However, once the actual bonds that are eligible for delivery get "converted" to the theoretical 6% security, the invoice price will get adjusted to the current market conditions. To make an informed decision which security to deliver, the seller has to calculate the actual price she would receive when the futures contract settles:

Invoice Price = Futures Settlement Price ×
Conversion Factor + Accrued Interest

The conversion factor brings all eligible securities to the "common denominator" (i.e., it is the present value of the cash flow of a deliverable bond, discounted by a 6% yield). The cheapest-to-deliver security would be a deliverable bond with the lowest converted futures price.

To illustrate this, let us take a look at the 2020 September 10-year Treasury futures contract as of June 10, 2020. The futures price is 138-05+, optically quite high, given the gap between the 6% theoretical coupon and the below 1% 10-year yield these days. The following table shows three of the many eligible securities:

Security	Price	Conversion Factor	Gross Basis
T 2 3/8 05/15/27	112-05 ¼	0.8072	20.215
T 2 ¼ 08/15/27	111-18 ¾	0.7943	58.753
T 0 5/8 03/31/27	100-09	0.7142	51.165

The *gross basis* would indicate that the first bond in the above table would be the cheapest-to-deliver. The seller would buy this bond today at 112-05¼ price (112.1641 in decimal terms), and would receive 0.8072 × 138-05+ (111.5352 in decimal terms) from the futures contract buyer (paid and received accrued interest would net each other out). The net difference is –\$0.6317, or 20.215 ticks (0.6317 × 32).

When yields are below 6%, the cheapest-to-deliver bond is typically one of the lower duration eligible bonds, and when yields are higher than 6%, the cheapest-to-deliver would typically be a longer-duration bond.

Treasury Bill Futures Contract

The futures contract on Treasury bills was the first contract on a short-term debt instrument and has been the model for most subsequent contracts on short-term debt. The contract traded on the International Money Market (a division of the CME) is based on three-month Treasury bills with a face value of \$1 million.
The contract is quoted and traded in terms of a futures "price," but the futures price is, in fact, just a different way of quoting the futures interest rate. Specifically, the futures price is the annualized futures rate subtracted from 100. For example, a futures price of 97.50 means that Treasury bills are trading in the

futures market at a rate of 2.50%. The actual price that the buyer pays the seller is calculated using the usual formula for Treasury bills:

$$\text{Invoice price} = \$1{,}000{,}000 \times [1 - \text{rate} \times (\text{days to maturity}/360)]$$

where the rate is expressed in decimal form. As this formula shows, each basis point change in the interest rate (or each 0.01 change in the futures price) leads to a $25 change in the invoice price for a 90-day bill. Consequently, the value of a 0.01 change in the futures contract is always $25.

The Treasury bill futures contract is considerably simpler than the T-bond and T-note futures contracts. First, because all Treasury bills of the same maturity are economically equivalent, there is effectively only one deliverable issue, namely, Treasury bills with three months to maturity. Three months may have 90, 91, or 92 days depending on the month in which the contract is initiated. The fact that the three-month bills may be either new three-month bills or older bills that currently have three months of remaining life makes little difference because the new and old issues will trade the same in the cash market. Thus, all the subtleties surrounding conversion factors and most deliverable issues are absent from the Treasury bill futures market. Furthermore, there is little uncertainty or choice involved in the delivery date because delivery must take place during a very narrow time frame, usually a three-day period. The rules of the exchange make clear well in advance the exact dates on which delivery will take place. Finally, because there are no conversion factors, there is no wildcard play in the Treasury bill futures market.

Although the Treasury bill futures contract is simple and thus may not provide as many speculative and arbitrage opportunities as the more complex long- and intermediate-term futures contracts, it does provide a straightforward means of hedging or speculating on the short end of the yield curve. Because the Treasury bill rate is a benchmark off which other short-term rates may be priced, the bill contract fills a well-defined need of many market participants.

Eurodollar Futures Contract

Eurodollar CDs are U.S. dollar–denominated CDs issued primarily in London by U.S., Canadian, European, and Japanese banks. These CDs earn a fixed rate of interest related to dollar LIBOR. The term LIBOR comes from the London Interbank Offered Rate and is the interest rate at which one London bank offers funds to another London bank of acceptable credit quality in the form of a cash deposit. The rate is "fixed" by the British Bankers Association every business morning by the average of the rates supplied by member banks. After December 2021, LIBOR will be phased out as a reference rate.

Three-month LIBOR is the underlying instrument for the Eurodollar futures contract. The contracts are traded on the International Monetary Market of the CME and the Eurex International Financial Futures Exchange (LIFFE). This contract has a $1 million face value and is traded on an index price basis. The index price basis in which the contract is quoted is equal to 100 minus the annualized futures LIBOR. For example, a Eurodollar futures price of 97.50 means a futures three-month LIBOR of 2.50%.

For illustration, assume that an investor buys one contract of Eurodollar futures at \$98.00 price, or equivalently, the underlying rate is 2.0%. One week later, the underlying rate goes up by 20 basis points. This means that the futures price would decline to 97.80, and the investor would face a loss of \$1 million × 0.2% × 90/360 = \$500. Note that the value of one contract of Eurodollar futures responds \$25 to 1 basis point in yield change, since \$1 million × 0.01% × 90/360 = \$25. Thus, given that buyers of Eurodollar futures benefit from declining rates, and sellers benefit from rates rising, we can also calculate the profit/loss of this for the example in this simple way: –1 × –20 bps × \$25 = –\$500. The –1 is because the buyer of futures loses when rates increase.

The minimum price fluctuation or tick for this contract is 0.005 or 1/2 basis point. Accordingly, the tick value for this contract is \$12.50 as determined by the following expression:

$$\text{Tick value} = \$1{,}000{,}000 \times (0.005 \times 90/360) = \$12.50$$

The Eurodollar futures contract is a cash settlement contract. There are Eurodollar futures contracts available to trade with quarterly expiration dates (March, June, September, and December) that extend out 10 years. Accordingly, it is possible for market participants to hedge or speculate on the level of three-month LIBOR for the next decade. The Eurodollar futures contract is used frequently to trade the short end of the yield curve and many hedgers believe this is the ideal contract for a wide range of hedging situations. Moreover, the Eurodollar futures market and interest rate swaps are intensely interconnected. When valuing swaps at their inception, the future path of floating rates is derived from positions in Eurodollar futures contracts.

In practice, it is common that investors, traders, and hedgers do not simply trade a single contract of Eurodollar futures, but buy or sell a series of contracts to get a somewhat broader exposure to the front end of the yield curve. "Packs" are groups of Eurodollar contracts that can be traded together with a single quote, making the trader's job easier by eliminating the need to enter multiple orders for each Eurodollar contract. The "white" pack contains the first four quarterly contracts (e.g., as of June 10, 2020, the Jun 20/Sep 20/Dec 20/Mar 21 contracts). The "red" pack would mingle the next four quarterly contracts (e.g., those of Jun 21/Sep 21/Dec 21/Mar 22). The "white" and "red" packs would be followed by the "green," "blue," "gold," "purple," "orange," "pink," "silver," and "copper" packs, by following the same logic. Given that each of these packs mingle four contracts, the value of 1 basis point would be \$100 for each of them (4 × \$25). However, trading packs of different colors would provide key rate exposures at distinct segments of the yield curve.

"Bundles" would mingle "packs" together: the "red" bundle would consist of the "white" and the "red" packs, and the "green" would contain all the first 12 quarterly Eurodollar contracts. Thus, the value of 1 basis point would differ by bundles: the "white" bundle has \$100, the "red" has \$200, and the "green" has

$300 value of 1 basis point, and the same logic applies to the full list of various colors, with the "copper" bundle having $1000 value of 1 basis point.

The 90-day sterling LIBOR interest-rate futures contract trades on the main London Futures Exchange, LIFFE. The contract is structured similarly to the Eurodollar futures contract described above. Prices are quoted as 100 minus the interest rate and the expiration months are March, June, September, and December. The contract size is £500,000. A tick is 0.01 or 1 basis point and the tick value is £12.5.

The LIFFE also trades short-term interest-rate futures for other major currencies including euros, yen, and Swiss francs. Short-term interest-rate futures contracts in other currencies are similar to the 90-day sterling LIBOR contract and trade on exchanges such as Deutsche Terminbourse in Frankfurt and MATIF (Marché à Terme International de France) in Paris.

Swap Futures Contracts

Interest-rate swaps are discussed in Chapter 64. The underlying instrument for the swaps futures contract is the notional price of the fixed-rate side of a 10-year interest-rate swap that has a notional principal equal to $100,000 and that exchanges semiannual interest payments at a fixed annual rate of 6% for floating interest-rate payments based on three-month LIBOR.

This swap futures contract is cash-settled, with a settlement price determined by the International Swap and Derivatives Association (ISDA) benchmark 10-year swap rate on the last day of trading before the contract expires. This benchmark rate is published with a one-day lag in the Federal Reserve Board's statistical release H.15. Contracts have settlement months of March, June, September, and December, just like the other CME interest-rate futures contracts that we have discussed.

LIFFE introduced the first swap futures contract called Swapnote, which is referenced to the euro interest-rate swap curve. Swapnotes are available in 2-, 5-, and 10-year maturities.

SOFR Interest Rate Futures Contract

The SOFR is the secured overnight financing rate and serves as a benchmark interest rate for repurchase agreements. With the demise of LIBOR, SOFR represents the heir apparent to be used as a reference rate for various interest rate contracts from interest rate swaps to forward rate agreements. The Federal Reserve publishes the SOFR every business day at 8:00 am. SOFR is calculated as the transaction-weighted median repo rate based on transaction data collected by the Federal Reserve.

There are two futures contracts that trade on the CME derived from the SOFR—the three-month SOFR futures contract and the one-month SOFR futures contract. The underlying price is the compounded daily SOFR interest during the reference quarter such that each basis point per annum of interest is equal to $25 per contract. Price is computed as (100 – R) where R is the compounded daily SOFR interest during the reference quarter. Both contracts have cash settlement.

Fed Funds Futures Contracts

The 30-day federal funds futures contract is designed for financial institutions and businesses who want to control their exposure to movements in the federal funds rate. These contracts have a notional amount of $5 million, and the contract can be written for the current month up to 24 months in the future. Underlying this contract is the simple average overnight federal funds rate (i.e., the effective rate) for the delivery month. As such, this contract is settled in cash on the last business day of the month. Just as the other short-term interest-rate futures contracts discussed earlier, prices are quoted on the basis of 100 minus the overnight federal funds rate for the delivery month. These contracts are marked to market using the effective daily federal funds rate as reported by the Federal Reserve Bank of New York.

Other Futures Contracts

If the yield curve were flat and moved in parallel shifts, a single futures contract would be sufficient for all fixed income hedging and speculative purposes. Different note or bond positions would differ only in the number of contracts needed for a hedge. For example, with perfectly correlated interest-rate changes, one could hedge long bonds with Treasury bill futures. It would require many multiples of the bond's par value in Treasury bills futures for the hedge, but it would work perfectly. The only challenge would be to get the scale of the hedges right.

Historically, the yield curve shifts parallel to itself, steepens or flattens, and becomes more or less curved. Consequently, multiple kinds of contracts are needed to hedge bonds of varying maturity. In addition, because credit spreads widen and narrow, at least one contract with credit risk embedded is needed to allow complete hedging.

The on-the-run (OTR) U.S. Treasury futures contracts are based on prices derived from the yields of on-the-run (most recently auctioned) 2-year, 5-year, and 10-year Treasury notes. These contracts are designed to give users synthetic exposure to the most liquid benchmark maturities on the U.S. Treasury yield curve.

Unlike traditional Treasury futures, OTR Treasury futures have cash settlement. The notional underlying is a U.S. Treasury note with a face value of $100,000 paying a 4% coupon rate per annum on a semiannual basis.

As noted above, credit-spreads widen and narrow and are not perfectly correlated to shifts in the yield curve. This fact suggests there should be a futures contract derived from bonds with exposure to credit risk. Consider the Barclays Capital U.S. Aggregate Bond Index futures contract that trades on the CME. The underlying instrument is the index value multiplied by $100. The index includes all of the sectors of the bond market: Treasury, agency, corporate, agency mortgage-backed, asset-backed, and commercial mortgage-backed.

MECHANICS OF FUTURES TRADING

Types of Orders

When a trader wants to buy or sell a futures contract, the price and conditions under which the order is to be executed must be communicated to a futures broker. The simplest type of order, yet potentially the most perilous from the trader's perspective, is the *market order*. When a market order is placed, it is executed at the best price available as soon as the order reaches the trading pit, the area on the floor of a futures exchange where all transactions for a specific contract are made. The danger of market orders is that an adverse move may take place between the time the trader places the order and the time the order reaches the trading pit.

To avoid the dangers associated with market orders, the trader can place a *limit order* (or *resting order*) that designates a price limit for the execution of the transaction. A *buy limit order* indicates that the futures contract may be purchased only at the designated price or lower. A *sell limit order* indicates that the futures contract may be sold only at the designated price or higher.

The danger of a limit order is that there is no guarantee that it will be executed at all. The designated price may simply not be obtainable. Even if the contract trades at the specified price, the order may not be filled because the market does not trade long enough at the specified price (or better) to fill all outstanding orders. Nevertheless, a limit order may be less risky than a market order. The trader has more control with a limit order because the price designated in the limit order can be revised based on prevailing market prices as long as the order has not already been filled.

The limit order is a conditional order: It is executed only if the limit price or a better price can be obtained. Another type of conditional order is the *stop order*. A stop order specifies that the order is not to be executed until the market reaches a designated price, at which time it becomes a market order. A *buy stop order* specifies that the order is not to be executed until the market rises to a designated price (i.e., trades at or above, or is bid at or above, the designated price). A *sell stop order* specifies that the order is not to be executed until the market price falls below a designated price (i.e., trades at or below, or is offered at or below, the designated price). A stop order is useful when a futures trader already has a position on but cannot watch the market constantly. Traders can preserve profits or minimize losses on open positions by allowing market movements to trigger a closing trade. In a sell (buy) stop order, the designated price is less (greater) than the current market price of the futures contract. In a sell (buy) limit order the designated price is greater (less) than the current market price of the futures contract.

There are two dangers associated with stop orders. Because futures markets sometimes exhibit abrupt price changes, the direction of the change in the futures price may be very temporary, resulting in the premature closing of a position. Also, once the designated price is reached, the stop order becomes a market order and is subject to the uncertainty of the execution price noted earlier for market orders.

A *stop-limit order,* a hybrid of a stop order and a limit order, is a stop order that designates a price limit. Thus, in contrast to the stop order, which becomes a market order if the stop is reached, the stop-limit order becomes a limit order if the stop is reached. The order can be used to cushion the market impact of a stop order. The trader may limit the possible execution price after the activation of a stop. As with a limit order, the limit price might never be reached after the order is activated, and therefore the order might not be executed. This, of course, defeats one purpose of the stop order—to protect a profit or limit a loss.

A trader also may enter a *market-if-touched order.* A market-if-touched is like a stop order in that it becomes a market order if a designated price is reached. However, a market-if-touched order to buy would become a market order if the market *falls* to a given price, whereas a stop order to buy becomes a market order if the market *rises* to a given price. Similarly, a market-if-touched order to sell becomes a market order if the market rises to a specified price, whereas the stop order to sell becomes a market order if the market falls to a given price. One may think of the stop order as an order designed to exit an existing position at an acceptable price (without specifying the exact price), and the market-if-touched order as an order designed to enter a position at an acceptable price (also without specifying the exact price).

Orders may be placed to buy or sell at the open or the close of trading for the day. An *opening order* indicates that a trade is to be executed only in the opening range for the day, and a *closing order* indicates that the trade is to be executed only within the closing range for the day.

Futures brokers may be allowed to try to get the best possible price for their clients. The *discretionary order* gives the broker a specified price range in which to fill the order. For example, a discretionary order might be a limit order that gives the broker a one-tick (i.e., 1 basis point or 1/32) discretion to try to do better than the limit price. Thus, even if the limit price is reached and the order could be filled at that limit, the broker can wait for a better price. However, if it turns out that the market goes in the wrong direction, the broker must fill the order but at no worse than one tick from the limit price. A *not held order* gives the broker virtually full discretion over the order. The not held order may be placed as any of the orders mentioned so far (market, stop, limit, etc.), but if the broker believes that filling the orders is not advisable, he or she need not fill them.

A client may enter orders that contain order cancellation provisions. A *fill-or-kill* order must be executed as soon as it reaches the trading floor, or it is canceled immediately. A *one-cancels-other order* is a pair of orders that are worked simultaneously, but as soon as one order is filled, the other is canceled automatically.

Orders may designate the time period for which the order is effective—a day, week, or month, or perhaps by a given time within the day. An *open order,* or *good-til-canceled order* is good until the order is specifically canceled. If the time period is not specified, it is usually assumed to be good only until the end of the day. For some orders, like the market order, a specific time period is not relevant, because they are executed immediately.

On execution of an order, the futures broker is required to provide confirmation of the trade. The confirmation indicates all the essential information about the trade. When the order involves the liquidation of a position, the confirmation shows the profit or loss on the position and the commission costs.

Taking and Liquidating a Position

Once an account has been opened with a broker, the futures trader may take a position in the market. If the trader buys a futures contract, she is said to have a long position. If the trader's opening position is the sale of the futures contract, she is said to have a short position.

The futures trader has two ways to liquidate a position. To liquidate a position before the delivery date, she must take an offsetting position in the same contract. For a long position, this means selling an identical number of contracts; for a short position, this means buying an identical number of contracts.

The alternative is to wait until the delivery date. At that time, the investor liquidates a long position by accepting the delivery of the underlying instrument at the agreed-on price or liquidates a short position by delivering the instrument at the agreed-on price. For interest-rate futures contracts that do not call for actual delivery (e.g., Eurodollar futures), settlement is in cash at the settlement price on the delivery date.

The Role of the Clearing Corporation

When an investor takes a position in the futures market, there is always another party taking the opposite position and agreeing to satisfy the terms set forth in the contract. Because of the *clearing corporation* associated with each exchange, the investor need not worry about the financial strength and integrity of the party taking the opposite side of the contract. After an order is executed, the relationship between the two parties is severed. The clearing corporation interposes itself as the buyer for every sale and the seller for every purchase. Thus, the investor is free to liquidate a position without involving the other party to the original transaction and without worry that the other party may default. However, the investor *is* exposed to default on the part of the futures broker through which the trade is placed. Thus, each institution should make sure that the futures broker (and specifically the *subsidiary* that trades futures) has adequate capital to ensure that there is little danger of default.

Margin Requirements

When first taking a position in a futures contract, an investor must deposit a minimum dollar amount per contract as specified by the exchange. (A broker may ask for more than the exchange minimum but may not require less than the exchange minimum.) This amount is called the *initial margin* and constitutes a good faith deposit. The initial margin may be in the form of Treasury bills. As the price of the futures contract fluctuates, the value of equity in the position changes. At the close of each trading day, the position is marked to market, so that any gain or loss from the position is reflected in the equity of the account. The price used to mark the position to market is the settlement price for the day.

Maintenance margin is the minimum level to which an equity position may fall as a result of an unfavorable price movement before additional margin is required. The additional margin deposited, also called *variation margin,* is simply the amount that will bring the equity in the account back to its initial margin level. Unlike original margin, variation margin must be in cash. If there is excess margin in the account, that amount may be withdrawn.[1]

If a variation margin is required, the party is contacted by the brokerage firm and informed of the additional amount that must be deposited. A margin notice is sent as well. Even if futures prices subsequently move in favor of the institution such that the equity increases above the maintenance margin, the variation margin must still be supplied. Failure to meet a request for variation margin within a reasonable time will result in the closing out of a position.

Margin requirements vary by futures contract and by the type of transaction—that is, whether the position is an outright long or short or a spread (a long together with a short), and whether the trade is put on as a speculative position or as a hedge. Margins are higher for speculative positions than for hedging positions and higher for outright positions than for spreads. Margin requirements also vary between futures brokers. Exchanges and brokerage firms change their margin requirements as contracts are deemed to be more or less risky, or as it is felt that certain types of positions (usually speculative positions) should be discouraged.

REPRESENTATIVE EXCHANGE-TRADED FUTURES OPTIONS CONTRACTS

Although futures contracts are relatively straightforward financial instruments, options on futures (or *futures options,* as they are commonly called) deserve extra explanation. Options on futures are very similar to other options contracts.

Like options on cash (or spot) fixed income securities, both put and call options are traded on fixed income futures. The buyer of a call has the right to buy

1. Although there are initial and maintenance margin requirements for buying stocks and bonds on margin, the concept of margin differs for futures. When securities are bought on margin, the difference between the price of the security and the initial margin is borrowed from the broker. The security purchased serves as collateral for the loan and interest is paid by the investor. For futures contracts, the initial margin, in effect, serves as good-faith money, indicating that the investor will satisfy the obligation of the contract. No money is borrowed by the purchaser. Similarly, the seller of futures borrows neither money nor securities.

the underlying futures contract at a specific price. The buyer of a put has the right to sell the underlying futures contract at a specific price. If the buyer chooses to exercise the option, the option seller is obligated to sell the futures in the case of the call or buy the futures in the case of the put.

An option on the futures contract differs from more traditional options in only one essential way: the underlying instrument is not a spot security, but a futures contract on a security. Thus, for instance, if a call option buyer exercises her option, she acquires a long position in futures instead of a long position in a cash security. The seller of the call will be assigned the corresponding short position in the same futures contract. For put options the situation is reversed. A put option buyer exercising the option acquires a short position in futures, and the seller of the put is assigned a long position in the same futures contract. The resulting long and short futures positions are like any other futures positions and are subject to daily marking to market.

An investor acquiring a position in futures does so at the current futures price. However, if the strike price on the option does not equal the futures price at the time of exercise, the option seller must compensate the option buyer for the discrepancy. Thus, when a call option is exercised, the seller of the call must pay the buyer of the call the current futures price minus the strike price. On the other hand, the seller of the put must pay the buyer of the put the strike price minus the current futures price. (These transactions are actually accomplished by establishing the futures positions at the strike price, then immediately marking to market.) Note that, unlike options on spot securities, the amount of money that changes hands at exercise is only the difference between the strike price and the current futures price, not the whole strike price. Of course, an option need not be exercised for the owner to take her gains; she can simply sell the option instead of exercising it.

We now turn to the options contracts themselves. We describe two of the most important contracts, the CME's options on the long-term bond futures contract and on the Eurodollar contract. There are also options on the 5- and 10-year note futures contracts, but because they are both very similar in structure to options on Treasury bond futures, they are not included in this section.

Options on Treasury Bond Futures

Options on CME Treasury bond futures are in many respects simpler than the underlying futures contracts. Usually, conversion factors, most deliverables, wildcard plays, and other subtleties of the Treasury bond futures contract need not concern the buyer or seller of options on Treasury bond futures. Although these factors affect the fair price of the futures contract, their impact is already reflected in the futures price. Consequently, they need not be reconsidered when buying or selling an option on the futures.

The option on the Treasury bond futures contract is in many respects an option on an index; the "index" is the futures price itself, that is, the price of the fictitious 20-year 6% Treasury bond. As for the futures contract, the nominal size of the contract is \$100,000. Thus, for example, with futures prices at 95, a call option struck at 94 has an intrinsic value of \$1000 and a put struck at 100 has an intrinsic value of \$5000.

In an attempt to compete with the OTC option market, *flexible Treasury futures options* were introduced. These futures options allow counterparties to customize options within certain limits. Specifically, the strike price, expiration date, and type of exercise (American or European) can be customized subject to CME constraints. One key constraint is that the expiration date of a flexible contract cannot exceed that of the longest standard option traded on the CME. Unlike an OTC option, where the option buyer is exposed to counterparty risk, a flexible Treasury futures option is guaranteed by the clearinghouse. The minimum size requirement for the launching of a flexible futures option is 100 contracts.

The premiums for options on Treasury bond futures are quoted in terms of points and 64ths of a point. An option premium of 1-10 therefore implies a price of $1^{10}/64\%$ of face value, or \$1156.25 (from \$100,000 × 1.15625%). Minimum price fluctuations are also 1/64 of 1%.

Although an option on the Treasury bond futures contract is hardly identical to an option on a Treasury bond, it serves much the same purpose. Because spot and futures prices for Treasury bonds are highly correlated, hedgers and speculators frequently find that options on bond futures provide the essential characteristics needed in an options contract on a long-term fixed income instrument.

Options on Eurodollar Futures

Options on Eurodollar futures fill a unique place among exchange-traded hedging products. These options are currently the only liquid listed option contracts based on a short-term interest rate.

Options on Eurodollar futures (traded on the CME) are based on the quoted Eurodollar futures price (i.e., 100 minus the annualized yield). Like the underlying futures, the size of the contract is \$1 million and each 0.01 change in price carries a value of \$25. Likewise, the option premium is quoted in terms of basis points. Thus, for example, an option premium quoted as 20 (or 0.20) implies an option price of \$500; a premium of 125 (or 1.25) implies an option price of \$3125.

Like other debt options, buyers of puts on Eurodollar futures profit as rates move up and buyers of calls profit as rates move down. Consequently, institutions with liabilities or assets that float off short-term rates can use Eurodollar futures options to hedge their exposure to fluctuations in short-term rates. Consider institutions that have liabilities that float off short-term rates. These include banks and thrifts that issue CDs and/or take deposits based on money market rates. Also included are industrial and financial corporations that issue commercial paper, floating-rate notes, or preferred stock that floats off money market rates. Likewise, those who make payments on adjustable-rate mortgages face similar risks.[2] In each instance, as short-term rates increase, the liability becomes more onerous for the borrower. Consequently, the issuers of these liabilities may need a means of capping their interest-rate expense. Although options on Eurodollar futures do not extend as far into the future as many issuers would like, they are effective tools for hedging many short-term rates over the near term. Consequently, an institution with floating-rate liabilities can buy an interest-rate *cap* by buying puts on Eurodollar futures. As rates move up, profits on the put position will tend to offset some or all of the incremental interest expense.

On the other side of the coin, and facing opposite risks, are the purchasers of floating-rate instruments—that is, investors who buy money market deposits, floating-rate notes, floating-rate preferred stock, and adjustable-rate mortgages. Investors who roll over CDs or commercial paper face the same problem. As rates fall, these investors receive less interest income. Consequently, they may feel a need to buy interest-rate *floors,* which are basically call options. As rates fall, calls on debt securities increase in value and will offset the lower interest income received by the investor.

In conclusion, options on Eurodollar futures can be used to limit the risk associated with fluctuations in short-term rates. This is accomplished by buying puts if the exposure is to rising rates, or by buying calls if the exposure is to falling rates.

Mechanics of Trading Futures Options

To take a position in futures options, one works with a futures broker. The types of orders that are used to buy or sell futures options are generally the same as the orders discussed for futures contracts. The clearinghouse associated with the exchange where the futures option is traded once again stands between the buyer and the seller. Furthermore, the commission costs and related issues that we discussed for futures also generally apply to futures options.

There are no margin requirements for the buyer of futures options, but the option price must be paid in full when the option is purchased. Because the option price is the maximum amount that the buyer can lose regardless of how adverse the price movement of the underlying futures contract, there is no need for margin.

Because the seller has agreed to accept all of the risk (and no reward other than the option premium) of the position in the underlying instrument, the seller generally is required to deposit not only the margin required for the underlying futures contract but also with certain exceptions, the option price as well. Furthermore, subsequent price changes adversely affecting the seller's position will lead to additional margin requirements.

2. To the extent that the interest-rate payment on an adjustable-rate mortgage has an upper and lower bound, the risk to issuers and investors is limited by the nature of the instrument.

OTC CONTRACTS

There is a substantial OTC market for fixed income options and forwards. (Forward contracts are the OTC equivalent of futures contracts.) For example, in the OTC market, one can easily buy or sell options on LIBOR, commercial paper, Treasury bills, and prime rates. One can buy and sell options on virtually any Treasury issue. One can buy and sell options on any number of mortgage securities. One can buy and sell options with expirations ranging from as short as one day to as long as 10 years. In the OTC market, one can easily take forward positions in three- and six-month LIBOR going out to about two years.

In the options market in particular, a natural division has evolved between the OTC market and the listed market. Given the relatively small number of futures contracts, the exchanges' need for standardization, and the synergy created by the futures options contract trading side by side with the underlying futures contract, the exchanges have been most successful with options on futures contracts. Because off-exchange options on futures are prohibited, futures options cannot be traded over the counter. On the other hand, because the OTC market is very good at creating flexible structures and handling a diversity of terms, the OTC market has been more successful than the exchanges in trading options on cash securities and on cash market interest rates.

In the following sections, we discuss the structure of the OTC fixed income derivative markets and their advantages and disadvantages relative to the exchange-traded markets. We also discuss the most important contracts traded in the OTC market. These are options on mortgage securities, options on cash Treasuries, caps and floors on LIBOR, and forward rate agreements on LIBOR.

The Structure of the OTC Market

As in other OTC markets, there is no central marketplace for OTC fixed income options and forward contracts. A transaction takes place whenever a buyer and seller agree to a price. Unlike an exchange transaction, the terms, size, and price of the contract generally remain undisclosed to other market participants. Accordingly, the OTC market is much less visible than the exchange markets and it is more difficult to ascertain the current market price for a given option or forward contract. Two groups, however, help to alleviate this problem. First, there are the OTC market-makers. Market-makers in OTC fixed income options and forwards are typically large investment banks and commercial banks. A market-maker, by definition, stands ready to buy or sell a given option or forward contract to accommodate a client's needs. To be effective, the market-maker must be willing and able to handle large orders and must keep the bid/ask spreads reasonably narrow.

The other group that helps bring order to the OTC market is the brokers. The sole job of the brokers is to bring together buyers and sellers; it is not the brokers' job to take positions in option and forward contracts. The buyers and sellers that the brokers bring together can be market-makers or the end users of the contracts. To do their job, the brokers must distribute information about the prices where they see trades taking place and the prices at which they believe further trades can be completed. This information is distributed to potential buyers and sellers over the phone and over publicly available media such as Telerate pages.

Because there is no central market for OTC fixed income options and forwards, there can be no clearinghouse. Consequently, those who position OTC contracts may have to give considerable weight to the creditworthiness of their counterparty. For example, entities that sell options or position forward rate agreements (FRAs) can have potential liabilities equal to several times their net worth. Furthermore, there is no guarantee that these counterparties have effective hedges against their positions or, in fact, that they are hedging at all. Furthermore, financial problems on the part of the counterparty can jeopardize the ability or willingness of the counterparty to make good on the terms of a contract even if it is hedged. Consequently, unlike the exchange-traded markets, where one neither knows nor cares who is on the other side of a trade, in the OTC market it is usually very important to know who is on the other side. Creditworthiness can be one of the most important considerations in the trade.

The potential credit problems associated with OTC trades are mitigated in a number of ways. First, some institutions will not buy options from or take either side of an FRA contract with any party other than a major entity with a sound credit rating. Second, some institutions require their counterparty to post collateral immediately after the transaction is completed. This collateral serves much the same purpose as initial margin in the futures and futures options market. Finally, some institutions reserve the right to call for additional collateral from their counterparties if the market moves against the counterparty. This is analogous to variation margin in the exchange-traded markets. Although these provisions may not be as good as a central clearinghouse, they are apparently good enough for a very large number of institutions and good enough for a very large market to develop.

Liquidity, in terms of being able to easily close out an existing position, can be a constraint in the OTC market. OTC options and forwards generally are not assignable transactions. Thus, for example, if one sells an option, the contingent liability associated with that option cannot be transferred to a third party without the express permission of the option buyer. If an option seller wants to cover a short option position, often the best strategy is to buy a similar option from a third party to offset the risks of the original option. However, if the credit of the offsetting party is in question, or the offsetting option is not identical, risks will remain for the option seller. The option buyer can face similar problems if closing out the option before expiration. Credit considerations and the fact that the option buyer may not be able to sell an identical option to offset the first option make it more difficult to effectively close out the long option position. Because FRAs involve contingent liabilities for both sides of the transaction, similar problems exist for both buyers and sellers of FRAs.

Some of the problems associated with the OTC market arise from the fact that the contracts are not standardized. However, nonstandardization leads to many benefits as well. As indicated earlier, OTC contracts can be specified in virtually any terms that are acceptable to both buyer and seller. A potential buyer or seller thus can approach a market-maker with whatever structure is needed and in many (but certainly not all) cases obtain the desired structure at a reasonable price. Compared to the very rigid structure of the exchange-traded markets, this is a remarkable advantage.

Caps and Floors on LIBOR

The primary OTC options covering the short end of the yield curve are the caps and floors on three- and six-month LIBOR. A cap on LIBOR is, in essence, a series of puts on LIBOR-based debt, whereas a floor on LIBOR is, in essence, a series of calls on LIBOR-based debt.

The buyer of a cap or floor holds most of the rights in the contract, as with other options. The seller of a cap or floor will of course receive an options premium from the buyer but is then obligated to perform on the contract.

To see how these contracts work, consider a five-year, $100 million cap on three-month LIBOR struck at 2%. Such a contract will specify reset dates occurring every three months for a total of 20 resets. The first reset will usually occur immediately or within a couple of weeks of the trade date, and the last reset will usually be about three months before the stated maturity of the contract. To determine what the payoff to the cap buyer will be, on every reset date one compares the three-month LIBOR (taken from a predetermined source) with the 2% strike rate. If the three-month LIBOR is at or below 2%, nothing is owed to the cap buyer. However, if the three-month LIBOR is above 2%, the cap seller must pay the cap buyer the monetary value of the amount by which three-month LIBOR exceeds 2%. In this case, for a 90-day interest accrual period, the value of each basis point is $2500 (from 0.0001 × $100,000,000 × 90/360). Thus, for example, if three-month LIBOR on a particular reset date is 2.50%, the cap seller owes the cap buyer $125,000 for that reset. If, on the next reset date, three-month LIBOR is 4%, the cap seller owes the cap buyer $500,000 for that reset. If, on the next reset date, three-month LIBOR is 1.50%, the cap seller owes nothing to the cap buyer for that reset. In most cases, the cap seller pays the cap buyer the amount of money owed for a particular reset at the end of the interest accrual period-in this case, three months after the reset date.

The mechanics of floors are similar, except that the payoff comes when rates fall below a given level, instead of when they rise above a given level. For example, if one buys a $25 million seven-year 3% floor on six-month LIBOR, there are a total of 14 reset dates. On each of these reset dates, one compares six-month

LIBOR to 3%. If six-month LIBOR is above 3%, nothing is owed to the buyer of the floor for that reset. However, if six-month LIBOR is below 3%, for a 180-day interest accrual period the floor seller owes the floor buyer $1250 for every basis point by which six-month LIBOR is below 3% (from 0.0001 × $25,000,000 × $^{180}/_{360}$).

Like other OTC options markets, the cap and floor market is composed of market-makers, end users, and brokers. The market-makers are once again the large investment banks and commercial banks. However, there are fewer market-makers and generally wider spreads in the cap and floor market than there are in the options market for mortgages or Treasury securities. Nonetheless, there is an active market out to 10 years, particularly for out-of-the-money caps and, to a lesser degree, out-of-the-money floors.

The end-user buyers of caps and floors are primarily institutions with risks that they need to cover. For example, institutions that fund short and lend long will tend to have losses as short-term rates rise. Similarly, businesses that fund by rolling over short-term obligations such as commercial paper or by bank borrowings tied to LIBOR or the prime rate will tend to have losses as short-term rates rise. These institutions, which include many thrifts, banks, and finance companies, as well as industrial and construction companies, can protect themselves against rising short-term rates by buying caps. End-user buyers of floors tend to be firms that face losses if rates fall. Such a case might occur, for example, if an institution borrows at a floating rate with a built-in floor. Such an institution may be structured so that floating rates, per se, pose no problem; the problem arises when the floating rate at which they borrow is no longer really floating because the floor has been hit. This institution may buy a floor so that it will receive monetary compensation from the floor seller whenever the floating rate falls below the floor rate, thus covering the risks of lower rates.

The sellers of caps and floors, other than the market-makers, are quite varied. In some cases, sellers sell caps or floors outright to bring in premium income. Others sell caps and/or floors to smooth out the cash flows on other fixed income instruments, such as certain derivative mortgage products. In other cases, sellers only implicitly sell the caps or floors. The following example illustrates both kinds of sellers.

When the cap market was developing, it quickly became obvious that there were many natural buyers of caps, but few natural sellers of caps. One successful effort to create sellers of caps occurred when investment bankers, who had many potential buyers of caps, realized that caps could be created as a derivative of the floating-rate note (FRN) market. Issuers of FRNs routinely issue notes reset off LIBOR. Furthermore, there were known buyers of *capped* FRNs, but of course, capped FRNs must have a higher coupon than uncapped FRNs to compensate the FRN buyer for the cap risk. If an issuer sells capped floating-rate notes, the issuer, in effect, buys a cap on LIBOR from the buyer of the FRN. This cap can then be sold to the investment banker, who in turn sells it to cap-buying clients. The deals that took place took exactly this form. The investment bankers underwrote capped FRNs for certain FRN issuers who agreed to make cap-like payments to their investment banker. The banker then sold caps to another client but did not incur any market risks because the two sets of potential payments offset one another. Using part of the proceeds of the sale of the cap, the investment bank agreed to make payments to the issuer to bring the cost of the floating-rate debt down to a level below that of uncapped floating-rate notes. Thus, the investment bankers, the issuers of the FRNs, the buyers of the FRNs, and the ultimate cap-buying clients all walked away with a satisfactory transaction.

Such a transaction illustrates how creative financing can be used to create a seller of an instrument when no obvious seller exists. In this example, the issuers of the FRNs are willing to sell caps, given the fact that they, in turn, find someone willing to sell the caps to them. The ultimate seller of caps is the buyer of the capped FRNs. The buyers of the FRNs are, however, only implicit sellers of caps in the sense that they never explicitly have a position in caps on their books.

This example, which is just one of dozens, shows how market-makers explicitly and implicitly induce end users of financial products to buy or sell the instruments that allow the market-makers to cover their positions in the OTC market. This is not to say that the market-makers are taking advantage of the other parties to their trades. As is often the case, all parties to a transaction can come out ahead.

Forward Rate Agreements

The forward rate agreement (FRA) market represents the OTC equivalent of the exchange-traded futures contracts on short-term rates. FRAs are a natural outgrowth of the interbank market for short-term funds. However, unlike the interbank market, virtually any creditworthy entity can buy or sell FRAs.

The liquid and easily accessible sector of the FRA market is for three- and six-month LIBOR. Rates are quoted widely for settlement starting one-month forward and settling once every month thereafter out to about six months forward. Thus, for example, on any given day forward rates are available for both three- and six-month LIBOR one month forward, covering, respectively, the interest period starting in one month and ending in four months, and the interest period starting in one month and ending in seven months. These contracts are referred to as 1×4 and 1×7 contracts. On the same day, there will be FRAs on three- and six-month LIBOR for settlement two months forward. These are the 2×5 and 2×8 contracts. Similarly, settlements occur three months, four months, five months, and six months forward for both three- and six-month LIBOR. These contracts are also denoted by the beginning and end of the interest period they cover.

On each subsequent day, contracts with the same type of structures, that is, contracts with one month, two months, and so on, to settlement date, are offered again. Thus, although on any given day a relatively limited number of structures are widely quoted, new contracts with new settlement dates are offered at the beginning of each day. This is quite different from the futures market, where the same contracts with the same delivery dates trade day after day.

As for other OTC debt instruments, there are market-makers and brokers who make the market work. However, unlike the other OTC derivative instruments, in the FRA market the commercial banks are clearly the dominant force among the market-makers. This dominance is due to the ability of the banks to blend their FRA transactions into their interbank transactions and overall funding operations. Consequently, many banks are willing to quote on a much wider variety of structures than the standard structures explained above. One can choose maturities other than three- and six-month LIBOR, and one can choose many settlement dates other than at an even number of months in the future.

In most cases, FRAs are written so that no money changes hands until the settlement date. To determine the cash flows on the settlement date, LIBOR taken from some predetermined source is compared to the LIBOR rate specified in the FRA contract. The actual dollar amount that changes hands is the dollar value of the difference between the two rates, *present valued* for a period equal to the maturity of the underlying LIBOR, either three or six months. The rationale behind present valuing is that if an FRA is used to hedge the rate on a deposit (or other short-term instrument), the loss (gain) due to a change in interest rates will be paid (saved) at the maturity of the deposit, not at the issue date. Thus, because cash payments on the FRA are made on the settlement date (which presumably is the same as the issue date of the deposit) the present value of the interest expense (or saving) on the deposit will equal the amount of money actually received or paid on the FRA.

Finally, one peculiarity of the FRA market deserves note. Unlike the case of the Eurodollar futures, if one *buys* an FRA, one profits from an *increase* in rates, and if one *sells* an FRA, one profits from a *decline* in rates. Furthermore, while the daily profit or loss on the Eurodollar futures trades is a *linear* function of the changes in the underlying LIBOR rate, the profit and loss on an FRA transaction would be a *convex* function of the underlying rate due to the present valuing of the difference of the contract and reference rates. In practice, though, this convexity bias has a lower impact in the current low interest rate environment than under high yield levels.

KEY POINTS

- A forward contract is an agreement for the future delivery of something at a specified price at the end of a designated period of time but differs from a futures contract in that it is nonstandardized and does not trade on an organized exchange.
- Parties to a forward contract are exposed to counterparty risk, which is the risk that the counterparty will not satisfy its contractual obligations.
- A futures contract is an agreement between a buyer (seller) and an established exchange or its clearinghouse in which the buyer (seller) agrees to take (make) delivery of something at a specified price during a designated period of time.
- The parties to a futures contract are required to satisfy margin requirements.

- An investor who takes a long futures position realizes a gain when the futures price increases; an investor who takes a short futures position realizes a loss when the futures price decreases.
- For the Treasury bond futures contract, the underlying instrument is \$100,000 par value of a hypothetical 20-year, 6% coupon Treasury bond.
- Conversion factors are used to adjust the invoice price of a Treasury bond futures contract to make delivery equitable to both parties.
- The short in a Treasury bond futures contract has several delivery options.
- The 2-year, 5-year, and 10-year Treasury note futures contracts are modeled after the Treasury bond futures contract.
- Three-month LIBOR is the underlying instrument for the Eurodollar futures contract. This futures contract is a cash settlement contract and is one of the most heavily traded futures contracts in the world.
- The federal funds futures contract is a cash settlement contract whose underlying is the average overnight federal funds for the delivery month.
- The underlying instrument for a swap futures contract is the notional price of the fixed-rate side of a 10-year interest-rate swap that has a notional principal equal to \$100,000 and that exchanges semiannual interest payments at a fixed annual rate of 6% for floating interest-rate payments based on three-month LIBOR.
- Interest rate options include options on fixed income securities and options on interest rate futures called futures options.
- Caps and floors are agreements between two parties whereby one party for an upfront fee agrees to compensate the other if a designated interest rate is different from a predetermined level.
- A forward rate agreement is an over-the-counter derivative instrument that is essentially a forward-starting loan, but with no exchange of principal, so the cash exchanged between the counterparties depend only on the difference in interest rates.
- The elements of an FRA are the FRA rate, reference rate, notional amount, contract period, and settlement date.
- The buyer of an FRA is agreeing to pay the FRA rate and the seller of the FRA is agreeing to receive the FRA rate. The amount that must be exchanged at the settlement date is the present value of the interest differential.
- In contrast to an interest-rate futures contract, the buyer of an FRA benefits if the reference rate increases and the seller benefits if the reference rate decreases.

CHAPTER
SIXTY-TWO

PRICING FUTURES AND PORTFOLIO APPLICATIONS

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One of the primary concerns most traders and investors have when taking a position in futures contracts is whether the futures price at which they transact will be a fair price. Buyers are concerned that the price may be too high and that they will be picked off by more experienced futures traders waiting to profit from the mistakes of the uninitiated. Sellers worry that the price is artificially low and that savvy traders may have manipulated the markets so that they can buy at bargain-basement prices. Furthermore, prospective participants frequently find no rational explanation for the sometimes violent ups and downs that occur in the futures markets. Theories about efficient markets give little comfort to anyone who knows of or has experienced the sudden losses that can occur in the highly leveraged futures markets.

Fortunately, the futures markets are not as irrational as they may at first seem; if they were, they would not be so successful. The interest-rate futures markets are not perfectly efficient markets, but they probably come about as close as any market. Furthermore, there are very clear reasons why futures prices are what they are, and there are methods by which traders, investors, and borrowers will quickly eliminate any discrepancy between futures prices and their fair levels.

In this chapter we will explain how the fair or theoretical value of a futures contract is determined. We then explain several portfolio applications of interest-rate futures.

PRICING OF FUTURES CONTRACTS

There are several different ways to price futures contracts. Fortunately, all lead to the same fair price for a given contract. Each approach relies on the *law of one price.* This law states that a given financial asset (or liability) must have the same price regardless of the means by which one goes about creating that asset (or liability). In this section we will demonstrate one way in which futures contracts can be

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combined with cash market instruments to create cash flows that are identical to other cash securities. The law of one price implies that the synthetically created cash securities must have the same price as the actual cash securities. Similarly, cash instruments can be combined to create cash flows that are identical to futures contracts. By the law of one price, the futures contract must have the same price as the synthetic futures created from cash instruments.

Illustration of the Basic Principles

To understand how futures contracts should be priced, consider the following example. Suppose that a 20-year $100 par value bond with a coupon rate of 12% is selling at par. Also suppose that this bond is the deliverable for a futures contract that settles in three months. If the current three-month interest rate at which funds can be loaned or borrowed is 8% per year, what should be the price of this futures contract?

Suppose the price of the futures contract is 107. Consider the following strategy:

Sell the futures contract at 107.

Purchase the bond for 100.

Borrow 100 for three months at 8% per year.

The borrowed funds are used to purchase the bond, resulting in no initial cash outlay for this strategy. Three months from now, the bond must be delivered to settle the futures contract and the loan must be repaid. These trades will produce the following cash flows:

From settlement of the futures contract	
Flat price of bond	107
Accrued interest (12% for three months)	+3
Total proceeds	110
From the loan	
Repayment of principal of loan	100
Interest on loan (8% for three months)	+2
Total outlay	102
Profit	8

This strategy will guarantee a profit of 8. Moreover, the profit is generated with no initial outlay because the funds used to purchase the bond are borrowed. The profit will be realized *regardless of the futures price at the settlement date.* Obviously, in a well-functioning market, arbitrageurs would buy the bond and sell the futures, forcing the futures price down and bidding up the bond price so as to eliminate this profit. This strategy of purchasing a bond with borrowed funds and simultaneously selling a futures contract to generate an arbitrage profit is called a *cash and carry trade.*

In contrast, suppose that the futures price is 92 instead of 107. Consider the following strategy:

Buy the futures contract at 92.

Sell (short) the bond for 100.

Invest (lend) 100 for three months at 8% per year.

Once again, there is no initial cash outlay. Three months from now a bond will be purchased to settle the long position in the futures contract. That bond will then be used to cover the short position (i.e., to cover the short sale in the cash market). The outcome in three months would be as follows:

From settlement of the futures contract	
Flat price of bond	92
Accrued interest (12% for three months)	+3
Total outlay	95
From the loan	
Principal received from maturing investment	100
Interest earned from the three-month investment (8% for three months)	+2
Total proceeds	102
Profit	7

The 7 profit is a pure arbitrage profit. It requires no initial cash outlay and will be realized regardless of the futures price at the settlement date. Because this strategy involves initially selling the underlying bond, it is called a *reverse cash and carry trade*.

There is a futures price, however, that will eliminate the arbitrage profit. There will be no arbitrage if the futures price is 99. Let's look at what would happen if the two previous strategies were followed and the futures price were 99. First, consider the following cash and carry trade:

Sell the futures contract at 99.

Purchase the bond for 100.

Borrow 100 for three months at 8% per year.

In three months, the outcome would be as follows:

From settlement of the futures contract	
Flat price of bond	99
Accrued interest (12% for three months)	+3
Total proceeds	102
From the loan	
Repayment of principal of the loan	100
Interest on the loan (8% for three months)	+2
Total outlay	102
Profit	0

There is no arbitrage profit.

Next, consider the following reverse cash and carry trade:

Buy the futures contract at 99.

Sell (short) the bond for 100.

Invest (lend) 100 for three months at 8% per year.

The outcome in three months would be as follows:

From settlement of the futures contract	
Flat price of bond	99
Accrued interest (12% for three months)	+3
Total outlay	102
From the loan	
Principal received from maturing investment	100
Interest earned from the three-month investment (8% for three months)	+2
Total proceeds	102
Profit	0

Thus neither strategy results in a profit. The futures price of 99 is the equilibrium price because any higher or lower futures price will permit arbitrage profits.

Theoretical Futures Price Based on Arbitrage Model

Considering the arbitrage arguments just presented, the equilibrium futures price can be determined on the basis of the following information:

- The price of the bond in the cash market.
- The coupon rate on the bond. In our example, the coupon rate was 12% per annum.

- The interest rate for borrowing and lending until the settlement date. The borrowing and lending rate is referred to as the *financing rate*. In our example, the financing rate was 8% per annum.

We will let

r = financing rate

c = current yield, or coupon rate divided by the cash market price

P = cash market price

F = futures price

t = time, in years, to the futures delivery date

and then consider the following cash and carry trade that is initiated on a coupon date:

Sell the futures contract at F.

Purchase the bond for P.

Borrow P until the settlement date at r.

The outcome at the settlement date is as follows:

From settlement of the futures contract	
Flat price of bond	F
Accrued interest	$+ctP$
Total proceeds	$F + ctP$
From the loan	
Repayment of principal of the loan	P
Interest on loan	$+ rtP$
Total outlay	$P + rtP$

The profit will equal

$$\text{Profit} = \text{total proceeds} - \text{total outlay}$$

$$\text{Profit} = F + ctP - (P + rtP)$$

In equilibrium, the theoretical futures price occurs where the profit from this strategy is zero. Thus, to have equilibrium, the following must hold:

$$0 = F + ctP - (P + rtP)$$

Solving for the theoretical futures price, we have

$$F = P + Pt(r - c) = P[1 + t(r - c)] \tag{62-1}$$

Alternatively, consider the following reverse cash and carry trade:

Buy the futures contract at F.

Sell (short) the bond for P.

Invest (lend) P at r until the settlement date.

The outcome at the settlement date would be as follows:

From settlement of the futures contract	
Flat price of bond	F
Accrued interest	$+ ctP$
Total outlay	$F + ctP$
From the loan	
Proceeds received from maturing of investment	P
Interest earned	$+ rtP$
Total proceeds	$P + rtP$

The profit will equal

$$\text{Profit} = \text{total proceeds} - \text{total outlay}$$
$$\text{Profit} = P + rtP - (F + ctP)$$

Setting the profit equal to zero so that there will be no arbitrage profit and solving for the futures price, we obtain the same equation for the futures price as Eq. (62-1).

Let's apply Eq. (62-1) to our previous example in which

$$r = 0.08$$
$$c = 0.12$$
$$P = 100$$
$$t = 0.25$$

Then the theoretical futures price is

$$\begin{aligned} F &= 100 + 100 \times 0.25(0.08 - 0.12) \\ &= 100 - 1 = 99 \end{aligned}$$

This agrees with the equilibrium futures price we derived earlier.

The theoretical futures price may be at a premium to the cash market price (higher than the cash market price) or at a discount from the cash market price (lower than the cash market price), depending on the value of $(r - c)$. The term $r - c$ is called the *net financing cost* because it adjusts the financing rate for the coupon interest earned. The net financing cost is more commonly called the *cost of carry,* or simply *carry. Positive carry* means that the current yield earned is greater than the financing cost; *negative carry* means that the financing cost exceeds the current yield. The relationships can be expressed as follows:

Carry	Futures Price
Positive ($c > r$)	Will sell at a discount to the cash price ($F < P$)
Negative ($c < r$)	Will sell at a premium to the cash price ($F > P$)
Zero ($r = c$)	Will be equal to the cash price ($F = P$)

In the case of interest-rate futures, carry (the relationship between the short-term financing rate and the current yield on the bond) depends on the shape of the yield-curve. When the yield-curve is upward-sloping, the short-term financing rate will generally be less than the current yield on the bond, resulting in positive carry. The futures price will then sell at a discount to the cash price for the bond. The opposite will hold true when the yield-curve is inverted.

A Closer Look at the Theoretical Futures Price

To derive the theoretical futures price using the arbitrage argument, we made several assumptions. We will now discuss the implications of these assumptions.

Interim Cash Flows. No interim cash flows owing to variation margin or coupon interest payments were assumed in the model. However, we know that interim cash flows can occur for both of these reasons. Because we assumed no variation margin, the price derived is technically the theoretical price for a forward contract (which is not marked to market at the end of each trading day). If interest rates rise, the short position in futures will receive margin as the futures price decreases; the margin can then be reinvested at a higher interest rate. In contrast, if interest rates fall, there will be variation margin that must be financed by the short position; however, because interest rates have declined, the financing can be done at a lower cost. Thus, whichever way rates move, those who are short futures gain relative to those who are short forward contracts that are not marked to market. Conversely, those who are long futures lose relative to those who are long forward contracts that are not marked to market. These facts account for the difference between futures and forward prices.

Incorporating interim coupon payments into the pricing model is not difficult. However, the value of the coupon payments at the settlement date will depend on the interest rate at which they can be reinvested. The shorter the maturity of the futures contract and the lower the coupon rate, the less important the reinvestment income is in determining the theoretical futures price.

The Short-Term Interest Rate (Financing Rate). In deriving the theoretical futures price, it is assumed that the borrowing and lending rates are equal. Typically, however, the borrowing rate is greater than the lending rate.

We will let

$$r_B = \text{borrowing rate}$$
$$r_L = \text{lending rate}$$

Consider the following strategy:

Sell the futures contract at F.

Purchase the bond for P.

Borrow P until the settlement date at r_B.

The futures price that would produce no arbitrage profit is

$$F = P + P\,(r_B - c) \tag{62-2}$$

Now consider the following strategy:

Buy the futures contract at F.

Sell (short) the bond for P.

Invest (lend) P at r_L until the settlement date.

The futures price that would produce no profit is

$$F = P + P(r_L - c) \tag{62-3}$$

Equations (62-2) and (62-3) together provide boundaries for the theoretical futures price. Equation (62-2) provides the upper boundary, and Eq. (62-3) the lower boundary. For example, assume that the borrowing rate is 8% per year, or 2% for three months, and the lending rate is 6% per year, or 1.5% for three months. Then, using Eq. (62-2) and the previous example, the upper boundary is

$$F\text{(upper boundary)} = \$100 + \$100(0.02 - 0.03) = \$99$$

The lower boundary using Eq. (62-3) is

$$F\text{(lower boundary)} = 100 + \$100(0.015 - 0.03) = \$98.50$$

In calculating these boundaries, we assumed no transaction costs were involved in taking the position. In actuality, the transaction costs of entering into and closing the cash position as well as the round-trip transaction costs for the futures contract, must be considered and do affect the boundaries for the futures contract.

Deliverable Bond and Settlement Date Unknown. In our example, we assumed that only one bond is deliverable and that the settlement date occurs three months from now. As explained in Chapter 61, futures contracts on Treasury bonds and Treasury notes are designed to allow the short position the choice of delivering one of a number of deliverable issues. Also, the delivery date is not known.

Because there may be more than one deliverable, market participants track the price of each deliverable bond and determine which is the cheapest to deliver. The futures price will then trade in relation to the bond that is cheapest to deliver.

The cheapest to deliver is the bond or note that will result in the smallest loss or the greatest gain if delivered by the short futures position.[1]

In addition to the reasons we have already discussed, there are several reasons why the actual futures price will diverge from the theoretical futures price based on the arbitrage model. First, there is the risk that although an issue may be the cheapest to deliver at the time a position in the futures contract is taken, it may not be the cheapest to deliver after that time. Thus, there will be a divergence between the theoretical futures price and the actual futures price. A second reason for this divergence is the other delivery options granted the short position. Finally, there are biases in the CME conversion factors.

Deliverable Is a Basket of Securities. The municipal index futures contract is a cash settlement contract based on a basket of securities. The difficulty in arbitraging this futures contract is that it is too expensive to buy or sell every bond included in the index. Instead, a portfolio containing a smaller number of bonds may be constructed to track the index. The arbitrage, however, is no longer risk-free because there is the risk that the portfolio will not track the index exactly. This is referred to as *tracking-error risk.* Another problem in constructing the portfolio so that the arbitrage can be performed is that the composition of the index is revised periodically. Therefore, anyone using this arbitrage trade must constantly monitor the index and periodically rebalance the constructed portfolio.

APPLICATIONS TO PORTFOLIO MANAGEMENT

This section describes various ways in which a money manager can use interest-rate futures contracts.

Interest-Rate Risk Control

Interest-rate risk control is probably the most common use of interest-rate futures. This is accomplished by altering the portfolio's duration. Money managers who have strong expectations about the direction of interest rates will adjust the duration of their portfolio to capitalize on their expectations. Specifically, if they expect interest rates to increase, they will shorten the duration of the portfolio; if they expect interest rates to decrease, they will lengthen the duration of the portfolio. Also, anyone using structured portfolio strategies must periodically adjust the portfolio duration to match the duration of some benchmark.

Although money managers can alter the duration of their portfolios with cash market instruments, a quick and less expensive means for doing so (especially on a

1. An alternative procedure is to compute the implied (break-even) repo rate. This rate is the yield that would produce no profit or loss if the bond were purchased and a futures contract were sold against the bond. The cheapest-to-deliver bond is the one with the highest implied repo rate.

temporary basis) is to use futures contracts. By buying futures contracts on Treasury bonds or notes, they can increase the duration of the portfolio. Conversely, they can shorten the duration of the portfolio by selling futures contracts on Treasury bonds or notes.

Hedging

Hedging is a special case of interest-rate risk control whereby the manager seeks to obtain a duration of zero.[2] Hedging with futures involves taking a futures position as a temporary substitute for transactions to be made in the cash market at a later date. If cash and futures prices move together, any loss realized by the hedger from one position (whether cash or futures) will be offset by a profit on the other position such that the the return earned is the risk-free rate. When the net profit or loss from the positions are exactly as anticipated, the hedge is referred to as a *perfect hedge.*

In practice, hedging is not that simple. The amount of net profit will not necessarily be as anticipated. The outcome of a hedge will depend on the relationship between the cash price and the futures price when a hedge is placed and when it is lifted. The difference between the cash price and the futures price is called the basis. The risk that the basis will change in an unpredictable way is called *basis risk.*

In most hedging applications, the bond to be hedged is not identical to the bond underlying the futures contract. This kind of hedging is referred to as *cross-hedging.* There may be substantial basis risk in cross-hedging. An unhedged position is exposed to price risk, the risk that the cash market price will move adversely. A hedged position substitutes basis risk for price risk.

A short (or sell) hedge is used to protect against a decline in the cash price of a fixed income security. To execute a short hedge, futures contracts are sold. By establishing a short hedge, the hedger has fixed the future cash price and transferred the price risk of ownership to the buyer of the futures contract. As an example of why a short hedge would be executed, suppose that a pension fund manager knows that bonds must be liquidated in 40 days to make a $5 million payment to the beneficiaries of the pension fund. If interest rates rise during the 40-day period, more bonds will have to be liquidated to realize $5 million. To guard against this possibility, the manager would sell bonds in the futures market to lock in a selling price.

A long (or buy) hedge is undertaken to protect against an increase in the cash price of a fixed income security. In a long hedge, the hedger buys a futures contract to lock in a purchase price. A pension fund manager may use a long hedge when substantial cash contributions are expected and the manager is concerned that interest rates will fall. Also, a money manager who knows that bonds are maturing in the near future and expects that interest rates will fall can employ a long hedge to lock in a rate.

2. Hedging is discussed in more detail in Chapter 63.

Asset Allocation

A pension sponsor may wish to alter the composition of the pension fund's assets between stocks and bonds. An efficient means of changing asset allocation is to use financial futures contracts: interest-rate futures and stock index futures.

Creating Synthetic Securities for Yield Enhancement

A cash market security can be synthetically created by using a position in the futures contract together with the deliverable instrument. The yield on the synthetic security should be the same as the yield on the cash market security. If there is a difference between the two yields, it can be exploited so as to enhance the yield on the portfolio.

To see how, consider an investor who owns a 20-year Treasury bond and sells Treasury futures that call for the delivery of that particular bond three months from now. The maturity of the Treasury bond is 20 years, but the investor has effectively shortened the maturity of the bond to three months.

Consequently, the long position in the 20-year bond and the short futures position are equivalent to a long position in a three-month riskless security. The position is riskless because the investor is locking in the price that will be received three months from now—the futures price. By being long the bond and short the futures, the investor has synthetically created a three-month Treasury bill. The return the investor should expect to earn from this synthetic position should be the yield on a three-month Treasury bill. If the yield on the synthetic three-month Treasury bill is greater than the yield on the cash market Treasury bill, the investor can realize an enhanced yield by creating the synthetic short-term security. The fundamental relationship for creating synthetic securities is as follows:

$$\text{RSP} = \text{CBP} - \text{BFP} \tag{62-4}$$

where

CBP = cash bond position
BFP = bond futures position
RSP = riskless short-term security position

A negative sign before a position means a short position. In terms of our previous example, CBP is the long cash bond position, the negative sign before BFP refers to the short futures position, and RSP is the riskless synthetic three-month security or Treasury bill.

Equation (62-4) states that an investor who is long the cash market security and short the futures contract should expect to earn the rate of return on a risk-free security with the same maturity as the futures delivery date. Solving Eq. (62-4) for the long bond position, we have

$$\text{CBP} = \text{RSP} + \text{BFP} \tag{62-5}$$

Equation (62-5) states that a cash bond position equals a short-term riskless security position plus a long bond futures position. Thus a cash market bond can be synthetically created by buying a futures contract and investing in a Treasury bill.

Solving Eq. (62-5) for the bond futures position, we have

$$\text{BFP} = \text{CBP} - \text{RSP} \tag{62-6}$$

Equation (62-6) tells us that a long position in the futures contract can be synthetically created by taking a long position in the cash market bond and shorting the short-term riskless security. Shorting the short-term riskless security is equivalent to borrowing money. Notice that it was Eq. (62-6) that we used in deriving the theoretical futures price when the futures was overpriced. Recall that when the futures price was 107, the strategy to obtain an arbitrage profit was to sell the futures contract and create a synthetic long futures position by buying the bond with borrowed funds. This is precisely what Eq. (62-6) states. In this case, instead of creating a synthetic cash market instrument as we did with Eqs. (62-4) and (62-5), we have created a synthetic futures contract. The fact that the synthetic long futures position was cheaper than the actual long futures position provided an arbitrage opportunity.

If we reverse the sign of both sides of Eq. (62-6), we can see how a short futures position can be synthetically created.

In an efficient market, the opportunities for yield enhancement should not exist very long. Even in the absence of yield enhancement, however, synthetic securities can be used by money managers to hedge a portfolio position that they find difficult to hedge in the cash market either because of lack of liquidity or because of other constraints.

PORTABLE ALPHA

There are two basic approaches to investment management: passive and active. The objective of passive management is to match the performance of a benchmark that represents a defined asset class while the objective of active management is to select individual assets that are likely to perform better than the average. The returns to an active strategy will consist of returns based on market exposure and returns based on selection skill. The returns resulting from superior selection skills are referred to as *alpha*. Pure alpha strategies are those with no market risk and thus returns do not depend on market direction. An example is a long/short strategy that is market neutral.

In a period when equity markets have increased volatility and lower prospects for increasing returns, institutional investors look to reallocate funds to asset classes with lower volatility such as fixed income securities. Moreover, institutional investors confront an environment of funding shortfalls and moderate returns, which necessitates the development of alternative and more efficient sources of returns. *Portable alpha strategies* can be employed to maintain exposure to a lower volatility asset class while producing returns that approach equities.

The portable alpha strategy can either be used as a core investment in an asset class or as an overlay strategy.

Portable alpha strategies refer to an investment methodology or process that blends traditional asset class exposure with alternative investment strategies in order to add returns without assuming additional risk. The concept is "portable" in the sense that the integration of alternative with traditional does not impact management style or acceptable risk parameters adversely, which means it is easily transferred into an existing asset class or benchmark through the application of an overlay program to achieve the targeted asset exposure. Thus, the alpha is created independently of the core portfolio and transferred with the use of derivatives in order to maintain the characteristics of the core portfolio.

The significance of portable alpha strategies is that the asset allocation decision can be separated from the search for alpha within the asset class. Thus, portable alpha is a return enhancement strategy and not an asset substitution strategy. The advantage of the portable alpha approach is its flexibility in terms of adding returns without additional risk.[3] Many portable alpha strategies involve long and short positions. Exchange-traded futures contracts can be integral to a portable alpha strategy either as a means to overlay an existing core portfolio or as a means to synthetically maintain the core exposure to the fixed income asset class.

The basis of "portable" alpha is that it explicitly changes the investment management process by separating the management of market returns and pure alpha returns. Pure alpha strategies are factor or market neutral and have no correlation with market direction. The objective of portable alpha strategies is to improve the efficiency of finding positive incremental returns. For equity strategies it involves stock selection and for fixed income it might involve bond selection or the exploitation of yield-curve inefficiencies. In any case, derivatives including futures and swaps are vital to achieve the strategic asset allocation exposures. This paradigm shift that explicitly separates market returns and alpha has implications for manager selection and risk management.

Since alpha is the total return less market returns, the production of alpha does not depend on market direction and therefore positive alpha is possible in all market environments. The portable alpha strategy can be implemented as an overlay on an existing asset class or as a separate investment that uses swaps and futures to maintain the overall strategic asset allocation mix. Theoretically, portable alpha strategies can be produced from any strategy assuming it contains alpha and there is sufficient liquidity to implement the strategy. Thus, there are three basic ways to develop a portable alpha generating strategy.

1. Identify an alpha generating long portfolios, use futures to eliminate market risk, and overlay the strategy on the existing asset class.

3. Furthermore, the implementation of portable alpha strategies significantly expands the universe of managers beyond the limitations imposed by style or orientation.

2. Identify pure alpha generating investments from the hedge fund or fund of fund communities, sell off a portion of the asset class, and replace with futures and alpha generating investments.
3. Replace entire asset class with pure alpha generating strategies and use derivatives to maintain targeted market exposure.

Portable alpha represents a change in the investment process and a different way to think about risk and return. Futures contracts are an integral part of the implementation of many portable alpha investment programs.

KEY POINTS

- The theoretical futures price is determined by the net financing cost, or carry.
- Carry is the difference between the financing cost and the cash yield on the underlying cash instrument.
- The basic futures pricing model must be modified to account for nuances of specific futures contracts.
- Uses of futures contracts by portfolio managers are altering a portfolio's duration (risk control), asset allocation, creation of synthetic securities to enhance returns, and portable alpha.
- Hedging is a special case of controlling interest-rate risk in which the portfolio wants to alter the portfolio's duration to zero.
- Portable alpha strategies can be employed to maintain exposure to a lower volatility asset class while producing returns that approach equities.

CHAPTER

SIXTY-THREE

CONTROLLING INTEREST-RATE RISK WITH FUTURES AND OPTIONS

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In Chapter 61 the features and characteristics of interest-rate futures and options were explained. In this chapter, our focus is on how these derivative instruments can be used to control the interest-rate risk of a portfolio.

CONTROLLING INTEREST-RATE RISK WITH FUTURES

The price of an interest-rate futures contract moves in the opposite direction from the change in interest rates: when rates rise, the futures price will fall; when rates fall, the futures price will rise. By buying a futures contract, a portfolio's exposure to a rate increase is increased. That is, the portfolio's duration increases. By selling a futures contract, a portfolio's exposure to a rate increase is decreased. Equivalently, this means that the portfolio's duration is reduced. Consequently, buying and selling futures can be used to alter the duration of a portfolio.

While managers can alter the duration of their portfolios with cash-market instruments (buying or selling Treasury securities), using interest-rate futures

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instead of trading long-term Treasuries themselves has the following three advantages:

Advantage 1: Transaction costs for trading futures are lower than trading in the cash market.

Advantage 2: Margin requirements are lower for futures than for Treasury securities; using futures thus permits greater leverage.

Advantage 3: It is easier to sell short in the futures market than in the Treasury market.

Futures also can be used in constructing a portfolio with a longer duration than is available with cash-market securities. For example, suppose that in a certain interest-rate environment a pension fund manager must structure a portfolio to have a duration of 15 to accomplish a particular investment objective. Bonds with such a long duration may not be available. By buying the appropriate number and kind of interest-rate futures contracts, a pension fund manager can increase the portfolio's duration to the target level of 15.

General Principles of Interest-Rate Risk Control

The general principle in controlling interest-rate risk with futures is to combine the dollar exposure of the current portfolio and the dollar exposure of a futures position so that the total dollar exposure is equal to the target dollar exposure. This means that the manager must be able to accurately measure the dollar exposure of both the current portfolio and the futures contract employed to alter the exposure.

There are two commonly used measures for approximating the change in the dollar value of a bond or bond portfolio to changes in interest rates: price value of a basis point (PVBP) and duration. PVBP is the dollar price change resulting from a 1 basis point change in yield. Duration is the approximate percentage change in price for a 100 basis point change in rates. (Given the percentage price change, the dollar price change for a given change in interest rates can be computed.) There are two measures of duration: *modified* and *effective*. Effective duration is the appropriate measure that should be used for bonds with embedded options. In this chapter when we refer to duration, we mean effective duration. Moreover, since the manager is interested in dollar price exposure, it is the effective *dollar* duration that should be used. For a 1 basis point change in rates, PVBP is equal to the effective dollar duration for a 1 basis point change in rates.

To estimate the effective dollar duration, it is necessary to have a good valuation model. It is the valuation model that is used to determine what the new values for the bonds in the portfolio will be if rates change. The difference between the current values of the bonds in the portfolio and the new values estimated by the valuation model when rates are changed is the dollar price exposure. Consequently, the starting point in controlling interest-rate risk is the development of a reliable valuation model. A reliable valuation model also is needed to value the derivative contracts that the manager wants to use to control interest-rate exposure.

Suppose that a manager seeks a *target duration* for the portfolio based on either expectations of interest rates or client-specified exposure. Given the target duration, a target dollar duration for a small basis point change in interest rates can be obtained. For a 50 basis point change in interest rates, for example, the target dollar duration can be found by multiplying the dollar value of the portfolio by the target duration and then dividing by 200. For example, suppose that the manager of a $500 million portfolio wants a target duration of 6. This means that the manager seeks a 3% change in the value of the portfolio for a 50 basis point change in rates (assuming a parallel shift in rates of all maturities). Multiplying the target duration of 6 by $500 million and dividing by 200 gives a target dollar duration of $15 million.

The manager then must determine the dollar duration of the current portfolio. The current dollar duration for a 50 basis point change in interest rates is found by multiplying the current duration by the dollar value of the portfolio and dividing by 200. Thus, for our $500 million portfolio, suppose that the current duration is 4. The current dollar duration is then $10 million (4 times $500 million divided by 200).

The target dollar duration is then compared with the current dollar duration. The difference between the two dollar durations is the dollar exposure that must be provided by a position in the futures contract. If the target dollar duration exceeds the current dollar duration, a futures position must increase the dollar exposure by the difference. To increase the dollar exposure, an appropriate number of futures contracts must be purchased. If the target dollar duration is less than the current dollar duration, an appropriate number of futures contracts must be sold. That is,

$$\text{If target dollar duration} - \text{current dollar duration} > 0, \text{ buy futures}$$

$$\text{If target dollar duration} - \text{current dollar duration} < 0, \text{ sell futures}$$

Once a futures position is taken, the *portfolio's dollar duration* is equal to the *current dollar duration without futures* plus the *dollar duration of the futures position*. That is,

$$\begin{aligned}\text{Portfolio's dollar return} &= \text{current dollar duration without futures}\\ &\quad + \text{dollar duration of futures position}\end{aligned}$$

The objective is to control the portfolio's interest-rate risk by establishing a futures position such that the portfolio's dollar duration is equal to the target dollar duration. Thus

$$\text{Portfolio's dollar duration} = \text{target dollar duration}$$

Or equivalently,

$$\begin{aligned}\text{Target dollar duration} &= \text{current dollar duration without futures}\\ &\quad + \text{dollar duration of futures position} \qquad (63\text{-}1)\end{aligned}$$

Over time, the portfolio's dollar duration will move away from the target dollar duration. The manager can alter the futures position to adjust the portfolio's dollar duration to the target dollar duration.

Determining the Number of Contracts

Each futures contract calls for delivery of a specified amount of the underlying instrument. When interest rates change, the value of the underlying instrument changes, and therefore, the value of the futures contract changes. How much the futures dollar value will change when interest rates change must be estimated. This amount is called the *dollar duration per futures contract*. For example, suppose that the futures price of an interest-rate futures contract is 70 and that the underlying interest-rate instrument has a par value of $100,000. Thus the futures delivery price is $70,000 (0.70 times $100,000). Suppose that a change in interest rates of 50 basis points results in the futures price changing by about $0.03 per contract. Then the dollar duration per futures contract is $2,100 (0.03 times $70,000).

The dollar duration of a futures position is then the number of futures contracts multiplied by the dollar duration per futures contract. That is,

$$\begin{aligned}&\text{Dollar duration of futures position}\\&\quad = \text{number of futures contracts} \times \text{dollar duration per futures contract} \qquad (63\text{-}2)\end{aligned}$$

How many futures contracts are needed to obtain the target dollar duration? Substituting Eq. (63-2) into Eq. (63-1), we get

$$\begin{aligned}&\text{Number of futures contracts} \times \text{dollar duration per futures contract}\\&\quad = \text{target dollar duration} - \text{current dollar duration without futures} \qquad (63\text{-}3)\end{aligned}$$

Solving for the number of futures contracts, we have

$$\begin{aligned}&\text{Number of futures contracts}\\&\quad = \frac{\text{target dollar duration} - \text{current dollar duration without futures}}{\text{dollar duration per futures contract}} \qquad (63\text{-}4)\end{aligned}$$

Equation (63-4) gives the approximate number of futures contracts that are necessary to adjust the portfolio's dollar duration to the target dollar duration. A positive number means that the futures contract must be purchased; a negative number means that the futures contract must be sold. Notice that if the target dollar duration is greater than the current dollar duration without futures, the numerator is positive, and therefore, futures contracts are purchased. If the target dollar duration is less than the current dollar duration without futures, the numerator is negative, and therefore, futures contracts are sold.

Dollar Duration for a Futures Position

Now we turn to how to measure the dollar duration of a bond futures position. Keep in mind what the goal is: it is to measure the sensitivity of a bond futures position to changes in rates.

The general methodology for computing the dollar duration of a futures position for a given change in interest rates is straightforward given a valuation model. The procedure is the same as for computing the dollar duration of any cash-market instrument—shock (change) interest rates up and down by the same number of basis points and determine the average dollar price change.

An adjustment is needed for the Treasury bond and note futures contracts. The pricing of the futures contract depends on the cheapest-to-deliver (CTD) issue.[1] Calculation of the dollar duration of a Treasury bond or note futures contract requires determining the impact of a change in interest rates will have on the price of a futures contract, which, in turn, affects how the futures price will change. The dollar duration of a Treasury bond and note futures contract is determined as follows:

$$\text{Dollar duration of futures contract} = \text{dollar duration of the CTD issue} \times \frac{\text{dollar duration of futures contract}}{\text{dollar duration of the CTD issue}}$$

There is a conversion factor for each issue that is acceptable for delivery for the futures contract. The conversion factor makes deliverable equitable to both the buyer and seller of the futures contract. For each deliverable issue, the product of the futures price and the conversion factor is the adjusted futures price for the issue. This adjusted price is called the *converted price*. Relating this to the preceding equation, the second ratio is approximately equal to the conversion factor of the cheapest-to-deliver issue. Thus we can write

$$\text{Dollar duration of futures contract} = \text{dollar duration of the CTD issue} \times \text{conversion factor for the CTD issue}$$

Why did we focus on dollar duration rather than duration? Recall that duration is the approximate percentage change in price. But what is the price of this leveraged instrument? The investor does not put up the full price of the position in order to acquire the position. Only the initial margin need be made in cash or a cash equivalent. Consequently, what is the base investment made by the investor? Rather than debate what should be used as the base investment in order to compute duration, let's simply ask why we are interested in calculating the exposure to changes in rates. As we have emphasized, it is to determine how a futures position will alter the exposure of a portfolio to changes in rates. Once we know how a futures position changes the dollar duration of a portfolio, we can determine for a portfolio its dollar duration. Given the funds invested by the investor in the portfolio, the portfolio's duration can be computed.

1. The cheapest-to-deliver issue is the one issue from among all those that are deliverable to satisfy a contract that has the highest return in a cash and carry trade. This return is called the *implied repo rate*.

Hedging with Interest-Rate Futures

Hedging with futures calls for taking a futures position as a temporary substitute for transactions to be made in the cash market at a later date. If cash and futures prices move together, any loss realized by the hedger from one position (whether cash or futures) will be offset by a profit on the other position. *Hedging is a special case of controlling interest-rate risk. In a hedge, the manager seeks a target duration or target dollar duration of zero*.

A *short hedge* (or *sell hedge*) is used to protect against a decline in the cash price of a bond. To execute a short hedge, futures contracts are sold. By establishing a short hedge, the manager has fixed the future cash price and transferred the price risk of ownership to the buyer of the futures contract. To understand why a short hedge might be executed, suppose that a pension fund manager knows that bonds must be liquidated in 40 days to make a $5 million payment to beneficiaries. If interest rates rise during the 40-day period, more bonds will have to be liquidated at a lower price than today to realize $5 million. To guard against this possibility, the manager can sell bonds in the futures market to lock in a selling price.

A *long hedge* (or *buy hedge*) is undertaken to protect against an increase in the cash price of a bond. In a long hedge, the manager buys a futures contract to lock in a purchase price. A pension fund manager might use a long hedge when substantial cash contributions are expected, and the manager is concerned that interest rates will fall. Also, a money manager who knows that bonds are maturing in the near future and expects that interest rates will fall can employ a long hedge to lock in a rate for the proceeds to be reinvested.

In bond portfolio management, typically the bond or portfolio to be hedged is not identical to the bond underlying the futures contract. This type of hedging is referred to as *cross-hedging*.

The hedging process can be broken down into four steps:

Step 1. Determining the appropriate hedging instrument

Step 2. Determining the target for the hedge

Step 3. Determining the position to be taken in the hedging instrument

Step 4. Monitoring and evaluating the hedge

We discuss each step below.

Determining the Appropriate Hedging Instrument

A primary factor in determining which futures contract will provide the best hedge is the degree of correlation between the rate on the futures contract and the interest rate that creates the underlying risk that the manager seeks to eliminate. For example, a long-term corporate bond portfolio can be better hedged with Treasury bond futures than with Treasury bill futures because long-term corporate bond rates are more highly correlated with Treasury bond futures than Treasury bill futures. Using the right delivery month is also important. A manager trying to lock in a rate or price for September will use September futures contracts because September futures contracts will give the highest degree of correlation.

Correlation is not, however, the only consideration if the hedging program is of significant size. If, for example, a manager wants to hedge \$600 million of a cash position in a distant delivery month, liquidity becomes an important consideration. In such a case, it might be necessary for the manager to spread the hedge across two or more different contracts.

Determining the Target for the Hedge

Having determined the right contract and the right delivery months, the manager then should determine what is expected from the hedge—that is, what rate will, on average, be locked in by the hedge. This is the *target rate* or *target price.* If this target rate is too high (if hedging a future sale) or too low (if hedging a future purchase), hedging may not be the right strategy for dealing with the unwanted risk. Determining what is expected (calculating the target rate or price for a hedge) is not always simple. We'll see how a manager should approach this problem for both simple and complex hedges.

Risk and Expected Return in a Hedge. When a manager enters into a hedge, the objective is to "lock in" a rate for the sale or purchase of a security. However, there is much disagreement about what rate or price a manager should expect to lock in when futures are used to hedge. Here are the two views:

View 1. The manager can, on average, lock in the current spot rate for the security (i.e., current rate in the cash market).

View 2. The manager can, on average, lock in the rate at which the futures contracts are bought or sold.

The truth usually lies somewhere in between these two views. However, as the following cases illustrate, each view is entirely correct in certain situations.

The Target for Hedges Held to Delivery. Hedges that are held until the futures delivery date provide an example of a hedge that locks in the futures rate (i.e., the second view). The complication in the case of using Treasury bond futures and Treasury note futures to hedge the value of intermediate- and long-term bonds is that because of the delivery options the manager does not know for sure when delivery will take place or which bond will be delivered. This is because of the delivery options granted to the short.[2]

To illustrate how a Treasury bond futures held to the delivery date locks in the futures rate, assume for the sake of simplicity that the manager knows which Treasury bond will be delivered and that delivery will take place on the last day of the delivery month. Suppose that for delivery on the September 1999 futures

2. These delivery options are explained in Chapter 61.

contract, the conversion factor for a deliverable Treasury issue is 1.283, implying that the investor who delivers this issue would receive from the buyer 1.283 times the futures settlement price plus accrued interest. An important principle to remember is that at delivery, the spot price and the futures price times the conversion factor must converge. *Convergence* refers to the fact that at delivery there can be no discrepancy between the spot price and futures price for a given security. If convergence does not take place, arbitrageurs would buy at the lower price and sell at the higher price and earn risk-free profits. Accordingly, a manager could lock in a September 1999 sale price for this issue by selling Treasury bond futures contracts equal to 1.283 times the par value of the bonds. For example, $100 million face value of this issue would be hedged by selling $128.3 million face value of bond futures (1,283 contracts).

The sale price that the manager locks in would be 1.283 times the futures price. This is the converted price. Thus, if the futures price is 113 when the hedge is set, the manager locks in a sale price of 144.979 (113 times 1.283) for September 1999 delivery, regardless of where rates are in September 1999. Exhibit 63-1 shows the cash flows for a number of final prices for this issue and illustrates how cash flows on the futures contracts offset gains or losses relative to the target price of 144.979.

Let's look at all the columns in Exhibit 63-1 and explain the computations for one of the scenarios—that is, for one actual sale price for the $11^{1}/_{4}$% Treasury bond. Consider the first actual sale price of 140. By convergence, at the delivery date the final futures price shown in column (2) must equal the Treasury bond's actual sale price adjusted by the conversion factor. Specifically, the adjustment is as follows. We know that

$$\text{Converted price} = \text{Treasury bond's price} \times \text{conversion factor}$$

and by convergence

$$\text{Final futures price} = \text{converted price}$$

so that

$$\text{Final futures price} = \text{Treasury bond's actual sale price} \times \text{conversion factor}$$

Thus, to compute the final futures price in column (2) of Exhibit 63-1 given the Treasury bond's actual sale price in column (1), the following is computed:

$$\text{Final futures price} = \frac{\text{Treasury bonds actual sale price}}{\text{conversion factor}}$$

Since the conversion factor is 1.283 for the $11^{1}/_{4}$% Treasury issue, for the first actual sale price of 140, the final futures price is

$$\text{Final futures price} = \frac{140}{1.283} = 109.1193$$

Column (3) shows the market value of the Treasury bonds. This is found by multiplying the actual sale price in column (1) by 100 to obtain the actual sale

EXHIBIT 63-1

Treasury Issue Hedge Held to Delivery

Instrument to be hedged: $100 million $11^{1}/_{4}$% Treasury Bonds of 2/15/15
Conversion factor for September 1999 = 1.283
Price of futures contract when sold = 113
Target price = (1.283 × 113) = 144.979
Par value hedged = $100,000,000
Number of futures contracts = 1,283
Futures position = Target = $144,979,000

(1)	(2)	(3)	(4)	(5)	(6)
Actual Price for 11.25% T-Bonds	Final Futures Price*	Market Value of Treasury Bonds	Value of Futures Position†	Gain or Loss from Futures Position†	Effective Sale Price‡
140	109.1192518	140,000,000	140,000,000	4,979,000	144,979,000
141	109.898675	141,000,000	141,000,000	3,979,000	144,979,000
142	110.6780982	142,000,000	142,000,000	2,979,000	144,979,000
143	111.4575214	143,000,000	143,000,000	1,979,000	144,979,000
144	112.2369447	144,000,000	144,000,000	979,000	144,979,000
145	113.0163679	145,000,000	145,000,000	–21,000	144,979,000
146	113.7957911	146,000,000	146,000,000	–1,021,000	144,979,000
147	114.5752143	147,000,000	147,000,000	–2,021,000	144,979,000
148	115.3546376	148,000,000	148,000,000	–3,021,000	144,979,000
149	116.1340608	149,000,000	149,000,000	–4,021,000	144,979,000
150	116.913484	150,000,000	150,000,000	–5,021,000	144,979,000
151	117.6929072	151,000,000	151,000,000	–6,021,000	144,979,000
152	118.4723305	152,000,000	152,000,000	–7,021,000	144,979,000
153	119.2517537	153,000,000	153,000,000	–8,021,000	144,979,000
154	120.0311769	154,000,000	154,000,000	–9,021,000	144,979,000
155	120.8106002	155,000,000	155,000,000	–10,021,000	144,979,000

*By convergence, must equal bond price divided by the conversion factor.
†Bond futures trade in even increments of 1/32. Accordingly, the futures prices and margin flows are only approximate.
‡Transaction costs and the financing of margin flows are ignored.

price per $1 of par value and then multiplying by the $100 million par value. That is,

$$\text{Market value of Treasury bonds} = (\text{actual sale price}/100) \times \$100{,}000{,}000$$

For the actual sale price of 140, the value in column (3) is

$$\begin{aligned}\text{Market value of Treasury bonds} &= (140/100) \times \$100{,}000{,}000\\ &= \$140{,}000{,}000\end{aligned}$$

Column (4) shows the value of the futures position at the delivery date. This value is computed by first dividing the futures price shown in column (2) by

100 to obtain the futures price per \$1 of par value. Then this value is multiplied by the par value per contract of \$100,000 and further multiplied by the number of futures contracts. That is,

$$\text{Value of futures position}$$
$$= (\text{final futures price}/100) \times \$100{,}0000 \times \text{number of futures contracts}$$

In our illustration, the number of futures contracts is 1,283. For the actual sale price of the bond of 140, the final futures price is 109.1193. Thus, the value shown in column (4) is

$$\text{Value of futures position} = (109.1193/100) \times \$100{,}000 \times 1{,}283$$
$$= \$140{,}000{,}062$$

The value shown in column (4) is \$140,000,000 because the final futures price of 109.1193 was rounded. Using more decimal places, the value would be \$140,000,000.

Now let's look at the gain or loss from the futures position. This value is shown in column (5). Recall that the futures contract was shorted. The futures price at which the contracts were sold was 113. Thus, if the final futures price exceeds 113, this means that there is a loss on the futures position—that is, the futures contract is purchased at a price greater than for which it was sold. In contrast, if the futures price is less than 113, this means that there is a gain on the futures position—that is, the futures contract is purchased at a price less than for which it was sold. The gain or loss is determined by the following formula:

$$(113/100 - \text{final futures price}/100) \times \$100{,}000 \times \text{number of futures contracts}$$

In our illustration, for a final futures price of 109.1193 and 1,283 futures contracts, we have

$$(113/100 - 109.1193/100) \times \$100{,}000 \times 1{,}283 = \$4{,}978{,}938.1$$

The value shown in column (5) is \$4,979,000 because that is the more precise value using more decimal places for the final futures price than shown in Exhibit 63-1. The value is positive, which means that there is a gain in the futures position. Note that for all the final futures prices above 113 in Exhibit 63-1, there is a negative value, which means that there is a loss on the futures position.

Finally, column (6) shows the effective sale price for the Treasury bond. This value is found as follows:

$$\text{Effective sale price for Treasury bond}$$
$$= \text{actual sale price of Treasury bond} + \text{gain or loss on futures position}$$

For the actual sale price of \$140 million, the gain is \$4,979,000. Therefore, the effective sale price for the Treasury bond is

$$\$140{,}000{,}000 + \$4{,}979{,}000 = \$144{,}979{,}000$$

Note that this is the target price for the Treasury bond. In fact, it can be seen from column (6) of Exhibit 63-1 that the effective sale price for all the actual sale prices for the Treasury bond is the target price. However, the target price is determined by the futures price, so the target price may be higher or lower than the cash (spot) market price when the hedge is set.

When we admit the possibility that bonds other than the deliverable issue used in our illustration can be delivered and that it might be advantageous to deliver other issues, the situation becomes somewhat more involved. In this more realistic case, the manager may decide not to deliver this issue, but if she does decide to deliver it, the manager is still assured of receiving an effective sale price of approximately 144.979. If the manager does not deliver this issue, it would be because another issue can be delivered more cheaply, and thus the manager does better than the targeted price.

In summary, if a manager establishes a futures hedge that is held until delivery, the manager can be assured of receiving an effective price dictated by the futures rate (not the spot rate) on the day the hedge is set.

The Target for Hedges with Short Holding Periods. When a manager must lift (remove) a hedge prior to the delivery date, the effective rate that is obtained is much more likely to approximate the current spot rate than the futures rate the shorter the term of the hedge. The critical difference between this hedge and the hedge held to the delivery date is that convergence generally will not take place by the termination date of the hedge.

To illustrate why a manager should expect the hedge to lock in the spot rate rather than the futures rate for very short-lived hedges, let's return to the simplified example used earlier to illustrate a hedge to the delivery date. It is assumed that this issue is the only deliverable Treasury bond for the Treasury bond futures contract. Suppose that the hedge is set three months before the delivery date, and the manager plans to lift the hedge after one day. It is much more likely that the spot price of the bond will move parallel to the converted futures price (i.e., the futures price times the conversion factor) than that the spot price and the converted futures price will converge by the time the hedge is lifted.

A one-day hedge is, admittedly, an extreme example. Other than underwriters, dealers, and traders who reallocate assets very frequently, few money managers are interested in such a short horizon. The very short-term hedge does, however, illustrate a very important point: *when hedging, a manager should not expect to lock in the futures rate (or price) just because he is hedging with futures contracts*. The futures rate is locked in only if the hedge is held until delivery, at which point convergence must take place. If the hedge is held for only one day, the manager should expect to lock in the one-day forward rate,[3] which will very nearly equal the spot rate. Generally, hedges are held for more than one day but not necessarily to delivery.

3. Forward rates are covered in Chapter 31.

How the Basis Affects the Target Rate for a Hedge. The proper target for a hedge that is to be lifted prior to the delivery date depends on the basis. The *basis* is simply the difference between the spot (cash) price of a security and its futures price; that is:

$$\text{Basis} = \text{spot price} - \text{futures price}$$

In the bond market, a problem arises when trying to make practical use of the concept of the basis. The quoted futures price does not equal the price that one receives at delivery. For the Treasury bond and note futures contracts, the actual futures price equals the quoted futures price times the appropriate conversion factor. Consequently, to be useful, the basis in the bond market should be defined using actual futures delivery prices rather than quoted futures prices. Thus the price basis for bonds should be redefined as

$$\text{Price basis} = \text{spot price} - \text{futures delivery price}$$

For hedging purposes, it is also useful frequently to define the basis in terms of interest rates rather than prices. The *rate basis* is defined as

$$\text{Rate basis} = \text{spot rate} - \text{futures rate}$$

where spot rate refers to the current rate on the instrument to be hedged and the futures rate is the interest rate corresponding to the futures delivery price of the deliverable instrument.

The rate basis is helpful in explaining why the two views of hedges explained earlier are expected to lock in such different rates. To see this, we first define the *target rate basis*. This is defined as the expected rate basis on the day the hedge is lifted. A hedge lifted on the delivery date is expected to have, and by convergence will have, a zero rate basis when the hedge is lifted. Thus the target rate for the hedge should be the rate on the futures contract plus the expected rate basis of zero or, in other words, just the futures rate. When a hedge is lifted prior to the delivery date, one would not expect the basis to change very much in one day, so the target rate basis equals the futures rate plus the current difference between the spot rate and futures rate, that is, the current spot rate.

The manager can set the target rate for any hedge equal to the futures rate plus the target rate basis. That is,

$$\text{Target rate for hedge} = \text{futures rate} + \text{target rate basis}$$

If projecting the basis in terms of price rather than rate is more manageable (as is often the case for intermediate- and long-term futures), it is easier to work with the target price basis instead of the target rate basis. The *target price basis* is just the projected price basis for the day the hedge is to be lifted. For a deliverable security, the target for the hedge then becomes

$$\text{Target price for hedge} = \text{futures delivery price} + \text{target price basis}$$

The idea of a target price or rate basis explains why a hedge held until the delivery date locks in a price with certainty, and other hedges do not. The examples have shown that this is true. For the hedge held to delivery, there is no uncertainty surrounding the target basis; by convergence, the basis on the day the hedge is lifted is certain to be zero. For the short-lived hedge, the basis probably will approximate the current basis when the hedge is lifted, but its actual value is not known. For hedges longer than one day but ending prior to the futures delivery date, there can be considerable basis risk because the basis on the day the hedge is lifted can end up being anywhere within a wide range. Thus the uncertainty surrounding the outcome of a hedge is directly related to the uncertainty surrounding the basis on the day the hedge is lifted (i.e., the uncertainty surrounding the target basis).

The uncertainty about the value of the basis at the time the hedge is removed is called *basis risk*. For a given investment horizon, hedging substitutes basis risk for price risk. Thus one trades the uncertainty of the price of the hedged security for the uncertainty of the basis. Consequently, when hedges do not produce the desired results, it is customary to place the blame on basis risk. However, basis risk is the real culprit only if the target for the hedge is defined properly. Basis risk should refer only to the unexpected or unpredictable part of the relationship between cash and futures prices. The fact that this relationship changes over time does not in itself imply that there is basis risk.

Basis risk, properly defined, refers only to the uncertainty associated with the target rate basis or target price basis. Accordingly, it is imperative that the target basis be defined properly if one is to assess the risk and expected return in a hedge correctly.

Determining the Number of Futures Contracts

The final step that must be determined before the hedge is set is the number of futures contracts needed for the hedge. This is called the *hedge ratio*. Usually the hedge ratio is expressed in terms of relative par amounts. Accordingly, a hedge ratio of 1.20 means that for every $1 million par value of securities to be hedged, one needs $1.2 million par value of futures contracts to offset the risk. *In our discussion, the values are defined so that the hedge ratio is the number of futures contracts.*

Earlier we defined a cross-hedge in the futures market as a hedge in which the security to be hedged is not deliverable on the futures contract used in the hedge. For example, a manager who wants to hedge the sale price of long-term corporate bonds might hedge with the Treasury bond futures contract, but since non-Treasury bonds cannot be delivered in satisfaction of the contract, the hedge would be considered a cross-hedge. A manager also might want to hedge a rate that is of the same quality as the rate specified in one of the contracts but that has a different maturity. For example, it is necessary to cross-hedge a Treasury bond, note, or bill with a maturity that does not qualify for delivery on any futures contract. Thus, when the security to be hedged differs from the futures contract specification in terms of either quality or maturity, one is led to the cross-hedge.

Conceptually, cross-hedging is somewhat more complicated than hedging deliverable securities because it involves two relationships. First, there is the relationship between the cheapest-to-deliver (CTD) issue and the futures contract.

Second, there is the relationship between the security to be hedged and the CTD. Practical considerations at times may lead a manager to shortcut this two-step relationship and focus directly on the relationship between the security to be hedged and the futures contract, thus ignoring the CTD altogether. However, in so doing, a manager runs the risk of miscalculating the target rate and the risk in the hedge. Furthermore, if the hedge does not perform as expected, the shortcut makes it difficult to tell why the hedge did not work out as expected.

The key to minimizing risk in a cross-hedge is to choose the right number of futures contracts. This depends on the relative dollar duration of the bond to be hedged and the futures position. Equation (63-4) indicated the number of futures contracts to achieve a particular target dollar duration. The objective in hedging is to make the target dollar duration equal to zero. Substituting zero for target dollar duration in Eq. (63-4) we obtain

$$\text{Number of futures contracts} = -\frac{\text{current dollar duration without futures}}{\text{dollar duration per futures contract}} \tag{63-5}$$

To calculate the dollar duration of a bond, the manager must know the precise point in time that the dollar duration is to be calculated (because volatility generally declines as a bond matures), as well as the price or yield at which to calculate dollar duration (because higher yields generally reduce dollar duration for a given yield change). The relevant point in the life of the bond for calculating volatility is the point at which the hedge will be lifted. Dollar duration at any other point is essentially irrelevant because the goal is to lock in a price or rate only on that particular day. Similarly, the relevant yield at which to calculate dollar duration initially is the target yield. Consequently, the numerator of Eq. (63-5) is the dollar duration on the date the hedge is expected to be delivered. The yield that is to be used on this date in order to determine the dollar duration is the forward rate.

Let's look at how we apply Eq. (63-5) when using the Treasury bond futures contract to hedge. The number of futures contracts will be affected by the dollar duration of the CTD issue. We can modify Eq. (63-5) as follows:

$$\begin{aligned}\text{Number of futures contracts} &= -\frac{\text{current dollar duration without futures}}{\text{dollar duration of the CTD issue}}\\ &\quad\times\frac{\text{dollar duration of the CTD issue}}{\text{dollar duration per futures contract}}\end{aligned} \tag{63-6}$$

As noted earlier, the conversion ratio for the CTD issue is a good approximation of the second ratio. Thus Eq. (63-6) can be rewritten as

$$\begin{aligned}\text{Number of futures contracts} &= -\frac{\text{current dollar duration without futures}}{\text{dollar duration of the CTD issues}}\\ &\quad\times\text{conversion factor for the CTD issue}\end{aligned} \tag{63-7}$$

An Illustration. An example for a single bond shows why dollar duration weighting leads to the correct number of contracts to use to hedge. The hedge illustrated is a cross-hedge. Suppose that on 6/24/99 a manager owned $10 million par value of a 6.25% Fannie Mae (FNMA) option-free bond maturing on 5/15/29 selling at 88.39 to yield 7.20%. The manager wants to sell September 1999 Treasury bond futures to hedge a future sale of the FNMA bond. At the time, the price of the September Treasury bond futures contract was at 113. The CTD issue was the 11.25% of 2/15/15 issue that was trading at the time at 146.19 to yield 6.50%. The conversion factor for the CTD issue was 1.283. To simplify, assume that the yield spread between the FNMA bond and the CTD issue remains at 0.70% (i.e., 70 basis points) and that the anticipated sale date is the last business day in September 1999.

The target price for hedging the CTD issue would be 144.979 (from 113 × 1.283), and the target yield would be 6.56% (the yield at a price of 144.979). Since the yield on the FNMA bond is assumed to stay at 0.70% above the yield on the CTD issue, the target yield for the FNMA bond would be 7.26%. The corresponding price for the FNMA bond for this target yield is 87.76. At these target levels, the dollar duration for a 50 basis point change in rates for the CTD issue and FNMA bond per $100 of par value is $6.255 and $5.453, respectively. As indicated earlier, all these calculations are made using a settlement date equal to the anticipated sale date, in this case the end of September 1999. The dollar duration for $10 million par value of the FNMA bond is then $545,300 ($10 million/100 times $5.453). Per $100,000 par value for the CTD issue, the dollar duration per futures contract is $6,255 ($100,000/100 times $6.255).

Thus we know

$$\begin{aligned}&\text{Current dollar duration without futures}\\&\qquad = \text{dollar duration of the FNMA bond}\\&\qquad = \$545{,}300\end{aligned}$$

$$\text{Dollar duration of the CTD issue} = \$6{,}255$$

$$\text{Conversion factor for CTD issue} = 1.283$$

Substituting these values into Eq. (63-7), we obtain

$$\text{Number of futures contracts} = \frac{\$545{,}300}{\$6{,}255} \times 1.283 = -112 \text{ contracts}$$

Consequently, to hedge the FNMA bond position, 112 Treasury bond futures contracts must be shorted.

Exhibit 63-2 uses scenario analysis to show the outcome of the hedge based on different prices for the FNMA bond at the delivery date of the futures contract. Let's go through each of the columns. Column (1) shows the assumed sale price for the FNMA bond, and column (2) shows the corresponding yield based on the actual sale price in column (1). This yield is found from the

EXHIBIT 63-2

Hedging a Nondeliverable Bond to a Delivery Date with Futures

Instrument to be hedged: $10 million FNMA 6.25% of 05/15/29
Price of FNMA as of hedge date (6/24/99) = 88.39
Conversion factor for September 1999 = 1.283
Price of futures contract when sold = 113
Target price for FNMA bonds = 87.76
Par value hedged = $10,000,000
Number of futures contracts = 112
Futures position = $12,656,000
Target market value for FNMA bonds = $8,776,000

(1) Actual Sale Price of FNMA Bonds	(2) Yield at Sale	(3) Yield of 11.25% Treasury Bond*	(4) Price of 11.25% Treasury Bond	(5) Futures Price†	(6) Value of Futures Position	(7) Gain or Loss on Futures Position	(8) Effective Sale Price‡
8,000,000	8.027	7.327	135.813	105.85581	11,855,850	800,150	8,800,150
8,100,000	7.922	7.222	137.031	106.80514	11,962,176	693,824	8,793,824
8,200,000	7.818	7.118	138.234	107.74279	12,067,193	588,807	8,778,807
8,300,000	7.717	7.017	139,422	108.66875	12,170,899	485,101	8,785,101
8,400,000	7.617	6.917	140.609	109.59392	12,274,519	381,481	8,781,481
8,500,000	7.520	6.820	141.781	110.50740	12,376,829	279,171	8,779,171
8,600,000	7.424	6.724	142.938	111.40920	12,477,830	178,170	8,778,170
8,700,000	7.330	6.630	144.094	112.31021	12,578,744	77,256	8,777,256
8,800,000	7.238	6.538	145.250	113.21122	12,679,657	–23,657	8,776,343
8,900,000	7.148	6.448	146.391	114.10055	12,779,261	–123,261	8,776,739
9,000,000	7.059	6.359	147.531	114.98909	12,878,778	–222,778	8,777,222
9,100,000	6.972	6.272	148.656	115.86594	12,976,985	–320,985	8,779,015
9,200,000	6.886	6.186	149.766	116.73110	13,073,883	–417,883	8,782,117
9,300,000	6.802	6.102	150.875	117.59548	13,170,694	–514,694	8,785,306
9,400,000	6.719	6.019	151.984	118.45986	13,267,504	–611,504	8,788,496
9,500,000	6.637	5.937	153.078	119.31255	13,363,005	–707,005	8,792,995

*By assumption, the yield on the cheapest-to-deliver issue is 70 basis points lower than the yield on the FNMA bond.
†By convergence, the futures price equals the price of the cheapest-to-deliver issue divided by 1.283 (the conversion factor).
‡Transaction costs and the financing of margin flows are ignored.

price/yield relationship. Given the assumed sale price for the FNMA bond, the corresponding yield can be determined. Column (3) shows the yield for the CTD issue. This yield is computed based on the assumption regarding the yield spread of 70 basis points between the FNMA bond and the CTD issue. Thus, by subtracting 70 basis points from the yield for the FNMA bond in column (2), the yield on the CTD issue (the 11.25% of 2/15/15) is obtained. Given the yield for the CTD issue in column (3), the price per $100 of par value of the CTD issue can be computed. This CTD price is shown in column (4).

Now we must move from the price of the CTD issue to the futures price. As explained in the description of the columns in Exhibit 63-1, by dividing the price for the CTD issue shown in column (4) by the conversion factor of the CTD issue (1.283), the futures price is obtained. This price is shown in column (5).

The value of the futures position is found in the same way as in Exhibit 63-1. First, the futures price per $1 of par value is computed by dividing the futures price by 100. Then this value is multiplied by $100,000 (the par value for the contract) and the number of futures contracts. That is,

$$\text{Value of futures position} \\ = (\text{futures price}/100) \times \$100{,}0000 \times \text{number of futures contracts}$$

Since the number of futures contracts sold is 112,

$$\text{Value of futures position} = (\text{final futures price}/100) \times \$100{,}0000 \times 112$$

The values shown in column (6) use the preceding formula. Using the first assumed actual sale price for the FNMA of $8 million as an example, the corresponding futures price in column (5) is 105.85581. Therefore, the value of the futures position is

$$\begin{aligned}\text{Value of futures position} &= (105.85581/100) \times \$100{,}000 \times 112 \\ &= \$11{,}855{,}850\end{aligned}$$

Now let's calculate the gain or loss on the futures position shown in column (7). This is done in the same manner as explained for Exhibit 63-1. Since the futures price at which the contracts are sold at the inception of the hedge is 113, the gain or loss on the futures position is found as follows:

$$(113/100 - \text{final futures price}/100) \times \$100{,}000 \times \text{number of futures contracts}$$

For example, for the first scenario in Exhibit 63-2, the futures price is 105.85581, and 112 futures contract were sold. Therefore,

$$(113/100 - 105.85581/100) \times \$100{,}000 \times 112 = \$800{,}150$$

There is a gain from the futures position because the futures price is less than 113. Note that for all the final futures prices above 113 in Exhibit 63-2, there is a negative value, which means that there is a loss on the futures position. For all futures prices below 113, there is a profit.

Finally, column (8) shows the effective sale price for the FNMA bond. This value is found as follows:

$$\text{Effective sale price for FNMA bond} \\ = \text{actual sale price of FNMA bond} + \text{gain or loss on futures position}$$

For the actual sale price of \$8 million, the gain is \$800,150. Therefore, the effective sale price for the FNMA bond is

$$\$8{,}000{,}000 + \$800{,}150 = \$8{,}800{,}150$$

Looking at column (8) of Exhibit 63-2, we see that if the simplifying assumptions hold, a futures hedge using the recommended number of futures contracts (112) very nearly locks in the target price for \$10 million par value of the FNMA bonds.

Refining for Changing Yield Spread. Another refinement in the hedging strategy is usually necessary for hedging nondeliverable securities. This refinement concerns the assumption about the relative yield spread between the CTD issue and the bond to be hedged. In the prior discussion, we assumed that the yield spread was constant over time. Yield spreads, however, are not constant over time. They vary with the maturity of the instruments in question and the level of rates, as well as with many unpredictable and nonsystematic factors.

Regression analysis allows the manager to capture the relationship between yield levels and yield spreads and use it to advantage. For hedging purposes, the variables are the yield on the bond to be hedged and the yield on the CTD issue. The regression equation takes the form

$$\text{Yield on bond to be hedged} = a + b \times \text{yield on CTD issue} + \text{error} \qquad (63\text{-}8)$$

The regression procedure provides an estimate of b, which is the expected relative yield change in the two bonds. This parameter b is called the *yield beta*. Our example that used constant spreads implicitly assumes that the yield beta b equals 1.0 and a equals 0.70 (because 0.70 is the assumed spread).

For the two issues in question, that is, the FNMA bond and the CTD issue, suppose that the estimated yield beta was 1.05. Thus yields on the FNMA issue are expected to move 5% more than yields on the Treasury issue. To calculate the number of futures contracts correctly, this fact must be taken into account; thus the number of futures contracts derived in our earlier example is multiplied by the factor 1.05. Consequently, instead of shorting 112 Treasury bond futures contracts to hedge \$10 million of the FNMA bond, the investor would short 118 (rounded up) contracts.

The formula for the number of futures contracts is revised as follows to incorporate the impact of the yield beta:

$$\begin{aligned}\text{Number of futures contracts} = &-\frac{\text{current dollar duration without futures}}{\text{dollar duration of the CTD issue}} \\ &\times \text{ conversion factor for the CTD issue} \\ &\times \text{ yield beta} \qquad (63\text{-}9)\end{aligned}$$

where the yield beta is derived from the yield of the bond to be hedged regressed on the yield of the CTD issue (Eq. 63-8).

The effect of a change in the CTD issue and the yield spread can be assessed before the hedge is implemented. An exhibit similar to that of Exhibit 63-2 can be constructed under a wide range of assumptions. For example, at different yield levels at the date the hedge is to be lifted (the second column in Exhibit 63-2), a different yield spread may be appropriate and a different acceptable issue will be the CTD issue. The manager can determine what this will do to the outcome of the hedge.

Monitoring and Evaluating the Hedge

After a target is determined and a hedge is set, there are two remaining tasks. The hedge must be monitored during its life and evaluated after it is over. Most futures hedges require very little active monitoring during their life. In fact, overactive management poses more of a threat to most hedges than does inactive management. The reason for this is that the manager usually will not receive enough new information during the life of the hedge to justify a change in the hedging strategy. For example, it is not advisable to readjust the hedge ratio every day in response to a new data point and a possible corresponding change in the estimated value of the yield beta.

There are, however, exceptions to this general rule. As rates change, dollar duration changes. Consequently, the hedge ratio may change slightly. In other cases, there may be sound economic reasons to believe that the yield beta has changed. While there are exceptions, the best approach is usually to let a hedge run its course using the original hedge ratio with only slight adjustments.

A hedge normally can be evaluated only after it has been lifted. Evaluation involves, first, an assessment of how closely the hedge locked in the target rate—that is, how much error there was in the hedge. To provide a meaningful interpretation of the error, the manager should calculate how far from the target the sale (or purchase) would have been had there been no hedge at all. One good reason for evaluating a completed hedge is to ascertain the sources of error in the hedge in the hope that the manager will gain insights that can be used to advantage in subsequent hedges. A manager will find that there are three major sources of hedging errors:

1. The dollar duration for the hedged instrument was incorrect.
2. The projected value of the basis at the date the hedge is removed can be in error.
3. The parameters estimated from the regression (a and b) can be inaccurate.

Recall from the calculation of duration in Chapter 5 that interest rates are changed up and down by a small number of basis points and the security is revalued. The two recalculated values are used in the numerator of the duration formula. The first problem just listed recognizes that the instrument to be hedged may be a complex instrument (i.e., one with embedded options) and that the valuation model does not do a good job of valuing the security when interest rates change.

The second major source of errors in a hedge—an inaccurate projected value of the basis—is the more difficult problem. Unfortunately, there are no satisfactory simple models like regression that can be applied to the basis. Simple models of the basis violate certain equilibrium relationships for bonds that should not be violated. On the other hand, theoretically rigorous models are very unintuitive and usually soluble only by complex numerical methods. Modeling the basis is undoubtedly one of the most important and difficult problems that managers seeking to hedge face.

HEDGING WITH OPTIONS

Hedging strategies using options involve taking a position in an option and a position in the underlying bond in such a way that changes in the value of one position will offset any unfavorable price (interest rate) movement in the other position. We begin with the basic hedging strategies using options. Then we illustrate these basic strategies using futures options to hedge the FNMA bond for which a futures hedge was used earlier in this chapter. Using futures options in our illustration of hedging the bond is a worthwhile exercise because it shows how complicated hedging with futures options is and the key parameters involved in the process. We also compare the outcome of hedging with futures and hedging with futures options.

Basic Hedging Strategies

There are three popular hedging strategies: (1) a protective put-buying strategy, (2) a covered call-writing strategy, and (3) a collar strategy. We discuss each strategy below.

Protective Put-Buying Strategy

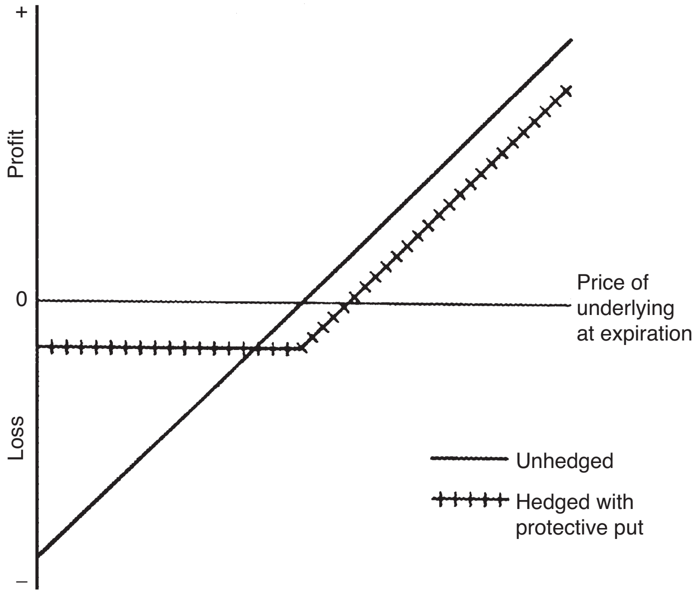
Consider a manager who has a bond and wants to hedge against rising interest rates. The most obvious options hedging strategy is to buy put options on bonds. This hedging strategy is referred to as a *protective put-buying strategy*. The puts are usually out-of-the-money puts and may be either puts on cash bonds or puts on interest-rate futures. If interest rates rise, the puts will increase in value (holding other factors constant), offsetting some or all of the loss on the bonds in the portfolio.

This strategy is a simple combination of a long put option with a long position in a cash bond. Such a position has limited downside risk, but large upside potential. However, if rates fall, the price appreciation on the bonds in the portfolio will be diminished by the amount paid to purchase the puts. Exhibit 63-3 compares the protective put-buying strategy to an unhedged position.

The protective put-buying strategy is very often compared with purchasing insurance. Like insurance, the premium paid for the protection is nonrefundable

EXHIBIT 63-3

Protective Put-Buying Strategy



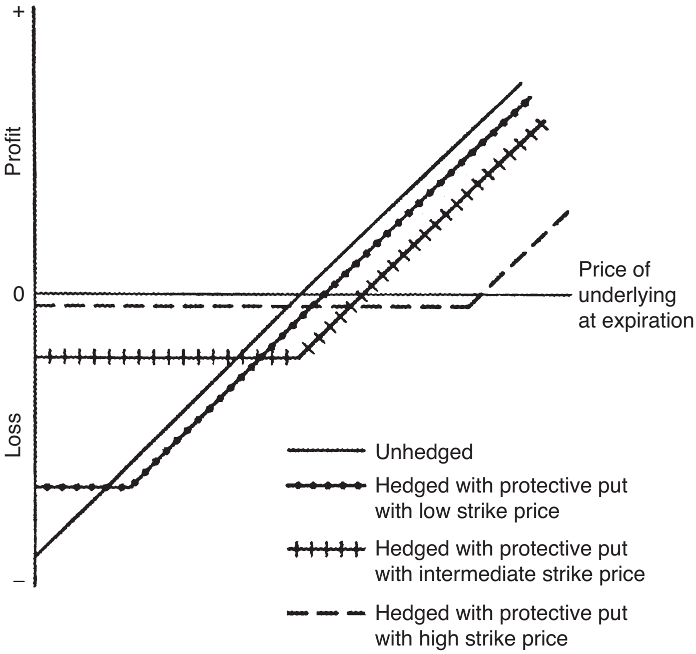
and is paid before the coverage begins. The degree to which a portfolio is protected depends on the strike price of the options; thus the strike price is often compared with the deductible on an insurance policy. The lower the deductible (i.e., the higher the strike price for the put), the greater is the level of protection, and the more the protection costs. Conversely, the higher the deductible (the lower the strike price on the put), the more the portfolio can lose in value, but the cost of the insurance is lower. Exhibit 63-4 compares an unhedged position with several protective put positions, each with a different strike price, or level of protection. As the exhibit shows, no one strategy dominates any other strategy, in the sense of performing better at all possible rate levels. Consequently, it is impossible to say that one strike price is necessarily the "best" strike price or even that buying protective puts is necessarily better than doing nothing at all.

Covered Call-Writing Strategy

Another options hedging strategy used by many portfolio managers is to sell calls against the bond portfolio. This hedging strategy is called a *covered call-writing strategy.* The calls that are sold are usually out-of-the-money calls and can be either calls on cash bonds or calls on interest-rate futures. Covered call writing is just an outright long position combined with a short call position. Obviously, this strategy entails much more downside risk than buying a put to protect the value

EXHIBIT 63-4

Protective Put-Buying Strategy with Different Strike Prices

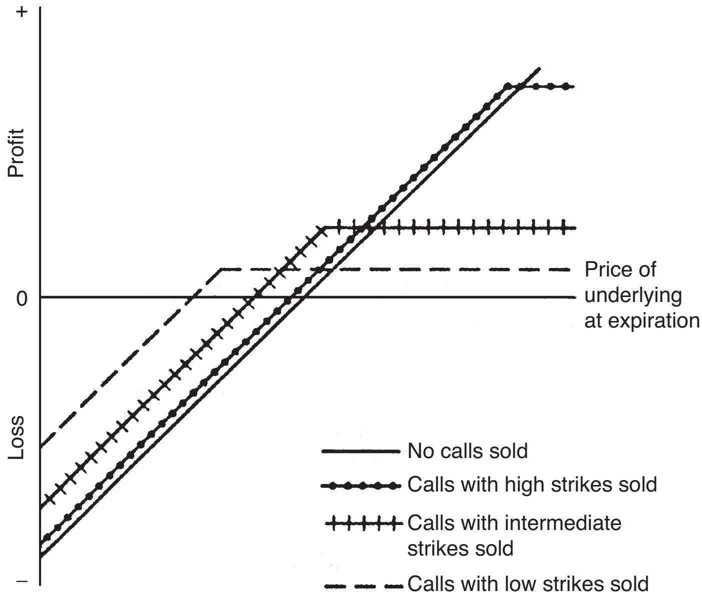


of the portfolio. In fact, many portfolio managers do not consider covered call writing a hedge.

Regardless of how it is classified, it is important to recognize that while covered call writing has substantial downside risk, it has less downside risk than an unhedged long position alone. On the downside, the difference between the long position alone and the covered call-writing strategy is the premium received for the calls that are sold. This premium acts as a cushion for downward movements in prices, reducing losses when rates rise. The cost of obtaining this cushion is that the manager gives up some of the potential on the upside. When rates decline, the call options become greater liabilities for the covered call writer. These incremental liabilities decrease the gains the manager would otherwise have realized on the portfolio in a declining rate environment. Thus the covered call writer gives up some (or all) of the upside potential of the portfolio in return for a cushion on the downside. The more upside potential that is forfeited (i.e., the lower the strike price on the calls), the more cushion there is on the downside. Exhibit 63-5 illustrates this point by comparing an unhedged position to several covered call-writing strategies, each with a different strike price. Like the protective put-buying strategy, there is no "right" strike price for the covered call writer.

EXHIBIT 63-5

Covered Call-Writing Strategy with Different Strike Prices



Collar Strategy

There are other hedging strategies employing options that are used frequently by managers. For example, many managers combine the protective put-buying strategy and the covered call-writing strategy. By combining a long position in an out-of-the-money put and a short position in an out-of-the-money call, the manager creates a long position in a *collar.* Consequently, this hedging strategy is called a *collar strategy*. The manager who uses the collar eliminates part of the portfolio's downside risk by giving up part of its upside potential. A long position hedged with a collar is shown in Exhibit 63-6.

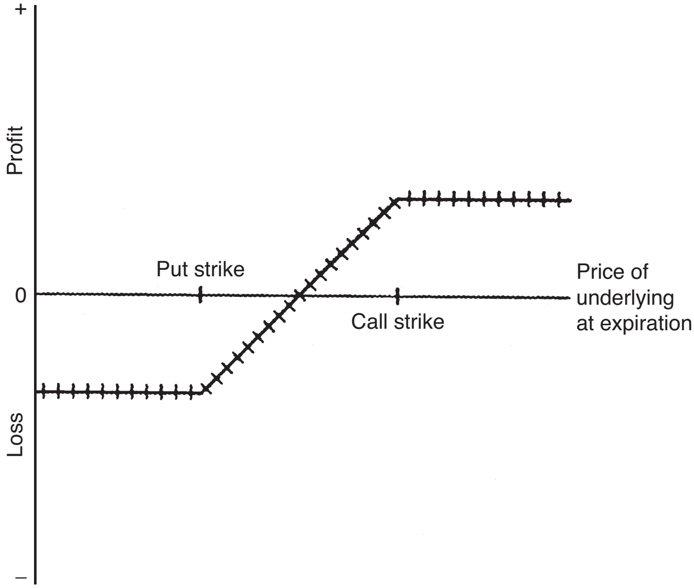
The collar in some ways resembles the protective put, in some ways resembles covered call writing, and in some ways resembles an unhedged position. The collar is like the protective put-buying strategy in that it limits the possible losses on the portfolio if interest rates go up. Like the covered call-writing strategy, the portfolio's upside potential is limited. Like an unhedged position, within the range defined by the strike prices, the value of the portfolio varies with interest rates.

Selecting the "Best" Strategy

Comparing the two basic strategies for hedging with options, one cannot say that the protective put-buying strategy or the covered call-writing strategy is necessarily

EXHIBIT 63-6

Long Position Hedged with a Collar



the better or more correct options hedge. The best strategy (and the best strike price) depends on the manager's view of the market. Purchasing a put and paying the required premium are appropriate if the manager is fundamentally bearish. If, instead, the manager is neutral to mildly bearish, it is better to receive the premium on the covered call-writing strategy. If the manager prefers to take no view on the market at all, and as little risk as possible, then the futures hedge is the most appropriate. If the manager is fundamentally bullish, then no hedge at all is probably the best strategy.

Steps in Options Hedging

Like hedging with futures, there are steps that managers should consider before setting their hedges. These steps include

Step 1. Determine the option contract that is the best hedging vehicle. The best option contract to use depends on several factors. These include option price, liquidity, and correlation with the bond(s) to be hedged. In price-inefficient markets, the option price is important because not all options will be priced in the same manner or with the same volatility assumption. Consequently, some options may be overpriced and some underpriced. Obviously, with other factors equal, it is better to use the underpriced options when buying and the overpriced options when selling.

Whenever there is a possibility that the option position may be closed out prior to expiration, liquidity is also an important consideration. If the particular option is illiquid, closing out a position may be prohibitively expensive, and the manager loses the flexibility of closing out positions early or rolling into other positions that may become more attractive. Correlation with the underlying bond(s) to be hedged is another factor in selecting the right contract. The higher the correlation, the more precisely the final profit and loss can be defined as a function of the final level of rates. Poor correlation leads to more uncertainty.

While most of the uncertainty in an options hedge usually comes from the uncertainty of interest rates themselves, the degree of correlation between the bonds to be hedged and the instruments underlying the options contracts add to that risk. The lower the correlation, the greater the risk.

Step 2. Find the appropriate strike price. For a cross-hedge, the manager will want to convert the strike price on the options that are actually bought or sold into an equivalent strike price for the actual bonds being hedged.

Step 3. Determine the number of contracts. The hedge ratio is the number of options to buy or sell.

Steps 2 and 3, determining the strike price and the number of contracts, can best be explained with examples using futures options.

Protective Put-Buying Strategy Using Futures Options

As explained earlier, managers who want to hedge their bond positions against a possible increase in interest rates will find that buying puts on futures is one of the easiest ways to purchase protection against rising rates. To illustrate a protective put-buying strategy, we can use the same FNMA bond that we used to demonstrate how to hedge with Treasury bond futures.[4] In that example, a manager held $10 million par value of a 6.25% FNMA bond maturing 5/15/29 and used September 1999 Treasury bond futures to lock in a sale price for those bonds on the futures delivery date. Now we want to show how the manager could use futures options instead of futures to protect against rising rates.

4. As explained in Chapter 61, futures options on Treasury bonds are used more commonly by institutional investors. The mechanics of futures options are as follows: If a put option is exercised, the option buyer receives a short position in the underlying futures contract and the option writer receives the corresponding long position. The futures price for both positions is the strike price for the put option. The exchange then marks the positions to market and the futures price for both positions is then the current futures price. If a call option is exercised, the option buyer receives a long position in the underlying futures contract and the option writer receives the corresponding short position. The futures price for both positions is the strike price for the call option. The exchange then marks the positions to market and the futures price for both positions is then the current futures price.

On 6/24/99, the FNMA bond was selling for 88.39 to yield 7.20%, and the CTD issue's yield was 6.50%. For simplicity, it is assumed that the yield spread between the FNMA bond and the CTD issue remains at 70 basis points.

Selecting the Strike Price

The manager must determine the minimum price that he wants to establish for the FNMA bonds. In our illustration, we will assume that the minimum price before the cost of the put options purchased is 84.453. This is equivalent to saying that the manager wants to establish a strike price for a put option on the hedged bonds of 84.453. But the manager is not buying a put option on the FNMA bond. He is buying a put option on a Treasury bond futures contract. Therefore, the manager must determine the strike price for a put option on a Treasury bond futures contract that is equivalent to a strike price of 84.453 for the FNMA bond.

This can be done with the help of Exhibit 63-7. We begin at the top left-hand box of the exhibit. Since the minimum price is 84.453 for the FNMA bond, this means that the manager is attempting to establish a maximum yield of 7.573%. This is found from the relationship between price and yield: given a price of 84.453 for the FNMA bond, this equates to a yield of 7.573%. (This gets us to the lower left-hand box in Exhibit 63-7.) From the assumption that the spread between the FNMA bond and the cheapest-to-deliver issue is a constant 70 basis points, setting a maximum yield of 7.573% for the FNMA bond is equivalent to setting a maximum yield of 6.873% for the cheapest-to-deliver issue. (Now we are at the lower box in the middle column of Exhibit 63-7.) Given the yield of 6.873% for the CTD issue, the minimum price before the cost of the puts purchased can be determined (the top box in the middle column of the

EXHIBIT 63-7

Calculating Equivalent Strike Prices and Yields for Hedging with Futures Options

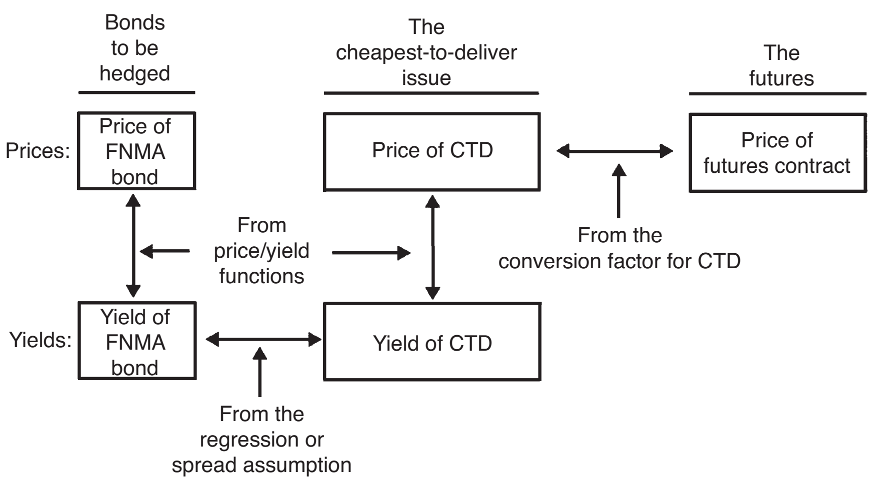


exhibit). A 6.873% yield for the CTD issue gives us a price of 141.136. (This is determined from the characteristics of the CTD issue.) The corresponding futures price is found by dividing the price of the CTD issue by the conversion factor. This gets us to the box in the right-hand column of Exhibit 63-7. Since the conversion factor is 1.283, the futures price is about 110 (141.136 divided by 1.283). This means that a strike price of 110 for a put option on a Treasury bond futures contract is roughly equivalent to a put option on our FNMA bond with a strike price of 84.453.

The foregoing steps are always necessary to obtain the appropriate strike price on a put futures option. The process is not complicated. It simply involves (1) the relationship between price and yield, (2) the assumed relationship between the yield spread between the bonds to be hedged and the cheapest-to-deliver issue, and (3) the conversion factor for the cheapest-to-deliver issue. As with hedging employing futures illustrated earlier in this chapter, the success of the hedging strategy will depend on (1) whether the cheapest-to-deliver issue changes and (2) the yield spread between the bonds to be hedged and the cheapest-to-deliver issue.

Calculating the Number of Options Contracts

The hedge ratio is determined using the following equation similar to Eq. (63-7) because we will assume a constant yield spread between the bond to be hedged and the cheapest-to-deliver issue:

$$\text{Number of options contracts} = \frac{\text{current dollar duration without options}}{\text{dollar duration of the CTD issue}} \times \text{conversion factor for CTD issue}$$

The dollar durations are as follows per 50 basis point change in rates:

Current dollar duration without options = \$512,320

Dollar duration of the CTD issue = \$6,021

Notice that the dollar durations are different from those used in calculating the number of futures contracts for the futures hedge. This is so because the dollar durations are calculated at prices corresponding to the strike price of the futures option (110) rather than the futures price (113). The number of futures options contracts is then

$$\text{Number of options contracts} = \frac{\$512{,}320}{\$6{,}021} \times 1.283 = 109 \text{ put options}$$

Thus, to hedge the FNMA bond position with put options on Treasury bond futures, 109 put options must be purchased.

Outcome of the Hedge

To create a table for the protective put hedge, we can use some of the numbers from Exhibit 63-2. Exhibit 63-8 shows the scenario analysis for the protective

EXHIBIT 63-8

Hedging a Nondeliverable Bond to a Delivery Date with Puts on Futures

Instrument to be hedged: $10 million FNMA 6.25% of 05/15/29
Price of FNMA as of hedge date (6/24/99) = 88.39
Conversion factor for September 1999 = 1.283
Price of futures contract when sold = 113
Target price per bond for FNMA bonds = 84.453
Effective minimum sale price = 83.908
Par value hedged = $10,000,000
Strike price for put = 110
Number of puts on futures = 109
Price per contract = $500.00
Cost of put position = $54,500

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Actual Sale Price of FNMA Bonds	Yield at Sale	Yield of 11.25% Treasury Bond	Price of 11.25% Treasury Bond*	Futures Price	Value of Put Options†	Cost of Put Position	Effective Sale Price‡
8,000,000	8.027	7.327	135.813	105.85581	451,717	54,500	8,397,217
8,100,000	7.922	7.222	137.031	106.80514	348,239	54,500	8,393,739
8,200,000	7.818	7.118	138.234	107.74279	246,036	54,500	8,391,536
8,300,000	7.717	7.017	139.422	108.66875	145,107	54,500	8,390,607
8,400,000	7.617	6.917	140.609	109.59392	44,263	54,500	8,389,763
8,500,000	7.520	6.820	141.781	110.50740	0	54,500	8,445,500
8,600,000	7.424	6.724	142.938	111.40920	0	54,500	8,545,500
8,700,000	7.330	6.630	144.094	112.31021	0	54,500	8,645,500
8,800,000	7.238	6.538	145.250	113.21122	0	54,500	8,745,500
8,900,000	7.148	6.448	145.391	114.10055	0	54,500	8,845,500
9,000,000	7.059	6.359	147.531	114.98909	0	54,500	8,945,500
9,100,000	6.972	6.272	148.656	115.86594	0	54,500	9,045,500
9,200,000	6.886	6.186	149.766	116.73110	0	54,500	9,145,500
9,300,000	6.802	6.102	150.875	117.59548	0	54,500	9,245,500
9,400,000	6.719	6.019	151.984	118.45986	0	54,500	9,345,500
9,500,000	6.637	5.937	153.078	119.31255	0	54,500	9,445,500

*These numbers are approximate because futures trade in 32nds.
†From maximum of [(110/100 – futures price/100) × $100,000 × 109, 0].
‡Does not include transaction costs or the financing of the options position.

put-buying strategy. The first five columns are the same as in Exhibit 63-2. For the put option hedge, column (6) shows the value of the put option position at the expiration date. The value of the put option position at the expiration date will be equal to zero if the futures price is greater than or equal to the strike price of 110.

If the futures price is below 110, then the options expire in the money, and the value of the put option position is

$$\text{Value of put option position} = (110/100 - \text{futures price}/100) \times \$100{,}000 \times \text{number of put options}$$

For example, for the first scenario in Exhibit 63-8 of \$8 million for the actual sale price of the FNMA bond, the corresponding futures price is 105.85581. The number of put options purchased is 109. Therefore

$$(110/100 - 105.85581/100) \times \$100{,}000 \times 109 = \$45{,}717$$

The effective sale price for the FNMA bonds is then equal to

$$\text{Effective sale price} = \text{actual sale price} + \text{value of put option position} - \text{option cost}$$

Let's look at the option cost. Suppose that the price of the put option with a strike price of 110 is \$500 per contract. With a total of 109 options, the cost of the protection is \$54,500 (109 × \$500, not including financing costs and commissions). This cost is shown in column (7) and is equivalent to 0.545 per \$100 par value hedged.

The effective sale price for the FNMA bonds for each scenario is shown in the last column of Exhibit 63-8. This effective sale price is never less than 83.908. This equals the price of the FNMA bonds equivalent to the futures strike price of 110 (i.e., 84.453) minus the cost of the puts (i.e., 0.545 per \$100 par value hedged). This minimum effective price is something that can be calculated before the hedge is ever initiated. (As prices decline, the effective sale price actually exceeds the target minimum sale price of 83.908 by a small amount. This is due only to rounding and the fact that the hedge ratio is left unaltered, although the relative dollar durations that go into the hedge ratio calculation change as yields change.) As prices increase, however, the effective sale price of the hedged bonds increases as well; unlike the futures hedge shown in Exhibit 63-2, the options hedge protects the investor if rates rise but allows the investor to profit if rates fall.

Covered Call-Writing Strategy with Futures Options

Unlike the protective put-buying strategy, covered call writing is not entered into with the sole purpose of protecting a portfolio against rising rates. The covered call writer, believing that the market will not trade much higher or much lower than its present level, sells out-of-the-money calls against an existing bond portfolio. The sale of the calls brings in premium income that provides partial protection in case rates increase. The premium received does not, of course, provide the kind of protection that a long put position provides, but it does provide some additional income that can be used to offset declining prices. If, instead, rates fall, portfolio appreciation is limited because the short call position constitutes a liability for the seller, and this liability increases as rates decline. Consequently, there is limited upside price potential for the covered call writer. Of course, this is not so bad if prices are essentially going nowhere; the added income from the sale of call options is obtained without sacrificing any gains.

To see how covered call writing with futures options works for the bond used in the protective put example, we construct a table much as we did before. With futures selling around 113 on the hedge initiation date, a sale of a 117 call option on futures might be appropriate. As before, it is assumed that the hedged bond will remain at a 70 basis point spread over the CTD issue. We also assume for simplicity that the price of the 117 calls is \$500 per contract. The number of options contracts sold will be the same, namely, 109 contracts for \$10 million face value of underlying bonds. Thus, the proceeds received from the sale of the 109 call options is \$54,500 (109 contracts × \$500) or 0.545 per \$100 par value hedged.

Exhibit 63-9 shows the outcomes of the covered call-writing strategy given these assumptions. The first five columns of the exhibit are the same as for Exhibit 63-8. In column (6), the liability resulting from the call option position is shown. The liability is zero if the futures price for the scenario is less than the strike price of 117. If the futures price for the scenario is greater than 117, the liability is calculated as follows:

$$(\text{Futures price}/100 - 117/100) \times \$100{,}000 \times \text{number of put options}$$

For example, consider the scenario in Exhibit 63-9, where the actual sale price of the FNMA bond is \$9.5 million. The corresponding futures price is 119.31255. The number of call options sold is 109. Therefore

$$(119.31255/100 - 117/100) \times \$100{,}000 \times 109 = \$252{,}068$$

That is,

$$\begin{aligned}\text{Effective sale price} = {} & \text{actual sale price} \\ & + \text{proceeds from sale of the call options} \\ & - \text{liability of call position}\end{aligned}$$

Since the proceeds from sale of the call options is \$54,500, then

$$\text{Effective sale price} = \text{actual sale price} + \$54{,}000 - \text{liability of call position}$$

The last column of Exhibit 63-9 shows the effective sale price for each scenario.

Just as the minimum effective sale price could be calculated beforehand for the protective put-buying strategy, the maximum effective sale price can be calculated beforehand for the covered call-writing strategy. The maximum effective sale price will be the price of the hedged bond corresponding to the strike price of the option sold plus the premium received. In this case, the strike price on the futures call option is 117. A futures price of 117 corresponds to a price of 150.111 (from 117 times the conversion factor of 1.283) and a corresponding

EXHIBIT 63-9

Writing Calls on Futures Against a Nondeliverable Bond

Instrument to be hedged: $10 million FNMA 6.25% of 05/15/29
Price of FNMA as of hedge date (6/24/99) = 88.39
Conversion factor for September 1999 = 1.283
Price of futures contract when sold = 113
Target maximum price for FNMA bonds per bond = 92.858
Par value hedged = $10,000,000
Strike price for call = 117
Number of calls on futures = 109
Price per contract = 500.00
Value of call position = 54,500
Target maximum value for FNMA bonds = $9,285,800

(1) Actual Sale Price of FNMA Bonds	(2) Yield at Sale	(3) Yield of 11.25% Treasury Bond	(4) Price of 11.25% Treasury Bond	(5) Futures Price*	(6) Liability of Call Options†	(7) Proceeds from Call Position	(8) Effective Sale Price‡
8,000,000	8.027	7.327	135.813	105.85581	0	54,500.00	8,054,500
8,100,000	7.922	7.222	137.031	106.80514	0	54,500.00	8,154,500
8,200,000	7.818	7.118	138.234	107.74279	0	54,500.00	8,254,500
8,300,000	7.717	7.017	139.422	108.66875	0	54,500.00	8,354,500
8,400,000	7.617	6.917	140.609	109.59392	0	54,500.00	8,454,500
8,500,000	7.520	6.820	141.781	110.50740	0	54,500.00	8,554,500
8,600,000	7.424	6.724	142.938	111.40920	0	54,500.00	8,654,500
8,700,000	7.330	6.630	144,094	112.31021	0	54,500.00	8,754,500
8,800,000	7.238	6.538	145.250	113.21122	0	54,500.00	8,854,500
8,900,000	7.148	6.448	146.391	114.10055	0	54,500.00	8,954,500
9,000,000	7.059	6.359	147.531	114.98909	0	54,500.00	9,054,500
9,100,000	6.972	6.272	148.656	115.86594	0	54,500.00	9,154,500
9,200,000	6.886	6.186	149.766	116.73110	0	54,500.00	9,254,500
9,300,000	6.802	6.102	150.875	117.59548	64,907	54,500.00	9,289,593
9,400,000	6.719	6.019	151.984	118.45986	159,125	54,500.00	9,295,375
9,500,000	6.637	5.937	153.078	119.31255	252,068	54,500.00	9,302,432

*These numbers are approximate because futures trade in 32nds.
†From maximum of [(Futures price/100 – 117/100) × $100,000 × 109, 0].
‡Does not include transaction costs or interest on the option premium received.

yield of 6.159% for the cheapest-to-deliver issue. The equivalent yield for the hedged bond is 70 basis points higher, or 6.859%, for a corresponding price of 92.313. Adding on the premium received of 0.545 per $100 par value hedged, the final maximum effective sale price will be about 92.858. As Exhibit 63-10 shows, if the hedged bond does trade at 70 basis points over the CTD issue as

EXHIBIT 63-10

Comparison of Alternative Strategies

(1) Actual Sale Price of FNMA Bonds	(2) Effective Sale Price with Futures Hedge	(3) Effective Sale Price with Protective Puts	(4) Effective Sale Price with Covered Calls
8,000,000	8,800,150	8,397,217	8,054,500
8,100,000	8.793,824	8,393,739	8,154,500
8,200,000	8,788,807	8,391,536	8,254,500
8,300,000	8.785,101	8,390,607	8,354,500
8,400,000	8,781,481	8,389,763	8,454,500
8,500,000	8,779,171	8,445,500	8,554,500
8,600,000	8,778,170	8,545,500	8,654,500
8,700,000	8,777,256	8,645,500	8,754,500
8,800,000	8,776,343	8,745,500	8,854,500
8,900,000	8.776,739	8,845,500	9,954,500
9,000,000	8,777,222	8,945,500	9,054,500
9,100,000	8,779,015	9,045,500	9,154,500
9,200,000	8,782,117	9,145,500	9,254,500
9,300,000	8,785,306	9,245,500	9,289,593
9,400,000	8,788,496	9,345,500	9,295,375
9,500,000	8,792,995	9,445,500	9,302,432

assumed, the maximum effective sale price for the hedged bond is, in fact, slightly over 92.858. The discrepancies shown in the exhibit are due to rounding and the fact that the position is not adjusted even though the relative dollar durations change as yields change.

Comparing Alternative Strategies

In this chapter we reviewed three basic strategies for hedging a bond position: (1) hedging with futures, (2) hedging with out-of-the-money puts, and (3) covered call writing with out-of-the-money calls. Similar but opposite strategies exist for managers who are concerned that rates will decrease. As might be expected, there is no "best" strategy. Each strategy has its advantages and its disadvantages, and we never get something for nothing. To get anything of value, something else of value must be forfeited.

To make a choice among strategies, it helps to lay the alternatives side by side. Using the futures example and the futures options examples, Exhibit 63-10 shows the final values of the portfolio for the various hedging alternatives. It is easy to see from Exhibit 63-10 that if one alternative is superior to another alternative at one level of rates, it will be inferior at some other level of rates.

Consequently, we cannot conclude that one strategy is the best strategy. The manager who makes the strategy decision makes a choice among probability distributions, not usually among specific outcomes. Except for the perfect hedge, there is always some range of possible final values of the portfolio. Of course, exactly what that range is, and the probabilities associated with each possible outcome, is a matter of opinion.

Hedging with Options on Cash Instruments

Hedging a position with options on cash bonds is relatively straightforward. Most strategies, including the purchase of protective puts, covered call writing, and buying collars, are essentially the same whether futures options or options on physicals are used. There are some mechanical differences in the way the two types of option contracts are traded, and there may be substantial differences in their liquidity. Nonetheless, the basic economics of the strategies are virtually identical.

Using options on physicals frequently relieves the manager of much of the basis risk associated with a futures options hedge. For example, a manager of Treasury bonds or notes usually can buy or sell options on the exact security held in the portfolio. Using options on futures, rather than options on Treasury bonds, is sure to introduce additional elements of uncertainty.

Given the illustration presented earlier, and given that the economics of options on physicals and options on futures are essentially identical, additional illustrations for options on physicals are unnecessary. The only important difference is the hedge ratio calculation and the calculation of the equivalent strike price. To derive the hedge ratio, we always resort to an expression of relative dollar durations. Thus, for options on physicals assuming a constant spread, the hedge ratio is

$$\frac{\text{Current dollar duration without options}}{\text{Dollar duration of underlying for option}}$$

If a relationship is estimated between the yield on the bonds to be hedged and the instrument underlying the option, the appropriate hedge ratio is

$$\frac{\text{Current dollar duration without options}}{\text{Dollar duration of underlying for option}} \times \text{yield beta}$$

Unlike futures options, there is only one deliverable, so there is no conversion factor. When cross-hedging with options on physicals, the procedure for finding the equivalent strike price on the bonds to be hedged is very similar. Given the strike price of the option, the strike yield is easily determined using the price/yield relationship for the instrument underlying the option. Then, given the projected relationship between the yield on the instrument underlying the option and the yield on the bonds to be hedged, an equivalent strike yield is derived for the bonds to be hedged. Finally, using the yield-to-price formula for the bonds to be hedged, the equivalent strike price for the bonds to be hedged can be found.

KEY POINTS

- Buying an interest-rate futures contract increases a portfolio's duration; selling an interest-rate futures contract decreases a portfolio's duration.
- The advantages of adjusting a portfolio's duration using futures rather than cash-market instruments are that transaction costs are lower, margin requirements are lower, and short selling in the futures market is easier.
- The general principle in controlling interest-rate risk with futures is to combine the dollar exposure of the current portfolio and that of a futures position so that it is equal to the target dollar exposure. The number of futures contracts needed to achieve the target dollar duration depends on the current dollar duration of the portfolio without futures and the dollar duration per futures contract.
- Hedging with futures calls for taking a futures position as a temporary substitute for transactions to be made in the cash market at a later date, with the expectation that any loss realized by the manager from one position (whether cash or futures) will be offset by a profit on the other position.
- Hedging is a special case of controlling interest-rate risk in which the target duration or target dollar duration is zero.
- Cross-hedging occurs when the bond to be hedged is not identical to the bond underlying the futures contract. A short or sell hedge is used to protect against a decline in the cash price of a bond; a long or buy hedge is employed to protect against an increase in the cash price of a bond.
- The steps in hedging include (1) determining the appropriate hedging instrument, (2) determining the target for the hedge, (3) determining the position to be taken in the hedging instrument, and (4) monitoring and evaluating the hedge.
- The key factor to determine which futures contract will provide the best hedge is the degree of correlation between the rate on the futures contract and the interest rate that creates the underlying risk that the manager seeks to eliminate.
- The manager should determine the target rate or target price, which is what is expected from the hedge. The hedge ratio is the number of futures contracts needed for the hedge.

- The basis is the difference between the spot price (or rate) and the futures price (or rate).
- In general, when hedging to the delivery date of the futures contract, a manager locks in the futures rate or price. Hedging with Treasury bond futures and Treasury note futures is complicated by the delivery options embedded in these contracts. When a hedge is lifted prior to the delivery date, the effective rate (or price) that is obtained is much more likely to approximate the current spot rate than the futures rate the shorter the term of the hedge.
- The proper target for a hedge that is to be lifted prior to the delivery date depends on the basis. Basis risk refers only to the uncertainty associated with the target rate basis or target price basis.
- Hedging substitutes basis risk for price risk.
- Hedging non-Treasury securities with Treasury bond futures requires that the hedge ratio consider two relationships: (1) the cash price of the non-Treasury security and the cheapest-to-deliver issue, and (2) the price of the cheapest-to-deliver issue and the futures price.
- In computing the hedge ratio for nondeliverable securities, the yield beta should be considered; regression analysis is used to estimate the yield beta and captures the relationship between yield levels and yield spreads.
- After a target is determined and a hedge is set, the hedge must be monitored during its life and evaluated after it is over. It is important to ascertain the sources of error in a hedge in order to gain insights that can be used to advantage in subsequent hedges.
- Three popular hedge strategies using options are the protective put-buying strategy, the covered call-writing strategy, and the collar strategy.
- A manager can use a protective put-buying strategy to hedge against rising interest rates. A protective put-buying strategy is a simple combination of a long put option with a long position in a cash bond.
- A covered call-writing strategy involves selling call options against the bond portfolio. A covered call-writing strategy entails much more downside risk than buying a put to protect the value of the portfolio, and many managers do not consider covered call writing a hedge.
- It is not possible to say that the protective put-buying strategy or the covered call-writing strategy is necessarily the better or more correct options hedge. The best strategy (and the best strike prices) depends on the manager's view of the market.
- A collar strategy is a combination of a protective put-buying strategy and a covered call-writing strategy. A manager who implements a collar

strategy eliminates part of the portfolio's downside risk by giving up part of its upside potential.

- The steps in options hedging include determining the option contract that is the best hedging vehicle, finding the appropriate strike price, and determining the number of options contracts. At the outset of options hedging, a minimum effective sale price can be calculated for a protective put-buying strategy and a maximum effective sale price can be computed for a covered call-writing strategy.
- The best options contract to use depends on the option price, liquidity, and correlation with the bond(s) to be hedged.
- For a cross-hedge, the manager will want to convert the strike price for the options that are actually bought or sold into an equivalent strike price for the actual bonds being hedged. When using Treasury bond futures options, the hedge ratio is based on the relative dollar duration of the current portfolio, the cheapest-to-deliver issue, and the futures contract at the option expiration date, as well as the conversion factor for the cheapest-to-deliver issue.
- While there are some mechanical differences in the way options on physicals and options on futures are traded and there may be substantial differences in their liquidity, the basic economics of the hedging strategies are virtually identical for both contracts. Using options on physicals frequently relieves the manager of much of the basis risk associated with an options hedge.

CHAPTER

SIXTY-FOUR

INTEREST-RATE SWAPS

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Financial institutions are routinely exposed to interest rate risks that arise from the fundamental nature of their business, as well as any interest rate uncertainty and volatility. This risk is especially severe for financial institutions that show a mismatch between the average duration of their assets and liabilities. In such cases, because the interest-rate sensitivity of assets and liabilities is not synchronized, any changes in market interest rates will have a disproportionate effect on the net worth of the institution. Given that direct restructuring of the asset and liability mix, which essentially involves changes in the contractual characteristics of such instruments, may not always be possible, institutions increasingly have to rely on synthetically managing the interest-rate exposure of the firm. This chapter and Chapter 67 examine the role of capital market innovations such as interest-rate swaps and interest-rate caps and floors (and derivatives such as interest rate collars and corridors) in asset/liability management. The focus in this chapter is on interest-rate swaps.

INTEREST-RATE SWAPS

An interest-rate swap is an agreement whereby two parties (called *counterparties*) agree to exchange periodic interest payments. The dollar amount of the interest payments exchanged is based on some predetermined dollar principal, which is called the *notional principal amount.* The dollar amount each counterparty

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pays to the other is the agreed-upon periodic interest rate multiplied by the notional principal amount. The only dollars that are exchanged between the parties are the interest payments, based on the notional principal amount (or simply *notional amount*). The notional amount also provides important documentation for corporate financial statements and helps determine the contingent liability of swap market-makers in the event that the market-maker is a regulated financial institution, such as a bank. The notional amount of swaps is also relevant for determining capital requirements.

FEATURES OF A GENERIC SWAP

In the most common type of swap, one party agrees to pay the other party fixed interest payments at designated dates for the life of the contract. This party is referred to as the *fixed-rate payer.* The other party agrees to make interest-rate payments that float with some index and is referred to as *the floating-rate payer.* The fixed-rate payment is determined as a spread over the relevant Treasury rate. Additionally, depending upon the credit risk of the counterparty, the spread may increase.

For example, suppose that for the next five years party X agrees to pay party Y 5% per year, while party Y agrees to pay party X six-month LIBOR. Party X is a fixed-rate payer/floating-rate receiver, while party Y is a floating-rate payer/fixed-rate receiver. Assume that the notional amount is $50 million, and that payments are exchanged every six months for the next five years. This means that every six months, party X (the fixed-rate payer/floating-rate receiver) will pay party Y $1.25 million (5% times $50 million divided by 2). The amount that party Y (the floating-rate payer/fixed-rate receiver) will pay party X will be six-month LIBOR times $50 million divided by 2. For example, if six-month LIBOR is 3%, party Y will pay party X $750,000 (3% times $50 million divided by 2). Note that we divide by two because a half-year's interest is being paid.

The interest-rate benchmarks that are commonly used for the floating rate in an interest-rate swap are those on various money market rates such as LIBOR,[1] Treasury bills, commercial paper composite, prime rate, certificate of deposit composite, and federal funds rate. Although the fixed rate at which the cash flows are determined is fixed over the life of the swap, the floating-rate cash flows vary based on the periodic valuation of the index at the swap reset date. Swaps may be structured so that the floating rate resets on a daily, weekly, monthly, quarterly, or semiannual basis for either monthly, quarterly, semiannual, or annual settlement.

Swap contracts are typically written between a market-maker or *swap dealer* and a nondealer financial institution. Since there is no exchange involved, the transaction is considered an over-the-counter (*OTC*) contract. However, the sheer

1. While many of the examples cited in this chapter reference LIBOR as the floating rate, we note that LIBOR is scheduled to be replaced by some form of the Secured Overnight Funding Rate (SOFR) and may not be published after 2020.

size and complex nature of the swap market, along with issues involved with sorting out the swap businesses of financial institutions that failed during the financial crisis that started in 2007, created concerns that the product was creating systemic risks to the financial system. As a result, the Dodd-Frank Act of 2010 reorganized much of swap trading around Swap Execution Facilities (*SEFs*) that "clear" contracts by acting as a centralized counterparty for transactions. While generic swaps are cleared, contracts with unusual terms and/or that are difficult to value are still executed *bilaterally* between counterparties and are not cleared through SEFs.

INTERPRETING A SWAP POSITION

There are two ways that a swap position can be interpreted: (1) as a package of forward/futures contracts and (2) as a package of cash flows from buying and selling cash market instruments.

Package of Forward Contracts

Interest-rate swaps can be viewed as a package of more basic interest-rate control tools, such as forward rate contracts. The pricing of an interest-rate swap will then depend on the price of a package of forward contracts with the same settlement dates and similar indices. Although an interest-rate swap may be nothing more than a package of forward contracts, it is not a redundant contract for several reasons. First, for forward or futures contracts, the longest maturity does not extend out as far as that of an interest-rate swap; an interest-rate swap with a term of 15 years or longer can be obtained. In view of this observation, the analogy with respect to forward/futures contracts applies mainly for short dated swaps since liquidity for futures/forwards is the highest for shorter maturities. Second, an interest-rate swap is a more transactionally efficient instrument; in one transaction an entity can effectively establish a payoff equivalent to a package of forward contracts. The forward contracts would each have to be negotiated separately. In recent years, due to the increased usage of swaps as hedging alternatives to Treasuries, the liquidity of the generic swap market has increased exponentially.

Package of Cash Market Instruments

In order to understand the equivalence of a swap as a package of cash market instruments, consider the following. Suppose that an investor enters into the following transaction:

- Buys \$50 million par of a five-year floating-rate bond that pays six-month LIBOR every six months.
- Finances the purchase of the five-year floating-rate bond by borrowing \$50 million for five years with the following terms: 5% annual interest rate paid every six months.

The cash flow of the above transaction is presented in Exhibit 64-1. The second column of the exhibit sets out the cash flow from purchasing the five-year floating-rate bond. There is a $50 million cash outlay and then cash inflows. The amount of the cash inflows is uncertain because they depend on future LIBOR. The third column shows the cash flow from borrowing $50 million on a fixed-rate basis. The last column shows the net cash flow from the entire transaction. As can be seen in the last column, there is no initial cash flow (no cash inflow or cash outlay). In all 10 six-month periods the net position results in a cash inflow of LIBOR and a cash outlay of $1.25 million. This net position, however, is identical to the position of a fixed-rate payer/floating-rate receiver.

EXHIBIT 64-1

Cash Flow for the Purchase of a Five-Year Floating-Rate Bond Financed by Borrowing on a Fixed-Rate Basis

	Cash Flow (in Millions of Dollars) from:		
Six-Month Period	Floating-Rate Bond	Borrowing Cost	Net(*)
0	–$50	+$50.0	$0
1	$+(\text{LIBOR}_1/2) \times 50$	–1.25	$+(\text{LIBOR}_1/2) \times 50 - 1.25$
2	$+(\text{LIBOR}_2/2) \times 50$	–1.25	$+(\text{LIBOR}_2/2) \times 50 - 1.25$
3	$+(\text{LIBOR}_3/2) \times 50$	–1.25	$+(\text{LIBOR}_3/2) \times 50 - 1.25$
4	$+(\text{LIBOR}_4/2) \times 50$	–1.25	$+(\text{LIBOR}_4/2) \times 50 - 1.25$
5	$+(\text{LIBOR}_5/2) \times 50$	–1.25	$+(\text{LIBOR}_5/2) \times 50 - 1.25$
6	$+(\text{LIBOR}_6/2) \times 50$	–1.25	$+(\text{LIBOR}_6/2) \times 50 - 1.25$
7	$+(\text{LIBOR}_7/2) \times 50$	–1.25	$+(\text{LIBOR}_7/2) \times 50 - 1.25$
8	$+(\text{LIBOR}_8/2) \times 50$	–1.25	$+(\text{LIBOR}_8/2) \times 50 - 1.25$
9	$+(\text{LIBOR}_9/2) \times 50$	–1.25	$+(\text{LIBOR}_9/2) \times 50 - 1.25$
10	$+(\text{LIBOR}_{10}/2) \times 50 + 50$	–51.25	$+(\text{LIBOR}_{10}/2) \times 50 - 1.25$

Transaction: Purchase for $50 million a five-year floating-rate bond: floating rate = LIBOR, semiannual payments

Borrow $50 million for five years: fixed rate = 5% semiannual payments

* The subscript for LIBOR indicates six-month LIBOR as per the terms of the floating-rate bond at time *t*.

It can be seen from the net cash flow in Exhibit 64-1 that a fixed-rate payer has a cash market position that is equivalent to a long position in a floating-rate bond and borrowing the funds to purchase the floating-rate bond on a fixed-rate basis. But the borrowing can be viewed as issuing a fixed-rate bond, or equivalently, being short a fixed-rate bond. Consequently, the position of a fixed-rate payer can be viewed as being long a floating-rate bond and short a fixed-rate bond.

What about the position of a floating-rate payer? It can be easily demonstrated that the position of a floating-rate payer is equivalent to purchasing a fixed-rate bond and financing that purchase at a floating rate, with the floating rate being the reference interest rate for the swap. That is, the position of a floating-rate payer is equivalent to a long position in a fixed-rate bond and a short position in a floating-rate bond.

TERMINOLOGY, CONVENTIONS, AND MARKET QUOTES

Here we review some of the terminology used in this market and explain how swaps are quoted.

The date that the counterparties commit to the swap is called the *trade date.* The date that the swap begins accruing interest is called the *effective date,* and the date that the swap stops accruing interest is called the *maturity date.* The *settlement date* refers to the actual date on which cash flows are exchanged.

Although our illustrations assume that the timing of the cash flows for both the fixed-rate payer and floating-rate payer will be the same, this is rarely the case in a swap. In fact, an agreement may call for the fixed-rate payer to make payments annually but the floating-rate payer to make payments more frequently (semiannually or quarterly). Also, the way interest accrues on each leg of the transaction differs, because there are several day-count conventions in the fixed income markets.

The terminology used to describe the position of a party in the swap markets is a blend of cash market jargon and futures jargon. The obvious reason as we just explained is that a swap position can be interpreted as a position in a package of cash market instruments or a package of futures/forward positions. The counterparty to an interest-rate swap is either a fixed-rate payer or floating-rate payer. There are a number of ways to describe these positions:

Fixed-Rate Payer

- Is short the bond market
- Has bought a swap
- Is long a swap
- Has established the price sensitivities of a longer-term liability and a floating-rate asset

Floating-Rate Payer

- Is long the bond market
- Has sold a swap
- Is short a swap
- Has established the price sensitivities of a longer-term asset and a floating-rate liability

To understand why the fixed-rate payer is viewed as short the bond market and the floating-rate payer is viewed as long the bond market, consider what happens when interest rates change. Those who borrow on a fixed-rate basis will benefit if interest rates rise because they have locked in a lower interest rate. But those who have a short bond position will also benefit if interest rates rise. Thus, a fixed-rate payer can be said to be short the bond market. A floating-rate payer benefits if interest rates fall. Because a long position in a bond benefits if interest rates fall, terminology describing a floating-rate payer as long the bond market has been adopted. From the discussion of both the interpretation of a swap as a package of cash market instruments above and the duration of a swap discussed later in this chapter, the description of a swap in terms of the sensitivities of long and short cash positions follows accordingly.

The convention that has evolved for quoting swaps levels is for a swap dealer to set the floating rate equal to the index and then quote the fixed rate that will apply. To illustrate this convention, consider the following 10-year swap offered by a dealer to market participants.

Floating-Rate Payer:
Pay floating rate of 6-month LIBOR
Received fixed rate of 3.75%

Fixed-Rate Payer:
Pay fixed rate of 3.85%
Receive floating rate of 6-month LIBOR

The offer price that the dealer would quote the fixed-rate payer would be to pay 3.85% and receive LIBOR flat. (The term *flat* means with no spread.) The bid price that the dealer would quote the floating-rate payer would be to pay LIBOR flat and receive 3.75%. The bid/offer spread is 10 basis points.

The fixed rate is some spread above the Treasury yield curve with the same term-to-maturity as the swap. In our illustration, suppose that the 10-year Treasury yield is 3.35%. Then the offer price that the dealer would quote to the fixed-rate payer is the 10-year Treasury rate plus 50 basis points versus receiving LIBOR flat. For the floating-rate payer, the bid price quoted would be LIBOR flat versus the 10-year Treasury rate plus 40 basis points. The dealer would quote the swap above as 40–50, meaning that it is willing to enter into a swap to receive LIBOR and pay a fixed rate equal to the 10-year Treasury rate plus 40 basis points; it would be willing to enter into a swap to pay LIBOR and receive a fixed rate equal to the 10-year Treasury rate plus 50 basis points. The difference between the Treasury rate paid and received is the bid/offer spread.

Swap spreads are driven by market supply and demand forces as well as credit risk considerations, and have varied over time. Prior to 2008, most swap spreads were generally positive, reflecting the perception that receiving fixed-rate cash flows as part of a contractual agreement was riskier than owning a

Treasury security. Since the financial crisis, however, most swap spreads have narrowed, and many have been negative for considerable periods of time. The factors driving swap spreads into negative territory continue to be debated, but can generally be narrowed down to several factors, including (1) the relative increases in Treasury supply due to consistent budget deficits, (2) the perception that the clearing of many transactions through Swap Execution Facilities (SEFs) has reduced counterparty exposure and improved the credit profile of swaps, and (3) changes in capital treatment that reduce dealers' incentives to pay fixed rates unless their rates (and spreads) are very low or negative.

APPLICATIONS

Here we describe how interest-rate swaps can be used in asset/liability management.

Converting Floating-Rate Debt to Fixed-Rate Debt Using Swaps

Fixed-rate payer/floating-rate receiver swaps can be used to convert floating-rate liabilities synthetically to fixed-rate liabilities because the floating cost of liabilities is "counterbalanced" by floating-rate receipts associated with the swap. Any increase or decrease in liability costs is matched by a similar change in the floating-rate inflows, as long as the notional amount of the swap is equal to the principal amount of the liability. The net effect of this strategy is to lock in the liability cost at a fixed rate as long as the swap is not terminated prior to maturity.

As an example, consider the case of a financial institution issuing floating-rate liabilities that are priced at a spread of 10 basis points over three-month LIBOR at a rate of 3.10%. The preponderance of the institution's assets, however, are fixed-rate instruments. As long as interest rates either remain stable or fall, the institution will be able to earn a spread over its floating-rate funding costs. However, if interest rates increase, the institution's spread will decrease. In order to synthetically convert the floating liability cost to fixed debt expense, the institution enters into an interest-rate swap for five years with another entity paying fixed and receiving floating cash flows. Suppose that the fixed-rate side of the swap is priced at a spread of 80 basis points over the five-year Treasury rate at a rate of 3.40% and that the floating side of the swap is three-month LIBOR at 3.00%. The funding cost to the institution in various interest-rate scenarios is illustrated in Exhibit 64-2.

In this example, if the institution had not swapped the floating-rate debt cost for fixed-rate cash flows, the liability rate would have repriced in every interest-rate scenario at a spread of 10 basis points over three-month LIBOR, assuming parallel shifts in the yield curve. By entering into the interest-rate swap, the floating outflow of the liability is partially canceled by the floating inflow from the swap in all interest-rate scenarios. The net funding cost is determined as follows:

Floating-rate liability cost + Fixed rate of swap – Floating rate of swap

The effectiveness of this strategy will depend on the extent of basis risk between the liability rate and the swap floating-rate index. In the previous example, because the liability rate and the floating side of the swap are both based on three-month LIBOR, there is no basis risk. However, in other instances, where the liability rate is keyed off another benchmark, such as the Treasury bill index or the prime rate, the existence of basis risk may mitigate the swap's effectiveness. For instance, if the liability rate increases by 1% and LIBOR increases by only 0.85%, the synthetic fixed rate will be 0.15% higher than it would have been in the absence of such imperfect correlation. Conversely, if the liability rate increases by 0.85% and LIBOR by 1%, the synthetic liability rate will be 0.15% lower than the swap fixed rate. The synthetic funding rate will also be affected by any discrepancies in the repricing frequency of the liability and the reset period of the swap. Ideally, close synchronization between these dates will minimize the deviation of the synthetic liability cost from the swap fixed rate that occurs because of reset date mismatch.

EXHIBIT 64-2

Converting Floating-Rate Debt to Fixed-Rate Debt Using Interest-Rate Swaps

		Swap Cash Flows		
Interest-Rate Scenario	**Liability Cost**	**Fixed Outflow**	**Floating Inflow (LIBOR)**	**New Funding Cost**
300 bps	6.10%	6.40%	6.00%	3.50%
200	5.10	5.40	5.00	3.5
100	4.10	4.40	4.00	3.5
Stable	3.10	3.40	3.00	3.5
–100	2.10	2.40	2.00	3.5
–200	1.10	1.40	1.00	3.5
–300	0.10	0.40	0.00	3.5

Converting Fixed-Rate Debt to Floating-Rate Debt Using Reverse Swaps

A similar strategy using reverse swaps, where the financial institution receives fixed-rate cash flows and pays floating-rate cash flows, is used to convert the fixed cost of liabilities to a synthetic floating rate. In this case, the fixed-rate interest cost of the liability is offset by the fixed-rate inflow of the swap. If the liability rate is higher (lower) than the swap fixed rate, then the synthetic floating rate will be higher (lower) than the swap floating rate. A financial institution that has fixed-rate debt and a preponderance of floating-rate assets, such as adjustable-rate mortgages, collateralized mortgage obligation (CMO) floater bonds, or floating-rate notes, may adopt this strategy to better match the average duration of their assets and liabilities.

As an example, consider the case of an institution that has three-year fixed-rate debt at a coupon rate of 3.85%. In order to convert this fixed-rate debt into floating-rate liabilities, the institution enters into a reverse swap (floating-rate payer/fixed-rate receiver) for three years. The terms of the swap involve paying three-month LIBOR and receiving fixed-rate cash flows at a spread of 65 basis points over the three-year Treasury yield at a rate of 3.70%. An illustration of this example is presented in Exhibit 64-3. An analysis of this illustration reveals that the effective funding cost is determined as follows:

Fixed-rate liability cost – Fixed rate of swap + Floating rate of swap

The institution has converted fixed-rate debt to LIBOR-based debt at a spread of 15 basis points over LIBOR. A schematic of the cash flows involved in synthetically converting floating-rate liability costs to fixed-rate funding, and vice versa, is presented in Exhibit 64-4. Although the dynamics of the cash flow are essentially reversed, most dealers will charge a higher spread (offer side) for fixed-rate-paying swaps than fixed-rate-receiving swaps (bid side). This bid/ask differential, which is a function of variables such as hedging costs, dealer inventory, relative supply of fixed- and floating-rate payers in the market, conditions in the Treasury market, and quality spreads in the domestic and international bond markets, is used to compensate the dealers for the market-making function.

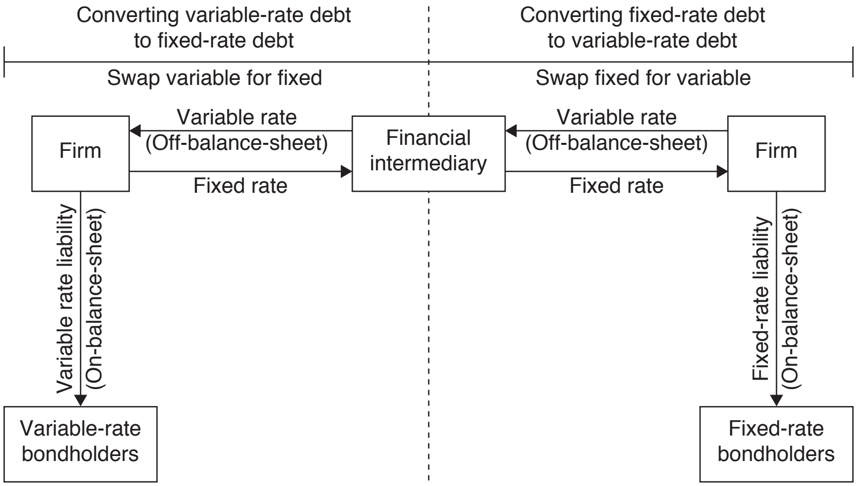
EXHIBIT 64-3

Converting Floating-Rate Debt to Fixed-Rate Debt Using Interest-Rate Swaps

		Swap Cash Flows		
Interest-Rate Scenario	**Liability Cost**	**Fixed Outflow**	**Floating Inflow (LIBOR)**	**New Funding Cost**
300 bps	3.85%	3.70%	6.00%	6.15%
200	3.85	3.70	5.00	5.15
100	3.85	3.70	4.00	4.15
Stable	3.85	3.70	3.00	3.15
–100	3.85	3.70	2.00	2.15
–200	3.85	3.70	1.00	1.15
–300	3.85	3.70	0.00	0.15

EXHIBIT 64-4

Synthetic Conversion of Interest-Rate Liability



In the foregoing discussion, it has been tacitly assumed that the payment frequencies and the payment basis of the fixed and floating legs of the swap and the liability being swapped are identical. Any differences in the frequencies or basis will change the net spread calculations. This observation also applies to asset swaps (discussed later). For example, in swapping a fixed liability to a floating-rate obligation, the net spread over LIBOR usually will be slightly different from the spread between the liability coupon and the coupon of the swap. This difference arises because swaps usually pay fixed on an actual/365 or 30 /360 basis and floating on an actual/360 basis. Hence, the net spread over LIBOR will be 360/365 of the nominal spread between coupons.

DOLLAR DURATION OF A SWAP

As with any fixed income contract, the value of a swap will change as interest rates change. As explained in Chapter 5, dollar duration is a measure of the change in the dollar value of an asset due to a change in interest rates. From our earlier discussion of how to interpret an interest-rate swap, it was explained that from the perspective of the party who pays floating and receives fixed, the position can be viewed as follows:

Long a fixed-rate bond – Short a floating-rate bond

This means that the dollar duration of an interest-rate swap from the perspective of a floating-rate payer is just the difference between the dollar duration of the two bond positions that constitute the swap. That is,

Dollar duration of a swap = Dollar duration of a fixed-rate bond –
Dollar duration of a floating-rate bond

Most of the interest-rate sensitivity of a swap will result from the dollar duration of the fixed-rate bond because the dollar duration of the floating-rate bond will be small. It will always be less than the length of time to the next reset date. Therefore, the dollar duration of a floating-rate bond for which the coupon rate resets every six months will be less than six months. The dollar duration of a floating-rate bond becomes smaller as the swap gets closer to its reset date.

INNOVATIONS IN SWAP MARKETS

In addition to allowing a firm to issue debt for which it has a comparative relative advantage and then swapping the cash flows to fine-tune the asset/liability gap, interest-rate swaps also serve other useful purposes, especially because of the off-balance-sheet treatment accorded them. It often has been argued that swaps are preferable to refunding because the latter often is constrained by restrictive covenants. Periodically, firms may want to make adjustments in the capital structure with respect to the composition of debt by refinancing longer-term debt with short-term debt at lower interest costs. In certain instances, this may not be easy to accomplish, especially if the debt is noncallable. Swaps provide an effective means to alter the covenants of a debt issue to accomplish asset/liability objectives without incurring the administrative, legal, and underwriting costs of issuing additional debt. In this case, the firm may swap the higher-coupon debt to a cheaper floating-rate liability based on a variety of indexes, such as the Treasury bill index, prime rate, and LIBOR. In recent years, swaptions have been increasingly used to contractually create callable liabilities at issuing entities.

In order to address such specific investor needs, several innovations, such as basis swaps, yield-curve swaps, amortizing swaps, asset swaps, forward swaps, equity swaps, and swaptions have been developed to further expand the degree of flexibility provided by generic swaps. A discussion of the salient features of these capital market innovations is presented in this section.

Basis Swaps

Basis swaps are designed to manage the basis risk inherent in a balance sheet where the asset returns and liability costs are based on different indexes. For instance, a financial institution that invests in a CMO floater with a return of 60 basis points over one-month LIBOR funded by six-month certificates of deposit at an interest cost of prime less 200 basis points is subject to basis risk, despite the minimal duration mismatch. This risk arises because the asset resets monthly off LIBOR, whereas the liability resets every six months based on movements in the prime rate. To alleviate this risk, the institution could enter into a floating-to-floating basis swap, where the institution receives cash flows that are reset every six months at a rate of prime less 150 basis points and pays swap cash flows on a monthly basis indexed off one-month LIBOR. The basis risk will be controlled for the *tenor,* or time period, of the swap.

As an illustration, assume one-month LIBOR is 3% and the prime rate is 4%. Without the basis swap, the spread earned by the institution is defined as the difference between the asset return and the liability cost, 1.60% (3.60% – 2.00%) in our illustration. (For the sake of simplicity, it is assumed that the asset returns are not constrained by caps inherent in CMO floaters.) Assuming that the correlation between the prime rate and one-month LIBOR is imperfect, in that a 1% change in the prime results in less or more than a 1% change in one-month LIBOR, the spread will not be maintained in all interest-rate scenarios. As previously indicated, the institution enters into a basis swap to lock in the spread over funding costs without incurring the basis risk between the prime rate and LIBOR. Although basis swaps are used most often to refine the interest-rate sensitivity of assets and liabilities, these swaps can also be used to arbitrage spreads between various funding sources. The dynamics of the basis swap are illustrated in Exhibit 64-5.

EXHIBIT 64-5

Locking in a Floating Spread over Funding Costs Using Basis Swaps

				Swap Cash Flows		
LIBOR	Asset Return[a]	Prime Rate	Liability Costs[b]	Floating Inflows[c]	Floating Outflows[d]	Net Spread[e]
1.00	1.60	3.00	1.00	1.50	1.00	1.10
3.00	3.60	4.00	2.00	2.50	3.00	1.10
5.00	5.60	6.00	4.00	4.50	5.00	1.10

[a] Asset return = LIBOR + 60 basis pionts.

[b] Liability costs = Prime – 200 basis points.

[c] Swap floating inflows = Prime – 150 basis points.

[d] Swap floating outflows = LIBOR.

[e] New spread = Asset return + Swap inflows – Liability costs – Swap outflows.

Yield-Curve Swaps

In a yield-curve swap, the counterparties agree to exchange payments based on the difference between interest rates at two points on a given yield curve. These swaps are therefore an example of a floating rate for floating-rate swap, or basis swap.

To illustrate a yield-curve swap, suppose party A agrees to receive six-month Treasury bill rate and to pay party B the yield on a 10-year Treasury minus 200 basis points, with the rate on both reset every six months. If at a reset date the six-month T-bill rate is 2.5% and 10-year Treasury yield is 4%, party A receives 2.5% and pays party B 2%. If the yield curve flattens such that the six-month Treasury bill rate is 3% and the 10-year Treasury is 3.5%, then party A receives 3% and pays 1.5%.

Amortizing and Accreting Swaps

In the preceding discussion, it was implicitly assumed that the notional amount does not change over the life of the swap. However, with respect to amortizing assets such as mortgage loans and other mortgage-backed instruments such as CMO bonds and automobile receivables, the spread over funding costs will not be maintained because of the asset principal balance declining over time. This declining spread is especially critical for assets whose average life and duration may exhibit dramatic changes due to the possibility of prepayments. In such instances, if bullet swaps with the same notional amount are used, there is the risk of being either underhedged or overhedged with respect to liability costs. If interest rates decrease and prepayments increase substantially, the average life of the asset will shorten. In such instances, the asset may not generate funds sufficient to earn a positive spread. On the other hand, if interest rates rise and prepayments slow down, resulting in an extension of the average life of the asset, the swap may have to be extended or additional swap coverage obtained (at higher cost, owing to bearish interest-rate conditions[2]) to maintain a positive spread.

In such instances, the institution may enter into an amortizing swap, which permits the notional amount of the swap, and hence the exchange of the cash flows, to change in accordance with the amortization rate of the asset. Note that the amortization rate of the notional amount cannot usually be changed over the life of the swap. Because the amortizing swap can be replicated by using a strip of swaps, the swap rate is determined as a blended rate of individual bullet swap rates. This feature of amortizing swaps also provides a market participant with the choice of entering into a series of swaps to match the amortization rate of assets or entering into an amortizing swap at an annual blended rate.

Although amortizing swaps improve the match between the asset and hedged liability cash flows, such swaps do not completely alleviate the risk of being overhedged with respect to liability costs. A major portion of this risk is mitigated for assets such as Planned Amortization Class (PAC) CMO bonds, which provide for a specified amortization rate within a wide band of prepayment scenarios. For assets that exhibit a higher degree of prepayment volatility, if falling interest rates lead to an increase in prepayments and an attendant shortening of average life, the firm may have to continue exchanging swap cash flows for a period longer than the average life of the asset, unless the swap can be terminated. An alternative version of amortizing swaps, labeled "balance guaranteed

2. A bearish interest-rate scenario refers to one in which rates are rising and market prices are falling (a bearish market). In a bullish interest-rate scenario, rates are falling, and market prices are rising.

swaps," has been used to guarantee floating-rate returns to investors. Rather than the swap's amortization being defined at a given rate, the swap's balance at any point in time is based on the actual outstanding balance of a reference pool of assets. The reference pool can be an MBS or ABS pool, a designated cohort, a CMO tranche, or some other asset that has variable balances.

In instances where the liability schedule is expected to increase, an interest-rate swap with an accreting balance may be used to fix the interest cost of the liabilities. Perhaps the most common example of this type of swap application is found in the construction industry, where accreting swaps may be used to fix the rate on a project funded with a floating-rate drawdown facility.

Forward Swaps

A forward swap allows a market participant to initiate a swap with a specified delayed start. Such swaps can be used to hedge debt refinancings or anticipated debt issuance in conjunction with expenditures expected in the future. For instance, suppose a firm has $200 million of noncallable fixed-rate debt maturing in three years. In order to lock in anticipated funding requirements three years hence for a period of five years at current rates, the firm could enter into a forward swap to pay fixed and receive floating cash flows starting three years from now. If rates have increased at the time of issuance, the firm would issue floating-rate debt and effectively convert the floating-rate funding to a fixed-rate liability, because the firm would be a floating-rate receiver.

Equity Swaps

In recent years, the concept of swapping cash flows has been applied to the equity area. In an *equity swap,* the cash flows that are swapped are based on the total return on some stock market index and an interest rate (either a fixed rate or a floating rate). Moreover, the stock market index can be a non-U.S. stock market index and the payments could be non-dollar denominated. For example, a money manager can enter into a two-year quarterly reset equity swap based on the German DAX market index versus LIBOR in which the money manager receives the market index in euros and pays the floating rate in euros.

Swaptions

Swaptions are representative of the class of second-generation derivative products that have developed around the swaps, caps, and floor markets. Swaptions can take many forms, but typically they are options to pay or receive a predetermined fixed rate in exchange for LIBOR at some time in the future. As the market develops, it is likely that additional variable-rate indexes will be used to determine floating-rate cash flows, especially if LIBOR is de-emphasized or phased out. Alternatively, swaptions can contain an option to cancel an existing swap. The second structure is essentially the same as the first, because a swap can be canceled by entering into a new swap in the opposite direction.

In view of this overlap between options to enter swaps and options to cancel swaps, the usual shorthand terminology of puts and calls is rarely used for swaptions. Rather, the option characteristic is spelled out in more detail—for instance, an option to receive fixed at 5% for three years, starting two years hence. Swaption exercise can be European (exercisable on only one date in the future) or American (exercisable on any date up to and including the expiration date), with the bulk of the interbank market structured as European exercise. A typical American swaption structure would be to enter into, say, a seven-year swap paying fixed at 4% at any time before maturity. As an example, if the option is exercised after one year, the option holder will pay 4% and receive LIBOR for seven years.

In terms of flexibility and costs, swaptions lie between swaps and customized interest-rate protection instruments, such as caps and floors. If LIBOR increases, the fixed payer of a swap, the holder of an option to pay fixed, and the cap buyer all benefit equally. If LIBOR decreases, the fixed payer of a swap incurs an opportunity loss and the holder of the swaption or cap loses only the up-front premium. The premium for a cap is usually greater than that for a swaption because the buyer of the cap essentially has purchased a strip of options, whereas the holder of a swaption owns only one option. If rates increase and the swaption is exercised, the owner of the swaption is exposed to the risk of a fall in interest rates. However, the holder of the cap can still take advantage of the beneficial movement in rates. In view of this observation, swaptions can be viewed as instruments that provide some of the protection and flexibility afforded by caps and floors.

The pricing of swaptions is still somewhat of an art. The development of models for pricing and hedging swaptions is on the cutting edge of options theory. Dealers differ greatly in the models they use to price such options, and the analytical tools range from modified Black-Scholes models to binomial lattice versions to systems based upon Monte Carlo simulations. As a result, bid/ask spreads are wide, and it pays to shop around, particularly for more complicated structures that cannot be reversed in the interbank markets.

Swaptions provide the sophisticated firm with an additional, flexible tool for asset/liability management. On the liability side, the primary uses of swaptions have been in hedging uncertain funding requirements and issuing synthetically callable debt. With respect to fixing liability costs, a corporation can lock in coupon rates for future funding by paying fixed in a forward swap. However, the firm may desire to preserve the opportunity to save on these funding costs in the event that rates decline in the future by purchasing a swaption, despite the attractiveness of the current interest-rate structure. In the event that funding requirements are uncertain, the flexibility of these instruments really comes into play as swaptions can lock in current rates without committing the firm to future borrowing.

Much of the current activity in swaptions has been fueled by an arbitrage between the swaption and callable bond markets. Historically, investors have not demanded full compensation for call options embedded in corporate bonds.

Hence, corporations can issue callable debt and then effectively strip off the embedded call option by writing a swaption, thereby lowering the all-in cost of the debt. On the asset side, the primary use of swaptions has been in hedging prepayable swapped assets, such as mortgage-backed instruments. An investor may purchase fixed-rate mortgage-backed securities, swap the fixed rate to floating, and earn an attractive spread over LIBOR. However, this spread is subject to erosion if the asset balance declines because of high prepayments. By giving up some of this spread and purchasing swaptions, the investor can reduce prepayment risk exposure. In addition to these types of specific uses, swaption volatility has also become a widely used indicator of future volatility embedded in current expectations.

ASSET SWAP

Our earlier applications focused exclusively on the use of interest-rate swaps and associated issues in swap-based liability hedging. Such swaps are referred to as *liability-based swaps. Asset-based swaps,* which use principles involved in liability hedging, are becoming increasingly popular to customize asset coupons and maturities, thereby expanding the asset universe available to portfolio managers. Asset swaps serve several useful functions, such as facilitating yield enhancement, creating assets that are not available in the marketplace, and changing the interest-rate sensitivity of the portfolio without actually trading the securities.

Similar to the use of swaps in converting fixed-rate debt to floating-rate debt and vice versa, interest-rate swaps also can be used to accomplish the same objective with fixed- and floating-rate assets. For instance, floating-rate notes (FRNs) can be converted synthetically to fixed-rate assets using a receive fixed-rate and pay floating-rate swap. Similarly, fixed-rate assets such as mortgage-backed securities (especially certain types of CMO bonds such as PAC classes) and receivable-backed securities (such as manufactured housing, credit card, and automobile loan collateralized bonds) can be converted to floating-rate instruments by using a receive floating-rate and pay fixed-rate swap. Asset-based swaps can also be used to alter the duration characteristics and, hence, the interest-rate sensitivity of an asset portfolio. For instance, a financial institution that has a predominance of long-term fixed-rate assets can reduce the duration of its portfolio, thereby increasing the interest-rate sensitivity of the assets by creating synthetic floating-rate assets. Characteristics of interest-rate swaps, such as amortizing features and option covenants, can be used to customize and reasonably ensure a particular yield level.

The flexibility afforded by swaps in the design of such synthetic assets becomes apparent when it is realized that investors seeking a particular type of asset, say, a floating-rate asset, can evaluate traditional floating-rate instruments, such as FRNs and CMO floaters as well as fixed-rate assets, by using interest-rate swaps to synthetically convert them to floating-rate assets. Asset-based swaps can also tailor the maturity (tenor) of the swap without having to depend on conditions in the debt markets. The latter feature is especially important for institutions that have "underwater" assets. Under current conditions, firms can always use a collateralized financing structure to raise funds and then reinvest the proceeds in assets of desired maturity and coupon. However, this option, besides being time-consuming, involves administrative, legal, and investment banking costs. Also, assets of particular maturity and coupon may not always be traded in the markets. Asset-based swaps fulfill this particular need in the market mainly because of ease of execution, customization features, and flexibility of swap termination.

TERMINATION OF INTEREST-RATE SWAPS

There are two ways to terminate a swap: (1) a reverse swap and (2) a swap sale.

Reverse Swap

The simplest way to terminate an interest-rate swap is to enter into an offsetting position. For illustrative purposes, assume that a firm entered into a five-year swap, paying fixed at a rate of 5.40% and receiving three-month LIBOR. After two years, the firm decides to terminate the swap by entering into a reverse swap, paying floating rate and receiving fixed rate. By matching the reset and settlement periods of the *reverse swap* to those of the original swap, the floating-rate payment of the reverse swap is counterbalanced by the floating-rate inflow from the original swap.

Two cases are illustrated in Exhibit 64-6—a bearish scenario and a bullish scenario. In a bearish interest-rate scenario, the new fixed rate on the reverse swap is likely to be higher than the fixed rate on the original swap. The new fixed rate in Exhibit 64-6 is assumed to be 6.40%. In this bearish scenario, there will be a profit associated with the reverse swap. The firm has effectively created an annuity of 1% of the notional amount for the remaining period of the swap.

In a bullish interest-rate scenario, rates are falling and market prices are rising. In the illustration in Exhibit 64-6, the new fixed rate is assumed to be 4.40%, resulting in a loss on the reverse swap. In this illustration, the firm has created a reverse annuity of 1% per annum for three years.

In either case, because the closing transaction involves receiving the fixed side of a swap, the spread over Treasury is based on the bid side of the market, whereas the original swap involves payment of the swap at the offer spread.

Swap Sale

Instead of managing the cash flows of two swaps and the credit risk of two counterparties, the firm may sell the swap for either a profit or loss in the secondary market. In the event that current market swaps with a maturity equal to the remaining maturity of the swap to be terminated are being offered at a higher

EXHIBIT 64-6

Termination of Interest-Rate Swaps

	Bearish	Bullish
Swap		
Pay fixed (5-year original maturity/3-year remaining maturity)	5.40%	5.40%
Receive 3-month LIBOR	LIBOR	LIBOR
Reverse Swap		
Receive fixed (3-year remaining maturity)	6.40%	4.40%
Pay 3-month LIBOR	LIBOR	LIBOR
Profit/(Loss)	1.00%	–(1.00%)

fixed rate, the swap could be sold for a fee. On the other hand, if current market swaps with a maturity similar to the swap to be liquidated are being originated at lower rates, then an exit fee may have to be paid for terminating the swap. Formally, the termination value of a swap is determined as the present value of an annuity discounted for the remaining term-to-maturity at the current swap rate. The periodic value of the annuity payments is approximated as the difference between the old fixed swap rate and the new fixed swap rate multiplied by the remaining notional amount of the original swap.[3] Formally, this is stated as

$$\text{Termination value of swap} = \text{PV of annuity at } r_s t$$

where

$$\text{Annuity payments } (r_s - r_m) \times \text{Notional amount}$$

$r_{s\,=}$ Original swap fixed rate
r_m = Current swap fixed rate
t = Time remaining to maturity of swap

KEY POINTS

- In the management of interest-rate volatility and associated asset/liability structural decisions, customized risk-management instruments such as interest-rate swaps provide a high degree of coverage flexibility and customization.

3. For a more detailed discussion of the calculation of the termination of the value of a swap that takes into days in payment periods, see chapter 14 in Frank J. Fabozzi, *Valuation of Fixed Income Securities and Derivatives* (New Hope, PA: Frank J. Fabozzi Associates, 1998).

- Interest-rate swaps can be used either to synthetically extend or to shorten the duration characteristics of any asset or liability.
- The benefit of interest-rate swaps is that direct changes in the contractual characteristics of either assets or liabilities are associated with administrative, legal, and investment banking costs.
- Additional swaps covenants, such as amortizing and accreting features and option riders, can be included in the contractual agreement either to better match the funding of an asset or to lock in the return of a synthetic asset.

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CHAPTER
SIXTY-FIVE

THE VALUATION OF INTEREST-RATE SWAPS AND SWAPTIONS

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An interest-rate swap is an agreement involving two parties who agree to exchange payments at future dates. The cash-flow amounts exchanged in the future are determined by an agreed-upon interest rate and the size, or notional principal, of the agreement. In the most basic interest-rate swap, commonly referred to as a "plain vanilla interest-rate swap," one party agrees to make variable payments that "float" with a short-term rate while the other party makes fixed-rate payments at an agreed-upon fixed-rate.

Swaps are important tools for risk managers, offering a cost-effective means to altering interest-rate exposure. This useful tool for controlling interest rates may be customized in a variety of ways. For example, in an amortizing swap the notional principal declines over time. In an accreting swap, the notional principal increases over time. Other swaps, named forward-start swaps, are swap agreements that commence at a specified date in the future. Another variation of the swap agreement is the basis swap that involves the exchange of payments referencing two different interest rates, such as three-month LIBOR and the three-month Treasury bill.

In this chapter, our focus is on more complex swap structures. We assume the reader is familiar with plain vanilla swaps and the traditional valuation method involving the use of implied forward rates from LIBOR futures contracts to value a swap agreement to compute the swap fixed-rate (SFR). In addition to swaps, we cover the valuation of swaptions. A swaption gives its owner the right to enter into a swap agreement at a future time.

Unlike plain vanilla interest-rate swaps, swaptions have cash flows that depend on an interest rate at a future point in time. This feature requires a versatile approach to valuation. The lattice approach to valuation proves useful due to two important features. First, the interest-rate model driving the lattice approach is fit to no-arbitrage conditions, meaning that the pricing fits the arbitrage values for cash flows using forward rates. Second, the interest-rate models behind the interest-rate lattice incorporate an assumed interest-rate volatility, enabling this approach to handle option-like features.

The balance of the chapter proceeds as follows. We begin by illustrating the lattice approach to valuation with a plain vanilla interest-rate swap. Next, we demonstrate the versatility of the lattice approach through the valuation of forward-start swaps. The chapter proceeds by presenting and pricing swaptions with a focus on the pricing impact of the important parameters (time-to-expiration, strike rate, and volatility). Next, the chapter presents basis swaps and concludes.

SWAP VALUATION USING THE LATTICE APPROACH

The traditional approach to valuing swaps involves obtaining a no-arbitrage value for the swap cash flows by discounting at the implied forward rates. The implied forward rates come from market prices of Eurodollar futures contracts. Unfortunately the traditional approach is not equipped for valuing cash flows that vary depending on interest rates in the future. For this purpose, the lattice model is a useful tool for valuing interest-rate derivative instruments such as swaps and swaptions. In contrast to the traditional approach to valuing swaps, the lattice model incorporates the volatility of interest rates to consider how interest rates may change in the future, providing a flexible valuation framework easily adapted to exotic (non–plain vanilla) instruments.

In general, the lattice approach to valuation begins with the construction of the interest-rate lattice.[1] The values on the interest-rate lattice represent possible interest rates in future periods, describing potential evolutions of interest rates through time. After constructing the interest-rate lattice, the swap cash flows are computed at each "node" on the lattice, resulting in the swap cash-flow lattice. The interest rates from the lattice are then used to compute the present value of the possible future cash flows. This process is referred to as *backwardation:* working backward through the tree to discount the expected future cash flows to a present value.

Constructing the interest-rate lattice begins with an interest-rate model to describe the dynamics of interest rates through time. Although many interest-rate models are used by practitioners, the most common models are one-factor models that describe the evolution of the short rate (one period interest rate) through time. The term *one factor* simply means that the short rate is the only interest rate being modeled and it solely determines the *term structure*. An interest-rate model makes important assumptions about the relationship between short-term interest rates and interest-rate volatility, typically measured as the standard deviation.[2] The examples in this chapter employ a version of the Kalotay, Williams, and Fabozzi interest-rate model.[3]

1. The approach employed here applies regardless of whether a lattice (binomial, trinomial), grid (finite differences), or paths (Monte Carlo) are used to generate the evolution of interest rates.

2. The details of term structure modeling are beyond the scope of this chapter.

3. Andrew J. Kalotay, George O. Williams, and Frank J. Fabozzi, "A Model for the Valuation of Bonds with Embedded Options," *Financial Analysts Journal* (May-June 1993), pp. 35–46. See also Chapter 34 in this handbook.

After selecting an interest-rate model to describe the possible evolution of the interest rate through time, it is useful to express that model in a lattice comprising discrete time periods. Each node on the binomial tree represents a possible short rate over that discrete time step. The interest rate may evolve to the next time step by taking two possible values. There are other models allowing for more than two possible rates in each subsequent period; for example, the trinomial model allows for three rates. To avoid complication, we illustrate the lattice valuation procedure using the binomial model. The important feature of the interest-rate models is that they satisfy the "no-arbitrage" condition, meaning the interest rates they produce match the implied spot rates from bond prices. Additionally, interest-rate models incorporate an assumption regarding interest-rate volatility. The volatility of interest rates is a critical component when valuing interest-rate contingent claims since the cash flows to the claim are determined by interest rates in the future. We will see later that the volatility assumption has direct effects on the value of swaptions.

To illustrate the lattice model approach to valuation, we begin by pricing a five-year plain vanilla interest-rate swap with a swap fixed-rate (SFR) of 3%. To simplify the presentation, and without loss of generality, we consider the swap to have semiannual payments instead of quarterly payments.

Exhibit 65-1 presents the interest-rate lattice that will be used in the valuation process. The model is a one-factor model and describes the possible paths of the short rate (one-period interest rate) through time. The current short rate is 0.3850%, and according to the model, the short rate for the next time period will be either 0.7950% or 0.6902%, where each of these values is equally likely. The interest-rate tree has 10 semiannual time periods, covering the five-year tenor of the swap agreement.

The next step in the valuation process is to compute the cash flow at each node. The swap payments occur in arrears, but are determined at the start of the period. For instance, the first swap payment is determined today, at $t = 0$, and is based on the current short rate of interest. Referring to Exhibit 65-1, the current rate is 0.3850%. At the end of the first period, the swap counterparty making the fixed-rate payment will make a payment of:

$$\text{Fixed-Rate Payment} = \text{SFR} \times \text{NP} \times (\text{Days in Period}/360)$$

where NP is the notional principal and Days in Period is the number of days in the payment period.

To simplify the presentation, we assume semiannual cash flows and that the fraction of the year is 0.5. The other swap counterparty, the floating-rate payer, makes a payment that is equal to:

$$\text{Floating-Rate Payment} = \text{Floating-Rate} \times \text{NP} \times (\text{Days in Period}/360)$$

Since the swap cash flows are typically netted, the swap cash flow at the end of the period will be:

$$\text{Net Cash Flow} = (\text{Floating-Rate} - \text{SFR}) \times \text{NP} \times (\text{Days in Period}/360)$$

Note that when the periodic floating-rate is greater than the SFR, the floating-rate payer makes the net cash-flow payment to the fixed-rate payer. Conversely, when the periodic floating-rate is less than the SFR, the fixed-rate payer makes payment of the net cash-flow amount to the floating-rate payer. Exhibit 65-2 presents the net cash flows at each node on the lattice in Exhibit 65-1 for the five-year semiannual swap agreement with a SFR of 3% and notional principal of $100. To illustrate the computation, refer to the node on the upper-right-hand side of the interest-rate lattice in Exhibit 65-1 where the short rate is 9.1446% at time 4.5 years. At that node, the short rate is 9.1446%. Recall the cash flow is determined at the start of the period but paid in arrears. Thus, the short rate at time 4.5 years determines the cash flow at t = 5 years. The net cash flow from the swap is:

$$\begin{aligned}\text{Net Cash Flow} &= (\text{Floating-Rate} - \text{SFR}) \times \text{NP} \times (\text{Days in Period}/360)\\ &= (9.1446\% - 3.0\%) \times 100 \times 0.5 = 3.0723.\end{aligned}$$

The procedure repeats for each node on the tree. Recall that the cash flows to the swap occur in arrears (at the end of the period) but are determined at the beginning of the period based on the interest rate at that time.

At this point in the valuation process, we have used the interest-rate lattice to compute the swap cash flows at each node on the lattice. To arrive at a value for the interest-rate swap, the next step is to construct another lattice referred to as the *cumulative swap valuation lattice*. Each node of the cumulative swap valuation lattice is the present value of the swap cash flows from all nodes on the cash-flow lattice occurring after that time (see Exhibit 65-2) discounted using the rates on the binomial lattice (see Exhibit 65-1). To illustrate the process, refer to the shaded region in the top right portion of Exhibit 65-3. The cumulative swap valuation at the nodes where t = 4.5 are the present values of the cash flows at t = 5. Note the time reference here—cash flows (t = 5) verse present value of cash flows (t = 4.5). Since the swap agreement matures at t = 5 years, there are no subsequent cash flows to consider. Thus, the values in the shaded region at t = 4.5 years are computed as the present values of the t = 5 cash flows (see Exhibit 65-3) discounted at the rates in Exhibit 65-1:

$$\begin{aligned}3.0723/(1 + 9.1446\%/2) &= 2.9380\\ 2.4693/(1 + 7.9386\%/2) &= 2.3750\\ 1.9458/(1 + 6.8917\%/2) &= 1.8810.\end{aligned}$$

Working backward to the next time step (t = 4) requires discounting the values at t = 4.5 plus the arrears cash flow that take place at t = 4.5. At each node, there are two possible values at the next time step and they are equally likely to occur. To illustrate, the values at the shaded t = 4 nodes in Exhibit 65-3 are determined as:

$$\begin{aligned}(0.5 \times 2.9380 + 0.5 \times 2.3750 + 2.3104)/(1 + 7.6208\%/2) &= 4.7846\\ (0.5 \times 2.3750 + 0.5 \times 1.8810 + 1.8079)/(1 + 6.6158\%/2) &= 3.8099.\end{aligned}$$

After computing the cumulative swap values at t = 4, backwardation continues by computing the values at t = 3.5 years. To illustrate, the shaded value in

EXHIBIT 65-1

Interest-Rate Tree

									9.1446%
								7.6208%	
							6.5216%		7.9386%
						5.4226%		6.6158%	
					4.4031%		5.6615%		6.8917%
				3.4300%		4.7075%		5.7433%	
			2.5178%		3.8225%		4.9149%		5.9828%
		1.5968%		2.9776%		4.0867%		4.9859%	
	0.7950%		2.1857%		3.3184%		4.2667%		5.1938%
0.3850%		1.3862%		2.5850%		3.5477%		4.3284%	
	0.6902%		1.8975%		2.8808%		3.7041%		4.5089%
		1.2034%		2.2441%		3.0799%		3.7576%	
			1.6472%		2.5009%		3.2156%		3.9143%
				1.9481%		2.6737%		3.2621%	
					2.1711%		2.7915%		3.3981%
						2.3211%		2.8319%	
							2.4234%		2.9500%
								2.4584%	
									2.5609%
Time in Years	**0.50**	**1.00**	**1.50**	**2.00**	**2.50**	**3.00**	**3.50**	**4.00**	**4.50**

EXHIBIT 65-2

Cash Flow Lattice Illustration; Five-Year Plain-Vanilla Swap, Semiannual Settlement, $100 Notional Principal, SFR = 3%

										3.0723
									2.3104	
								1.7608		2.4693
							1.2113		1.8079	
						0.7016		1.3308		1.9458
					0.2150		0.8537		1.3717	
				–0.2411		0.4112		0.9574		1.4914
			–0.7016		–0.0112		0.5433		0.9930	
		–1.1025		–0.4071		0.1592		0.6334		1.0969
	–1.3075		–0.8069		–0.2075		0.2739		0.6642	
		–1.1549		–0.5513		–0.0596		0.3520		0.7544
			–0.8983		–0.3780		0.0399		0.3788	
				–0.6764		–0.2496		0.1078		0.4571
					–0.5259		–0.1631		0.1310	
						–0.4145		–0.1042		0.1990
							–0.3394		–0.0841	
								–0.2883		–0.0250
									–0.2708	
										–0.2195
Time in Years	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**

EXHIBIT 65-3

Cumulative Swap Valuation Lattice; Five-Year Plain-Vanilla Swap, Semiannual Settlement, $100 Notional Principal, SFR = 3%

Value Lattice

										2.9380
									4.7846	
								5.8667		2.3750
							6.2657		3.8099	
						6.0786		4.5818		1.8810
					5.3698		4.7561		2.9515	
				4.1975		4.4151		3.4469		1.4481
			2.5771		3.6131		3.4203		2.1968	
		0.5799		2.4011		2.9411		2.4468		1.0692
	–1.5892		0.7923		2.0558		2.2411		1.5345	
		–1.1495		0.8084		1.6386		1.5672		0.7378
			–0.7893		0.6788		1.2025		0.9540	
				–0.5999		0.4902		0.7949		0.4484
					–0.5358		0.2893		0.4458	
						–0.5203		0.1177		0.1957
							–0.5122		0.0014	
								–0.4752		–0.0247
									–0.3868	
										–0.2168
Time in Years		**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**

Exhibit 65-3 at $t = 3.5$ is computed as the present value of the nodes at $t = 4$ plus the arrears cash flow received at $t = 4$:

$$(0.5 \times 4.7846 + 0.5 \times 3.8099 + 1.7608)/(1 + 6.5216\%/2) = 5.8667.$$

The process continues through each node, arriving finally at the present value of the swap. Referring to Exhibit 65-3, the present value of the swap with \$100 notional principal, 3% swap fixed-rate, and five-year tenor is –1.5892. Recall that we computed the cash flows from the perspective of the fixed-rate payer, meaning that the cash flow is negative (an outflow) when the floating-rate is less than the swap fixed-rate. Thus, the negative value indicates that the present value of the fixed-rate payments (3% SFR) is greater than the present value of receiving the floating-rate payments. At the time the counterparties enter into a plain vanilla swap, the present value is zero, meaning the SFR can be determined in the lattice model by iterating on the SFR until the present value at $t = 0$ of the cumulative swap valuation line equals zero. In this example, a SFR of 2.6650% results in the initial value of the swap equaling zero, illustrating why the swap value is negative to the fixed-rate payer in the example where the SFR is 3%. Interest rates must have declined since the inception of the SFR 3% plain vanilla swap.

It is important to note that the value of the plain vanilla swap obtained through the lattice model is identical to the value obtained through the traditional valuation method. This equivalence is due to the fact that the interest-rate model is derived through no-arbitrage conditions based on forward rates determined by market data. The key advantage to the lattice approach will be clear in later sections when we value interest-rate swaptions and need to account for volatility in the possible paths of future interest rates.

Now that we have introduced the binomial lattice, we proceed by introducing more complicated swap structures and swaptions.

FORWARD START SWAPS

A forward start swap is a swap agreement commencing at some specified date in the future. An example is a two-year swap that begins three years from today. We refer to a forward start swap by the date at which the swap begins and the maturity date of the swap using the notation (y_{start}, y_{end}). Thus, the two-year swap beginning three years from today is denoted (3,5). In addition to the start date and maturity date, the forward start swap agreement also specifies the swap fixed-rate and the notional principal. The swap fixed-rate for a forward start swap is referred to as the forward swap fixed-rate.

To illustrate the valuation of a forward start swap, we will use the interest-rate lattice presented in Exhibit 65-1 to value the two-year swap that begins three years from today with a fixed-rate of 3.250% and notional principal of 100. The process begins by calculating the swap cash flows at each node on the interest-rate lattice and then constructing the cumulative valuation lattice through the process outlined in the previous section. Exhibit 65-4 presents the cumulative valuation

EXHIBIT 65-4

Cumulative Swap Valuation Lattice for (3,5) Forward-Start Swaps, SFR = 3.250%

									2.8184
								4.5487	
							5.5164		2.2548
						5.8014		3.5722	
					5.4998		4.2283		1.7602
				4.6750		4.2874		2.7123	
			3.3845		3.8305		3.0907		1.3267
		1.6427		2.9115		2.9476		1.9562	
	–0.4794		1.5803		2.3515		2.0883		0.9473
–2.7754		–0.1503		1.3480		1.7650		1.2927	
	–2.2170		–0.0192		1.0445		1.2066		0.6156
		–1.7392		–0.0343		0.7233		0.7111	
			–1.4335		–0.1079		0.4324		0.3258
				–1.2535		–0.1926		0.2020	
					–1.1218		–0.2464		0.0728
						–0.9964		–0.2431	
							–0.8407		–0.1478
								–0.6320	
									–0.3402
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**

lattice for this swap. Note that the swap begins three years from today and the possible values at time $t = 3$ years are highlighted in the lattice.

The cumulative value lattice produces seven possible values for the forward start swap at $t = 3$ years, and these values can be used to determine the value of the swap agreement. At this point, the missing link is the probability of each of the possible lattice values. The probability of reaching any node in the tree is determined by the number of paths through the lattice that arrive at that node. In the binomial lattice, where there are two possible movements for the rate in the next period, the following formula can be used to calculate the number of paths arriving at any given node:

$$\text{Number of Paths} = \frac{n!}{j!(n-j)!'}$$

where n is the number of periods and j is the number of down-states. Exhibit 65-5 presents the number of paths arriving at each node. By referring to the paths at time 3 in the tree, we illustrate the computation using the above formula. Since time on the tree at $t = 3$ corresponds to the sixth semiannual time step, $n = 6$. At the very top node, there are no down nodes so $j = 0$. Evaluating the formula, we

EXHIBIT 65-5

The Number of Paths Arriving at Each Lattice Node

										1
									1	
								1		10
							1		9	
						1		8		45
					1		7		36	
				1		6		28		120
			1		5		21		84	
		1		4		15		56		210
	1		3		10		35		126	
0		2		6		20		70		252
	1		3		10		35		126	
		1		4		15		56		210
			1		5		21		84	
				1		6		28		120
					1		7		36	
						1		8		45
							1		9	
								1		10
									1	
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	1

find that the number of paths arriving at the top node is 6!/(0!(6!)) = 1 path, which makes sense since the one and only path arriving at the top node consists solely of up-movements. At the node that is second from the top at $t = 3$, the time periods are still 6 but at this node there is one down-step so $j = 1$. Evaluating the formula, there are 6!/(1!(5!)) = 6 possible paths arriving at this node.

To finish the demonstration, we compute the number of nodes at the third node from the top at $t = 3$. At this node, $n = 6$ and there are two down nodes so $j = 2$. Applying the formula, the number of paths arriving at the third node are 6!/(2!(4!)) = 15 paths.

Across the six nodes at $t = 3$, there are a total of 64 possible paths. The probability of arriving at each node is simply the number of paths to that node divided by the number of possible paths arriving at all nodes at this time. The value of the forward start swap is determined by weighting each of the cumulative swap valuation nodes corresponding to the forward start swap start date by the probability of arriving at that node. This calculation is illustrated in Exhibit 65-6, which presents the seven nodes at $t = 3$ and the corresponding cumulative swap valuation from the $t = 3$ node in Exhibit 65-5. The probability of arriving at each node is computed as the number of paths arriving at that node divided by the total number of paths arriving at any node at this time. The product of the cumulative swap valuation and the probability result in the probability weighted value. Summing the probability weighted values results in the forward start swap value. In this case, the value for 100 notional principal of the (3,5) forward start swap with a 3.250% forward start fixed-rate is 1.87089. Note that this is the value to the fixed-rate payer. Recall that we computed the cash flows at each node as the rate on the interest-rate lattice minus the swap fixed-rate. Thus, the positive value indicates that the value of the floating-rate payments exceeds the value of the fixed-rate

EXHIBIT 65-6

Calculation of the Probability Weighted Value for Year 3

Node	Cumulative Swap Valuation	Number of Paths Arriving at Node	Probability of Arriving at This Node	Probability Weighted Value
1	5.8014	1	1.56%	0.09065
2	4.2874	6	9.38%	0.40194
3	2.9476	15	23.44%	0.69085
4	1.7650	20	31.25%	0.55156
5	0.7233	15	23.44%	0.16952
6	–0.1926	6	9.38%	–0.01805
7	–0.9964	1	1.56%	–0.01557
TOTAL	14.3356	64	100.00%	1.87089

payments, implying a positive value to the fixed-rate payer. The value to this swap for the floating-rate swap payer is the negative of this amount, –1.87089. The SFR that would produce an FSS value of zero is 4.233% and is computed in the same manner as the iterative routine used to compute the SFR of a zero value plain vanilla swap.

Once we understand the process, we can value forward-start swaps with the same SFR that begin at each node on the lattice and end at five years. That is to say we may compute the values of the otherwise identical (0,5), (0.5,5), (1,5), (1.5,5), (2,5), (2.5,5), (3.5,5), (4,5), and (4.5,5) swaps. Exhibit 65-7 illustrates the computation of forward start swap values at each time period on the lattice.

VALUING SWAPTIONS

A swaption is an option contract on an interest-rate swap. The owner of a swaption has the right to initiate a swap agreement on or by a specified future date. The swaption specifies several important features of the swap, including the tenor of the swap and the swap fixed-rate. The swap fixed-rate is the strike rate for the option. Unlike a forward start swap, where both counterparties have the obligation to participate in the swap, the swaption owner has the right, but not the obligation, to enter into the swap. We will demonstrate the valuation procedure for swaptions using the interest-rate lattice and discuss how the important parameters affect the swaption valuation.

A payer's swaption (a pay fixed swaption) gives the owner the right to enter into an interest-rate swap as the fixed-rate payer and receive floating-rate payments. Swaptions may be either European or American style. The difference is that the owner of a European style swaption may exercise their right to enter into the swap at the expiration of the swaption, while the owner of an American style swaption may exercise that right any time up to the expiration date. For our purposes, we will consider European style swaptions.

A receiver's swaption (receive fixed swaption) gives the owner the right to enter into an interest-rate swap as the floating-rate payer and fixed-rate receiver. As an example, consider a swaption with a fixed-rate of 3.650%, option expiration date of two years, and the swap tenor is three years. The buyer of this swaption has the right at the end of two years to enter into a swap in which they make floating-rate payments and receive fixed-rate payments of 3.650%. We introduce the notation ($y_{expiration}$, y_{tenor}) for swaptions to refer to the expiration date of the swaption and the tenor of the swap. Thus, the receiver's swap is a (2,3) swaption.

To illustrate swaption pricing, we will price several payers' swaps with a strike rate of 3.650%. The lattice approach is helpful to value swaptions, and the valuation example uses the interest-rate lattice from Exhibit 65-1. After constructing the interest-rate lattice, the next step in the valuation process is to construct the pay fixed cash-flow lattice for a plain vanilla swap with a notional principal of $100, based on a swap fixed-rate of 3.650%. Recall that at each node on the

EXHIBIT 65-7

Probability Weighted Cumulative Valuation Swap Values (SFR = 3.250%, 100 Notional Principal, Maturing in Five Years) and Value of Forward Start Swaps

									0.0055
								0.0178	
							0.0431		0.0396
						0.0906		0.1116	
					0.1719		0.2312		0.1238
				0.2922		0.4019		0.2967	
			0.4231		0.5985		0.5071		0.2177
		0.4107		0.7279		0.6908		0.4279	
	–0.2397		0.5926		0.7348		0.5710		0.2331
–2.7754		–0.0751		0.5055		0.5516		0.3535	
	–1.1085		–0.0072		0.3264		0.3299		0.1515
		–0.4348		–0.0086		0.1695		0.1556	
			–0.1792		–0.0169		0.0709		0.0534
				–0.0783		–0.0181		0.0221	
					–0.0351		–0.0135		0.0051
						–0.0156		–0.0076	
							–0.0066		–0.0026
								–0.0025	
									–0.0007
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**
FWD Start Pay Fixed Swaps	–1.3482	–0.0993	0.8293	1.4386	1.7797	1.8709	1.7332	1.3750	0.8265
FWD Start Receive Fixed Swaps	1.3482	0.0993	–0.8293	–1.4386	–1.7797	–1.8709	–1.7332	–1.3750	–0.8265

lattice, the cash flow is determined by the swap fixed-rate, the notional principal, the corresponding node on the interest-rate lattice:

$$\text{Cash Flow}_{i,j} = (F_{i,j\text{-}1} - SFR) \times NP_j \times 0.5$$

where $F_{i,j\text{-}1}$ is the floating-rate at node (i,j-1), indicating the arrears cash flow at time j. Exhibit 65-8 presents the cash-flow lattice for the plain vanilla swap with a strike rate of 3.650%. To illustrate the computation of the cash flows, refer to the top-right node on the tree. Note that this cash flow occurs at time $t = 5$, but is determined by the rate at $t = 4.5$. The corresponding rate from the interest-rate lattice is 9.1446%, so the cash flow at this node is:

$$\text{Cash Flow}_{1,5} = (9.1446\% - 3.650\%) \times 100 \times 0.5 = 2.7473$$

After constructing the cash-flow lattice in Exhibit 65-8, the next step in the swaption valuation process is to construct the cumulative swap valuation lattice for the plain vanilla pay-fixed swaption. Exhibit 65-9 presents the cumulative valuation lattice. The cumulative swap valuation lattice can then be used to value pay fixed swaptions.

To illustrate the swaption valuation, we price the (3,2) pay fixed swaption, as illustrated in Exhibit 65-10. The option expires in year 3 and the values corresponding to expiration are referred to as the expiration values. The expiration value at each node (here $t = 3$) come from the values in the cumulative valuation lattice (see Exhibit 65-9). Recall that the swaption gives the owner the right, but not the obligation to enter into the pay fixed swap. The owner will only exercise this right when the value of the two-year swap commencing at $t = 3$ is positive. Thus, the expiration values for the swaption are the maximum of zero or the value at the corresponding node on the cumulative valuation lattice. To illustrate, at the bottom node on the tree at $t = 3$, the cumulative valuation for the pay-fixed swap is –0.7711. Intuitively, this makes sense since the bottom nodes correspond to low interest rates that adversely affect the fixed-rate payer.

After determining the expiration values for the swaption, the remaining portion of the lattice is populated using backward induction. The corresponding rates from the interest-rate lattice determine the discount factors. To illustrate the process, the top value at year 2.5 in Exhibit 65-10 is computed as:

$$0.5\,(5.058457 + 3.537322)/(1 + 4.4031\%/2) = 4.205307$$

Repeating this process throughout the lattice in Exhibit 65-10 results in a value of \$1.170195 for the (3,2) pay fixed swaption per \$100 of notional principal. It is worth noting that the lattice valuation process requires as inputs the interest-rate lattice and the swaps valuation lattice. Once these have been determined, it is straightforward to price any variation of the swaption having the same fixed-rate. The lattice valuation framework is very flexible and handles easily any adjustments such as varying the notional principal (amortizing or accreting). This flexibility makes the lattice approach to valuation attractive.

EXHIBIT 65-8

Pay Fixed Cash-Flow Lattice for Plain Vanilla Swap (Strike Rate = 3.65%)

										2.7473
									1.9854	
								1.4358		2.1443
							0.8863		1.4829	
						0.3766		1.0058		1.6208
					–0.1100		0.5287		1.0467	
				–0.5661		0.0862		0.6324		1.1664
			–1.0266		–0.3362		0.2183		0.6680	
		–1.4275		–0.7321		–0.1658		0.3084		0.7719
	–1.6325		–1.1319		–0.5325		–0.0511		0.3392	
		–1.4799		–0.8763		–0.3846		0.0270		0.4294
			–1.2233		–0.7030		–0.2851		0.0538	
				–1.0014		–0.5746		–0.2172		0.1321
					–0.8509		–0.4881		–0.1940	
						–0.7395		–0.4292		–0.1260
							–0.6644		–0.4091	
								–0.6133		–0.3500
									–0.5958	
										–0.5445
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**

EXHIBIT 65-9

Cumulative Swap Valuation Lattices, Five-Year, Semiannual, Plain Vanilla Swap and Strike Rate of 3.65%

Value Lattice									2.6272
								4.1713	
							4.9558		2.0624
						5.0585		3.1920	
					4.5738		3.6628		1.5669
				3.5634		3.5373		2.3295	
			2.0837		2.8952		2.5209		1.1325
		0.1477		1.7888		2.1913		1.5713	
	–2.1743		0.2672		1.4080		1.5146		0.7524
–4.6732		–1.6585		0.2157		1.0031		0.9058	
	–3.9251		–1.3433		0.0939		0.6295		0.4200
		–3.2589		–1.1752		–0.0434		0.3225	
			–2.7672		–1.0647		–0.1476		0.1296
				–2.4020		–0.9635		–0.1880	
					–2.0842		–0.8289		–0.1239
						–1.7711		–0.6345	
							–1.4255		–0.3449
								–1.0245	
									–0.5377
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**

EXHIBIT 65-10

(3,2) Pay Fixed Swaption, Strike Rate of 3.65%

						5.058457
					4.205307	
				3.448802		3.537322
			2.768908		2.81059	
		2.153258		2.158727		2.191292
	1.615948		1.571992		1.571144	
1.170195		1.091484		1.019616		1.003132
	0.728946		0.626107		0.494444	
		0.371439		0.244479		0
			0.121241		0	
				0		0
					0	
						0
Time in Years	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**

VALUING BASIS SWAPS AND NON-LIBOR-BASED SWAPS

To this point, we have focused on the valuation of swap structures involving the exchange of floating and fixed-rate payments in which the floating leg of the swap is based off LIBOR. Next, we generalize our discussion to include swaps in which both legs of the swap float and to swap structures based on interest rates other than LIBOR.

A basis swap is a swap agreement in which both legs of the swap are based on different rates. For example, the spread between the 90-day Treasury bill rate and the three-month LIBOR is referred to as the *TED spread*. In a LIBOR TED swap, one counterparty makes payments based on LIBOR and receives payments based on the 90-day Treasury bill rate plus a spread. This is referred to as a *pay LIBOR TED swap*.

We illustrate the lattice approach to valuation for a one-year pay LIBOR TED swap with a *Spread* of 0.376%. Since each leg of the swap references a floating-rate, the lattice approach requires a lattice for each rate. Exhibit 65-11 presents the one-year interest-rate lattices for LIBOR and the 90-day Treasury bill rate. Note that we assume a 10% volatility for LIBOR and 7.5% for the Treasury bill rate. In previous examples, we assumed semiannual periodicity for payments. In this example we assume quarterly.

After the two interest-rate lattices are in place, the next step in the valuation process is to compute the cash flows for the pay LIBOR TED swap. Each cash flow at node i in period j is computed as follows. Note that in the example

EXHIBIT 65-11

One-Year Interest-Rate Lattices for LIBOR TED Swap

LIBOR Interest-Rate Lattice, 10% Volatility

			1.01%
		0.68%	
	0.44%		0.91%
0.35%		0.61%	
	0.40%		0.82%
		0.56%	
			0.75%
Time in Years	**0.25**	**0.5**	**0.75**

90-day T-Bill Interest-Rate Lattice, 7.5% Volatility

			0.29%
		0.22%	
	0.17%		0.26%
0.14%		0.20%	
	0.15%		0.24%
		0.18%	
			0.21%
Time in Years	**0.25**	**0.50**	**0.75**

we ignore the exact day count and assume each period is exactly one quarter of the year.

$$CF_{i,j} = (\text{T-Bill}_{i,j-1} + \text{Spread} - \text{LIBOR}_{i,j-1}) \times 0.25 \times NP_j$$

It is important to point out that the *Spread* is the adjustment to the Treasury bill rate such that the present values of the two payment streams are equal. To obtain the spread that equates the two cash-flow streams, we can iterate on the *Spread* value.

Following the two interest-rate lattices in Exhibit 65-11, the next step is the computation of the pay LIBOR TED swap cash flow at each node on the tree. To illustrate, consider the highest node on the tree at maturity of the swap. Referring to Exhibit 65-11, the LIBOR and Treasury bill rate at this node are 1.01% and 0.29%, respectively. Using the *Spread* of 0.376%, the payment on \$100 notional principal is:

$$\begin{aligned} CF_{i,j} &= (\text{T-Bill}_{i,j-1} + \text{Spread} - \text{LIBOR}_{i,j-1}) \times 0.25 \times NP_j \\ &= (0.29\% + 0.376\% - 1.01\%) \times 0.25 \times NP_j \\ &= -0.085 \end{aligned}$$

EXHIBIT 65-12

Cash Flows for Pay LIBOR TED Swap, Spread of 0.376%

				–0.0854
			–0.0204	
		0.0258		–0.0683
	0.0415		–0.0095	
		0.0322		–0.0529
			0.0004	
				–0.0389
Time in Years	**0.25**	**0.5**	**0.75**	**1**

The cash flows for the swap at all times are presented in Exhibit 65-12. After constructing the cash flows, the final step for valuing the pay LIBOR TED swap is to compute the cumulative value lattice. This procedure is exactly the same as demonstrated in previous sections. The values are presented in Exhibit 65-13. Note that the present value of the expected payments is zero, indicating that the spread of 0.376% produces zero value for the swap. This means the present value of the LIBOR and the Treasury bill plus *spread* legs are identical. For spreads greater (smaller) than 0.376%, in this example the pay LIBOR TED swap would have positive (negative) present value. To note the flexibility of the lattice approach to valuation, note that it is straightforward to extend the valuation for a swaption on a basis swap following the procedure outlined in the previous section.

EXHIBIT 65-13

Cumulative Value Lattice for Pay LIBOR TED Swap, Spread of 0.376%

				–0.0852
			–0.0969	
		–0.0576		–0.0682
	0.0000		–0.0699	
		–0.0254		–0.0528
			–0.0454	
				–0.0388
Time in Years	**0**	**0.25**	**0.5**	**0.75**

FACTORS AFFECTING SWAP VALUATION

The flexibility of the lattice approach to valuation facilitates the analysis of a swaption's sensitivity to changes in the swaption terms and changes in market inputs such as volatility. In this section, we illustrate the sensitivity of swaption valuations to interest-rate volatility and the strike rate.

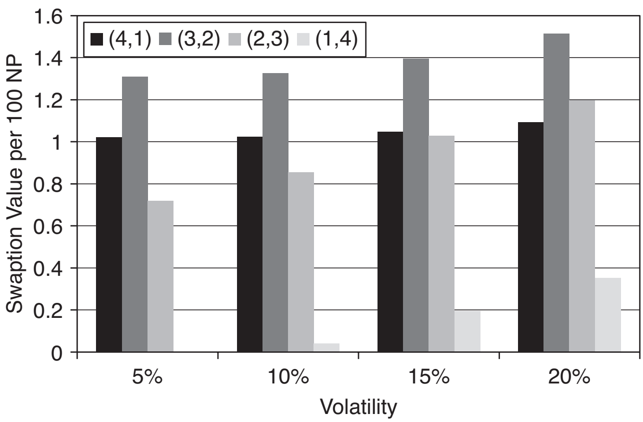
There are two main determinants of the values in the interest-rate lattice: the current term structure and interest-rate volatility. Recall that the interest-rate lattice is the basic building block in the lattice approach to valuing swaptions. Changing the expiration date of a swap changes the value of the swaption, but the directional change in value depends on the current term structure, volatility, and strike price. Interest-rate volatility, however, increases the value of swaptions, holding all else constant.

The chart in Exhibit 65-14 illustrates the effect of interest-rate volatility and the expiration of the swap on the valuation of four different pay fixed swaptions. To construct the example, we use the LIBOR interest-rate lattice from Exhibit 65-1 and consider pay fixed swaptions each having a strike rate equal to 3.5%. In the figure, there is not a monotonic relation between the swaption expiration and value. Each swaption's value, however, does increase as volatility increases.

We next consider the joint effect of the strike rate and interest-rate volatility on interest-rate swaptions. Exhibit 65-14 illustrates that swaption values increase as interest-rate volatility increases, holding all else constant. The strike rate has an important impact on the value of the swaption. For a pay

EXHIBIT 65-14

Pay Fixed Swaption Values and Volatility, Strike Rate = 3.5%



fixed swaption, in which the option owner has the right to enter into a swap agreement where they pay the fixed-rate and receive floating payments, as the strike rate increases, the value of the pay fixed swaption declines since the value of the fixed-rate payments rises relative to the floating-rate payments that party will receive. Conversely, in a receive fixed swaption, in which the option owner has the right to enter into a swap agreement where they receive fixed-rate payments and make floating-rate payments, the value of that right increases as the strike rate increases.

Exhibit 65-15 illustrates the joint effect of the strike rate and interest-rate volatility on the value of a (2,3) pay fixed swaption. The surface plot of the swaption value is increasing in the volatility (at higher levels of volatility, the swaption's value is greater), and decreasing in the strike rate (at lower strike rates, the pay-fixed swaption's value is greater). Exhibit 65-16 illustrates the receive fixed swaption value across strike rates and levels of volatility. It is important to note that, across the strike rate dimension, the graph in Exhibit 65-16 is the mirror image of Exhibit 65-15, demonstrating that strike rate has the opposite impact on the values of receive fixed swaptions as it has on pay fixed options. The value of the receiver's swaption, is positively related to the level of volatility, in which the receiver's swaption increases in value as the assumed lever of interest-rate volatility increases.

EXHIBIT 65-15

The Effect of Strike Rate and Interest-Rate Volatility on the (2,3) Pay Fixed Value

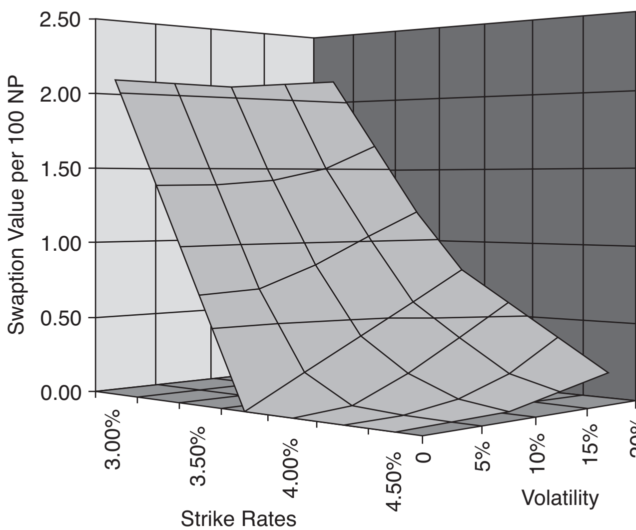
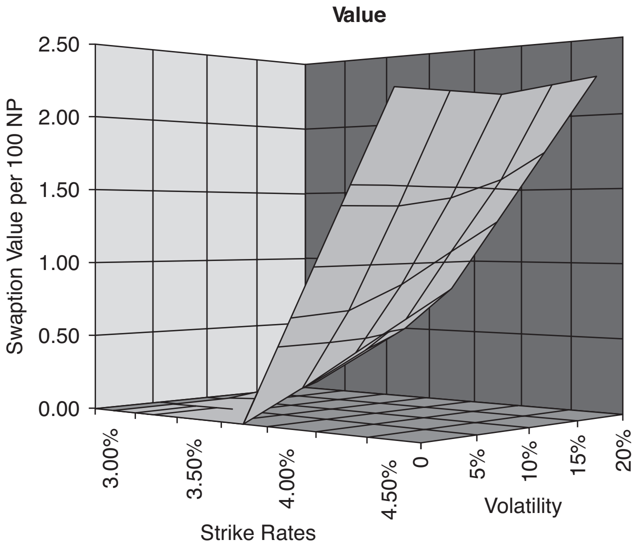


EXHIBIT 65-16

The Effect of Strike Rate and Interest-Rate Volatility on the (2,3) Receive Fixed Swaption Value



KEY POINTS

- Interest-rate swap agreements involve two parties agreeing to exchange payments in the future at agreed-upon terms.
- Exotic swap agreements are customized contracts. Common variations include forward-start swaps, amortizing notional principal swaps, accreting notional principal swaps, basis swaps, and non-LIBOR swaps.
- Swaptions are option contracts in which the owner has the right, but not the obligation, to enter into a swap agreement in the future.
- The lattice approach to swap and swaption valuation is a powerful, flexible valuation framework easily adapted to handle variations of exotic swaps.
- Swaption values are determined by market inputs such as the term structure of interest rates and interest-rate volatility in addition to contract specifications such as tenor and strike rate. Holding all else constant, volatility increases swaption values. Holding all else constant, increasing the strike rate decreases the value of a pay-fixed swaption but increases the value of a receive-fixed contract.

CHAPTER

SIXTY-SIX

THE BASICS OF INTEREST-RATE OPTIONS

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As the sophistication and diversity of investors and financial products have grown, the need for derivative instruments such as options has increased accordingly. Knowledge of option strategies is necessary for everyone who wishes to maintain a competitive edge in an increasingly technical market. The analysis of many complex products, such as swaptions or bonds with embedded calls (like callable bonds or mortgage-backed securities) relies on having the ability to understand and price options.

In Chapter 61, option contracts were described: exchange-traded options on physical securities, exchange-traded options on futures, and over-the-counter (OTC) options. In this chapter we will review how options work, their risk/return profiles, the basic principles of option pricing, and some common trading and portfolio management strategies. A more detailed discussion of hedging strategies is provided in Chapter 63.

Throughout most of the discussion, our focus will be on options on physicals. The principles, however, are equally applicable to options on futures or options on off-balance sheet contracts like interest-rate swaps.

HOW OPTIONS WORK

An *option* is the right but not the obligation to buy or to sell a security at a fixed price. The right to buy is called a *call,* and the right to sell is called a *put;* a call makes money if prices rise and a put makes money if prices fall.

If the owner of an option uses the option to buy or to sell the underlying security, we say that the option has been *exercised.* Because the holder is never required to exercise an option, the holder can never lose more than the purchase price of the option—an option is a limited-liability instrument.

An option on a given security can be specified by giving its strike price and its expiration date. The *strike price* is the price on the optional purchase. For example, a call with a strike price of par is the right to buy that security at par. The *expiration date* is the last date on which the option can be exercised: after that, it is worthless, even if it had value on the expiration date. If an option is allowed to expire, it is said to be *terminated.* On or before the expiration date, the option holder may decide to sell the option for its market value. This is called a *pair-off.*

Some options can be exercised at any time until expiration: they are called *American* options. On the other hand, some options can only be exercised at expiration and are called *European* options. Because it is always possible to delay the exercise of an American option until expiration, an American option is always worth at least as much as its European counterpart. In practice, there are only a limited number of circumstances under which early exercise is advantageous, so the American option rarely costs significantly more than the European.

The easiest way to analyze a position in a security and options on that security is with a *profit/loss graph.* A profit/loss graph shows the change in a position's value between the *analysis date* ("now") and a *horizon date* for a range of security prices at the horizon.

Suppose that a call option struck at par is bought today for 1 point. At expiration, if the security is priced below par, the option will be allowed to expire worthless; the position has lost 1 point. If the security is above par at expiration, the option will be exercised; the position has made 1 point for every point the security is above par, less the initial one-point cost of the option. Exhibit 66-1 shows the resulting profit/loss graph.

EXHIBIT 66-1

Long Call versus Underlying Security Price
Call Struck at Par, at Expiration, with 1-Point Premium

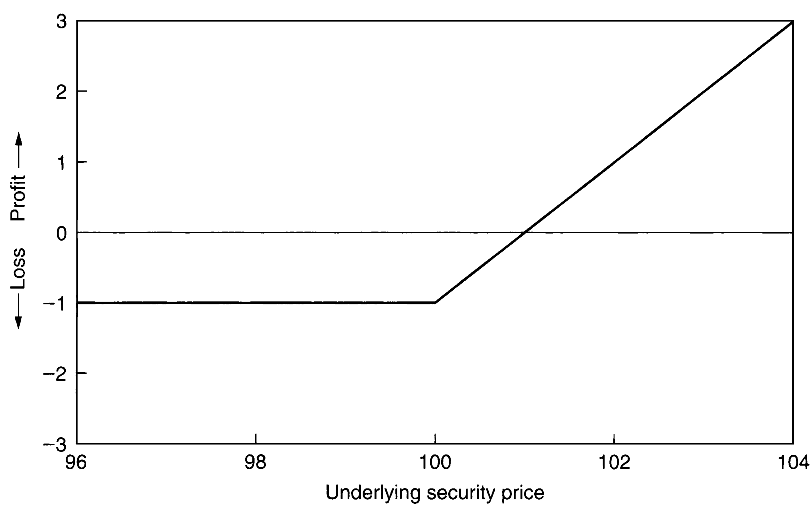
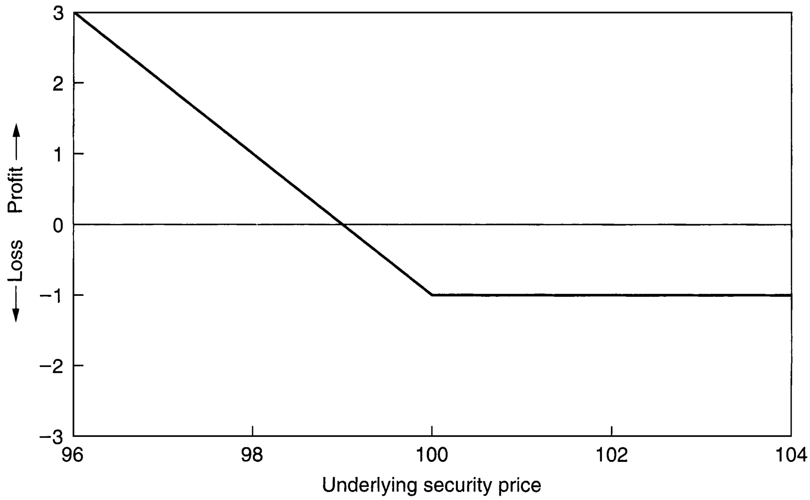


EXHIBIT 66-2

Long Put versus Underlying Security Price
Put Struck at Par, at Expiration, with 1-Point Premium



Note that if the price of the underlying increases by 1 point, the option purchase breaks even. This happens because the value of the option at expiration is equal to the initial purchase price. A price of 101 is the break-even price for the call: the call purchase will make money if the price of the underlying exceeds 101 at expiration.

A put is the reverse of a call. Look at Exhibit 66-2, which is the profit/loss graph of a put option struck at par bought for 1 point. At expiration, the put is worth nothing if the security's price is more than the strike price and is worth 1 point for every point that the security is priced below the strike price. The break-even price for this trade is 99, so the put purchase makes money if the underlying is priced below 99 at expiration.

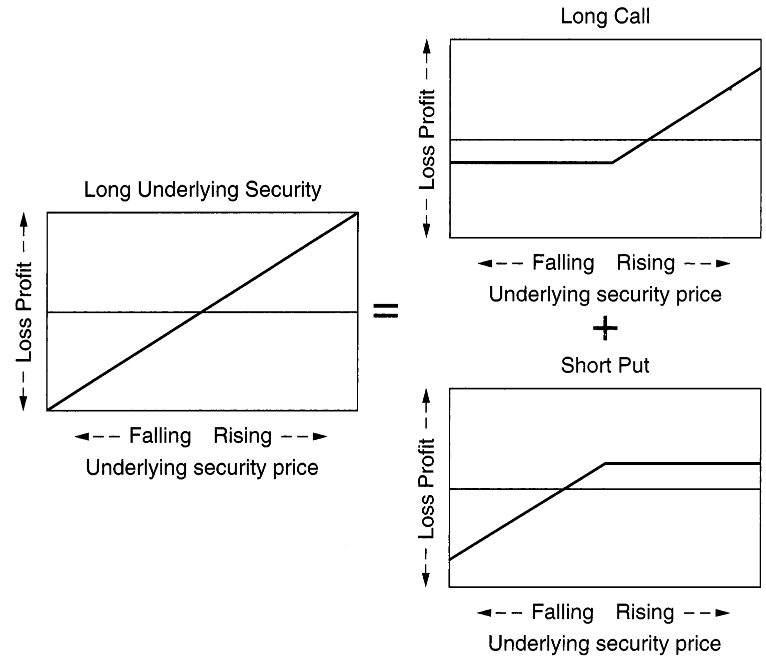
Put-Call Parity

A put and a call struck at-the-money split up the profit/loss diagram of the underlying security into two parts. Consider the position created by buying a call and selling a put such that the strike price of the two options is equal to the price of the underlying. If the price of the security goes up, the call will be exercised; if the price of the security goes down, the put will be exercised. In either case, at expiration the underlying is delivered at the strike price. Thus, in terms of profit and loss, owning the call and selling the put are the same as owning the underlying.

Exhibit 66-3 divides the profit/loss graph of the underlying security into graphs for a long call and a short put, respectively. The following three facts

EXHIBIT 66-3

Long Security = Long Call + Short Put



can be deduced:

Long security = long call + short put	(Exhibit 66-3)
Long call = long security + long put	(Exhibit 66-4)
Long put = short security + long call	(Exhibit 66-5)

This relationship is called *put-call parity;* it is one of the foundations of the options markets. Using these facts, a call can be created from a put by buying the underlying, or a put made from a call by selling the underlying. This ability to convert between puts and calls at will is essential to the management of an options position.

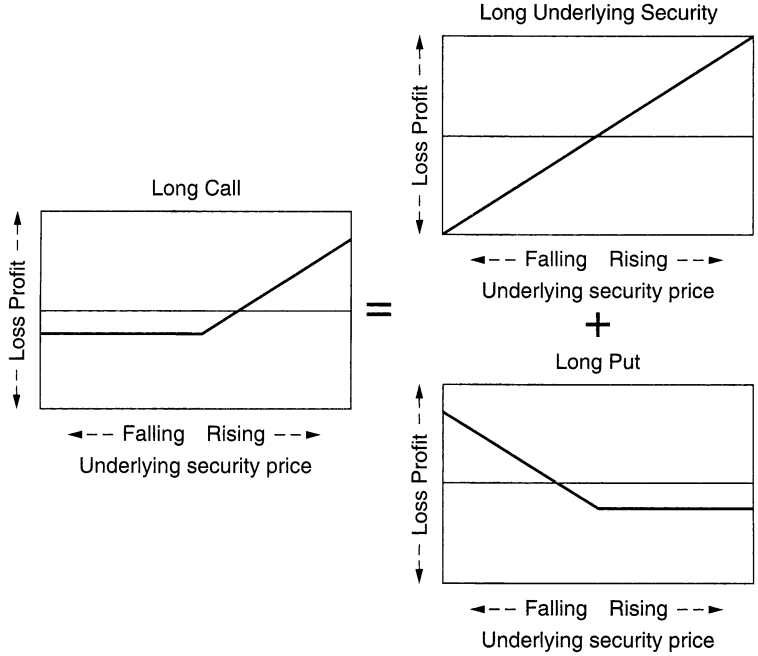
Valuing an Option

The first fact to determine about an option is its worth. There are many option valuation models for each class of options, each of which uses different parameters and returns slightly different values. However, the five main determinants of option value are the price of the underlying, the strike price of the option, the expiration of the option, the volatility of the underlying, and the cost of financing the underlying.

The most apparent component of option value is intrinsic value. The *intrinsic value* of an option is its value if it were exercised immediately. An option with

EXHIBIT 66-4

Long Call = Long Security + Long Put



intrinsic value is an *in-the-money* option. When the underlying security trades right at the strike price, the option is called *at-the-money.* Otherwise, an option with no intrinsic value is called *out-of-the-money.*

An option may have value over and above its intrinsic value, called *time value.* The intrinsic value is the value of the option if exercised immediately, whereas the time value is the remaining value in the option due to time expiration. Clearly, the more time there is to expiration, the greater is the time value.

Exhibit 66-6 graphs the value of an option as time to expiration increases. Exhibit 66-7 compares the value of an option at expiration with the values of options with one and three months to expiration. There is a sharp corner in the graph at the strike price that becomes more pronounced as the time to expiration decreases. This sharp corner makes an at-the-money option increasingly difficult to hedge as expiration approaches.

If the option is out-of-the-money, it has some time value because there is a chance that the option will expire in-the-money; as it gets further out-of-the-money, this is less likely and the time value decreases.

If the option is in-the-money, its time value is due to the fact that it is better to hold the option than the corresponding position in the underlying security because if the security trades out-of-the-money the potential loss on the option is

EXHIBIT 66-5

Long Put = Short Security + Long Call

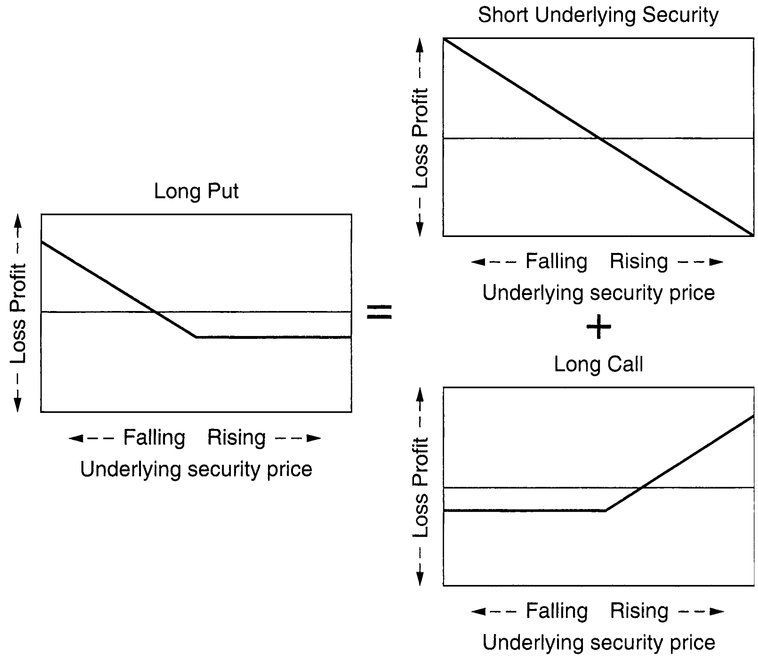


EXHIBIT 66-6

Call Option Value versus Time Until Expiration
Three Calls: At-the-Money, 1 Point In-the-Money, 1 Point Out-of-the-Money

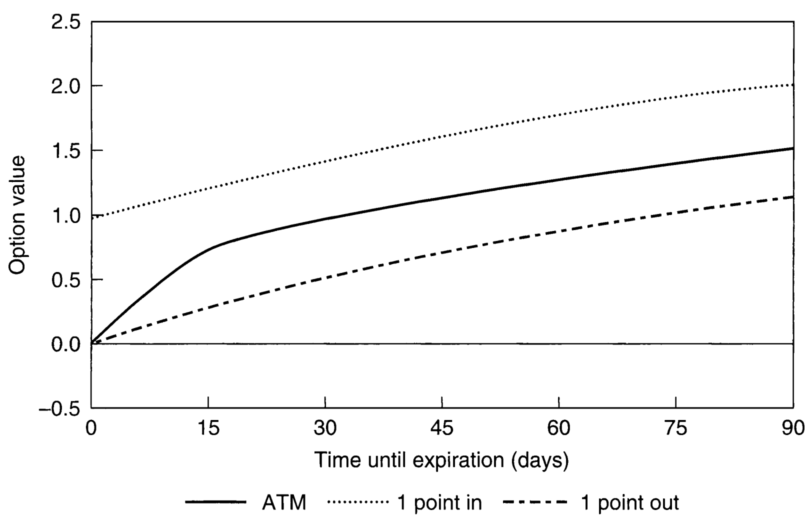
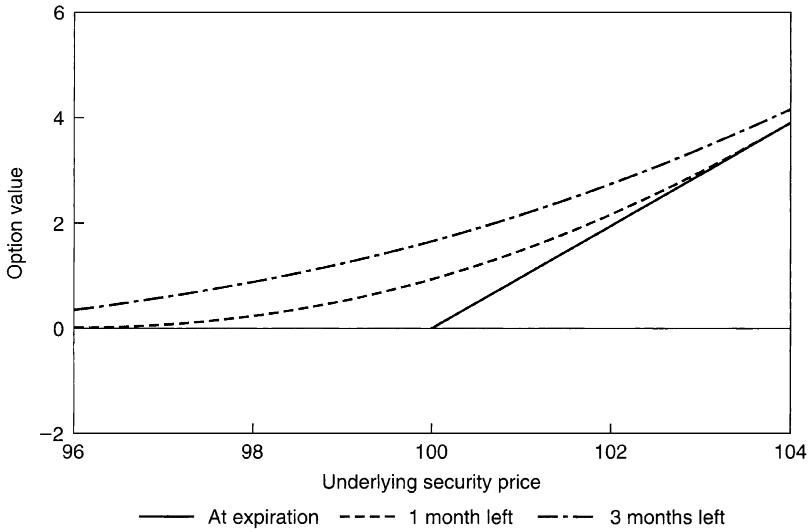


EXHIBIT 66-7

Call Option Value versus Underlying Security Price
Call Struck at Par with One and Three Months to Expiration



limited to the value of the option; as the option gets further in-the-money, this possibility becomes more farfetched and the time value decreases.

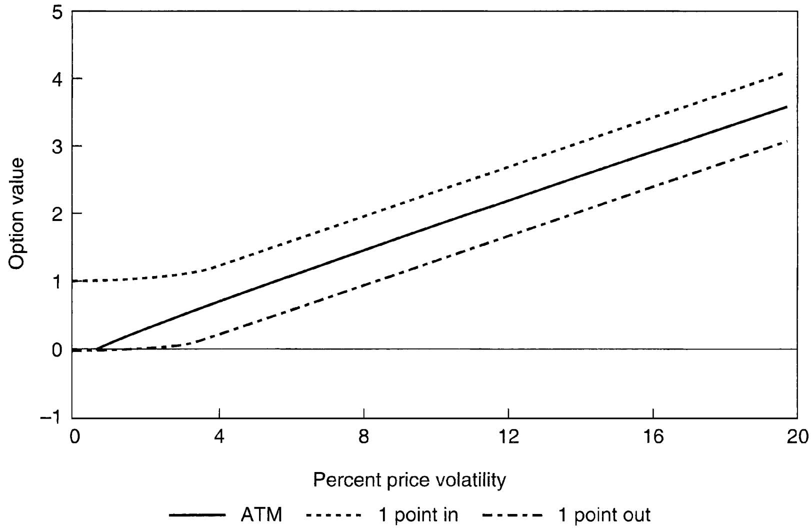
Either way, the time value depends on the probability that the security will trade through the strike price. In turn, this probability depends on how far from the strike price the security is trading and how much the security price is expected to vary until expiration.

Volatility measures the variability of the price or the yield of a security. It measures only the magnitude of the moves, not the direction. Standard option pricing models make no assumptions about the future direction of prices but only about the distribution of these prices. Volatility is the ideal parameter for option pricing because it measures how wide this distribution will be. We discuss volatility in more detail at the end of this chapter.

The higher the volatility of a security, the higher is the price of options on that security. If a security had no volatility, for example, that security would always have the same price at time of purchase of an option as at its expiration, so all options would be priced at their intrinsic value. Increasing the volatility of a security increases the time value of options on that security as the chance of the security price moving through the strike price increases. Increases in the value of an at-the-money option are approximately proportional to increases in the volatility of the underlying. Exhibit 66-8 shows how the price of an option behaves as the volatility of the underlying security increases.

EXHIBIT 66-8

Call Option Value versus Percent Price Volatility
Three Calls: At-the-Money, 1 Point In-the-Money, 1 Point Out-of-the-Money; Three Months from Expiration



The final factor that influences options prices is the *carry* on the underlying security. Carry is the difference between the value of the coupon payments on a security and the cost of financing that security's purchase price. With the usual upward-sloping yield-curve, most securities have a positive carry.

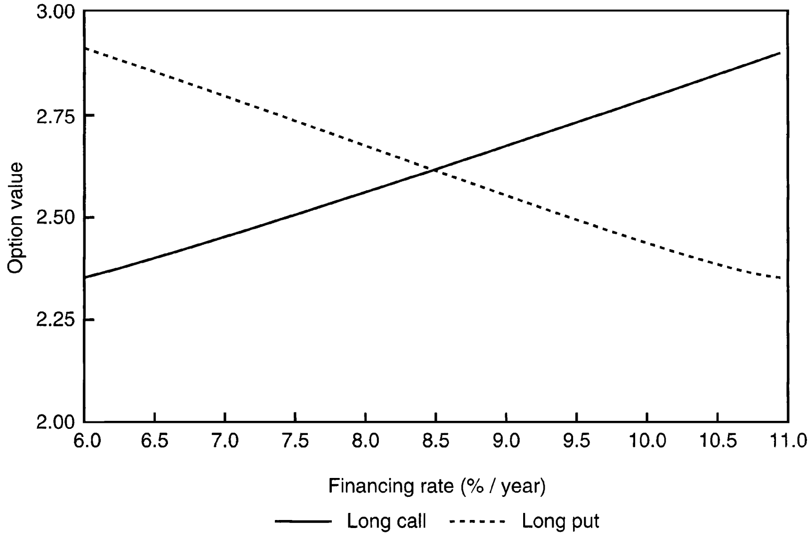
The effect of the carry can be seen by comparing the price of an at-the-money call with an at-the-money put where the underlying security has a positive carry. The writer of the call anticipates the chance of being required to deliver the securities and thus buys the underlying as a hedge; the put writer hedges by selling the underlying. The call writer earns the carry while the put writer loses the carry, so the call should cost less than the put. When the yield-curve inverts and short-term rates are higher than long-term rates, carry becomes negative and calls cost more than puts.

By put-call parity, selling an at-the-money call and buying an at-the-money put are equivalent to shorting the underlying security. The cash taken out of the option trade, accounting for transaction costs, compensates the option holder for the carry on the position in the underlying until expiration. This trade is called a *conversion,* and it is used frequently to obtain the effect of a purchase or sale of securities when buying or selling the underlying is impossible for accounting reasons.

Exhibit 66-9 compares the cost of an at-the-money call and put for a range of financing rates. The two graphs intersect where the call and the put have the same value: this happens when the cost of financing the underlying is equal to the coupon

EXHIBIT 66-9

Treasury Option Value versus Financing Rate
Long Call, Long Put Struck at Par, Three Months to Expiration



yield on the security, so the carry is zero and there is no advantage to holding the underlying over shorting it.

Exhibit 66-10 summarizes the parameters that affect the value of an option and how much raising each parameter affects that value.

Delta, Gamma, and Theta: Hedging an Option Position

More precise quantitative ways to describe the behavior of an option are needed to manage an option position. Options traders have created the concepts of delta,

EXHIBIT 66-10

The Effect of an Increase of a Factor on Option Values

	Call	Put
Underlying price	Increase	Decrease
Strike price	Decrease	Increase
Carry	Decrease	Increase
Time to expiration	Increase	Increase
Volatility	Increase	Increase

gamma, and theta for this purpose. Delta measures the price sensitivity of an option, gamma the convexity of the option, and theta the change in the value of the option over time.

For a given option, the *delta* is the ratio of changes in the value of the option to changes in the value of the underlying for small changes in the underlying. A typical at-the-money call option would have a delta of 0.5; that means for a 1-cent increase in the price of the underlying the value of the call would increase by 0.5 cent. On the other hand, an at-the-money put would have a delta of –0.5; puts have negative deltas because they decrease in value as the price of the underlying increases (see Exhibit 66-10).

The standard method of hedging an options position is called *delta hedging,* which unsurprisingly makes heavy use of the delta. The idea behind delta hedging is that for small price moves, the price of an option changes in proportion with the change in price of the underlying, so the underlying can be used to hedge the option. For example, 1,000,000 calls with a delta of 0.25 would for small price movements track a position of 250,000 of the underlying bonds, so a position consisting of 1,000,000 of these long calls and 250,000 of the security sold short would be delta-hedged. The total delta of a position shows how much that position is long or short. In the preceding example, the total delta is

$$0.25 \times 1{,}000{,}000 - 1 \times 250{,}000 = 0$$

so the position is neither long nor short.

Intuitively, the delta of an option is the number of bonds that are expected to be delivered into this option. For example, an at-the-money call has a delta of 0.5, which means that one bond is expected to be delivered for every two calls that are held. In other words, an at-the-money call is equally as likely to be exercised as not. An option that is deeply out-of-the-money will have a delta that is close to 0 because there is almost no chance that the option will ever be exercised. An option that is deeply in-the-money almost certainly will be exercised. This means that a deeply in-the-money put has a delta of –1 because it is almost certain that the holder of the option will exercise the put and deliver one bond to the put writer.

Put-call parity tells us that a position in the underlying security may be duplicated by buying a call and selling a put with the same strike price and expiration date. Thus the delta of the call less the delta of the put should be the delta of the underlying. The delta for the underlying is 1, so we get the following equation:

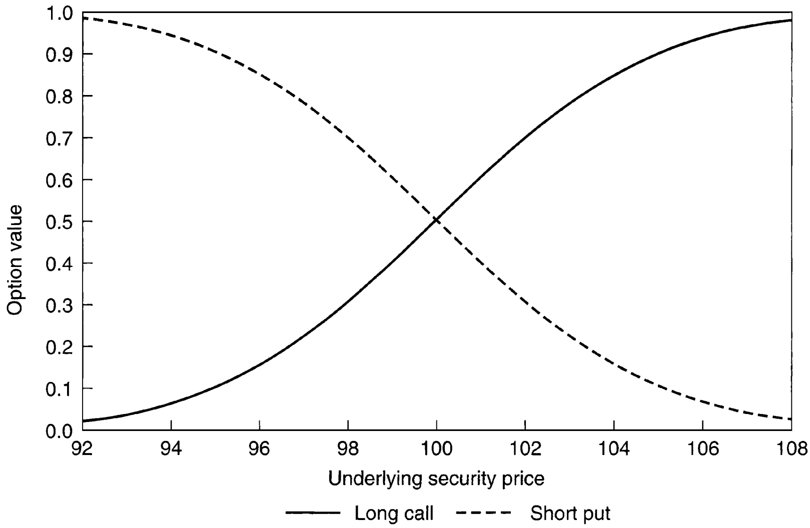
$$\text{Delta}(call) - \text{delta}(put) = 1$$

where call and put are options on the same security with the same strike price and expiration date. This says that once the call is bought and the put sold, the bond is certain to be delivered; if the call is out-of-the-money, the put is in-the-money. Moreover, as the chance of having the underlying delivered into the call becomes smaller, the chance of having to accept delivery as the put is exercised becomes larger. Exhibit 66-11 compares the deltas for a long and a short put.

Making the position delta-neutral does not solve all hedging problems, however. This is demonstrated in Exhibit 66-12. Each of the three positions

EXHIBIT 66-11

Option Delta versus Underlying Security Price
Long Call, Short Put Struck at Par, Three Months to Expiration



shown is delta-neutral, but position 1 is clearly preferable to position 2, which is, in turn, better than position 3. The difference between these three positions is *convexity*. A position such as position 1 with a profit/loss graph that curves upward has a positive convexity, whereas position 3 has a graph that curves downward and thus has negative convexity.

Gamma measures convexity for options; it is the change in the delta for small changes in the price of the underlying. If a position has a positive gamma, then as the market goes up the delta of the position increases and as it declines the delta decreases. Such a position becomes longer as the market trades up and shorter as the market trades down. A position like this is called *long convexity* or *long volatility.* These names come from the fact that if the market moves in either direction this position will outperform a position with the same delta and a lower gamma. Exhibit 66-13 shows this phenomenon.

A long option always has a positive gamma. The delta of a call increases from 0 to 1 as the security trades up, and the delta of a put increases also, moving from −1 to 0. Exhibits 66-1 and 66-2 show that the profit/loss graph of options curves upward. Because of this, options traders often speak of buying or selling volatility as a synonym for buying or selling options.

A position with a zero gamma is called *flat convexity* or *flat gamma.* Here, a change in the underlying security price does not change the delta of the position. Such a position trades like a position in the underlying with no options bought or sold. If the position has in addition a delta of zero, then its value is not affected by

EXHIBIT 66-12

Delta-Neutral Positions with Different Gamma

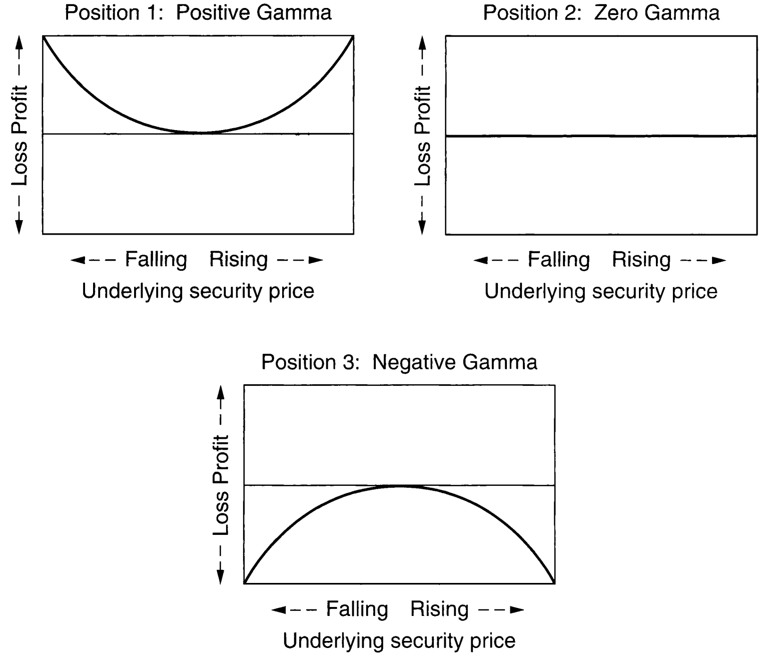
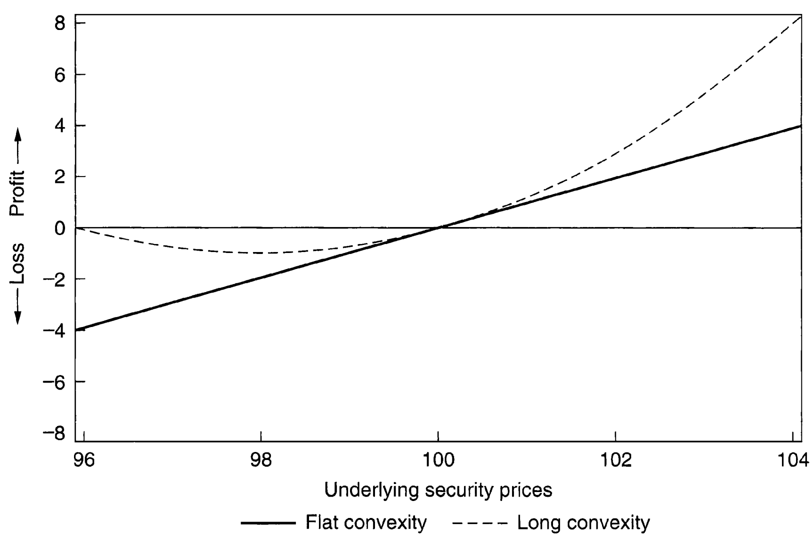


EXHIBIT 66-13

Profit/Loss Diagram with Convexity
Long Security with Flat and Long Convexity



small changes in the price of the underlying security in either direction. Position 2 in Exhibit 66-12 is a profit/loss graph for a position with no delta or gamma.

A position with negative gamma is called *short volatility* or *short convexity.* The profit/loss curve slopes downward in either direction from the current price on the underlying; thus the position gets longer as the market trades down and shorter as the market trades up. Either way, this position loses money if there are significant price movements. Position 3 demonstrates this behavior.

A position that is long volatility is clearly preferable to an otherwise identical position that is short volatility. The holder of the short-volatility position must be compensated for this. In order to create a position that is long volatility it is necessary to purchase options and spend money; moreover, if the market does not move, the values of the options will decrease as their time to expiration decreases, so the position loses money in a flat market.

Conversely, creating a position that is short volatility involves selling options and taking in cash. As time passes, the value of these options sold decreases because their time value falls, so the position makes money in a flat market. Large losses could be sustained in a volatile market, however.

To describe the time behavior of options, there is one last measure called *theta.* The theta of an option is the overnight change in value of the option if all other parameters (prices, volatilities) stay constant. This means that a long option has a negative theta because as expiration approaches, the time value of the option will erode to zero. For example, a 90-day at-the-money call that costs 2 points might have a theta of –0.45 ticks per day.

Exhibit 66-14 shows the effects of different volatility exposures.

EXHIBIT 66-14

Comparison of Different Volatility Positions (All Positions Are Delta-Neutral)

	Short Volatility	Flat Volatility	Long Volatility
Convexity	Position has negative convexity: gamma < 0	Position has no convexity: gamma = 0	Position has positive convexity: gamma > 0
Options purchased	More sold than bought	Sold as many as bought	More bought than sold
Time value	Position earns value as time passes: theta > 0	Position stays flat as time passes: theta = 0	Position loses value as time passes: theta < 0
Market moves	Position loses money if the market moves in either direction	Position is invariant with respect to market moves	Position makes money if the market moves in either direction

OPTIONS STRATEGIES—REORGANIZING THE PROFIT/LOSS GRAPH

Investors have many different goals: reducing risk, increasing rates of return, or capturing gains under expected market moves. Often these objectives are simply to rearrange the profit/loss graph of a position in accordance with the investor's expectations or desires. By increasing the minimum value of this graph, for example, the investor reduces risk.

Options provide a precise tool to accomplish this rearrangement. Because it is impossible to replicate the performance of an option position using just the underlying, options allow a much broader range of strategies to be used. The following characteristics of options provide an explanation.

Directionality

Both a put and a call are directional instruments. A put, for example, performs only in a decreasing market. This property makes options ideal for reducing directional risk on a position. Take, for example, a position that suffers large losses in a downward market and makes a consistent profit if prices rise. By purchasing a put option, some of these profits are given up in exchange for dramatically increased performance if the market declines.

Convexity

Buying and selling options makes it possible to adjust the convexity of a position in almost any fashion. Because OTC options can be purchased for any strike price and expiration, convexity can be bought or sold at any place in the profit/loss graph. For example, an investor holding mortgage-backed securities priced just over par might anticipate that prepayments on this security would start to increase dramatically if the market traded up, attenuating possible price gains. In other words, the investor feels that the position is short convexity above the market. To adjust the profit/loss graph, calls could be purchased with strike prices at or above the market. This trade sells some of the spread over Treasuries in exchange for increased performance in a rising market.

Fee Income

An investor who wishes to increase the performance of a position in a stable market can sell convexity by writing options and taking in fees. This increases the current yield of the position, at the cost of increasing volatility risk in some area of the profit/loss graph. A typical example of this is the venerable covered call strategy, where the manager of a portfolio sells calls on a portion of the portfolio, forgoing some profits in a rising market in exchange for a greater return in a stable or decreasing market.

Leveraged Speculation

Investors with a higher risk/reward profile wish to increase their upside potential and are willing to accept a greater downside risk. In this case, options can be used as a highly leveraged position to capture windfall profits under a very specific market move. A strongly bullish investor might purchase 1-point out-of-the-money calls with 30 days to expiration for 1/2 point. If the market traded up 2 points by expiration, the option then would be worth 1 point, and the investor would have doubled the initial investment; a corresponding position in the underlying would have appreciated in value by only about 2%. Of course, if the market did not trade up by at least 1 point, the calls would expire worthless.

CLASSIC OPTION STRATEGIES

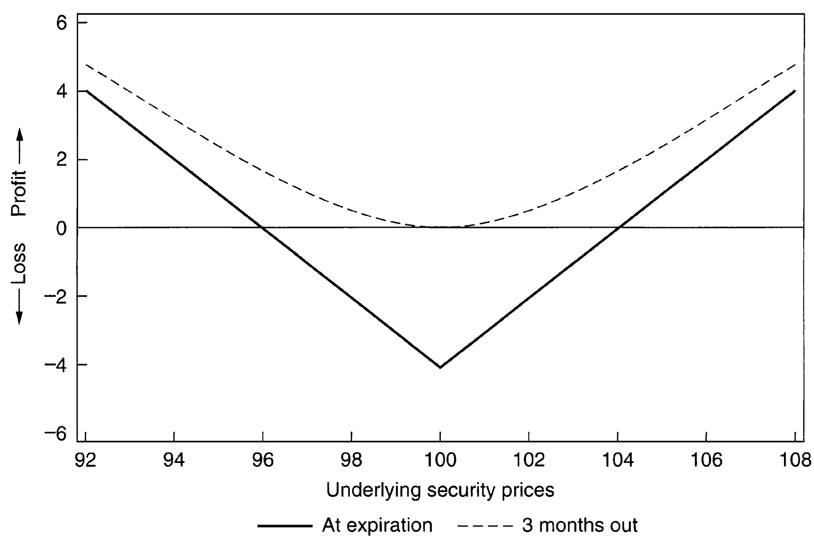
This section gives a brief explanation of some of the simplest pure options strategies.

Straddle

The most pure convexity trade is called a *straddle,* composed of one call and one put with the same strike price. Exhibit 66-15 shows the profit/loss graph of a straddle struck at-the-money at expiration and with three months to expiration.

EXHIBIT 66-15

Profit/Loss Diagram for a Long Straddle
Struck at Par, at Expiration, and Three Months Out



This position is delta-neutral because it implies no market bias. If the market stays flat, the position loses money as the options' time value disappears by expiration. If the market moves in either direction, however, either the put or the call will end up in-the-money, and the position will make money. This strategy is most useful for buying convexity at a specific strike price. Investors who are bearish on volatility and anticipate a flat market could sell straddles and make money from time value.

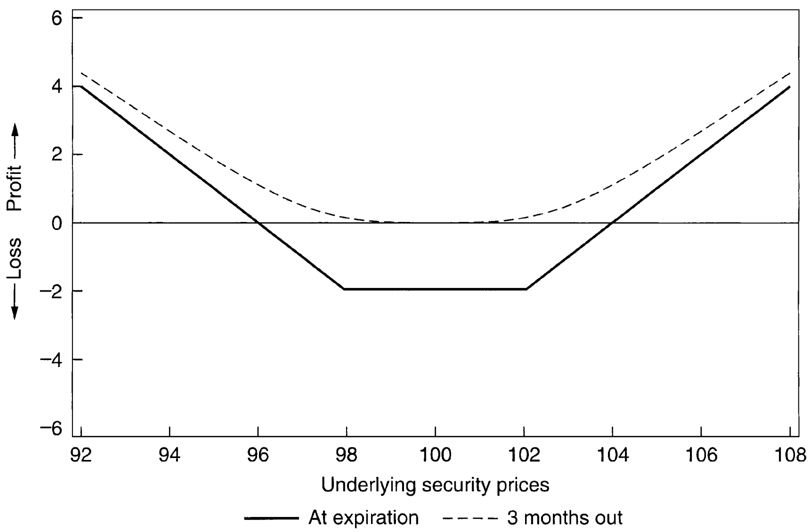
Strangle

A *strangle* is the more heavily leveraged cousin of a straddle. An at-the-money strangle is composed of an out-of-the-money call and an out-of-the-money put. The options are struck so that they are both equally out-of-the-money, and the current price of the security is halfway between the two strikes. The profit/loss graph is found in Exhibit 66-16.

Just like a straddle, a strangle is a pure volatility trade. If the market stays flat, the position loses time value, whereas if the market moves dramatically in either direction the position makes money from either the call or the put. Because the options in this position are both out-of-the-money, the market has to move significantly before either option moves into the money. The options are much cheaper, however, so it is possible to buy many more options for the same money.

EXHIBIT 66-16

Profit/Loss Diagram for a Long Strangle
Struck at Par, at Expiration, and Three Months Out



This is the ideal position for the investor who is heavily bullish on volatility and wants windfall profits in a rapidly moving market.

Writing strangles is a very risky business. Most of the time the market will not move enough to put either option much into the money, and the writer of the strangle will make the fee income. Occasionally, however, the market will plummet or spike, and the writer of the strangle will suffer catastrophic losses. This accounts for the picturesque name of this trade.

Spread Trades

Spread trades involve buying one option and funding all or part of this purchase by selling another. A *bull spread* can be created by owning the underlying security, buying a put struck below the current price, and selling a call above the current price. Because both options are out-of-the-money, it is possible to arrange the strikes so that the cost of the put is equal to the fee for the call. If the security price falls below the put strike or rises above the call strike, the appropriate option will be exercised and the security will be sold. Otherwise, any profit or loss will just be that of the underlying security. In other words, this position is analogous to owning the underlying security except that the final value of the position at expiration is forced to be between the two strikes. Exhibit 66-17 shows the profit/loss graph of this position at expiration and with three months left of time value.

EXHIBIT 66-17

Profit/Loss Diagram for a Bull Spread
Struck at Par, at Expiration, and Three Months Out

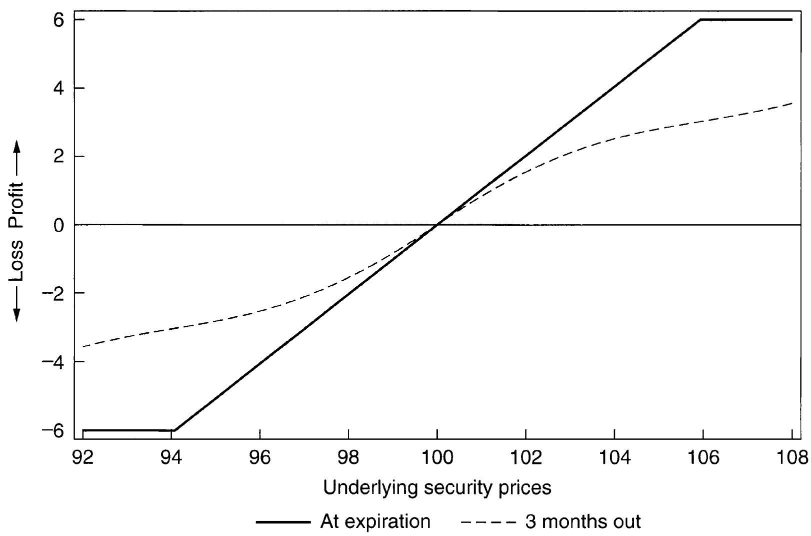
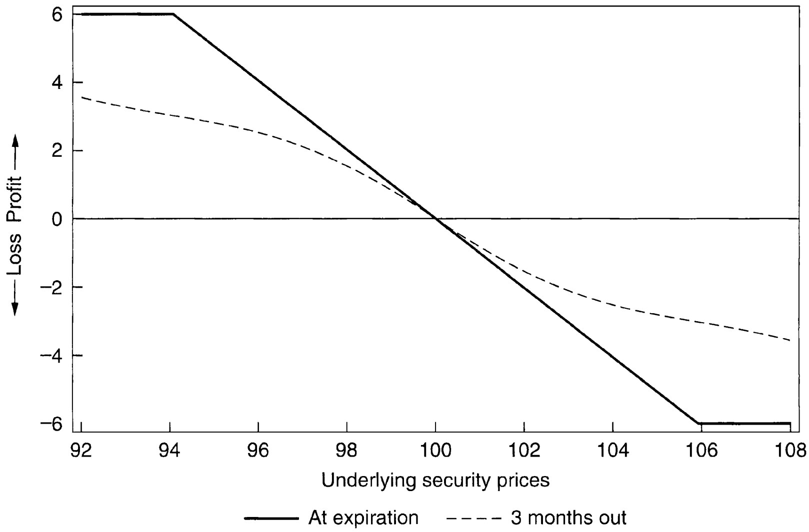


EXHIBIT 66-18

Profit/Loss Diagram for a Bear Spread Struck at Par, at Expiration, and Three Months Out



The other spread trade is a *bear spread:* It is the reverse of a bull spread. It can be created by selling a bull spread. Using put-call parity, it also can be set up by holding the underlying security, buying an in-the-money put, and selling an in-the-money call. A bear spread is equivalent to a short position in the underlying, where the position must be closed out at a price between the two strike prices. Exhibit 66-18 shows the profit/loss graph of a bear spread.

PRACTICAL PORTFOLIO STRATEGIES

The strategies discussed in the preceding section are the basic techniques used by speculators to trade options. The usual fixed income investor has a lower risk/reward profile than the speculator and specific objectives that must be accomplished; a floor on rate of return or an increase in current yield, for example. Such investors need a class of strategies different from that needed by speculators; even though the same strategies are often used, the risk is carefully controlled.

Portfolio Insurance

This is the most obvious and one of the most commonly used options strategies. An investor with a portfolio of securities who fears a decreasing market buys puts on some or all of the portfolio; if the market falls, the puts are exercised, and the securities are sold at the strike price. Alternatively, the investor may keep the underlying security and pair off the in-the-money puts, receiving cash in compensation for the decreased value of the security. Either way, the investor has limited losses on the portfolio in exchange for selling off return in a stable or rising market.

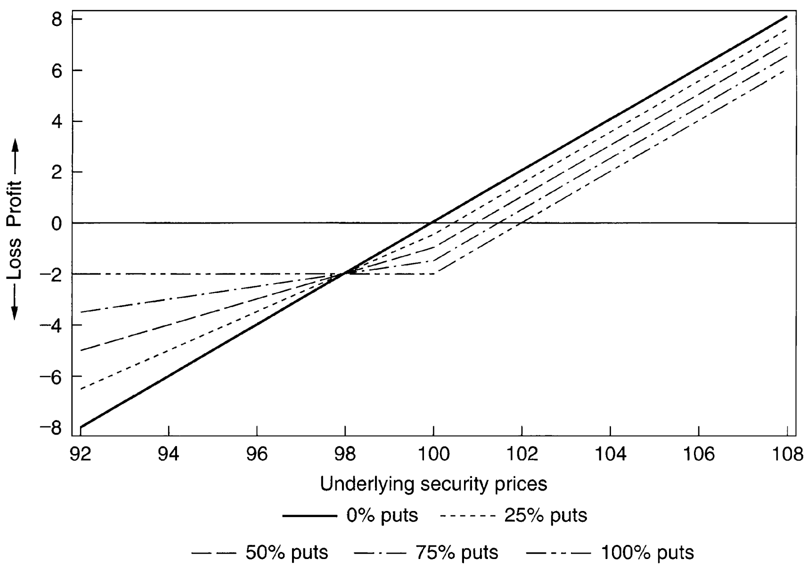
As the strike price of the put increases, so does its cost and the resulting impact on the stable market rate of return. Often, out-of-the-money options are used; the floor on returns is lower because the strike price is lower, but the lower cost of the options means that less return is given up if the market is flat or rises. By put-call parity, such a position is equivalent to holding a call option struck at or in-the-money.

Another popular strategy is to buy at-the-money options on a portion of the portfolio. This reduces but does not eliminate downside risk: Exhibit 66-19 shows the profit/loss graphs at expiration for positions with different percentages of the portfolio hedged with an at-the-money put. Note that all the graphs intersect at a single point. This is the point where the initial cost of the option is equal to the value of the option at expiration, which is the break-even price for this trade.

It is not possible to buy options on many classes of securities that may well be held in a portfolio. Perfect insurance for such securities is unattainable, but cross-market hedging often will permit a reduction in downside risk to acceptable levels.

EXHIBIT 66-19

Hedged Underlying Security with Puts
Long Puts Struck at Par, at Expiration



Covered Calls

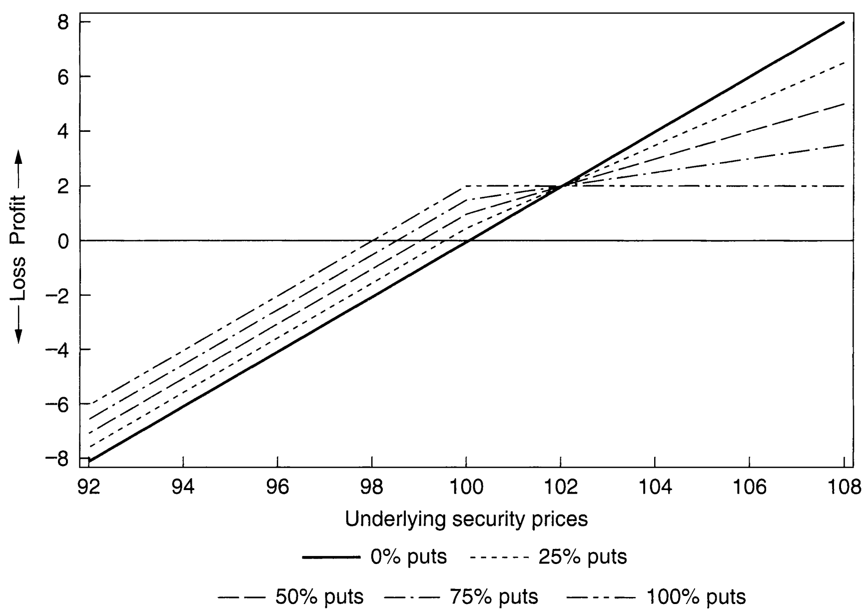
Writing covered calls is a strategy that sells volatility in return for fees. An investor who holds a portfolio sells calls on some or all of the portfolio in return for fees. If the market stays the same or falls, the investor pockets the option fees. If the market increases until the calls are in-the-money, the investor is called out by the option holder. In other words, possible gains on the portfolio are sold for fee income.

Often the investor wishes to preserve some upside potential. Just as in the portfolio insurance example, there are two different ways to do this. The calls can be struck out-of-the-money, that is, above the current market price. This strategy allows all gains up to the strike price to be captured. If the bonds in the portfolio are currently trading below the original purchase price, a popular strategy is to sell calls struck at this purchase price. This provides fee income and increased current yield but prevents the possibility that the bonds will be called at a price below the original purchase price and the portfolio will book a capital loss.

Otherwise, calls can be sold on a portion of the portfolio. This allows unlimited price gains to be captured on the remainder. Exhibit 66-20 shows the profit/loss graph of a covered call program where different portions of the portfolio have calls sold against them.

EXHIBIT 66-20

Covered Call Writing Program
Short Calls Struck at Par, at Expiration



Buy-Writes and Writing Puts

Buy-writes and writing puts are two very closely related strategies for selling volatility that most investors think of as entirely different. To execute a buy-write, a bond is purchased, and simultaneously, a call is written on this bond for the fee income. If the security is trading above the strike price at expiration, the security is called, and the investor is left with just the option fee. If the price of the security has fallen, the investor is left holding the security, but the total cost of the security is reduced by the fee from the call. By put-call parity, this trade is identical to writing a put struck at-the-money. In both cases, the investor is delivered the security only if the price of the security is lower than the price of the original sale.

In the MBS market, a buy-write is composed of forward purchases and short calls on forward delivery contracts (standard TBA transactions). If the call is exercised, it offsets the forward sale, and the buyer never takes delivery of the security, keeping the fee income. Otherwise, the buyer will receive the security on the forward settlement date for the original forward sale price, although the total price is decreased by the value of the option fee.

Put writing is a more general strategy that applies to all fixed income options markets. The investor writes a put for the fee income and receives the underlying instrument at expiration if the security trades below the strike price. This can be a very effective strategy if carefully structured. An investor may feel that a security offers real value if bought at a certain price below the market. The investor could then write puts struck at that price. If the security falls below the strike, it is delivered at a price that is more agreeable than the current price. Otherwise, the investor simply pockets the fee income.

VOLATILITY

Volatility plays a key role in the valuation of options and in option strategies. In this section we focus on methods for estimating volatility.

Statistically, volatility is a measure of the dispersion or spread of observations around the mean of the set of observations. If volatility seems strangely like a standard deviation, then you remember your statistics. When people speak of volatility, all they really are talking about is a standard deviation.

For fixed income securities, volatility is expressed in yield or price units, either on a percentage or on an absolute basis. Price volatilities can be computed for any security. Yield volatilities should be computed only for those securities with a consistent method for computing yield. Given the complexity of calculating a yield on a MBS and the variation of results, the predominant volatility measure in the MBS market is price volatility. The government bond market, where yields are easily calculated, favors yield volatility.

There are two types of volatility: empirical volatility and implied volatility. Each is described below.

Empirical Volatility

Empirical volatility is the actual, historical market volatility of a specific security. These numbers typically are calculated for various time periods (10 days, 30 days, 360 days) and usually are annualized.[1] Calculating an empirical volatility is nothing more than calculating the standard deviation of a time series. Thus an absolute volatility is the annualized standard deviation of daily price or yield changes, assuming a normal distribution.

Percentage volatility is the annualized standard deviation of the daily change in the log of prices or yields, assuming a lognormal distribution of prices or yields. Similar to the daily absolute yield changes, the logs of the daily yield changes have a slight bias toward lower yields. The intuitive approach to calculating a percentage volatility is to find the standard deviation of daily *returns,* assuming a normal distribution. This approach is equivalent to the lognormal assumption as long as the distribution can be characterized as being equally normal and log normal and, the changes in prices are taken on a small interval, such as daily.

As mentioned previously, empirical volatility can be measured over various time periods. The most common interval on which the standard deviation is taken is 30 days; other common intervals are 10 days and 360 days. The choice of interval determines how quickly and to what degree an empirical volatility responds to deviations. As the time period shortens, volatility increasingly reflects current conditions but is more unstable as each sample asserts greater influence in the deviation. Conversely, as the interval increases, more of a lag and a smoothing are introduced into the calculation.

The interval used to calculate an empirical volatility should be chosen to match the length of the option contract. This provides the investor with an indication of how volatile the underlying security has been recently and how this relates to the volatility employed to price the option.

With no industry standard for volatility units, converting between the price and yield expression of absolute or percentage volatility is a useful skill. The path to follow to convert from one unit to the next is shown in Exhibit 66-21. The modified duration of a security provides the link between price and yield volatilities. Modified duration is defined as the percentage change in price divided by the absolute change in yield.

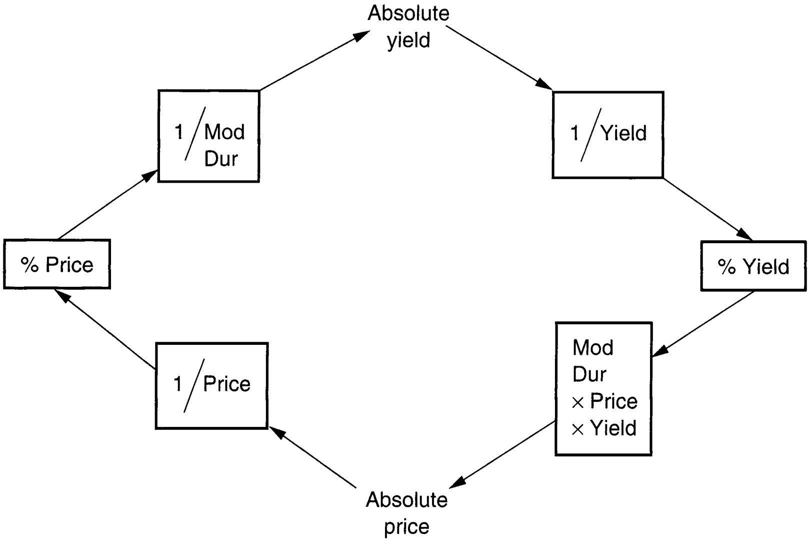
Implied Volatility

Implied volatility is merely the market's expectation of future volatility over a specified time period. An option's price is a function of the volatility employed, so where an option's price is known, the implied volatility can be derived. Although it sounds straightforward, calculating an implied volatility is far more

1. When annualizing a volatility, certain assumptions are inherent to the calculation. To convert from daily to yearly volatility, for example, the daily volatility is multiplied by the square root of the number of business days in the year, approximately 250.

EXHIBIT 66-21

Converting Volatility Measures



complicated than calculating an empirical volatility because expectations cannot be observed directly. An option pricing model along with a mathematical method to infer the volatility must be employed. The result of this calculation is a percentage price volatility that can be converted to the various types of volatility measures discussed previously (see Exhibit 66-21).

Owing to the existence and liquidity of fixed income options, proxies for implied volatilities can be derived from Treasuries. Options on Treasury futures listed on the Chicago Board of Trade (CBOT) are often the best vehicles for implied volatility calculations. The resulting implied volatility provides a good indication of the market's expected volatility for the Treasuries with maturities similar to that of the particular bond futures contract in question. The implied volatility on the 10-year bond futures contract, for example, is a useful proxy for the market's expected volatility on intermediate-term Treasury securities.

KEY POINTS

- An option is the right but not the obligation to buy (a call option) or to sell (a put option) a security at a fixed price (strike price or exercise). The expiration date is the last date on which the option can be exercised. Some options can be exercised at any time until expiration (American options); some options can only be exercised at expiration (European options).

- The relationship among the price of a security, the price of a put, and the price of a call is called the put-call parity and is one of the foundations of the options markets.
- The price of an option is the sum of its intrinsic value and time value.
- Volatility measures the variability of the price or the yield of a security. It measures only the magnitude of the moves, not the direction. Standard option pricing models make no assumptions about the future direction of prices but only about the distribution of these prices. Volatility is the parameter used for option pricing because it measures how wide this distribution will be. The higher the volatility of a security, the higher is the price of options on that security.
- To manage an option position, quantitative ways to describe the behavior of an option are needed. These include an options delta, gamma, and theta.
- Any investor with specific goals can use option strategies to tailor the performance of a portfolio.
- Because it is impossible to obtain the effects of options by using only the underlying securities, a whole new universe of strategic possibilities is opened up. In particular, investors with contingent liabilities cannot create an adequate hedge without the use of options.
- Increased liquidity in the options markets and a better understanding of the properties of options make option strategies more accessible to the average investor and allow these strategies to be used for a wider range of securities. In particular, the over-the-counter options markets allow the purchase and sale of options with any desired strike price and expiration date.
- Refinements to option valuation technology continue to improve cross-market arbitrage trades where securities and options in one market can duplicate securities in another. As options trading removes the arbitrages, the relationships among the various markets are reinforced.

CHAPTER
SIXTY-SEVEN

INTEREST-RATE CAPS AND FLOORS

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Interest-rate caps and floors provide asymmetric interest-rate risk management capabilities similar to those provided by options, except that protection can be customized to a much greater degree. As indicated by the nomenclature, *interest-rate caps,* also referred to as *interest-rate ceilings,* allow the purchaser to ''cap'' the contractual rate associated with a liability. Alternatively, *interest-rate floors* allow the purchaser to protect the total rate of return of an asset. The seller of the cap pays the purchaser any amount that the contractual rate closes above the periodic capped rate on the last day of each contractual period. Conversely, the purchaser of the floor receives from the seller any amount that the contractual rate closes below the periodic protected rate on the relevant date. The protection provided by caps and floors is asymmetric, in that the purchaser is protected from adverse moves in the market but maintains the advantage of beneficial moves in market rates. In this respect, caps and floors differ from interest-rate swaps and are more akin to put and call options based on the level of an interest rate. Recall that interest-rate swaps seek to insulate the user from the economic effects of interest-rate volatility, regardless of the direction of interest rates.

Interest-rate protection obtained by purchasing caps and floors can be customized by selecting various contractual features. The following decision variables are commonly used in determining the parameters of either interest-rate caps or floors.

The version of this chapter that appeared in the third edition was coauthored with Dr. John Breit.

FEATURES OF INTEREST-RATE CAPS AND FLOORS

The *underlying index* from which the contractual payments will be determined can be chosen from a set of indexes based on LIBOR,[1] commercial paper, prime rate, Treasury bills, or certificates of deposit. Because these instruments are originated along several maturities, an additional variable associated with the index concerns the maturity of the index.

The *strike rate* is the rate at which the cash flows will be exchanged between the purchaser and seller of the customized interest-rate protection instrument. Caps with a higher strike rate have lower up-front premiums, although the trade-off between the premium and the strike rate is not directly proportional. Similarly, floors with a lower strike rate have a lower up-front premium. Increasing (decreasing) the strike rate does not necessarily result in a proportionate decrease in the up-front fee for interest-rate caps (floors).

The term of the protection may range from several months to about 30 years, although the liquidity of longer-dated caps is not very good.

The *settlement frequency* refers to the frequency with which the strike rate will be compared to the underlying index to determine the periodic contractual rate for the interest-rate protection agreement. The most common frequencies are monthly, quarterly, and semiannually. At settlement, the cash flows exchanged could be determined on either the average daily rate prevalent during the repricing interval or the spot rate on the settlement date.

The *notional amount* of the agreement on which the cash flows are exchanged is usually fixed, unless the terms of the agreement call for the amortization of the notional amount. For instance, in ‘‘spread enhancement’’ strategies, which involve the purchase of an amortizing asset such as a fixed-rate mortgage-backed security funded by floating-rate capped liabilities, amortization of the cap notional amount may be necessary in order to maintain the spread. Unless the amortization feature is included in the design of the cap, the spread between the asset cash flows and the liability costs will be eroded.

PRICING OF CAPS AND FLOORS

The *upfront premium* is the fee paid by the purchaser to the seller of the interest-rate agreement at the inception of the contract. This fee is similar to the premium paid to purchase options and is determined by factors such as the strike rate, the current level of the contractual rate, the volatility of the underlying index, the length of the agreement, the notional amount, and any special features, such as amortization of the notional principal.

1. While many of the examples cited in this chapter reference LIBOR as the underlying index, we note that LIBOR is scheduled to be replaced by some form of the Secured Overnight Funding Rate (SOFR) and may not be published after 2020.

The pricing of both caps and floors draws heavily on option pricing theory; for instance, an increase in market volatility results in a higher premium for both the cap and the floor. The strike rate for a cap is inversely related to the premium paid for the cap because rates have to advance before the cap is in the money or the payoff is positive. On the other hand, the strike rate for interest-rate floors is positively correlated with the up-front premium. A higher strike indicates that the likelihood of the index falling below this rate is greater, which indicates a higher likelihood of positive payoff from the floor. The longer the term-to-maturity the greater the premium, because optional protection is available for a longer period of time. Hence, there is a higher probability that the payoff associated with these instruments will be positive. With respect to the payment frequency, the agreement with a shorter payment frequency will command a higher premium because there is a greater likelihood of payoff and the payments are determined only on the settlement date. This may be an important determinant of cash flows, especially in highly volatile markets. Any advantageous changes in market volatility for interest-rate agreements with longer settlement frequencies may not result in a payoff for the purchaser of the agreement because the option-like characteristics of caps and floors are European rather than American in design.

There also may be additional contractual features associated with caps and floors, such as variable premiums, cost of termination options prior to stated maturity, conversion privileges from one program to another, and purchase of a combination of programs, such as *interest-rate collars* and *corridors*.

INTEREST-RATE CAPS

As noted above, an interest-rate cap can be used to create an upper limit on the cost of floating-rate liabilities. The purchaser of the cap pays an up-front fee to establish a ceiling on a particular funding rate. If the market rate exceeds the strike rate of the cap on the settlement date, the seller of the cap pays the difference. As an illustration, consider the following example, where an institution purchases an interest-rate cap to hedge the coupon rate of LIBOR-indexed liabilities, which reprice every three months.

Notional amount:	$10,000,000
Underlying index:	3-month LIBOR
Maturity:	3 years
Cap strike level:	6%
Premium:	145 basis points or 1.45% of $10,000,000 = $145,000
Settlement frequency:	Quarterly
Day count:	Actual/360

The up-front premium can be converted to an annual basis-point equivalent by treating \$145,000 as the present value of a stream of equal quarterly payments with a future value of zero at the maturity of the cap. Ideally, this should be computed at the rate at which the up-front premium can be funded for three years. Assuming that this premium can be funded at a rate of 5% and the cap has 12 reset periods, the annual basis-point equivalent of the up-front premium is 52 basis points.[2]

In this example, the payments to the purchaser of the cap by the seller can be determined as the quarterly difference between the three-month LIBOR index and the cap strike rate of 6% times the notional amount of the agreement. Specifically, the cap payments are computed as follows:

$$(\text{Index rate} - \text{Strike rate}) \times (\text{Days in settlement period}/360) \times \text{Notional amount}$$

For instance, where three-month LIBOR is 7%, the payments made by the cap seller, assuming 90 days in the settlement period, would be determined as follows:

$$(7\% - 6\%) \times (90/360) \times 10{,}000{,}000 = \$25{,}000$$

The purchaser does not receive any payments when the reference rate, as indicated by the value of three-month LIBOR, is below the strike rate of 6%. The payoff profile of this capped liability is illustrated in Exhibit 67-1. Because the annual amortized premium of the cap is 52 basis points, the maximum rate associated with the capped liability at a strike of 6% is 6.52%. In interest-rate scenarios where the value of three-month LIBOR is below 6%, the interest expense of the capped liability is higher than the unhedged interest expense by the amount of the amortization of the up-front premium. Given that the maximum risk exposure associated with the purchase of the cap is limited to the up-front premium, the dynamics of caps are similar to those of debt options. On a more specific basis, because the purchaser of the cap benefits in rising rate scenarios, the conceptual options analog is a strip of put options. However, caps can be purchased for maturities longer than those associated with a strip of puts. By increasing the strike rate of the cap, say, from 6% to 6.5%, the up-front premium (and hence the annual amortized premium) can be reduced. However, as illustrated in Exhibit 67-2, the maximum interest expense of the capped liability increases with a higher cap strike rate.

There are several advantages associated with the use of the cap in protecting the interest expense of a floating-rate liability. The purchaser of the cap can obtain protection against higher rates and also fund the liabilities at a floating rate to take advantage of lower interest rates. In this respect, the capped liability strategy can result in a lower cost of funds than certain fixed-rate alternatives.

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2. This represents the annuity over three years (12 periods), which when discounted quarterly (1.25%) at an annual rate of 5% equals the up-front premium of 145 basis points.

EXHIBIT 67-1

Effective Interest Expense of a Capped Liability

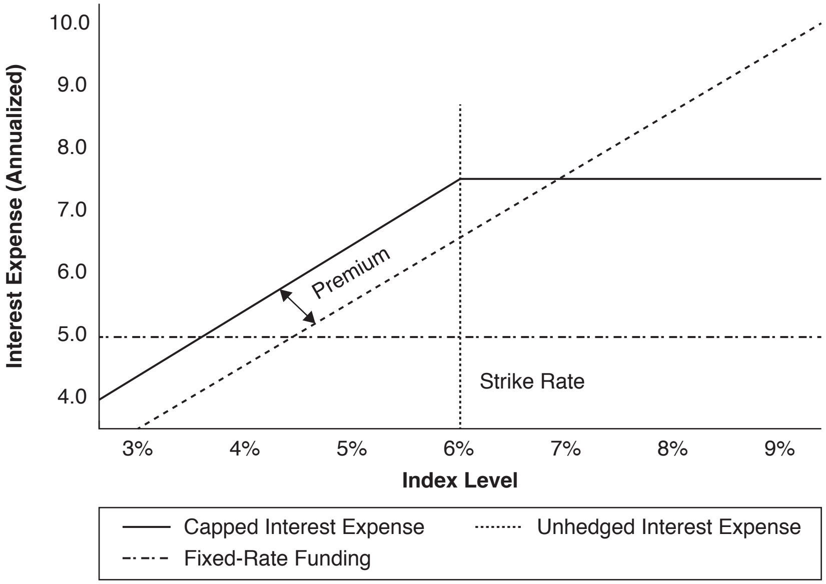
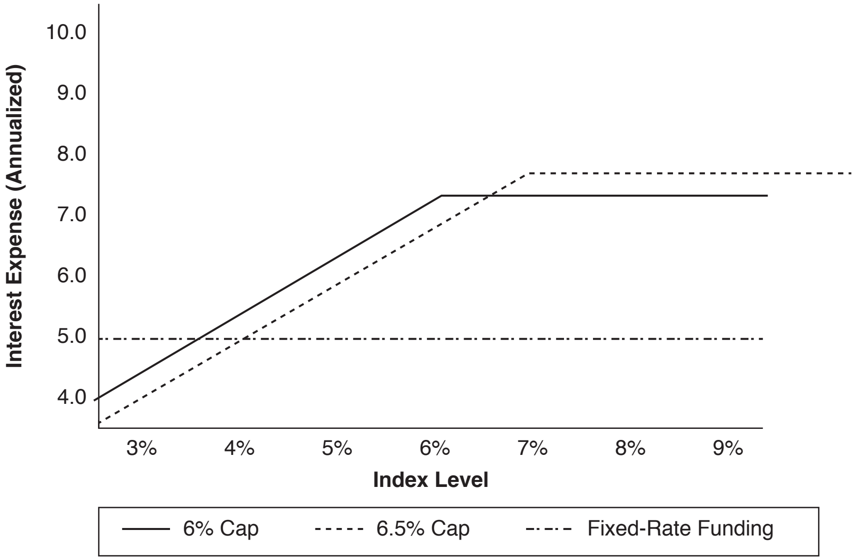


EXHIBIT 67-2

Effective Interest Cost Under Two Cap Levels



In addition to capping the cost of liabilities, interest-rate caps can also be used to synthetically offset embedded caps in floating-rate instruments such as CMO floaters and adjustable-rate mortgages. For instance, consider the case of an institution owning a CMO floater bond that reprices monthly at a spread of 60 basis points over LIBOR with an 8% cap (i.e., a maximum coupon rate) when LIBOR is at 3.0%. Because the only sources of cash flow available to CMO bonds are the principal, interest, and prepayment streams of the underlying mortgages, CMO floaters must be structured with a cap that is set at the time of issuance. The institution could strip off the embedded cap in the CMO floater by buying a cap at a strike rate of 7.4% (i.e., the LIBOR rate at which the coupon cap will be reached). With a strike rate that is 440 basis points out of the money, the cap could be purchased fairly inexpensively. If LIBOR exceeds 7.4%, the loss in coupon by the embedded cap feature of the CMO bonds would be compensated by the cash inflows from the cap. The same strategy could be applied to strip caps inherent in adjustable-rate mortgages. However, the exercise of stripping caps associated with adjustable-rate mortgages is somewhat more difficult because the product is typically associated with both periodic and lifetime caps. While there is theoretical appeal in this strategy, the efficacy of the process may be hampered by the presence of multiple caps as well as the unexpected prepayments associated with the assets.

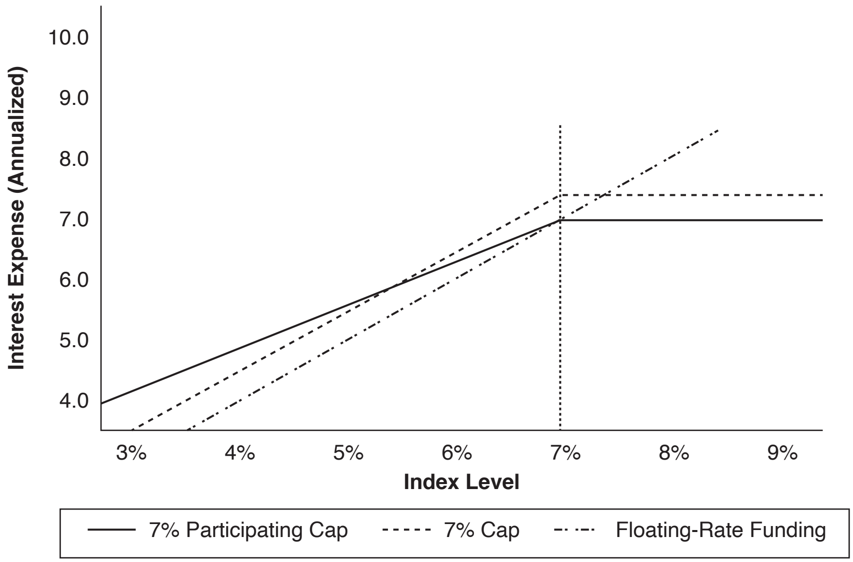
PARTICIPATING CAPS

It is difficult to pinpoint the exact nature of financial instruments labeled as participating caps. A common theme in the definition of such instruments is the absence of an up-front fee used to purchase the cap. The confusion in definition arises from the variations of the term *participating*. One type of participating cap involves the purchase of cap protection where the buyer obtains full protection in the event that interest rates rise. However, in order to compensate the seller of the cap for this bearish protection, the buyer shares a percentage (the participation) of the difference between the capped rate and the level of the floating-rate index in the event that interest rates fall.

For illustrative purposes, assume that a firm purchases a LIBOR participating cap at a strike rate of 7% with a participation rate of 60%. If LIBOR increases to levels greater than 7%, the firm will receive cash flows analogous to a nonparticipating cap. However, if LIBOR is below the capped rate, say, 5%, then the firm gives up 60% of the difference between LIBOR and the capped rate, that is, (7% – 5%) × 0.6 = 1.2%. In this case, the effective interest expense would be 6.20% (5.00% + 1.20%) instead of LIBOR plus the annual amortized premium, as in a nonparticipating cap. In bullish interest-rate scenarios, the effective interest expense using a participating cap would be higher than a nonparticipating cap owing to the participation feature. However, in bearish interest-rate scenarios, the effective interest cost of the floating-rate liability would be higher for a nonparticipating cap owing to the annualized cost of the up-front premium. An illustration of the effective interest costs using both hedging alternatives is presented in Exhibit 67-3.

EXHIBIT 67-3

Effective Interest Expense for Participating Cap



Other participating instruments, also known as *participating swaps,* combine the analytical elements of interest-rate swaps and caps to create a hedge for floating-rate liability costs. In a participating swap structure, the firm uses interest-rate swaps to convert the floating liability rate to a fixed rate and uses caps to create a maximum upper limit on the remainder of the interest expense of the floating-rate liability. However, what distinguishes this structure is that the caps are purchased without paying an up-front fee. The purchase is funded by executing the swap (fixed-rate payer/floating-rate receiver) at an off-market rate involving a higher spread than the current market rate for equivalent maturity swaps. Such participations can be structured in one of the following ways.

The buyer decides the maximum rate on the floating-rate liability, which leads to the problem of determining the mixture of notional amounts of caps and swaps.

The buyer decides on the relative mix of swaps and caps, which leads to the problem of determining the maximum rate level that can be attained with this combination.

Regardless of the choice by the buyer, the following relationship should hold in this type of participating structure:

$$\text{(Present value of annuity at } r_o - r_m, t) \times (\text{\% of swap}) = \text{Cap premium} \times (\text{\% of cap})$$

or

$$\text{Present value of annuity at } r_o - r_m, t \times (\% \text{ of swap}) = \text{Cap premium} \times (1 - \% \text{ of swap})$$

or

$$\% \text{ of cap } \frac{\text{Present value of annuity at } r_{o\,-}\, r_m, t}{\text{Cap premium} + \text{Present value of annuity at } r_{o\,-}\, r_m, t}$$

where

r_m = Current market swap fixed rate for t periods
r_o = Off-market swap fixed rate for t periods

As an example, consider the case of an institution desiring to cap a floating-rate liability expense that floats at a spread of 10 basis points over three-month LIBOR at a maximum rate of around 7% for a period of five years using this type of participating cap structure. The current market rate on a five-year pay-fixed and receive-floating (three-month LIBOR) swap is 80 basis points over the five-year Treasury yield at a rate of 4.40%. The current level of LIBOR is 4% and off-market five-year swaps are priced at a fixed rate of 5%. The cap premium for a five-year cap indexed off three-month LIBOR at a strike rate of 7% is 200 basis points, or 2% of notional amount.

The value of the annuity for five years is the difference between the off-market and the current market swap rate (that is, 5% – 4.40% = 0.60%). The present value of this annuity for five years at a discount rate of 4.40% (current swap rate) is 2.76%. Therefore, using the above equation for participating structures, the amount of the caps is defined as [2.76/(2.76 + 2.0000)] = 58%. Hence, the amount of swaps is (1 – 0.58) = 0.42, or 42%. Using this structure, the effective liability expense in various interest-rate scenarios is presented in Exhibit 67-4. In this example, the synthetic fixed rate using swaps is based on the higher off-market rate, whereas the blended rate is determined as a weighted average of the cap and the swap fixed rate.

EXHIBIT 67-4

Effective Interest Expenses Using Participating Cap Structure

LIBOR	Unhedged	Capped Rate 58% Caps	Synthetic Fixed Rate 42% Swaps	Blended Rate
6.0%	6.1%	7.1%	6.0%	6.64%
4.0	4.1	7.1	4.0	5.80
2.0	2.1	7.1	2.0	4.96

In bullish interest-rate scenarios, the blended rate is higher than the unhedged expense owing to the existence of the swap. The full benefit of the fall in rates is attained only partially by the portion of the liability mix that is capped. As interest rates increase, the blended rate is also higher than current market swaps owing to the existence of the higher-priced off-market swap that is used to fund the cap premium.

INTEREST-RATE FLOORS

Interest-rate floors are used to protect the overall rate of return associated with a floating-rate asset. As an example, consider the case of a financial institution that owns adjustable-rate mortgages in its portfolio. In the event that interest rates decrease, the coupon payments on floating-rate assets will be lower because the repricing of variable-coupon assets is based on a floating-rate index. In order to protect the asset rate of return in bullish interest-rate scenarios, the firm could purchase an interest-rate floor. Analogous to caps, the protective features of a floor can be customized by choosing various attributes of interest-rate protection. As an illustration, consider the following interest-rate floor purchased by an institution to protect the return on Treasury bill–indexed floating-rate assets:

Notional amount:	$10,000,000
Underlying index:	3-month Treasury bill
Maturity:	3 years
Floor strike level:	2%
Premium:	85 basis points or 0.85% of $10,000,000 = $85,000
Settlement frequency:	Quarterly
Day count:	Actual/360

The cash-flow dynamics of interest-rate floors are opposite to those of interest-rate caps, as illustrated in Exhibit 67-5. As can be seen in this illustration, a floor is beneficial in bullish interest-rate scenarios. Hence, purchasing a floor is analogous to buying a strip of call options. In bearish interest-rate scenarios, the floating-rate asset earns returns constrained only by the contractual features of such instruments (if any), such as embedded caps. However, the asset return is reduced marginally by the amortization of the floor premium. In bullish interest-rate scenarios, where the asset returns are subject to erosion, the seller of the floor pays the buyer the difference between the strike rate of the floor and the value of the underlying index, adjusted for the days in the settlement period to compensate for the loss in asset coupon.

INTEREST-RATE COLLARS

Interest-rate collars involve the purchase of a cap to hedge a floating-rate liability at a higher strike rate and the sale of a floor at a lower strike rate to offset the cost of purchasing the cap. If the underlying index rate exceeds the capped rate on the reference date, the seller of the cap pays the firm the amount above the capped rate; if the market rate is less than the floor strike rate, the firm pays the buyer the difference between the floor rate and the index level. If the market rate is between the strike rate of the cap and the strike rate of the floor, the effective interest costs of the firm are normal floating-rate funding costs plus the amortized cap premium (outflow) less the amortized floor premium (inflow). The net effect of this strategy is to limit the coupon rate of the floating-rate liability between the floor strike rate and the cap strike rate. The coupon liability rate is adjusted by the net amount of the amortized cap premium paid and the amortized floor premium received to determine the effective interest cost.

For example, assume that a firm has floating-rate liabilities that are indexed at three-month LIBOR. In order to cap this floating-rate liability for one year, the firm purchases an interest-rate cap at a strike rate of 8% for a premium of 85 basis points. In order to offset this cost, the firm sells a floor at a strike rate of 5% for a premium of 60 basis points. The profit and loss profile of this strategy is presented in Exhibit 67-6. As interest rates rise above the cap strike rate, the firm receives cash flows from the seller of the cap offsetting the higher outflow on the floating-rate liability. As interest rates fall below the floor strike rate, the falling interest expenses associated with the floating-rate liability are offset by the cash outflows to the buyer of the floor. In interest-rate scenarios between the floor and cap strike rate, there are no cash outflows or inflows associated with the hedges. This results in interest expenses associated with the floating-rate liability equal to normal borrowing costs. However, effective interest costs will be slightly higher to account for the net cap less floor premium, unless the collar is structured with a zero premium. In zero-premium collars, the idea is to equate the premium paid with the premium received. However, this strategy could be potentially risky as a higher notional amount may have to be sold to equate the premia. In view of this consideration, the short side of the zero-premium strategy involves notional amounts greater than the notional amount of the long side of the strategy.

The main benefit from an interest-rate collar is that the firm obtains protection from interest-rate increases at a considerably lower cost than with the purchase of a cap. However, in return for the benefit of lower-cost interest-rate protection, the firm gives up the benefit from market rallies below the floor strike rate. Because the interest-rate protection is obtained without fixing rates, interest-rate collars are sometimes also described as *swapping into a bond.* However, this is an inefficient form of creating a collar because of the bid–ask volatility spread[3] associated with the structure. Given that the strategy involves buying a cap and

3. See the discussion on termination of caps and floors later in this chapter.

EXHIBIT 67-5

Effective Return of a Floored Asset

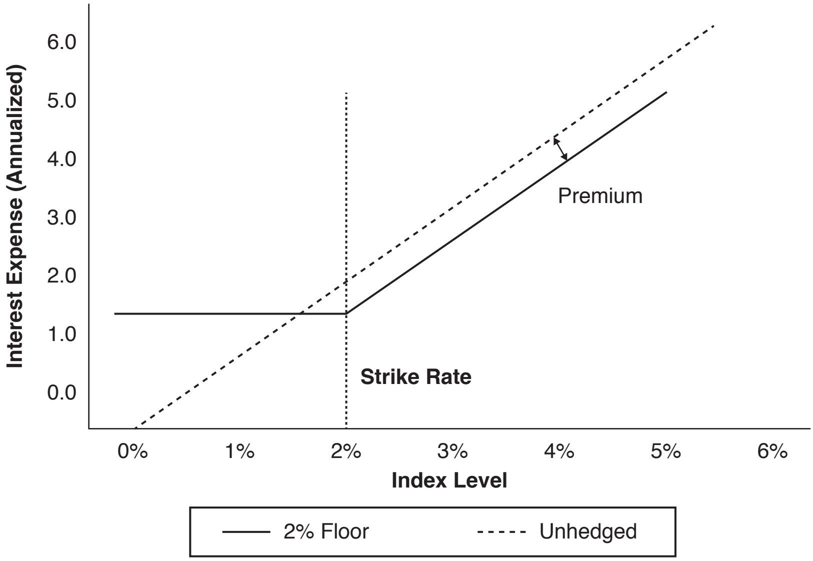
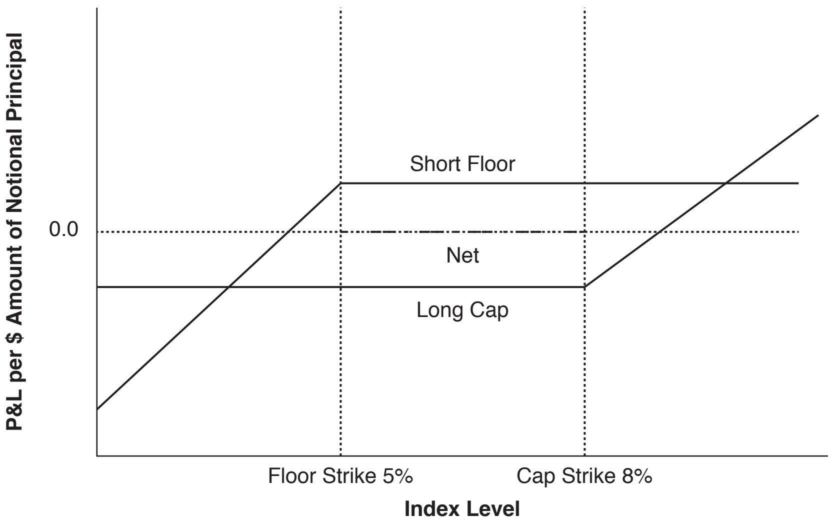


EXHIBIT 67-6

Interest-Rate Collar



selling a floor, the premium paid for the cap is based on a higher offer volatility, whereas the premium received for the floor is based on a lower bid volatility.

INTEREST-RATE CORRIDORS

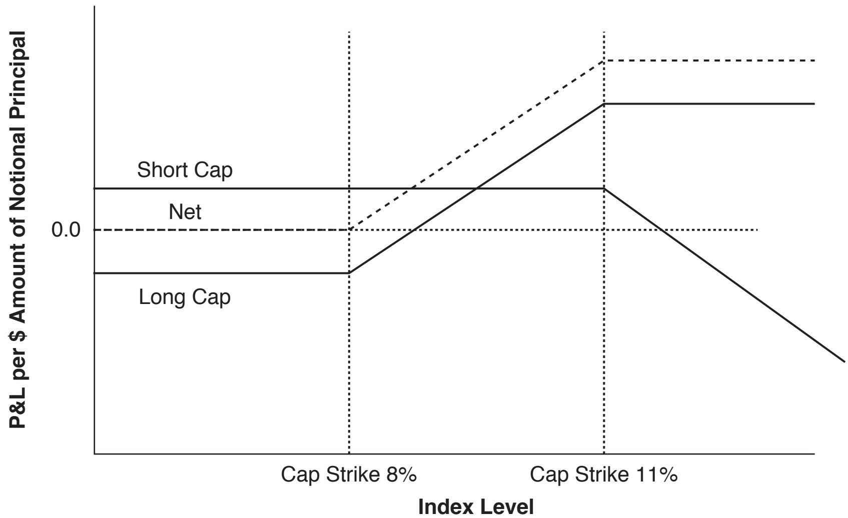
An alternative strategy to reduce the cost of the cap premium is to buy a cap at a particular strike rate and sell a cap at a higher strike rate, reducing the cost of the lower strike cap and hedging the interest expense of a floating-rate liability. In contrast to an interest-rate collar, the firm maintains all the benefit of falling interest rates, because there is no sale of a floor. As long as rates are below the strike rate of the lower strike cap, the effective interest expense of the firm is limited to normal borrowing cost plus the amortized net cap premium. As interest rates increase above the lower strike rate, the interest cost to the firm is capped until market rates are above the higher strike cap. As interest rates rise above the strike rate of the second cap, interest costs increase by the amount of the outflow of the cap.

As an illustration, consider the case of a firm that purchases a cap at a strike rate of 8% and sells a cap at a strike rate of 11% to offset the cost of the first cap. The profit and loss profile of this strategy is presented in Exhibit 67-7. At market rates below 8%, the caps are out of the money, and the firm's effective interest cost floats at normal borrowing costs plus the net amortized cap premium. As interest rates increase above 8%, the first cap is in the money and starts paying cash flows to the firm to offset the higher coupon associated with the floating-rate liability. This allows the firm to cap the effective interest expense at a rate of 8% plus the net amortized cap premium. However, at rates higher than 11%, the second cap becomes in the money, and the firm has to start paying cash flows to the cap buyer. The net effect of this development is to increase the liability costs by the amount of cash outflows associated with the second cap.

Although interest-rate corridors allow the firm to offset the cost of capping floating-rate liabilities, a word of caution is in order, especially if the caps are struck under the auspices of a zero-premium strategy. Cap premiums are determined by principles of option pricing theory; consequently, the premium received for an 11% cap will be less than the premium paid for the 8% cap because of the higher strike rate and bid–offer volatility spreads. Therefore, in a zero-premium strategy, to equate the premium received for the higher strike cap to that paid for the lower strike cap, the notional amount of caps sold must be larger than the notional amount of caps purchased. Although this allows the firm to cap the liability rate at zero cost up to the strike rate of 11%, the firm is exposed to tremendous risk in a high-interest-rate, or "doomsday," scenario. As market interest rates increase to over 11%, the cash outflows paid to the buyer of the higher-strike cap may negate any cash flows received from the lower-strike cap and result in much higher interest costs than the lower-strike cap rate. The extent of this offsetting effect will be an inverse function of the ratio of the notional amount of higher-strike to lower-strike caps—the greater this ratio, the smaller will be the effect of the cash inflows of the lower-strike cap and the higher will be the effective interest cost.

EXHIBIT 67-7

Interest-Rate Corridor



CAP/FLOOR PARITY

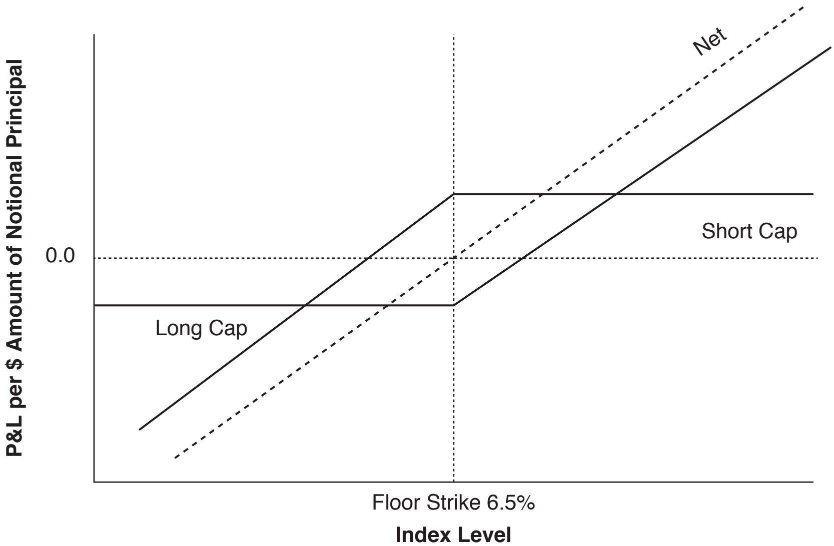
Similar to put/call parity for options, which essentially specifies the relationship between these types of options and the price of the underlying security, caps and floors are related to interest-rate swaps. As an example, consider a strategy that involves buying a cap at 6.50% and selling a floor at 6.50%, both based off the same index, for example, LIBOR. This is equivalent to entering into an interest-rate swap, paying fixed at 6.5%, and receiving floating payments based on LIBOR. If interest rates increase to above the cap level, say, 8%, the cap will pay 1.5%. At the same level, the holder of the swap will receive LIBOR at 8%. This translates into a positive cash flow of the difference between LIBOR and the fixed rate of the swap, that is, 8% – 6.5% = 1.5%. If interest rates decrease to below the floor level, say, 4.5%, the holder of the floor pays the difference between the index and the floor strike rate, that is, 6.5% – 4.5% = 2%. At the same level, the swap holder loses the difference between the swap fixed rate and LIBOR, that is, 2%. Therefore, the cap/floor swap parity may be stated as

Long cap + Short floor = Fixed swap

However, for cap/floor swap parity to hold, the fixed rate of the swap should be paid on the same basis (actual/360 days, 30/360 days, or actual/365 days) as the floating rate, not on a varying basis for the two rates. A graphical illustration of cap/floor swap parity is presented in Exhibit 67-8.

EXHIBIT 67-8

Synthetic Swap Cap/Floor Swap Parity



The cost of a market swap is zero because no premium cash flows are exchanged at inception. Therefore, using cap/floor swap parity, the cost of a cap should be the same as the cost of a floor struck at the same rate on an identical index. This relationship should hold irrespective of the pricing model used to value the caps and floors. Unless this relationship is true at every point, an arbitrage exists in these markets that could be used to emulate the characteristics of the overpriced instrument. For instance, if caps are overpriced, a synthetic cap could be created by buying a floor and entering into an interest-rate swap, paying fixed at the floor strike rate, and receiving floating using the same underlying index as the floor. Such arbitrage possibilities due to deviation from cap/floor swap parity also ensure efficient pricing in these markets.

TERMINATION OF CAPS AND FLOORS

As is apparent from the discussion on the characteristics of caps (floors), these instruments are essentially a strip of put (call) options on forward interest rates. Hence, caps and floors are priced using the same theoretical and analytical concepts involved in pricing options. The termination value of caps and floors can be determined using concepts similar to those involved in determining the market value of options (i.e., the premium) prior to expiration; by contrast to interest-rate swaps, where the termination of swaps is based on the bid–ask spread to the Treasury yield, the bid–ask spread for caps and floors is stated in terms of volatility. On a practical basis, this is a much "cleaner" method of determining bid–ask spreads in the cap and floor market than deriving forward curves using bid and ask yield spreads. In order to compensate the financial intermediary for the market-making function, the offer volatility is higher than the bid volatility. Because option premia are directly related to volatility, the difference between the offer premium and bid premium for either a cap or floor prior to maturity will be directly related to the magnitude of the spread between bid and offer volatility.

KEY POINTS

- Swaps, floors, and caps are customized risk-management instruments.
- Whereas interest-rate swaps are intended to insulate the user from changes in interest rates, caps and floors are designed to provide asymmetric coverage in capping liability costs and protecting the rate of return on assets.
- In either case, the user retains the right to participate in upside movements of the market. In order to reduce the up-front cost of purchasing caps and floors, the user can either enter into participating agreements that involve giving up a proportional share of beneficial market moves or enter into agreements, such as collars and corridors, that are analogous to option spread strategies.
- Because the termination of such agreements involves exit costs, these instruments may prove beneficial for passive hedging where interest-rate protection is desired for longer periods of time.

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CHAPTER

SIXTY-EIGHT

CREDIT DERIVATIVES

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Since the turn of the century, the credit derivatives market has become the main destination for those wishing to hedge credit risk and those looking for credit-based investments not available in the traditional cash credit markets. Two products dominate. The first is the single-name credit default swap (CDS), which transfers the default risk of a specific corporate or sovereign. The second is the CDS index, essentially a portfolio of CDS packaged into a single transaction. Together they constitute over 90% of all credit derivative transactions.

The purpose of this chapter is to set out a comprehensive description of the CDS contract, and specifically the detailed mechanics of how it works. We follow this with a detailed description of the mechanics of the CDS indices. We defer a detailed discussion of the pricing and risk management of CDS and CDS indices to Chapter 68. However, we begin with a history of the evolution of the credit derivatives market.

EVOLUTION OF THE CREDIT DERIVATIVES MARKET

The credit derivatives market began in the early 1990s as a branch of structured finance that involved creating highly bespoke transactions customized to a particular requirement. These included hedging a credit risk, creating a structured investment product, or managing the regulatory capital of both sovereign and corporate credit risk.

By the mid 1990s the concept of a CDS contract had been established. However, the market lacked standardized legal definitions for the credit events that trigger the contract, and for the protected debt obligations. This meant that pretrade negotiations between parties often required legal assistance in order to ensure that the triggering events and the hedged debt obligations were clearly defined and understood. In addition to increasing transaction costs, this meant that trades could take several days to approve and settle.

The significant growth phase of the CDS market therefore only started following the publication of the first *Credit Derivative Definitions* by the International

The author acknowledges the helpful comments of Samuel Morgan and Mark Ames.

Swaps and Dealers Association (ISDA) in 1999. This document, which became known as ISDA '99, was a response to the legal disputes that arose following the Asian crisis of 1997 and the Russian default of 1998. In addition to the new definitions, ISDA '99 also created a short-form confirmation document that required parties to simply tick a box in order to specify the characteristics of their trade. This made it possible for the market to develop a standard contract, i.e., a contract that has a certain number of characteristics that a majority of buyers and sellers can agree on and which therefore attracts the greatest liquidity. Following its adoption of ISDA '99, the CDS market began a period of very rapid expansion, growing from a total outstanding notional of $632 billion in 2001 to $62 trillion by the end of 2007.[1]

A number of important changes were made to the credit derivatives market between 2000 and 2003. Many of these changes were in response to some of the credit events that had occurred[2] after the end of the dot.com boom and the events of September 11, 2001, and addressed such issues as reference entity specification, guarantees, debt restructuring, deliverability, and successors. Of these, perhaps the most problematic, since it led to a regional split in the market standard, was in relation to the treatment of restructuring as a credit event. This is discussed in detail later.

The period from 2004 to 2007 saw the arrival of the CDS indices. These were adopted very rapidly by the market and became highly traded and highly liquid. They were particularly favored by credit investors who viewed them as a simple and cheap way to take a macro-level exposure to the credit markets, in much the same way as equity index futures permit investors to take a macro-level exposure to the equity markets.

In late 2003, the credit derivatives market established an automatic trade confirmation system at the Depository Trust and Clearing Corporation (DTCC) in New York, the aim being to speed up the confirmation of trades and to remove the backlog of unsigned confirmations that had built up. Then in late 2007, the DTCC also established itself as the keeper of the comprehensive trade database—the official legal record for all confirmed trades. It also set an infrastructure to automate and standardize post-trade processing.

The period 2008–2010 saw a considerable upheaval in the CDS market as regulators responded to the aftermath of the Lehman bankruptcy and the financial crisis. Despite the fact that there were $72 billion of CDS linked to Lehman Brothers registered at the DTCC at the time of its bankruptcy, settlement of the credit event went smoothly as it used a market-wide auction procedure.[3] Nevertheless, this event caused regulators to become very concerned about

1. These numbers come from the ISDA which conducts a semiannual survey of its members who are distributed around the world.

2. These included Argentina, Armstrong, Conseco, Enron, Marconi, National Power, Railtrack, Worldcom, and Xerox.

3. The Trade Information Warehouse at the DTCC, which handled the bulk of the triggered Lehman referenced CDS contracts, reported no failures to perform.

systemic risk in the financial sector caused by the large number of outstanding contracts and a lack of transparency with respect to where the actual credit risk was sitting.[4]

In an attempt to reduce counterparty risk, regulators decided to require standard credit derivatives trades to be assigned to a centralized counterparty (CCP). To prepare the ground for these changes, the market introduced some new legal protocols. The first protocol, known as “Big Bang,” was introduced in April 2009 and made the following changes:

1. Creation of a market-wide determinations committee (DC) charged with determining whether or not a credit event has occurred.
2. An automatic market-wide auction mechanism for the settlement of triggered CDS contracts following all credit events with the exception of restructuring.
3. Moving the date on which the CDS credit event protection[5] begins to the date 60 days before the date on which the request to consider whether a credit event has occurred is made to the determinations committee. This change was made in order to ensure that all existing contracts are triggered by a credit event even if the contract was initiated after the credit event occurred, but before the credit event had been determined.

At the same time, there was also a recouponing process in which the market switched to trading all CDS contracts on each credit with the same coupon irrespective of when the trade was done. This differed from the previous convention in which the coupon on a CDS was set at trade initiation in order to ensure that the contract had zero initial value. The market has also changed so that standard contracts now trade with a full first coupon, i.e., the first coupon starts accruing on the previous coupon payment date even if it is traded mid-period. Both changes have been made in order to increase the fungibility of contracts and to facilitate contract netting as a precursor to the centralized clearing of CDS contracts.

In late 2009, a second protocol known as “Small Bang” was adopted. This extended the “Big Bang” protocol to deal with the restructuring event as a trigger for the CDS. This protocol was intended for the European CDS market since restructuring is not a standard credit event in the North American CDS market

At the start of 2010, the DTCC formally linked itself to the Federal Reserve System where it is expected to fall under a global oversight framework involving U.S. and international regulators. The initiative to move credit derivative trades

4. It is worth noting that of the more than 900,000 OTC derivative contracts on Lehman’s trading books, only one has been challenged due to an open confirmation. See *Report of the Financial Crisis Inquiry Commission* at http://www.fcic.gov/report.

5. For a succession event, the legal protection begins 90 days before the request.

onto CCPs was well underway, especially for CDS indices, with over $15 trillion of index trades already cleared by ICE in North America and Europe by early 2011. The first CDS to be cleared via a CCP and in compliance with the new Dodd-Frank regulations was traded in February 2011. Although most CCPs are based at exchanges, trading in the CDS market trades continue to be executed in the OTC market. The CCP then steps into the trade, placing itself between the two initial parties.

As of 2011, the size of the CDS market and CDS index markets is roughly half what it was at the market peak in 2007. A significant part of this decline can be attributed to the numerous compression cycles (discussed below) that have been carried out in the last two years. Some of it may also be due to the decrease in CDS-based and CDS index–based hedging activities of more exotic credit derivatives, in particular synthetic CDOs. Indeed a snapshot of the credit derivatives market in early 2011 shows that CDS made up 57% of the gross notional of credit derivatives, whereas CDS indices made up 34%, leaving just 9% to other transaction types.[6]

Market Participants

Since its inception, the credit derivatives market has been dominated by commercial and investment banks. Commercial banks have used CDS to hedge the credit risk of their loan book. The advantage of CDS is that they permit the bank to hedge the risk of a specific loan privately and bilaterally. This is often preferred to selling the loan because the sale of a loan by a bank usually requires the bank to notify the borrower and such a sale may be considered to be a negative signal by the borrower and as such may be damaging to the bank–borrower relationship. Surveys of the credit derivatives market have generally found that commercial banks buy more protection than they sell as their loan book hedging requires them to be net protection buyers. Their reason for selling protection is to earn income and diversify their portfolio credit exposure.

Investment banks and the dealer arms of commercial banks play an important role in the credit derivatives markets where they act as dealers. Overall they tend to run balanced books with equal amounts of protection bought and sold.

Insurance companies are also an important user of credit derivatives, primarily as a form of investment on the asset side of their business where they tend to be net sellers of protection. Hedge funds are an important market participant as they are able to play the credit markets from a long or short position and they also tend to buy roughly as much protection as they sell. They are particularly attracted by the ability to go short and the ability to leverage as the upfront payment needed to enter a CDS contract is typically much smaller than the contract notional.

Other users of the market with a lower market share include pension funds, mutual funds, and companies. Funds may be more interested in CDS indices in

6. These numbers are based on a snapshot of market positions on February 11, 2011, taken from the DTCC Trade Information Warehouse Reports.

particular, as they provide a quick way to establish a diversified macro credit exposure onto which they can then add specific credit exposures.

The use of credit derivatives by companies is generally quite bespoke as it may be connected with a need to hedge or assume a very specific credit exposure that they may not wish to sell or cannot find in the bond market. For example, a company may use a CDS to hedge the credit risk of future receivables from a specific company.

Uses of Credit Derivatives

The considerable growth in the size of the CDS and CDS index market has been driven by its various uses. These are as follows:

- *Transferring credit risk:* CDS are first and foremost a tool used to transfer credit risk from one party to another. For example, banks can use CDS to transfer loan credit risk off their balance sheets into the capital markets where this risk may be assumed by an investor. This creates new loan capacity on their balance sheet.
- *Hedge credit risk:* Before the advent of CDS, it was difficult to hedge an existing credit risk by shorting corporate bonds. Buying protection using a CDS is a much easier way to achieve the same objective. CDS indices can also be used as a hedge against changes in the market-wide pricing of credit risk and also the default of individual reference entities.
- *Customization:* As the CDS market is a bilateral OTC market, parties can structure the features of a CDS in almost any way they wish. Features that can be varied include the currency, maturity, and seniority. The more the customization deviates from the market standard, the greater the associated cost and the lower the subsequent liquidity.
- *Ease*: A CDS index makes it simpler for an investment manager to assume an exposure to a diversified portfolio of credits in one transaction. The tight bid/offer spread also makes the cost of unwinding the position cheaper than the cash equivalent.
- *Leverage and yield enhancement:* A CDS and a CDS index typically require only a small upfront payment. This makes it easier to leverage the underlying risk and return compared to a fully funded cash bond.
- *Pure credit play:* The CDS and CDS index are almost a pure credit play since unlike fixed-rate corporate bonds, they have very little interest-rate sensitivity. This isolation of the credit risk is attractive for credit fund managers.
- *Risk decomposition:* CDS can be used to hedge out specific risks in securities with multiple risks. For example, they can be used to hedge

out the credit risk of convertible bonds in an attempt to isolate the economics of the embedded equity option.

- *Speculation:* CDS enable market participants to express a positive or negative view on an underlying credit while a CDS index makes it possible to go long or short macro-level credit.
- *Structured credit investments:* CDS can be used as the building blocks for more exotic structured credit investments that are created to provide a more tailored risk-return profile to specific types of investor.
- *Manage regulatory capital:* Banks can use CDS to hedge credits that have a high regulatory capital charge, provided such a hedge is recognized as being economically effective by regulators.

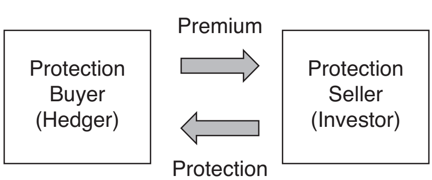
THE CREDIT DEFAULT SWAP

The simplest way to think of the CDS is as an insurance contract in which one party, the "protection buyer," pays a premium to be protected against a credit loss on a specific face amount of bonds or loans issued by a specified corporate or sovereign reference entity. The other party, known as the "seller of protection," receives the premium and takes on the credit risk. Since there is a buyer and a seller of the credit risk, a CDS contract does not create credit risk, it simple transfers it from the protection buyer to the protection seller as shown in Exhibit 68-1. However, unlike an insurance contract, a CDS is a traded contract that can be valued at any time. The protection seller is any investor who takes a view that the premium is attractive given his or her view of the risk of default of the reference entity.

Care needs to be taken when trading CDS to be clear about to which side of the contract we are referring. In the market, "buying" a CDS contract is usually associated with buying protection. However, buying protection is economically equivalent to shorting credit risk or selling a corporate bond issued by the reference entity. Equally, "selling" a CDS contract is economically equivalent to assuming credit risk and so is akin to buying a corporate bond issued by the

EXHIBIT 68-1

A CDS Is a Bilateral Contract Between a Protection Buyer and a Protection Seller



reference entity. Indeed we will demonstrate this equivalence in Chapter 69. To avoid misunderstandings, the term *buying a CDS* should always be qualified with the word *protection;* that is, *buying CDS protection*. Equally *selling a CDS* should be qualified as *selling CDS protection*. Note that this differs from the CDS index market, in which the "buyer" is usually an investor who is selling protection on the underlying portfolio of CDS. This is another reason why clarity is essential in order to prevent confusion.

CDS MECHANICS

As just stated, the purpose of the contract is to transfer the *credit event* risk of a specified face value amount of debt obligations issued by a stated *reference entity* (a corporate or sovereign) from the protection buyer to the protection seller.

The debt obligations covered by the contract are known as the *deliverable obligations* and these are usually bonds and loans of a specified seniority. This seniority is defined by specifying a *reference obligation* of the issuer with respect to which the deliverable obligations should be senior or *pari passu*. If a credit event occurs, then the protection buyer will receive a payment, which is economically equal to the difference between the price of the impaired deliverable obligations and par.

The reason for protecting a basket of deliverable obligations rather than a specific obligation is that it enhances the liquidity of the market because the same contract can be used by hedgers to protect themselves against any one of many obligations of the issuer. If the market were to trade CDS on each specific debt obligation of the issuer, then liquidity and fungibility would be reduced and the cost of protection would almost certainly increase. However, there is a negative side effect because the protection buyer has the right to choose which bond is protected by the contract. He is therefore long a *delivery option*. The effect of this and how it is treated is discussed below in the section on restructuring-type credit events.

To enter into a CDS, a party trades via a dealer. This is done via the telephone or an electronic trading system. At initiation, the party usually makes an upfront payment that (depending on various factors discussed below) can be positive or negative, i.e., the payment could be from the protection seller to the protection buyer or vice versa. The model used to determine the upfront value is set out in detail in Chapter 69.

Credit protection starts on the *effective date*. Prior to the 2009 "Big Bang" protocols, this was the calendar date immediately following the trade date. However, under the new protocols, protection now begins 60 days before any request to consider whether a credit event occurred is made to the determinations committee. This change was made to ensure that all existing contracts would cancel out irrespective of whether they were traded yesterday or last year. This can create a rather strange scenario in which a protection buyer can buy protection *after the credit event* and be paid out. However, this is not as anachronistic as it may seem since the protection would have to be purchased before the credit event was determined. Also, if the information that a likely credit event had occurred was already public at the time of the purchase then the cost of the protection would have been high and close to its post-credit event determination value.

Credit protection lasts until the scheduled termination date, more commonly known as the CDS maturity date. This will fall on one of the following dates: March 20, June 20, September 20, or December 20 of a specified year. These dates are not adjusted for holidays if they fall on a weekend. They are known as the *CDS Dates*. What this means is that at any moment in time, the scheduled termination date of the most liquid T-year CDS contract will be on the first CDS Date that falls after the date exactly T years in the future. So, for example, on April 3, 2011, the standard five-year CDS contract has a scheduled termination date of June 20, 2016. The most liquid contracts have terms of 1, 3, 5 7, and 10 years, with greatest liquidity focused on the 5-year contract.

The Premium Leg

To pay for the credit protection, the protection buyer pays the protection seller a combination of an upfront payment (which may be negative) plus a regular fixed coupon. These payments are known as the *premium leg* of the CDS. Here we will discuss the fixed coupon, deferring the discussion of the upfront payment to the end of this section.

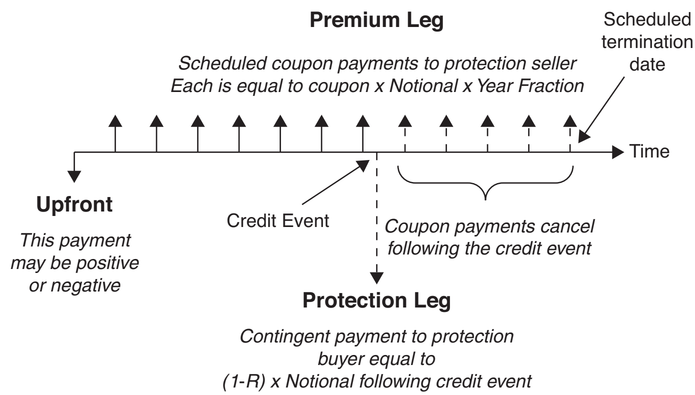
The fixed coupon is specified at contract initiation and determines the size of the quarterly regular payments from the protection buyer to the protection seller. The size of each actual cash payment is calculated by multiplying the fixed coupon by the contract notional. This is then multiplied by the year fraction between the current and previous coupon date calculated according to an actual 360-day count convention.

Before 2009, the size of this coupon depended not just on the reference entity but also on when the CDS trade was initiated. This was because the coupon was set such that the value of the CDS contract at inception was zero, thereby requiring no upfront payment. However since 2009, contracts linked to each issuer now have a fixed coupon irrespective of when they were traded. As a result, the price of the credit risk is not reflected in the size of the coupon, but in the size of the upfront payment.

The exact details of how the premium schedule is calculated are beyond the scope of this section, although more information can be found in Chapter 69. However, it is worth noting that since 2008, the market standard is for contracts to trade with a full first coupon even if they are traded between two coupon payment dates. This enables a new contract to always have exactly the same cash flows as another existing contract with the same maturity date. This is discussed with specific examples in Chapter 69.

EXHIBIT 68-2

The Premium and Protection Legs of a CDS



Note: In this example we have a three-year CDS contract with quarterly coupon payments on the premium leg.

A key feature of the premium leg is that the payments terminate following a credit event. This is shown in Exhibit 68-2. All that is paid by the protection buyer on the premium leg is the amount of coupon that has accrued between the previous coupon payment date and the credit event. This feature of a CDS means that once a credit event has occurred, the premium leg terminates and the contract can be closed out.

The Protection Leg

The other leg of the CDS is the *protection leg,* also known as the contingent leg. This is the payment from the protection seller to cover the loss on the face value of debt, which is only triggered if there has been a credit event. Economically, the value of the payment equals par minus the recovery price of the deliverable obligations. Determination of the size of the recovery price or value is now done using a market-wide auction process that is discussed in detail below.

The market provides two mechanisms for the protection seller to effect the payment of protection. Either the protection seller can choose to pay a cash amount equal to par minus the recovery price determined by an auction, or the protection seller can request physical settlement, which means that they will pay the contract notional in cash and receive the corresponding face value of deliverable obligations at the price determined by the auction.

There are also two mechanisms for the protection buyer to receive the payment of protection. Either the protection buyer can choose to receive a cash amount equal to par minus the recovery price determined by the auction, or the protection buyer can request physical settlement, which means they will receive the notional amount in cash and deliver the corresponding face value of deliverable obligations at the price determined by the auction.

The protection buyer who elects for physical settlement can choose which deliverable obligations to deliver. They are long a "delivery option" whose value depends on the range of prices of the deliverable obligations. The protection seller who has chosen physical settlement has to accept what is delivered. This is discussed in more detail below.

The Upfront Payment

The cost of protection is paid for through both the payment of the fixed coupon on the premium leg of the CDS and through upfront payment. This is the cost that has to be paid in order to enter into the CDS contract and may be positive or negative. Whether it is positive or negative depends primarily on whether the party is buying or selling protection and how the market perceived credit quality of the reference credit compares with the fixed coupon on the CDS. The market perceived credit quality of the reference credit is captured by the CDS "quoted" spread, which is defined in detail in Chapter 69.

For example, consider a short protection CDS position on a credit that trades with a fixed coupon of 100 bp, but whose credit quality has recently deteriorated so that its CDS market quoted spread is currently 160 bp. This will require an upfront payment as the protection buyer will pay cash to the protection seller in order to offset the fact that the coupon is not high enough to compensate the protection seller for the market perceived credit risk of the reference credit. Before 2009, this contract would have had no upfront cost, as it would have paid a coupon of 160 bp.

Once a CDS has been traded, its mark-to-market value begins to change due to changes in the market view of the credit risk of the reference entity as expressed by the quoted spread and changes in interest rates.

For those familiar with the valuation of CDS contracts before the introduction of fixed coupons, the valuation and risk management has not changed in any significant way. Once the contract has traded and the upfront payment made, the value of the contract looking forward is identical to before. For example, consider a long protection CDS contract with a coupon of 100 bp in which the current quoted spread is 160 bp. This will have a positive value for the protection buyer as he is paying only 100 bp for protection, which the market now considers to be worth 160 bp. However we do not have enough information to determine whether the position has a positive P&L (ignoring for a moment the impact of coupons paid) since this depends on the upfront value when the contract was entered into. Before the arrival of fixed coupons, the coupon on the CDS would have told us the spread when the contract was initiated and as the initial cost would have been zero, the mark to market of the CDS would, excluding coupons, be the P&L of the position.

The valuation and risk management of a CDS are covered in Chapter 69.

CREDIT EVENTS

The *credit event* is the term used by the credit derivative market to define each of the events that can trigger the payment of the CDS protection. Companies can default or enter into a restructuring. The situation is even more complicated for sovereign debt since countries do not formally file for bankruptcy. Instead they can default in a number of different ways, for example, by repudiating their debt or by re-denominating their foreign currency debt. The standard credit events used in CDS need to be broad enough to encompass this range of scenarios. A list of the main such credit events is provided in Exhibit 68-3.

In Exhibit 68-3 we have stipulated which credit events are "hard" and which are "soft." This designation refers to what happens to the debt obligations of the reference entity following the credit event. For most credit events, the debt becomes immediately due and payable. This means that all debt obligations, irrespective of maturity and coupon, which are *pari passu* with each other have an equal claim on the remaining value of the company and so should trade at the same price. These are what we call *hard credit events*.

EXHIBIT 68-3

The Main Credit Events Used in the CDS Market

Credit Event	Hard or Soft	Description
Bankruptcy	Hard	Corporate becomes insolvent or is unable to pay its debts.
Failure to pay	Hard	Failure of the reference entity to make due payments, taking into account some grace period.
Obligation acceleration	Hard	Obligations have become due and payable earlier than they would have due to default and have been accelerated. This event is used mainly in the case of emerging market sovereigns.
Obligation default	Hard	Obligations have become due and payable prior to maturity. This event is used rarely.
Repudiation/ Moratorium	Hard	A reference entity or government authority rejects the validity of the obligations. This is used for sovereign credits.
Restructuring	Soft	Changes in the debt obligations of the reference entity which result in a credit deterioration for the debt holders.

The Restructuring Credit Event

There is only one soft credit event. This is the event of restructuring in which a company does not file for bankruptcy but agrees with its creditors a consensual restructuring of its debt obligations, but in a way that has a negative impact for the creditors.

The restructuring credit event refers to out-of-court pre-insolvency restructuring that usually requires the unanimous approval of all impaired creditors. Since the company continues to trade as a going concern, debt does not become immediately due and payable. Therefore, a restructuring credit event does not cause all *pari passu* debt to trade at the same price and so the debt obligations continue to trade with prices that take into account a term structure, and coupon effects (i.e., higher coupon bonds trade at a higher price than lower coupon bonds of the same maturity).

The reason why we single out soft credit events is that they present a delivery option for the protection buyer. Recall that the protection buyer can choose which obligations they wish to deliver from a basket of possible deliverables. As the deliverable obligations continue to trade at different prices caused by different coupons and maturities, there may be some value in the delivery option, and the protection buyer will always be motivated to deliver the cheapest bond or loan he can find.

As a result, if the debt obligations held by the protection buyer are not the cheapest to deliver, it will be economically preferable to sell these in order to buy the cheapest to deliver, gaining the price difference as a windfall gain. The act of always delivering the cheapest deliverable causes the protection seller to take a larger loss than if another deliverable had been chosen.

Such a situation occurred following the restructuring of the debt of the U.S. insurer Conseco Inc. in 2000. In this case, banks that held short-maturity loans that were not particularly impaired by the restructuring, and which had bought CDS protection on these loans, were able to sell these loans for close to par and use the proceeds to purchase deep discount bonds trading in the $65 to $80 range, which they could then deliver in return for par. They were therefore able to make a windfall gain at the expense of the protection sellers.

Following this, complaints were made by Conseco protection sellers. This resulted in the introduction of a new clause that formed part of the revised CDS documentation released in 2001. Called the *modified-restructuring (Mod-Re) clause,* it was intended to reduce the value of the delivery option following a restructuring by reducing the range of deliverable obligations in the basket. This was done by restricting the maturity of the deliverable obligations. This clause only applied to the North American CDS market.

In 2003, Europe followed by introducing its own restructuring clause. As it was a variation of the North American clause, it was known as *modified-modified restructuring (Mod-Mod Re).* These regional differences were due to the differing requirements of the local financial regulators and the differing importance of banks versus investors in the different regions.

We now have three different restructuring clauses, each with its own restrictions on the maturity of the deliverables. These are as follows:

- *Old-Restructuring (Old-Re):* This is the pre-2003 standard which only imposes a 30-year maturity limit on deliverables.
- *Modified-Restructuring (Mod-Re):* The exact maturity limits of the Mod-Re deliverable obligations are quite complicated. A rough and ready approximation is that the deliverable obligations cannot have a maturity longer than the greater of the scheduled termination date of the CDS and the restructuring date plus 30 months. If we use RMLD to denote the restructuring maturity limitation date then

$$\text{RMLD} = \text{Max}\ [\text{TD}, \text{RD} + 30 \text{ months}]$$

  where TD is the scheduled termination date of the CDS contract and RD is the date of the restructuring event.
- *Modified-Modified Restructuring (Mod-Mod Re):* This is similar to modified restructuring. The difference is that the formula for the restructuring maturity limitation date is given by

$$\text{RMLD} = \text{Max}\ [\text{TD}, \text{RD} + \text{A}]$$

  where A equals 60 months for restructured obligations and 30 months for nonrestructured obligations.

There is a fourth alternative, which is to remove restructuring from the list of credit events. This is simply called No-Restructuring (No-Re). The situation as of early 2011 is summarized in Exhibit 68-4.

EXHIBIT 68-4

The Standard Credit Events by Region for CDS and CDS Indices

Geographic Region	Credit Events in Standard CDS and CDS Index Contracts
North America*	Bankruptcy Failure to pay
Europe	Bankruptcy Failure to Pay Restructuring according to Mod-Mod Re
Asia	Bankruptcy Failure to Pay Restructuring according to Old-Re

*The Standard North American Contract is known as SNAC.

Settlement of a Credit Event

Ultimately, the post-credit event settlement of a CDS contract is all about determining the final recovery price for the deliverable obligations. This is done via an auction. The main objectives of the auction process are as follows:

1. To be able to handle cases in which the notional of protection bought approaches or exceeds the total outstanding notional of deliverable obligations. In this case there can be a short squeeze as protection buyers who do not own deliverables attempt to buy these obligations in order to settle their contracts. In the past this has led to the prices of deliverable obligations to rise after the credit event as protection buyers rush to buy them in order to deliver them.
2. To ensure that the recovery price is the same across the entire CDS market. This is necessary if market participants who are both long and short protection to the same maturity on a reference credit are to be sure that they will be hedged. This requires a common recovery price to be set via a public auction procedure described below.
3. To handle the soft restructuring credit event. Recall that hard credit events cause all of the *pari passu* debt obligations to trade at the same price. However following restructuring credit events, the debt obligations continue to trade with a term structure and the value of this delivery option led to the introduction of the Mod-Re and Mod-Mod Re restructuring clauses as described earlier. The auction needs to be able to handle these restructuring clauses.

As we shall see, these requirements have all been met by the procedure that we now describe in detail.

THE CDS SETTLEMENT TIMELINE

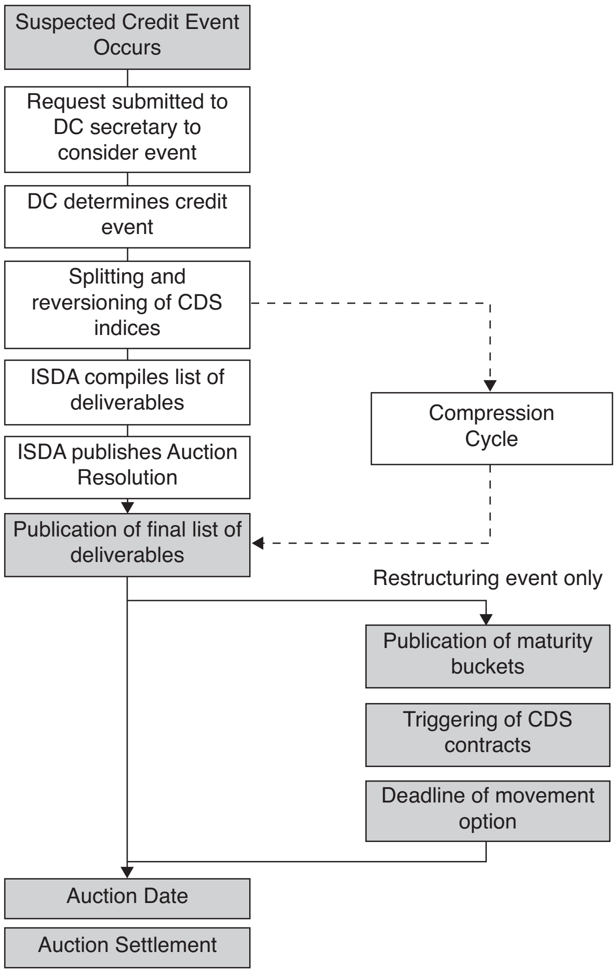
We now set out the mechanics of settlement of a CDS contract once a credit event has occurred. Many important changes have been made to these mechanics over the past few years. To provide an overview, Exhibit 68-5 shows a timeline of the different stages that begin with credit event determination.

Credit Event Determination

Until 2009, the determination of whether a credit event had occurred was a bilateral decision that involved the protection buyer sending the protection seller evidence that a credit event had occurred. This evidence would consist of publicly available information such as newspaper or wire service reports of a bankruptcy,

EXHIBIT 68-5

Timeline for a Credit Event



failure to pay, or restructuring.[7] In most cases in which the source of the information was reputable and the events described clearly satisfied one of the specified credit events, the contract would trigger.

However, in cases in which the information was not public, was unclear, or was contested, there was a risk that different pairs of parties could come to different conclusions. This would be a problem for hedged intermediaries who would find

7. Or any other form of credit event included in the contract.

that one contract might be triggered but the offsetting contract would not, or that the recovery rate on one contract was not the same as the recovery rate on the offsetting contract, generating an unexpected gain or loss.

To address this concern, the market introduced a new credit event determination procedure as part of the legal protocols ushered in by the 2009 Big Bang. This introduced a new body known as the *determinations committee* (DC) that is tasked with the job of determining whether a credit event has occurred. In actual practice there are five such DCs, one for each of the following: the Americas, Asia (excluding Japan), Japan, Australia-New Zealand, and EMEA (Europe, the Middle East, and Africa).

In order to remove any bias and to ensure that decisions are not finely balanced, the membership of each committee consists of both buy-side and sell-side representatives, and the approval of decisions of the committee requires an 80% supermajority.

The credit event determination process begins when any market participant who has signed up to the new credit derivative protocols introduced in 2009 makes a request to the secretary of the DC to investigate whether a specific reference credit has experienced a credit event. This request should be accompanied by a notice of publicly available information reporting that a credit event may have occurred. The DC then has two business days to meet, investigate, and then vote on whether a credit event has occurred. If more time is needed, they can vote to extend this time period.

Once the credit event has been determined and it is a hard credit event, all CDS contracts linked to this reference credit are automatically triggered. This is a change from the pre-Big Bang procedure in which one of the parties to the CDS would choose to trigger the contract.

However if the credit event is determined to be a restructuring, either the protection buyer or the protection seller must choose to trigger the contract. Furthermore, the exact constituents of the basket of deliverable obligations depend on which party triggered first. This is discussed in more detail below.

The rationale for not making the triggering automatic is that restructuring is not a bankruptcy event but could be a precursor to one. As a result, a protection buyer may prefer not to trigger, thereby keeping the CDS protection "alive" for a later and possibly lower recovery hard credit event.

The Compression Cycle

One of the recent innovations of the credit derivatives market has been the use of what has become known as the "compression cycle." This is a procedure designed to enable groups of counterparties to cancel out mutually offsetting positions. This process is run periodically (typically once a quarter) across the entire credit derivatives market.

Although previously a rather ad hoc procedure, it has also become an important stage in the settlement of a credit event, where it is run across the relevant CDS contracts after it has been determined that a credit event has occurred and before the auction begins. However, this is only done for those contracts held by dealers who choose to participate in the compression cycle. The effect of running the compression cycle is to reduce the number of contracts that have to participate in the subsequent auction. This will reduce the amount of physical assets needed to settle the credit event.

The main provider of this compression service is a company called TriOptima. A third party is used to provide this service because compression is all about the cancellation of sets of contracts between three or more dealers. To do this, the parties either need to reveal their full positions list to each other or they need to involve a neutral third party. Dealers prefer the latter, and so introduce a third party to collect the information on the condition that they do not disclose position data to the other parties.

An algorithm is run that calculates the specific set of transactions that if executed would most reduce the outstanding number of contracts. These transactions are then reported back to the dealers who then can choose whether or not to execute them. Between 2008 and 2010, this compression process eliminated around $14.5 trillion of credit derivative contracts from the market.

Deliverables for a Nonrestructuring Credit Event

Within a short period of the credit event being determined by the DC to be a hard credit event, the DC publishes a timetable of when the credit event was determined, when the auction will be held and when the auction will be settled. A list of the deliverable obligations is also published.[8] For hard credit events, there is just one auction as there is just one basket of deliverables for all CDS contracts since the maturity limitation is at 30 years.

Deliverables for a Restructuring Credit Event

When the credit event is a restructuring, the situation depends on the region. In North America, there is no restructuring credit event in standard contracts and so there is only one auction. In Asia, the use of the old-restructuring convention means that there is only one basket for all contracts. In Europe, the situation is more complicated. The market standard is to include a restructuring credit event. However the standard restructuring clause is modified-modified restructuring in which the basket of deliverables depends on the scheduled termination date of the CDS contract.

The purpose of the standard modified-modified restructuring clause found in European CDS contracts is to limit the basket of deliverables in order to reduce the value of the delivery option. In approximate terms, the restructuring maturity limitation date for a deliverable into a CDS contract with a scheduled termination date (TD) is given by

$$\text{RMLD} = \text{Max}\ [\text{TD}, \text{RD} + 60\ \text{Months}]$$

8. All of this information is publicly available on the ISDA website: http://www2.isda.org/.

for restructured obligations, and

$$\text{RMLD} = \text{Max}\,[\text{TD}, \text{RD} + 30 \text{ Months}]$$

for nonrestructured obligations. In both cases the basket of deliverables depends mainly on the TD of each CDS contract.

Reconciling this restructuring clause with an auction mechanism presents an immediate difficulty. If the reference credit has a large number of deliverable obligations distributed across the maturity spectrum, it is possible that there will be a different basket of deliverable obligations for each possible CDS scheduled termination date. Given that the longest maturity CDS contracts have a scheduled termination date in around 10 years, and given that CDS scheduled termination dates are quarterly, this implies that we could have more than 30 distinct baskets of deliverables[9] for a given reference entity. However, holding this many auctions in parallel would be organizationally burdensome. It would also split the universe of relevant contracts across many auctions, resulting in a loss of liquidity and price competition in each auction.

To overcome this problem, the market has decided to run a maximum of eight different auctions by assigning each CDS contract to one of eight maturity buckets. The buckets and what they contain are listed in Exhibit 68-6. In practice, fewer than eight buckets may be used if a lack of deliverables across the maturity spectrum means that two or more buckets are identical. In this case only the earliest of these buckets will have an auction. In addition, a minimum liquidity requirement states that an auction will only be held if 300 or more contracts

EXHIBIT 68-6

The Maximum Set of Auction Buckets Used After a Restructuring Credit Event

Bucket
Nonrestructured debt obligations out to 30 months and restructured debt obligations out to 5 years;
All deliverable obligations to 5 years;
All deliverable obligations to 7.5 years;
All deliverable obligations to 10 years;
All deliverable obligations to 12.5 years;
All deliverable obligations to 15 years;
All deliverable obligations to 20 years; and
All deliverable obligations to 30 years.

9. Out to 30 months there is just one bucket according to Mod-Mod Re. Beyond 30 months, the remaining deliverable buckets depend on the contract scheduled termination date. These are quarterly so for example could be in 33, 36, 39, …, 120 months giving a total of 1 + 30 = 31 buckets.

linked to that bucket are triggered and if there are five or more dealers who are party to these transactions.

If a bucket is not used, then the protection buyer and seller have a *movement option*. This allows the protection buyer to choose to move the contract to use the next earliest maturity bucket. The protection seller also has a movement option and can also choose to move the contract to the longest maturity 30-year bucket. If both parties wish to exercise the movement option, then the protection buyer's decision is the one that takes priority.

Prior to the auction, each CDS contract must be assigned to one of these buckets. To simplify matters, one of the duties performed by the DC is to calculate and publish a table that maps ranges of scheduled termination dates to specific buckets. However, there is one final step before CDS holders know which maturity bucket, and hence which auction, is relevant to their contract. This is the triggering decision.

Restructuring: Triggering a Credit Default Swap

Unlike hard credit events, the triggering of a contract following a restructuring credit event is not automatic. In fact it is actually asymmetric in the sense that the basket of deliverable obligations depends on which party, if any, is the first to trigger the contract. The rules are as follows:

- If the contract is triggered by the protection buyer, then the basket that applies is the one that corresponds to the scheduled termination date of the CDS contract.
- If the contract is triggered by the protection seller, then the basket that applies is the longest maturity (30-year) basket.

The consequence of these rules is that each party wants the other to trigger. To see why, consider the holder of five-year CDS protection. He will prefer the protection seller to trigger because the 30-year bucket contains more deliverable obligations than the 5-year bucket, and so the value of the delivery option is greater. At the same time the protection seller wants the protection buyer to trigger since he does not wish to be delivered a long-dated obligation.

However, the protection buyer also knows that if he fails to trigger within the specified period, the ability to trigger for this credit event is lost. This is known as *use it* or *lose it*. Suffice to say that both protection buyers and sellers will usually wait until the last moment to trigger. However, great care needs to be taken not to miss the triggering deadline altogether.

There is another complicating factor, which is that the decision period for the protection buyer and seller are not always the same. Typically these periods begin together, but the protection buyer has five days, whereas the protection seller has three days to decide.[10]

10. A discussion of all of the issues is beyond the scope of this chapter. For more information, see Dominic O'Kane, "Testing the Protocols," Nomura International Fixed Income Research, March 2010.

If the contract is not triggered by either party, it does not follow that the protection is lost altogether. It just means that it cannot be used for this credit event but can be used for any subsequent credit event.

The Auction Process

Before the auction, holders of CDS contracts need to decide whether they wish to use cash or physical settlement. A protection buyer who elects for physical settlement will end up with par in cash and a short position in the deliverable obligation after the auction. This replicates the economics of delivering a bond to the protection seller in return for par. Equally a protection seller who elects for physical settlement will end up paying par in cash and owning a deliverable obligation. This replicates the economics of paying par and taking delivery of a deliverable obligation from the protection buyer.

The auction breaks the link between the protection buyer and seller since each party to a CDS can choose a settlement mechanism that may be different to that of their counterparty.

Prior to the auction, market participants who wish to have physical settlement are able to submit physical settlement requests via their dealers. These must arrive before 5 p.m. on the day before the auction. Each request must be in line with the market participant's net CDS position (i.e., a net long protection position must correspond with a request to sell bonds, and vice versa).

A protection seller will choose physical rather than cash settlement in order to realize a view that the current recovery price is too low and will rise after the auction. This view requires the protection seller to hold the physical asset.

The auction is a two-stage process that is administered by Creditex and Markit. It is carried out via the Creditex inter-dealer electronic trading platform. This means that non-dealers cannot participate directly but must do so via their chosen dealer. Both stages occur on the same auction date, with stage one usually occurring in the morning and stage two in the afternoon.

Auction: Stage One

Stage one of the auction is used to determine an indicative recovery price for the deliverable obligations and the net open interest to buy or sell physical assets that will be used in stage two of the auction. Stage one is limited to parties who have CDS positions and have submitted physical settlement requests.

The process is short, lasting only 15 minutes. In this time, the participating dealers submit two-way bid/offer prices for the deliverable obligations. At the same time, the dealers submit physical settlement requests on behalf of their customers and on their own behalf. Note that there is a maximum limit on the bid/offer spread submitted by dealers that prevents dealers from making uncompetitive markets. There is also a minimum trade size. Both of these constraints are set in advance by the DC and are a function of the liquidity and market outstanding notional of the reference credit.

At the end of this 15-minute period, the auction administrator has a further 15-minute period during which they calculate and then publish the indicative recovery price. This is more formally known as the internal market midpoint price (IMMP) and is calculated using an algorithm that rejects outlying price combinations (to prevent manipulation) and averages the remaining bid/offer spreads that are then rounded to the nearest 1/8th of a point. The internal market midpoint price will then be used in stage two of the auction procedure to constrain the final auction price.

The final calculation is the net open interest, which is simply the aggregation of the physical settlement requests. This establishes the size and direction of the demand of market participants to use physical settlement, i.e., the total amount of deliverable obligations to be traded in stage two of the auction and whether the net open interest is to buy or sell these deliverable obligations.[11]

Auction: Stage Two

Stage two of the auction occurs when the parties bid to satisfy the net open interest determined in stage one. This process results in a market-wide recovery price that is then used to settle all CDS contracts, including both those that are cash and physically settled.

Stage two begins two or three hours after the end of stage one, thereby giving market participants time to decide how to respond to the results of stage one. Unlike stage one it is an auction that is open to all parties who have signed up to the ISDA protocol, not just those who hold a CDS position in the relevant reference entity. This maximizes the number of participants and should maximize the chances of a competitive auction.

If the net open interest of stage one of the auction is to sell bonds, then the aim of stage two is to match this open interest with those who wish to buy the bonds. If the net open interest of stage two of the auction is to buy bonds, then the aim of stage two of the auction is to find bond sellers.

At the start of stage two, auction participants have a 15-minute window during which they submit limit orders of a size that is only limited by the size of the net open interest. The order prices can be at whatever price they decide. To do so, they have to commit that they will be willing to transact the limit order size of deliverable obligations at the final auction price.

When this period is over, an order matching algorithm is run on all of the submitted orders. If the open interest was to buy bonds, then the auction is one in which participants submit offer prices to sell bonds. The open interest is then filled starting at the lowest price until all of the open interest has been filled. The price at which this happens is the final auction price. If the open interest was to sell bonds, then the auction is one in which participants submit bid prices to buy bonds. The open interest is then filled starting at the highest price

11. The open interest, the various bids and offers, and the calculated internal market midpoint price are all published on the www.creditfixings.com website.

until all of the open interest has been filled. The price at which this happens is the final auction price.

This final auction price may not become the official final auction price, as there is a condition that requires that the final price be within a certain range, known as the *cap amount,* of the IMMP calculated in stage one. If the final auction price is above the IMMP by more than the cap amount, then it is set equal to the IMMP plus the cap amount. If the final auction price is below the IMMP by more than the cap amount, then it is set equal to the IMMP minus the cap price.

After the auction, dealers are paired off with each other so that the demand to buy or sell deliverable obligations that were submitted in the first stage of the auction can be satisfied by the demand to satisfy the open interest that was filled by the orders submitted in the second stage of the auction. The dealers then in turn enter into trades with their customers to satisfy their physical settlement requests, and the settlement procedure is then complete.

CDS INDICES

Following the CDS, the most important product in the credit derivatives market is the CDS index. Unlike CDS, CDS indices are primarily used by investors to easily obtain a diversified credit exposure as they enable an investor to take a broad exposure to the credit market in a single transaction. The upfront cost required to enter into a CDS index is usually a small percentage of the notional and this makes it possible to leverage the risk of a CDS position. CDS indices are also used as a way to hedge the credit risk associated with a broad portfolio of credit names. This can be useful for credit funds, hedge funds, or banks wishing to hedge the so-called systemic market credit risk.

The first CDS indices appeared in 2002 to the extent that there were competing index providers in each regional market. This situation persisted until the middle of 2004. At this time the North American indices fell under the name CDX, while their European and Asian equivalents fell under the name iTraxx. The main CDS indices that now trade are listed in Exhibit 68-7. Of these the most liquid are the North American and European investment-grade indices, known as CDX IG and iTraxx Europe, respectively.

Note that in the CDS index market, "buying the index" means assuming the credit risk by selling protection and receiving the coupon. This differs from the CDS market, in which "buying" generally means buying protection. It is worth noting that the CDS indices are equally weighted when issued. This differs from stock indices, which are either market cap-weighted or price-weighted. It also differs from the traditional fixed income benchmark indices found in the credit markets, which are almost always weighted by the outstanding debt of each issuer. This was done for reasons of simplicity and to maximize diversification. However, this can change during the life of an index if one or more companies in the index splits (de-merges) or two or more of the companies in the index merge.

CDS Index Constituents

A CDS index is essentially a portfolio of CDS in which the credits in the index satisfy a certain set of inclusion criteria. For example, the CDX IG index is the CDS index, which contains the 125 most liquid investment-grade (IG) credits that trade in the CDS market and are domiciled in North America. The main inclusion criteria for the main CDS indices are shown in Exhibit 68-7.

At any moment in time, there is not just one of each of the CDS indices trading in the market but several series. This is because a new series of each CDS index is issued every six months. Although the new version of the index will have the same credit inclusion criteria as the whole series, the actual credit names of each series of the index may differ if certain credits were upgraded or downgraded, defaulted, or became less liquid since the previous issue date. The most recently issued series of any index is known as the "on-the-run" and is usually the most liquid.

There is also a further subdivision of a CDS index series by maturity. On the issue date, new series of a specific index are issued with terms which will typically include 1, 3, 5, 7, and 10 years. The maturity date of the T-year index will be on one of the standard CDS Dates—March 20, June 20, September 20, and December 20.

EXHIBIT 68-7

The Standard CDS Indices Showing the Type and Number of Credits in Each

Name	Domicile and Type of Credits	Number of Credits
CDX.NA.IG	North American investment-grade	125
CDX.NA.HY	North American high-yield	100
CDX.NA.XO	North American crossover[12]	35
CDX.EM	Emerging market sovereign	15
CDX.EM.Diversified	Emerging market sovereign/corporate	40
iTraxx Europe	European investment-grade	125
iTraxx Europe Crossover	European crossover	40
iTraxx Japan	Japanese investment-grade	50
iTraxx Asia ex-Japan	Asian non-Japanese investment-grade	50
iTraxx Australia	Australian investment-grade	25

12. The term *crossover* refers to credits that were initially investment-grade but have since been downgraded to subinvestment-grade.

For a series that rolls on March 20 and September 20 each year, the corresponding maturity dates will be June 20 and December 20 T years later. This means that the time to maturity of the term T index will actually be T years plus three months at issue and this will have fallen to T years minus three months by the time the next series of the index is issued six months later. This allows an investor to continuously roll his index position into the next "on-the-run" index and so be able to maintain his average maturity at close to T years.

CDS Index Mechanics

To enter into a CDS index, the buyer (or protection seller) pays an upfront cost. The value of this may be positive or negative, and so may actually result in a payment to the index buyer. This depends on the size of the fixed coupon paid by the index and the current trading level of the index.

Each series of a CDS index has its coupon set on the issue date, and this coupon is fixed thereafter. It is usually set at a value that makes the initial upfront value of the index close to zero. Once the index series has been issued, changes in the market perceived credit quality of the index causes the upfront value to change. This is exactly analogous to the mechanics of the CDS market, in which contracts linked to each specific reference entity adopted a fixed coupon in 2009.

The economics of a CDS index are identical to those of a portfolio of CDS contracts where the coupons on the CDS contracts equal the index coupon. As with a CDS, there is both a premium leg and a protection leg.

The Premium Leg

The premium leg of a CDS index is the payment of the coupon to the buyer of the index. The actual payment amounts are determined by multiplying the index fixed coupon by the day count fraction[13] that has elapsed since the previous coupon date and then by the *surviving notional* of the index reference portfolio. The surviving notional at initiation is the contract notional. However, over time this may change if there are credit events.

As credits in the reference portfolio experience credit events, the surviving notional of the index is reduced in proportion to the number of credits remaining. So if two credits in a reference portfolio of initially 125 credits experience a credit event, the surviving notional of the index is 123/125 times the initial notional and the size of the coupon is also reduced to 123/125 times the initial coupon. Note that the notional does not depend on the size of the recovery rate of the defaulted credits, just the number of credit events.

The economics of a CDS index premium leg are therefore equivalent to that of a portfolio of CDS premium legs linked to each of the reference credits in the index, which all pay a fixed coupon equal to the index coupon. The premium leg

13. The day count fraction is usually calculated according to an Actual 360 basis convention.

is paid until the end of the contract, the exception being the unlikely case of all of the credits in the reference portfolio experiencing a credit event.

The Protection Leg

The protection leg of the CDS index is identical to that of an equally weighted portfolio of CDS protection legs on the reference portfolio. If a credit event occurs on a reference credit in the index, the index buyer must pay the index seller the loss on that credit. The process is as follows:

1. The credit is immediately removed from that index series across all maturities.
2. The new index without the credit is thereafter assigned a new version number to distinguish it from earlier versions of the index series.
3. The reference credit that was removed then becomes a standalone CDS position with the notional corresponding to its notional size in the index, e.g., if the index position size was $10 million and there were 125 credits in the index, then the notional of the standalone CDS contract will be $80,000.

The standalone CDS position then takes part in the standard auction procedure as described earlier. In economic terms, this will result in the index buyer having to pay the index seller par minus the auction recovery rate on the CDS notional.

There is an added complication if the credit event was a restructuring. In this case, the index buyer and seller have the option to trigger the standalone contract. If they both choose not to trigger, then the standalone CDS position continues to sit on their respective books until maturity or until it is triggered by a subsequent credit event. However, this is usually only a consideration for European and Asian index holders since, as shown in Exhibit 68-4, the standard for North American indices is to exclude restructuring as a credit event.

IMPORTANCE OF THE CDS MARKET

The credit derivatives market has become an important branch of the credit markets. The ease with which a single-name CDS can be traded has made it an invaluable hedging tool for many, most notably bank loan risk managers. The CDS index has also become an important investment tool for credit investors seeking to quickly and easily obtain a macro-level credit exposure.

In the aftermath of the financial crisis of 2008, the market quickly responded with a number of fundamental changes in the format and mechanics of the contract to increase fungibility and so decrease counterparty risk. The triggering and settlement of credit events were revised to ensure that there is a common market-wide process and to minimize the risk of failing to settle.

Many of the changes were intended to facilitate making all market participants face centralized counterparties (CCPs) rather than dealers in an attempt to reduce the systemic risk associated with the default of a major dealer. This process began in 2009 and by February 2011, one of the major clearing houses, the ICE Trust in North America and ICE Clear in Europe, had together cleared more than $15 trillion of credit derivatives, of which over 80% were CDS indices.

One area of valid criticism of the market was its opaqueness pre-2008, which was unsurprising given the OTC nature of credit derivative transactions. The publication of high-level position data by the New York–based DTCC who are responsible for CDS settlements has added a new level of transparency with respect to market size, the reference entities being traded and the different types of counterparties.

A recurring pattern of the credit derivative market has been that each time there is a credit crisis that exposes any flaws in the mechanics of the market, the market moves quickly to attempt to eliminate such flaws so that the same problems will not recur. This reflects the importance that the market attributes to a well-functioning credit derivatives market. As a result, the market is now better settled, more transparent, less exposed to systemic risk, and better regulated than it has ever been.

KEY POINTS

- The credit derivatives market is dominated by the single-name credit default swap (CDS) and the CDS indices.
- The growth of the CDS and CDS index market has been driven by its many uses. These include transferring credit risk, hedging credit risk, isolating credit risk, leveraging and yield enhancement, structured credit investments, and managing regulatory risk.
- The simplest way to think of the CDS is as an insurance contract in which one party, the "protection buyer," pays a premium to be protected against a credit loss on a specific face amount of bonds or loans issued by a specified corporate or sovereign reference entity.
- The other party to the CDS, known as the "seller of protection," receives the premium and takes on the credit risk. The protection seller makes a contractual payment to the protection buyer if a credit event occurs during the tenure of the contract.
- The "credit event" is the term used by the credit derivative market to define each of the events that can trigger the payment of the CDS protection. Credit events may include bankruptcy, failure to pay, obligations acceleration, repudiation/moratorium of debt, and restructuring of debt.

- The event of restructuring is a "soft" credit event since debt can continue to trade with a term structure after a restructuring. Since this can create a potentially valuable "delivery option" for protection buyers, it is excluded from the standard CDS contract on North America–domiciled companies. However, regulatory and other differences mean that it is included in standard contracts on Europe- and Asia-domiciled companies.
- To avoid a "short squeeze" following a credit event and to ensure that the same recovery rate is used across the market, the CDS market has introduced an auction process in which holders of the relevant CDS engage and only the net amount of deliverable obligations need to be physically traded.
- Credit default swap indices are equally weighted portfolios of up to 125 CDS that can be traded in one single highly liquid transaction. The CDS index market provides asset managers with a highly liquid way to assume or hedge an exposure to market-wide or sector-wide credit risk.
- Following the financial crisis of 2008–2009, the credit derivative market made a number of substantial reforms in order to ensure a well-ordered market-wide settlement mechanism following credit events, to improve transparency and reduce systemic risk via the use of centralized counterparties.
- A CDS or CDS index contract can be sold at any time before maturity, allowing the owner to realize any gain or loss resulting from changes in the market perceived credit quality of the reference entity.

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CHAPTER
SIXTY-NINE

CREDIT DERIVATIVE VALUATION AND RISK

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The purpose of this chapter is to set out the valuation methodology for credit swaps (CDS) and CDS indices. As described in Chapter 68, a credit default swap (CDS) is the most commonly traded credit derivative contract. It is also the building block for the CDS indices. An understanding of the valuation and risk management of CDS is therefore essential if we are to understand the valuation and risk management of CDS indices and other credit derivatives.

CDS VALUATION

For valuation purposes the essential features of a CDS contract are as follows:

- A regular fixed coupon is paid on the premium leg from the protection buyer to the protection seller according to a frequency and basis convention as set out in Exhibit 69-1. The coupon is paid until contract maturity date or a credit event, whichever occurs first. If the credit event occurs between two coupon payment dates, the market standard convention is that the portion of the coupon that had accrued from the previous payment date until the Event Determination Date[1] must be paid by the protection buyer.
- A payment of par minus the recovery rate is paid following a credit event. The recovery rate is set at the auction (which was described in Chapter 68) and paid shortly after on the auction settlement date.

We therefore have future cash flows which are contingent on a credit event. The CDS value is given by the expected present value of these flows calculated in the "risk-neutral" measure (i.e., using probabilities of a credit event that exactly reprice the term structure of market prices of quoted CDS).

The author acknowledges the helpful comments from Samuel Morgan and Mark Ames.

1. This is the date the question to determine a credit event was submitted to the determinations committee (DC).

EXHIBIT 69-1

Standard CDS Contract Specifications for North American and European Markets

Specification	North America	Europe
Maturity Date	CDS dates unadjusted	CDS dates unadjusted
Accrual Dates	CDS dates adjusted except for maturity date	CDS dates adjusted except for maturity date
Payment Dates	CDS dates that are holiday adjusted	CDS dates that are holiday adjusted
Coupons	100 bp and 500 bp	25 bp, 100 bp, 500 bp, and 1,000 bp
Frequency	Quarterly	Quarterly
Day Count Basis	Actual/360	Actual/360
Pay Accrued on Default	Yes	Yes

The precise rules that generate the schedule of premium leg payments are listed in Exhibit 69-1. The CDS dates referred to in this exhibit are March 20, June 20, September 20, and December 20.

Need for a Model

The pricing and risk management of a CDS contract requires the use of a pricing model. There are a number of reasons for this:

1. The CDS market is OTC. As such, there is no central location where trades are executed from which prices can be instantly reported. Prices are instead agreed bilaterally and privately. Market pricing providers such as Markit[2] only provide end-of-day pricing based on aggregating pricing submissions from various dealers.
2. Even if CDS contracts were exchange-traded, the quotation of prices would be complicated by the fact that there are so many different variations in the contracts outstanding. Consider just those contracts written against a single reference entity and assume that the longest maturity contract is 10 years and that all contracts trade with the same coupon and credit events. Since maturity dates are on a quarterly schedule, we can have as many as 40 different contracts being traded, albeit with varying degrees of liquidity. Quoting so many numbers per issuer can be cumbersome. A model that allows pricing based on a smaller number of market inputs is certainly preferable.

2. www.markit.com.

3. Although there is the concept of a standard CDS contract, market participants can request customized features which may deviate from this standard. For example, a company may wish to buy a forward CDS contract in which protection starts at some future date. To price this correctly relative to other CDS, a model is required that must also reprice the current market prices.
4. A valuation model is also important for risk management. With bonds, we need, at the very least, to introduce the concept of a yield-to-maturity and yield-curve before we can start to hedge the interest rate risk of a bond portfolio with other bonds. The same is true with a portfolio of credit default swaps. A model is needed in order to be able to quantify spread risk and to hedge the credit risk sensitivity of one CDS against another.

The value of a CDS contract is simply the upfront value at which the CDS contract should trade. For a protection seller, this is equal to the expected present value of the incoming coupons on the premium leg minus the expected present value of the protection leg. For a protection buyer, it is the negative of this since the protection buyer is receiving the protection but paying the coupons.

Even without a model, we can begin to think about the factors that affect the CDS value. We consider the two legs separately:

1. The value of the premium leg is the expected present value of the coupons paid until maturity or a credit event, whichever happens first. If the credit quality of the reference credit falls then this will make an early credit event more likely and so it is more likely that not all of the coupons will be received. The expected present value of the premium leg will then fall. Also, as it is an annuity of fixed coupons, its present value will also fall if interest rates rise. The value of the premium leg also increases with CDS maturity since more coupons are to be paid.
2. The value of the protection leg increases if the credit deteriorates since it becomes more likely that the payment of par minus the recovery rate will be received. It will also increase with increasing contract maturity as protection for a longer period is always more valuable than for a shorter period. However, it falls as interest rates increase since it is the present value of a future contingent payment.

Before we move on to describe a model that can value each of the legs, we first wish to show that it is possible to actually determine the no-arbitrage value of the upfront cost of protection by reference to the cash bond market.

THE CDS–BOND RELATIONSHIP

Subject to a number of important assumptions, there is a fundamental no-arbitrage relationship between the upfront value of a CDS and the price of a specific floating rate bond issued by the same reference entity. Specifically, our aim is to show that there is an exact relationship between the upfront cost of a time T maturity CDS, U, and the price P of a floating rate note with a time T maturity where the floating rate note pays a floating rate coupon equal to LIBOR plus a spread C. This spread must be equal to the fixed spread of the CDS. We need to consider the following trading strategy:

1. At time zero, an investor borrows an amount $P + U$ at a funding rate of LIBOR. This assumes that the investor has a credit quality similar to that of highly rated commercial banks. This funding is locked in until future time T. Interest payments are made quarterly.
2. At time zero, the investor uses P of the borrowed money to buy one unit of face value of a time T maturity floating rate note issued by the reference entity at a specific seniority. The full price of this bond is P. For simplicity we assume that the purchase begins on a coupon payment date so that there is no accrued interest to consider.
3. At the same time, the investor uses U of the borrowed money to buy CDS protection on one unit of face value of the reference entity that matures at future time T. Note that U can be positive or negative. Following this, the now hedged investor will have to make quarterly coupon payments.

To analyze this strategy, we need to determine the payments at four different types of event: (1) initiation, (2) coupon payment dates, (3) following a credit event, and (4) maturity time T (assuming that no credit event has occurred). These are shown in Exhibit 69-2.

For simplicity we assumed that the credit event occurs on a coupon payment date so that the repayment of the funding simply costs par, i.e., the face value of the borrowing, which in this case is (P + U), and so that there is no coupon accrued to be paid on the CDS.

As the initial net cash flow is zero—the strategy costs nothing to enter—the expected value of the future payments should equal zero. For this to be true, we require that $P + U = 100\%$, i.e., there is a fundamental no-arbitrage relationship

EXHIBIT 69-2

No-Arbitrage Strategy of Bond Plus CDS Protection

Time	Funding	Bond	CDS	Net
Initiation	$P + U$	$-P$	$-U$	0
Coupon Dates	$-(P + U)\Delta L$	$(L + C)\,\Delta$	$-C\Delta$	$-(P + U)L\Delta + L\Delta$
Credit Event	$-(P + U)$	R	$(100\% - R)$	$100\% - (P + U)$
Maturity	$-(P + U)$	100%	0	$100\% - (P + U)$

between the upfront cost of the CDS and the price of a floating rate note issued by the same reference entity. For example, if the LIBOR floater is priced at par, then the upfront value is zero. However if the LIBOR floater is worth more than par, then the upfront cost of protection is negative. If the LIBOR floater is worth less than par, then the upfront cost of protection is positive.

In order to establish this relationship, we have had to make a number of simplifying assumptions. The main ones are:

1. We assumed that the bond buyer funded at LIBOR flat and that funding at this level can be locked in until the maturity of the CDS. In practice, the funding of the bond will be done in the repo market where it will generally not be possible to lock-in the funding level for any extended period. The hedged investor therefore has funding risk, which can work for or against them. There may also be a haircut on the amount funded and this depends on the market risk of the bond, which is used as collateral in the repo.
2. We assumed the existence of a T-maturity *pari passu* floater, which pays LIBOR plus C where C is equal to the fixed spread of the CDS contract.
3. We ignored the effect of the delivery option, which could allow the protection buyer to deliver a cheaper bond (if one exists). This is most likely to be of value if the CDS includes restructuring as a credit event. The value of this option should make the cost of protection higher.
4. We assumed that the credit event falls on a coupon payment date. In practice a default between coupon payment dates will mean an additional payment by the protection buyer of the accrued coupon on the CDS. For the bond, it may mean that the unpaid coupons are added to the bondholders' claim in bankruptcy.
5. We ignored the effect of counterparty risk on the CDS. Counterparty risk is typically mitigated by the posting of upfront collateral.
6. We ignored tax effects that may treat the coupon and principal differently.
7. We ignored transaction costs and market technical effects. In the latter case, we note that since the CDS market makes it easier to short credit risk, any negative news on a credit will typically impact the CDS market first, causing the CDS upfront price to increase before bond prices fall.

What we have done here is to establish a link between the upfront costs of CDS and the pricing of a specific bond issued by the same reference entity. However, in practice, this is not a viable way to price CDS contracts since it is almost certain that the required T-maturity *pari passu* floater, which pays a spread equal to the coupon on the CDS, does not exist. Also, the list of assumptions means that although there is a strong relationship between bond prices and CDS upfront costs, the relationship is not exact.

The CDS Basis

The difference between the cash and CDS market is known as the CDS basis. It is defined as

$$\text{CDS Basis} = \text{CDS Par Spread} - \text{Bond LIBOR Spread}$$

This is not an exact definition since there are various ways to quote the bond LIBOR spread.[3] One LIBOR spread widely used by the market is the asset swap spread of a bond of the issuer with a similar maturity to the CDS, which is trading at a price close to par.

Trading the CDS basis has become a relative value strategy of a number of credit investors, in particular credit hedge funds. The aim of basis trading is to determine which of the assumptions listed above is driving the difference between CDS spreads and bond spreads and to take a view on whether these are correctly or incorrectly priced and liable to change.

The standard basis trade is the "negative basis trade" in which the investor buys the bond and buys protection. It is called a negative basis trade because the investor receives the bond spread and pays the CDS spread—the investor receives negative of the basis as defined above.

Valuation of an Existing Contract

Consider an investor who sells protection using a five-year CDS contract at time zero. The upfront cost, which is the amount paid in cash to enter the contract is $U(0)$. In return, the investor receives a regular coupon C and we call the expected present value of this the value of the premium leg. He also has to pay the counterparty $(1 - R)$ on the face value of the protection if there is a credit event between the effective date and the contract maturity time. The expected present value of payment is the value of the protection leg. We can therefore state that $U(0)$ is the cost of this where

$$U(0) = V_{\text{Premium}}(0,5) - V_{\text{Protection}}(0,5)$$

This is at initiation. Subsequently, at time t, the value of the premium leg and protection leg will change as coupons are received, maturity approaches, and the market's view of the default risk of the reference credit changes. At this time the value of the contract is given by

$$U(t) = V_{\text{Premium}}(t,5) - V_{\text{Protection}}(t,5)$$

One year later, the investor wishes to unwind his position. Given that he sold protection, he must now buy protection. The cost of entering into the long protection position is given by $-U(1)$ where

$$U(1) = V_{\text{Premium}}(1,5) - V_{\text{Protection}}(1,5)$$

3. These include the asset swap spread, the par floater spread, the discount margin, and the zero volatility spread.

Since the coupon dates and any contingent protection payments on this new contract match exactly the coupon payment dates and any contingent protection payment on the existing contract, the combined position has future cash flows equal to zero. The mark-to-market value of this short protection CDS position at any time is therefore simply the upfront cost of buying protection to the same maturity as the initial contract. This is different from the P&L which is the money earned or lost by first selling protection and then closing out the trade one year later by buying protection. This is equal to the upfront cost $U(1)$ which was received plus all of the rolled-up coupon payments minus the cost of repaying any initial loan $U(0)$.

Market Pricing

The pricing of CDS is done with reference to the spreads at which the current market standard contracts trade. These are for contracts that terminate at the main maturity points, which include six months and 1, 2, 3, 4, 5, 7, and 10 years. The market has two conventions for quoting spreads. They are:

1. Par Spreads: The T-year par spread is defined as the coupon that would be paid for protection on a T-year contract *which has no initial cost*.
2. Flat Quoted Spread: The T-year flat quoted spread is defined as the level at which a flat CDS par spread curve needs to be marked in order that the model-implied upfront value matches the upfront value quoted in the market. It therefore ignores the shape of the term structure of the CDS market—it is the CDS equivalent of the bond yield-to-maturity.

The par spread was the quotation convention for the CDS market until 2010. The "problem" with the par spread is that calculation of the upfront value requires knowledge of the full term structure of par spreads of quoted CDS contracts with the same or shorter maturities. Therefore, several par spreads may be needed to calculate one CDS upfront value and one CDS upfront value cannot be used to imply a term structure of par spreads. As a result, the quoted flat spread has become the market standard. Its existence is based on a need to have a spread-based quotation for the price of a CDS contract. Use of the quoted flat spread also entails using the market standard recovery rate assumption, which is currently set at 40% for senior unsecured debt.

Because the quoted spread convention assumes that the spread curve is flat, there is a one-to-one mapping (based on the pricing model that we will describe below) between the T-year maturity quoted flat CDS spread and the upfront cost of a T-year CDS contract. Note also that if the par spread curve is actually flat, then the quoted flat spreads will all be the same for all maturity points and par and quoted flat spreads will be equal.[4] In order to assist clarity, we will be using the notation in Exhibit 69-3 to denote these different coupons and spread measures in what follows.

4. This presumes that the same recovery rate assumption is used.

EXHIBIT 69-3

Notation for Spreads and Coupons

Symbol	Description
$C(T)$	The coupon of a T-year maturity CDS contract.
$U(t)$	The upfront value of a T-year maturity CDS contract at time t.
$S(t, T)$	The time t par spread paid on a T-year maturity CDS contract that has no initial cost.
$\bar{S}(t, T)$	The "quoted" spread is the level of a flat par CDS spread curve that sets the model-implied upfront cost of a T-year CDS equal to its market value at time t.

MODEL

To value a CDS, we need a model. This model must satisfy the following requirements:

1. It must capture a credit event as a single event that can occur at any future time.
2. It must capture the timing of the default and the fact that the market may expect the future default rate to be a varying function of time, i.e., it can have a term structure.
3. It must capture the payment of par minus the recovery rate following a credit event.
4. It must be able to reprice the term structure of market prices exactly.
5. It must be fast to calibrate to the market and fast to price.

The standard model in the market is based on the use of the survival probability $Q(T)$. This is the probability that the reference credit survives without experiencing a credit event from today (time zero) to time T in the future. The value of $Q(T)$ must be between 0 and 1, and must be a constant or decreasing function of T.

Valuation of the Premium Leg

The premium leg of a CDS is the payment of the fixed coupon that continues at quarterly intervals until a credit event or maturity, whichever occurs first. Each coupon is therefore a conditional payment—conditional on the reference entity surviving until the coupon payment date. We also need to discount these future conditional coupons at the LIBOR rate. If we assume that the premium leg has N remaining coupons, we can write

$$V_{\text{Premium}} = C(T)\sum_{i=1}^{N} \Delta(t_{i-1}, t_i) Z(t_i) Q(t_i)$$

That is, for each payment date we multiply the fixed coupon $C(T)$ by the year fraction $\Delta(t_{i-1}, t_i)$ since the previous coupon payment date in the corresponding basis.[5] We then weight it by the probability of the reference entity surviving to the coupon payment date by multiplying by $Q(t_i)$. We finally discount it back to today at the LIBOR rate using the discount factor $Z(t_i)$.

By itself, this equation fails to take into account the coupon accrued that has to be paid if there is a credit event between coupon payment dates as it assumes that the CDS only pays a coupon if the reference credit survives up to the coupon payment date. An exact calculation of the value of the contribution of the coupon accrued is beyond the scope of this chapter. However, we can approximate the value of the contribution by simply assuming that if the reference credit experiences a credit event in the period before the coupon is paid, it will on average occur in the middle of the period. In this case, the amount of accrued coupon will be

$$\frac{C(T)\Delta(t_{i-1}, t_i)}{2}$$

i.e., one-half of the full coupon. The probability of defaulting in the period before the coupon is due to be paid is given by $Q(t_{i-1}) - Q(t_i)$. For simplicity and without any significant loss of accuracy we can assume that this is then paid at the end of the period. We therefore have a coupon accrued contribution given by

$$\frac{C(T)}{2}\sum_{i=1}^{N} \Delta(t_{i-1}, t_i) Z(t_i)(Q(t_{i-1}) - Q(t_i))$$

Adding this to the value of the premium leg above gives

$$V_{\text{Premium}} = \frac{C(T)}{2}\sum_{i=1}^{N} \Delta(t_{i-1}, t_i) Z(t_i)(Q(t_i) + Q(t_{i-1}))$$

We can rewrite this as

$$V_{\text{Premium}} = C(T)A(T)$$

where

5. The market standard is Actual/360. Care needs to be taken since in practice there may be a difference between the accrual dates and the actual payment dates. In particular the actual final payment date at maturity is usually holiday/weekend adjusted while the final accrual date is not.

$$A(T) = \frac{1}{2}\sum_{i=1}^{N} \Delta(t_{i-1}, t_i) Z(t_i)(Q(t_i) + Q(t_{i-1}))$$

The quantity is known as the risky annuity. It is the expected present value of the premium leg assuming it pays an annualized coupon of \$1 and any accrued fraction of this coupon if there is a credit event. It is a function of the entire shape of the survival curve since each premium payment is weighted by the survival probability to the premium payment date.

Value of the Protection Leg

The protection leg pays $(1 - R)$ at the time of a credit event.[6] To find the present value of this we have to take into account when the payment occurs. We need to split the time between today and the end of the contract into lots of small intervals and determine the probability of defaulting in each small time period and then discount the payment back to today.

Suppose we split the time between now, time 0, and the maturity date in T years into M such intervals of length T/M. The value of the protection is then given by

$$V_{\text{Protection}} = (1 - R)\sum_{n=1}^{M} Z(t_n)(Q(t_{n-1}) - Q(t_n))$$

where $(1-R)$ is the amount paid following a credit event, which we assume does not depend on the timing of the credit event, and $Q(t_{n-1}) - Q(t_n)$ is the probability of defaulting between time t_{n-1} and t_n.

In practice, the value of M must be a large number in order to best capture the full shape of the survival probability curve and the discount curve. However, it cannot be too large otherwise it would become numerically slow to price a CDS contract.[7]

The Upfront Cost

Here we define the upfront cost as the cost which must be paid by a protection buyer to enter into a CDS contract. It is therefore the expected present value of the protection leg minus the expected present value of the premium leg; that is, it is given by

$$U(0) = V_{\text{Protection}} - V_{\text{Premium}}$$

where

6. Strictly speaking, payment occurs on the settlement date of the post-credit event auction. The two steps in the auction are described in Chapter 68.

7. A discussion of appropriate values for M is provided in Dominic O'Kane, *Modelling Single-Name and Multi-name Credit Derivatives* (John Wiley & Sons, 2008).

$$V_{\text{Premium}} = \frac{C(T)}{2}\sum_{i=1}^{N}\Delta(t_{i-1},t_i)Z(t_i)(Q(t_i)+Q(t_{i-1})) = C(T)A(T)$$

and

$$V_{\text{Protection}} = (1-R)\sum_{n=1}^{M} Z(t_n)(Q(t_{n-1})-Q(t_n))$$

These are all at time 0.

The Upfront and the Par CDS Spread

The T-year par spread $S(T)$ is the value of the coupon on the T-year CDS, which makes the current value of the contract equal to zero. Therefore

$$S(T)A(T) - V_{\text{Protection}} = 0 \Rightarrow V_{\text{Protection}} = S(T)A(T)$$

But the value of the contract at time zero using its actual coupon is

$$U(0) = V_{\text{Protection}} - C(T)A(T)$$

and we can substitute in the protection leg value to write this as

$$U(0) = \left(S(T) - C(T)\right)A(T)$$

The situation changes when we calculate the value of the contract using the flat spread. This is simply defined via the equation

$$U(0) = (\overline{S}(T) - C(T))\overline{A}(T)$$

This equation looks almost identical to the par spread valuation above. However there is one major difference. The value of the risky annuity here is only a function of the quoted flat spread $\overline{S}(T)$, whereas the value of the risky annuity using the par spread is a function of the *term structure of par spreads*. Clearly, the quoted flat spread does not take into account the term structure of spreads.

Interpolation of the Survival Curve

Before we can use this model, we must calibrate it to the term structure of market prices. This can mean a number of things. It could mean calibrating it to a term structure of upfront costs, a term structure of par spreads, or a term structure of flat spreads. Whichever it is, we will usually have market price data at maturity points starting at six months and then up to 10 years in annual steps. To use these 11 market prices to calibrate a term structure of survival probabilities we need to simplify the term structure of survival probabilities so that it is described by exactly 11 variables. Then we will have one unknown variable for each piece of data and we should then be able to fit exactly the market prices using this simplified term structure.

There are many ways to do this simplification. The market standard is to introduce the continuously compounded forward default rate $h(t)$. This is defined in terms of the survival probability as

$$Q(T) = \exp\left(-\int_0^T h(t)dt\right)$$

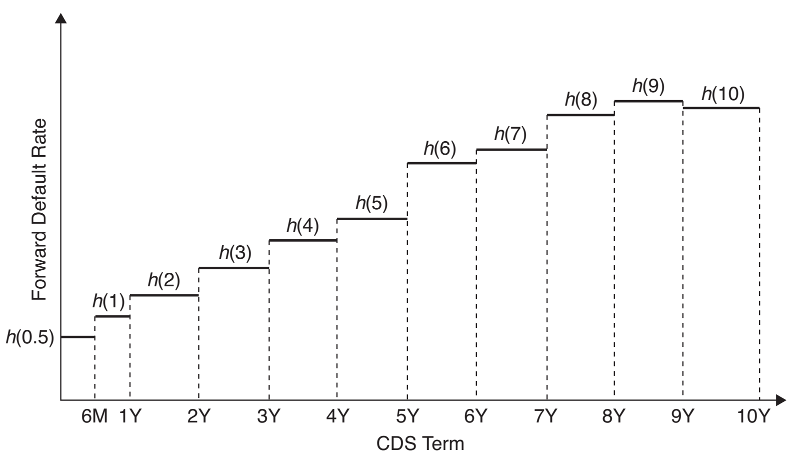
A common simplification is to assume that this continuously compounded forward default rate is piecewise flat as shown in Exhibit 69-4.

Given 11 market prices, the term structure of this continuously compounded forward default rate takes 11 different values: $h(0.5)$, $h(1.0)$, $h(2.0), \ldots, h(10)$, where each $h(t)$ is the value of the continuously compounded forward default rate from the previous time to time t. We then have

$$Q(0.5) = \exp(-0.5 \times h(0.5))$$
$$Q(1) = Q(0.5) \times \exp(-0.50 \times h(1.0))$$
$$\ldots$$
$$Q(10) = Q(9.0) \times \exp(-h(10.0))$$

EXHIBIT 69-4

Piecewise Flat Term Structure of the Forward Default Rate in Which We Calibrate to the 6M, 1Y, 2Y, ..., 10Y CDS Upfront Prices



However, the power of this approach is that it allows us to interpolate the value of the survival curve to other times. So, for example, we have

$$Q(0.3) = \exp(-0.3 \times h(0.5))$$
$$Q(0.7) = Q(0.5) \times \exp(-0.20 \times h(1.0))$$
$$Q(1.9) = Q(1.0) \times \exp(-0.90 \times h(2.0))$$

The whole term structure of survival probabilities is determined by these 11 values of the continuously compounded forward default rate. As long as the value of $h(t)$ is greater than or equal to zero, the term structure of CDS spreads will be arbitrage-free.[8]

Calibration by Bootstrap

Given the model and this interpolation scheme, we need one more input before we can calibrate the values of the continuously compounded forward rates to the market prices of CDS. This is the value of the expected recovery rate R. Note that this does not have to be the same value as the one used by the market to convert the flat quoted spread to an upfront and back which is currently set equal to 40%. It can be a value chosen by the model user.[9] With all of this information, the calibration can then be performed. This is done using a bootstrap.[10] The process is as follows:

1. Search for the value of $h(0.5)$ for which the model-implied upfront value equals the market quoted upfront of the six-month contract given the fixed coupon. As there is one unknown and one price, we should be able to determine $h(0.5)$ so that the market price is fitted exactly.
2. Using $h(0.5)$, now search for the value of $h(1.0)$ for which the model implied upfront equals the market quoted upfront of the one-year contract given its fixed coupon.
3. Repeat step two for each next longer maturity CDS, each time using knowledge of all the previously calibrated values of $h(t)$ to calculate the next one.

8. A term structure of CDS spreads can exhibit an arbitrage if the value of the protection leg to time T_1 is greater than the value of the protection leg to time T_2 where $T_2 > T_1$. In some cases this can allow for a strategy which can guarantee a positive income at no initial cost.

9. The effect of choosing a different recovery rate is that although the model will be calibrated to the market prices of quoted CDS contracts, the value of the protection and premium legs taken separately may differ from the value of the protection and premium legs according to the market standard recovery rate assumption.

10. A bootstrap is the name given to an algorithm that recursively solves a system of coupled equations one at a time, with each solution being found only after a set of the previous parameters have been found.

At the end of this process, we should have a value of h for each market price. From this we are able to compute the market-implied value of $Q(T)$ to any future time T. The value of $Q(T)$ that emerges from our market calibration is the "risk-neutral" survival probability. By risk-neutral, we mean the probability that, according to our model, reprices the market prices of CDS spreads—any other set of probabilities would not reprice the market and hence could create arbitrage possibilities. These spreads are credit-specific, forward-looking measures of the compensation required by a protection seller to sell protection until time T.

It is generally found[11] that credit spreads overcompensate the investor for the expected loss based on the incidence of default of other credits that had the same credit rating. There are a number of reasons why this may be the case. Mainly it is because the market is forward looking and may not consider historical default probabilities, especially when averaged over an economic cycle, to be appropriate given the current state of the economy. Also, because there is typically a large systemic and hence nondiversifiable component to credit spreads, investors demand an additional premium.

NEW AND EXISTING CONTRACTS

The price calculated by a CDS valuation model is the full price, i.e., the cash amount actually paid for the protection. One of the contractual details that determines this value is the date when the contract starts accruing the premium. In order to improve market fungibility of CDS contracts, the standard is for all new contracts to have a full first coupon; i.e., they begin accruing from the previous coupon payment date even if the contract was traded and settled more recently. This makes all contracts with the same maturity date identical in terms of their cash flows. It also means that a hedger who buys protection mid-payment period will have to pay for protection that was not received and should expect to be reimbursed for this through the value of the upfront payment. After all, the upfront cash amount to be paid to enter into this contract for protection is the expected present value of the protection leg minus the expected value of the premium leg. This premium leg will include a full first coupon.

The simplest example we can use to examine the effect of this is to assume that the CDS has a fixed coupon of 100 bp and the par spread to the same maturity is also at 100 bp. However, the par spread is based on a CDS contract that starts accruing at $T + 1$, i.e., one day after the trade date, which must by definition have zero upfront value. Calibration of our CDS model determines the survival probability curve that ensures that this is the case. In more general terms, the value of the same maturity CDS used to calibrate the CDS valuation model is given by:

$$U_{Calibration}(t) = V_{Protection} - C(T)A(t,T) = 0$$

11. For a literature review. see John Hull, Mirela Predescu, and Alan White, "Bond Prices, Default Probabilities and Risk Premiums," *Journal of Credit Risk* 1(2) (2005), pp. 53–60.

If we then use this curve to price our existing contract, we will find that the value of the contract will be

$$U_{Contract}(t) = V_{Protection} - C(T)A(t_0, 0)$$

where t_0 is the time of the previous coupon. But we can then write

$$A(t_0, T) \approx A(t, T) + \Delta(t_0, 0)$$

which should be a very good approximation.[12] This gives

$$U_{Contract}(t) = V_{Protection} - C(T)A(t, T) - C(T)\Delta(t_0, 0)$$

The first two terms on the right-hand side equal the value of the CDS contract we are calibrating to, which is zero, and so we have

$$U_{Contract}(t) = -C(T)\Delta(t_0, 0)$$

This is the negative of the coupon which has accrued since the previous coupon date. The protection buyer therefore finds that the contract pays him for the portion of coupon which accrued since the last coupon date which he has to pay on the next payment date, but whose benefit he did not enjoy since he wishes to enter the contract today. Clearly the payment of the coupon can be up to three months in the future (this is offset by the fact that the further in the future the coupon payment occurs the less that has accrued) while the upfront cost is paid on the settlement date which is the trade date plus three days, holiday adjusted. For this reason, setting the value of the contract equal to the negative of the accrued coupon is a good approximation but one that would only be exact in a world of zero interest rates.

There is one more issue to consider—the CDS contract provides protection against a credit event which occurred between T-60 and today. If such an event has been determined by the Determinations Committee (see Chapter 68) then the CDS contract would be in its post-credit event settlement process and the upfront cost would be close to par minus the expected recovery rate. If the event has not been determined, the implicit assumption is that market expectations that a credit event occurred in the past 60 days are already priced into the CDS spread curve.

RISK MANAGEMENT

We now wish to understand the factors that drive the valuation of a CDS contract. Specifically, we want to be able to calculate the hedge ratios needed to ensure that the value of a portfolio of CDS contracts on the same reference credit is immunized

12. It is based on the observation that any already accrued coupon will either be paid on the next coupon date if there is no default or it will be paid immediately if there is a default. In this sense it is a risk-free payment made at some point in the short period between today and the next coupon date. Since the period is short we can almost always ignore the time-value issue and not discount it.

against parallel moves in the CDS spread curve and the LIBOR interest rate curve. We begin by writing the time t upfront value of a (short protection) CDS contract as

$$U(t,S(t,T)) = \left(C - S(t,T)\right) A(T,S(t,T))$$

where $S(t, T)$ is the time T maturity par CDS spread as seen at time t. Note that we have inserted an explicit par spread dependency into the upfront value and the risky annuity term $A(T, S(t, T))$ to remind ourselves that a change in the par spread followed by a recalibration will cause the term structure of survival probabilities to change and so will change the present value of the risky annuity and the value of the upfront.

Spread DV01 of a CDS

The credit duration of a CDS contract is usually known as the Spread DV01. It is defined as the change in the upfront value of the contract for a 1 bp parallel bump upward in the CDS spread curve. For a short protection position, we can write this as

$$\text{Spread DV01} = U(t,S+1bp) - U(t,S)$$

This gives

$$\text{Spread DV01} = -A(T,S+1bp)\cdot 1bp + \left(S-C\right)\cdot\left(A(T,S) - A(T,S+1bp)\right)$$

There are two contributions to the Spread DV01:

1. The first term describes a fall in the upfront value of the short protection position by $A(T, S + 1\ bp)$ times the change in the spread. The value falls because we have sold protection and the credit quality of the reference credit, as implied by the spread which was bumped, has worsened so the position has lost value.
2. There is a second term due the fact that the change in spread also causes the value of $A(T, S)$ to change. Because this term is multiplied by the spread difference $(S - C)$, it is usually much smaller then the first term. Also, the sign of the change is driven by the sign of $(S - C)$. If this is positive, it means that this term will offset the effect of the first term and reduce the Spread DV01. If negative it can increase the Spread DV01.

The Spread DV01 of a short protection position is therefore typically close in value to the negative of the risky annuity given by $A(T, S)$ multiplied by 1 basis point and approaches[13] it if $S = C$. The spread sensitivity from the perspective of a long protection position is simply the negative of that of a short protection position.

Hedging different CDS positions using the Spread DV01 is only really effective if the quoted spread or par spread of the different contracts move by

13. It does not equal it exactly, since when $S = C$ the Spread DV01 equals –A(S + 1) and not –A(S).

the same amount. For contracts of differing maturity, this requires the CDS curve to move in parallel shifts, which is not always the case. For this reason, use of the Spread DV01 should generally only apply to contracts of a similar maturity. To go beyond Spread DV01, we would need to calculate the sensitivity of a CDS contract to movements of different curve points (e.g., 1-year, 3-year, 5-year, 7-year, and 10-year), and determine the set of positions in each of these contracts needed to immunize the hedged portfolio against spread movements.[14]

Interest Rate Duration of a CDS

The interest rate sensitivity of a CDS contract is known as its IR DV01. It is defined as the change in the upfront value of the contract for a 1 bp parallel bump upward in the LIBOR curve while keeping the par spread curve fixed. As the only interest rate dependency is in the annuity term, we have

$$\text{IR } 01 = (C - S) \cdot (A^*(T) - A(T))$$

where $A^*(T)$ is the value of the risky annuity calculated using the bumped interest rate curve. Since this is the present value of future cash flows, we can conclude that $A^*(T) - A(T) < 0$. We can therefore conclude that: (1) if $C = S$ the interest rate sensitivity of a CDS is zero, (2) if $S < C$ then the IR DV01 is negative, and (3) if $S > C$ then the IR DV01 is positive.

In general the interest rate sensitivity of a CDS is low, especially when compared with a fixed-rate corporate bond with the same maturity date. This is due to the fact that the bond has coupons plus a payment of par at maturity, while the CDS is effectively a credit risky annuity with annualized coupon payments of $(C - S)$ and unlike a bond there is no payment of par at maturity. In fact the interest rate sensitivity of a CDS actually closely resembles the interest rate sensitivity of a same-maturity par floating rate note issued by the reference entity.

Example

Exhibit 69-5 shows an example[15] of the pricing of a real CDS trade to buy protection until March 20, 2016. The CDS coupon (deal spread) has been fixed at 100 bp. The pricing of the CDS is captured by the current flat spread, called the "quoted spread," to the contract maturity date, which is 34.32 bp. This is the only spread quote needed to determine the upfront value. Both the deal and the quoted spread assume the market standard recovery rate of 40%.[16]

14. This procedure is discussed in detail in O'Kane, *Modelling Single-Name and Multi-name Credit Derivatives.*

15. The valuation here reproduces that produced by the standard CDS valuation calculator found on Bloomberg, which is accessed via the code CDSW.

16. These would only differ if the user was attempting to price a fixed recovery default swap.

EXHIBIT 69-5

The Value of the CDS Contract

Trade Description

Notional:	$10m	Trade Date:	3rd February 2011
Maturity:	20 March 2016	Settlement:	8th February 2011
Buy/Sell:	Buy Protection	Quoted Spread:	34.32 bp
Deal Spread	100 bp	Currency:	USD

Valuation Results

Price	103.22035	Accrued	–$12,778 (46 days)
Principal	–$322,035	Spread DV01:	5,036.41
Cash Amount	–$334,813	IR DV01:	84.26

We explain the valuation outputs in Exhibit 69-5:

- **Price:** This is the "clean" price for a protection seller who was to buy the CDS together with a par LIBOR floating rate note. It excludes the payment of accrued interest that would need to be added to the actual price paid.
- **Principal:** This is the clean (excluding accrued interest) value of the contract. It is computed by subtracting the accrued interest from the cash amount defined below.
- **Accrued Interest:** This is the amount of coupon that has accrued since the last coupon payment date or the first accrual date. For a new contract and an existing contract this is always the CDS Date that falls before the trade date. For a protection buyer the accrued interest is always negative while for a protection seller it is always positive. The valuation shows 46 days of a 100 bp coupon that has accrued from the previous payment date December 20, 2010, to T+1 calendar, which falls on February 4, 2011.
- **Cash Amount:** This is the actual upfront amount that has to be paid to enter into this contract. The valuation is –$334,813 meaning that the protection buyer receives $334,813 to enter into this contract. This is because the protection buyer who enters into this contract has to pay an annualized coupon of 100 bp for up to five years for a reference entity with a quoted flat spread of 34.32 bp. Because the coupon being paid is higher than the cost of protection implied by the quoted spread, the protection buyer has to be compensated upfront.
- **Spread DV01:** The spread sensitivity of the long protection position is calculated to be $5,036, meaning that a 1 bp increase in the quoted spread curve would cause the value of the CDS position to increase by this amount.

- **IR DV01:** The interest rate sensitivity of the contract is also positive, but much smaller at $84.24. This makes it very clear that a CDS is almost purely a credit-spread product.

Exhibit 69-6 shows the cash flows on the premium leg of the CDS. We see the payment dates and the corresponding amounts calculated using the Actual 360-day count convention. We also see the discount factors implied by the LIBOR deposit rates and swap rates used. Finally we see the survival probabilities implied by our CDS valuation model. The default probability is simply one minus the survival probability.

EXHIBIT 69-6

Payment Dates, Amounts, and the Corresponding Discount Factors and Survival Probabilities for the Example CDS Trade. Note That the Payment Dates Have Been Holiday Adjusted.

Payment Date	Amount ($)	Discount Factor	Survival Probability	Default Probability
Tue 8 Feb 2011		0.999965	0.999920	0.000080
Mon 21 Mar 2011	25,277.78	0.999681	0.999268	0.000732
Mon 20 Jun 2011	25,277.78	0.999050	0.997822	0.002178
Tue 20 Sep 2011	25,555.56	0.998083	0.996362	0.003638
Tue 20 Dec 2011	25,277.78	0.996830	0.994920	0.005080
Tue 20 Mar 2012	25,277.78	0.994574	0.993480	0.006520
Wed 20 Jun 2012	25,555.56	0.991120	0.992031	0.007969
Thu 20 Sep 2012	25,555.56	0.987678	0.990585	0.009415
Thu 20 Dec 2012	25,277.78	0.984285	0.989157	0.010843
Wed 20 Mar 2013	25,000.00	0.979280	0.987747	0.012253
Thu 20 Jun 2013	25,555.56	0.972176	0.986309	0.013691
Fri 20 Sep 2013	25,555.56	0.965123	0.984874	0.015126
Fri 20 Dec 2013	25,277.78	0.958198	0.983456	0.016544
Thu 20 Mar 2014	25,000.00	0.951042	0.982056	0.017944
Fri 20 Jun 2014	25,555.56	0.943351	0.980627	0.019373
Mon 22 Sep 2014	26,111.11	0.935557	0.979170	0.020830
Mon 22 Dec 2014	25,277.78	0.928074	0.977761	0.022239
Fri 20 Mar 2015	24,444.44	0.920894	0.976400	0.023600
Mon 22 Jun 2015	26,111.11	0.913285	0.974950	0.025050
Mon 21 Sep 2015	25,277.78	0.905980	0.973548	0.026452
Mon 21 Dec 2015	25,277.78	0.898733	0.972147	0.027853
Mon 21 Mar 2016	25,277.78	0.888739	0.970749	0.029251

Approximation

For those wishing to evaluate trading strategies, the Bloomberg pricer found under CDSW can be limiting and a simple Excel-based pricer would be quite useful, even if it is not exact. It is therefore worth describing a simple approximation that is based on the observation that the value of the risky annuity of a new CDS contract can be linked directly to the quoted flat spread $\overline{S}$ and the recovery rate assumption R using the following approximation

$$A(\overline{S},T) \approx \frac{1-\exp\left(-\left(\mathrm{W}+\frac{\overline{S}}{(1-R)}\right)T\right)}{\mathrm{W}+\frac{\overline{S}}{(1-R)}} \times \frac{365}{360}$$

where W is the swap rate to the contract maturity in T years and the ratio of 365/360 is used to adjust for the Actual 360 convention used to determine the size of premium payments.[17] The value of a long protection CDS position is simply given using the standard valuation equation:

$$U(t) = \left(\overline{S} - C\right) A(\overline{S},T)$$

Taking the example above where the quoted spread is 34.23 bp, the time from today to contract maturity is 5.122 years and the five-year swap rate is 2.4%, we find that

$$A(\overline{S},T) = \frac{1-\exp\left(-\left(0.024+\frac{0.003432}{(1-0.4)}\right)\cdot 5.122\right)}{0.024+\frac{0.003432}{(1-0.4)}} \times \frac{365}{360} = 4.81764$$

We therefore calculate

$$U_{Existing}(t) = \$10{,}000{,}000 \cdot \frac{(34.32-100)}{10000} \cdot 4.81764 - \$12{,}778 = -\$329{,}992$$

This should be compared to the cash amount calculated by the Bloomberg valuation (not shown) which was –\$334,813, a difference of about \$5,000 on a \$10 million face value. Note that we had to subtract the 46 days of accrued coupon which have to be paid by the protection buyer at the end of this coupon period. These are worth \$12,778. The reason for doing this is that this contract requires the protection buyer to pay a full coupon on the next payment date. However the quoted spread of 34.32 bp is for a contract that starts accruing from T + 1. To account for this we need to

17. Using an Actual 360 basis the sum of the actual coupon payments over a year exceeds the amount implied by the annualized coupon by this ratio in non-leap years. Any good approximation of the risky annuity needs to account for this.

compensate the protection buyer for having to make this extra future payment and to a very good first approximation, this can be done by subtracting the accrued coupon. The valuation is within 1.5% of the Bloomberg result—corrections to the interest rate used to discount the CDS cash flows to account for the slope in the swap curve can further improve the accuracy of this approximation.[18]

CDS INDEX VALUATION

The mechanics of the CDS index have been set out in Chapter 68. We showed that a CDS index is equivalent to a portfolio of CDS in which the individual CDS all pay the same index coupon given by $C_I(T)$. In this section, we wish to show that for valuation purposes a CDS index can actually be treated as though it were a CDS contract. We recall from Chapter 68 that the buyer of a time T-maturity CDS index is selling protection on a portfolio of P different time T-maturity CDS contracts, and receiving a coupon $C_I(T)$ in return for assuming this risk. Credit events in the portfolio result in the relevant CDS being removed from the index and settled via the standard auction procedure described in Chapter 68.

On each coupon payment date the size of the coupon payment is proportional to the size of the remaining portfolio of CDS. It therefore falls in absolute terms as credit events occur.

Therefore, unlike a single-name CDS, a CDS index does not have a single credit event which causes it to pay out a single loss and then cancel. Instead, the contract remains active[19] until maturity, with loss payments being made as and when credit events occur.

Index Valuation

From the perspective of an index buyer (protection seller), the CDS index value is equal to the premium legs of the P underlying CDS contracts that each pay the index coupon, minus the expected present value of the P protection legs. Using the notation set out in Exhibit 69-5, we can therefore write the value of the index premium leg as

$$\frac{C_I(T)}{P}\sum_{p=1}^{P} A_p(T)$$

18. The main reason for the difference is the upward sloping swap curve in February 2011, which rises from 0.46% at six months to 2.4% at five years. This is not consistent with our assumption of a flat swap curve. Using a maturity-weighted average swap rate of 1.67%, we obtained a valuation with an error of less than 0.1%.

19. Strictly speaking, the CDS index contract would cancel if all of the credits in the reference portfolio experienced a credit event. However given that the reference portfolio usually consists of 50–125 individual credits, the probability of this happening within the lifetime of a typical CDS index contract is considered to be close to zero.

EXHIBIT 69-7

Notation Used in the Valuation of CDS Indices

Symbol	Description
$C_I(T)$	The coupon of a T-year maturity CDS index.
$U_I(T)$	The upfront value of a T-year maturity CDS index.
$S_I(T)$	The par spread paid on a T-year maturity CDS index which has no initial cost.
$S_P(T)$	The par spread paid on a T-year maturity CDS on reference credit p.
$\bar{S}_I(T)$	The "quoted" spread is the level of a flat par CDS index spread curve which sets the model-implied upfront cost of a T-year CDS index equal to its market value.

We can also write the value of the index protection leg in terms of the individual CDS spreads as

$$\frac{1}{P}\sum_{p=1}^{P} S_p(T)A_p(T)$$

We are assuming here that the reference credits are all equally weighted.[20] The value of the index (short protection) position is then

$$V^{Index} = \frac{1}{P}\sum_{p=1}^{P}(C_I(T) - S_p(T))A_p(T)$$

The most common application for CDS index pricing is Bloomberg's CDSW function. This treats a CDS index as a standard CDS contract. As with CDS, price quotations for the CDS indices are almost exclusively done using the "quoted" flat index spread defined as the level at which we would mark a flat CDS index par spread so that, when using the standard CDS pricing model, it would cause the index model price to refit the market upfront index price. We therefore have

$$V^{Index} = \frac{1}{P}\sum_{p=1}^{P}(C_I(T) - S_p(T))A_p(T) = (C_I(T) - \bar{S}_I(T))\bar{A}_I(T)$$

The point here is that this mapping of a CDS index onto a single CDS contract allows us to use our single-name CDS analytics to value and risk manage the

20. This is always the case on the issue date of an index. However, if one or more company splits or merges then this could cause some reference credits to have a smaller or larger notional than the others. Even if this does occur, it does not affect any of the index pricing analysis presented in this chapter.

CDS index. By doing so, we price the CDS index as though it has its own index survival probability $Q_I(t)$. Note that if we assume that the expected recovery rates of all of the credits in the index are the same, we can write

$$Q_I(t) = \frac{1}{P}\sum_{p=1}^{P} Q_p(t) = N_I(t)$$

where $N_I(t)$ is the expected surviving notional of the index at time t. We do not use this relationship in pricing because it assumes that all recovery rates are the same, which is not always the case. However, in general, it is approximately true and does provide some intuition about the interpretation of the index survival probability.

The CDS Index Basis

If this relationship is not obeyed, there is then a theoretical mispricing. However, this theoretical mispricing may not be arbitrageable for a number of reasons:

1. Model prices are usually mid-market. Therefore, if we take into account the cost of crossing the bid-offer spread that would need to be done to monetize any mispricing, this mispricing may not be a real arbitrage opportunity after all.
2. Obtaining accurate and contemporaneous flat spreads for all of the constituents of a CDS index may not be possible.
3. Where CDS and CDS indices trade with different restructuring clauses, the replication is not exact and this relationship should not be exactly obeyed.

Despite these caveats, CDS indices have traded away from their CDS-implied spread. This will generally be due to market technical factors such as a market demand to buy or sell systemic versus single-name credit protection. If the deviation becomes large enough to be arbitraged, then hedge funds and other market players will step in to monetize the profit until their activities eliminate the arbitrage.

Risk Management

Since the CDS index contract is valued as though it was a single-name CDS contract, its price sensitivities are identical to those of a single-name CDS contract with the same term structure of par spreads or quoted spread, the same recovery rate, the same maturity, and the same interest rate environment. As a result, we refer the reader to the section on CDS risk management.

KEY POINTS

- Since the introduction of fixed coupons for CDS contracts in 2009, entry to a CDS contract almost always involves some initial upfront cash payment, which can be positive or negative.
- From the perspective of a protection seller, the size and sign of the initial cash value of the contract depends on whether the fixed coupon is sufficient to compensate the protection seller for the market perceived risk of a credit event. If the coupon is low, the protection seller may receive cash at trade initiation. If the coupon is high, the protection seller may have to pay cash at trade initiation. The situation is reversed for a protection buyer.
- The purpose of the valuation of CDS and CDS indices is to calculate this upfront cash payment. This requires a model in order to determine the expected present value of the premium and protection leg of the contract.
- This model needs to take into account the probability of and the timing of a credit event. For the premium leg, it needs to take into account the risk that not all coupons will be paid. For the protection leg it needs to value the unknown payment of par minus recovery made at the time of the credit event, if one occurs. It also needs to be flexible enough to exactly reprice the term structure of quoted market spreads.
- One type of market quote is the CDS par spread. This is the value of the coupon that would need to be paid on the premium leg of a CDS in order for the contract to have zero upfront value on trade date. The value of a CDS is a function of the term structure of CDS par spreads.
- Since 2011, the CDS market has also begun to use an alternative measure known as the flat "quoted" spread. This is the level at which a flat term structure of par spreads would need to be set in order that they reprice the market quoted upfront value. As a result, only one quoted spread is needed to value a CDS contract.
- The probability of a CDS experiencing a credit event as implied by CDS market spreads usually exceeds the historical default probability implied by the default rate of credits that were initially assigned the same credit rating. This is because spreads are forward-looking and embed a risk premium.
- The model allows the holder of a CDS position to calculate the sensitivity of the value of the contract to changes in the quoted spread and so enables him to hedge it with other CDS contracts.
- For valuation purposes, a CDS index can be treated as a single-name CDS and valued and risk-managed using the same model as the CDS.

PART
TEN

PERFORMANCE ATTRIBUTION ANALYSIS

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CHAPTER
SEVENTY

PRINCIPLES OF PERFORMANCE ATTRIBUTION

Barclays

Performance measurement and attribution is an important function of portfolio management. It helps bring clarity to the sources of portfolio risk and performance, quantify the contributions of individual decision-makers, and identify structural issues. Performance attribution algorithms typically follow either a sector-based allocation or a factor-based allocation methodology, but neither is sufficient to cope with the complexity of modern portfolio management. In this chapter, we first discuss the principles of performance attribution. We review the sector-based and factor-based attribution frameworks and then describe a hybrid attribution model[1] that blends the two and has the flexibility to adapt to the particular management structure of most portfolios. The chapter finishes with the application of performance attribution, both as a portfolio management tool and a data quality tool. Where possible, we introduce the best practices for performance measurement and discuss practical considerations in real-world applications. Throughout the chapter, we utilize examples produced by the Hybrid Performance Attribution (HPA) model[2] as implemented in POINT, the portfolio analytics and modeling platform then offered by Barclays.

PRINCIPLES OF PERFORMANCE ATTRIBUTION

Managing a global diversified portfolio of financial assets is a complex task that requires adopting views in different markets and implementing them with regular trading activities. Expressing and implementing views in a variety of markets that interact with each other in complex ways, makes it very difficult to quantify the

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This chapter was coauthored by Anthony Lazanas, António Baldaque da Silva, Chris Sturhahn, Eric P. Wilson, and Pam Zhong when they were employees of Barclays.

1. For another discussion of the hybrid performance attribution model also see Chapter 27 in Lev Dynkin, Anthony Gould, Jay Hyman, Vadim Konstantinovsky, and Bruce Phelps, *Quantitative Management of Bond Portfolios* (Princeton University Press, 2007).
2. For details of the model see Anthony Lazanas, Chris Sturhahn, and Pamela Zhong, *The Barclays Capital Hybrid Performance Attribution (HPA) Model* (Barclays Capital Publications, October 2010).

contribution of each decision-maker to the performance of the portfolio. Performance attribution is a mathematical framework that attempts to split the total outperformance of a portfolio versus a benchmark into the contributions of individual decisions and actions.

Complex portfolios are typically managed by breaking down the investment process into a sequence of decisions made by different managers, each of whom specializes in a specific market or type of security. Traditionally, this process follows product and sector lines. Risk-factor-based portfolio management became popular with the advent of modern portfolio risk management and the realization that certain risks are common for multiple asset classes. Foreign exchange (FX) and interest rates are examples of risks that are now commonly being managed separately for the entire portfolio while product/sector experts focus on managing excess returns.

The total outperformance of a portfolio depends on the combined outcome of the decisions of all portfolio agents, as well as the market performance. Often, the effects of different agents' decisions depend on each other in a way that makes it difficult to disentangle them. A successful performance attribution algorithm will do so in a way that satisfies three important requirements:

- *Additivity*: The contribution of two or more agents combined is equal to the sum of the contributions from those agents.
- *Completeness*: The sum of all outperformance contributions is equal to the total portfolio outperformance.
- *Fairness*: The allocation of outperformance to different interacting agents is performed in a way that is perceived to be fair by all agents.

These requirements are important because performance attribution is often used to measure the skill level and determine the compensation of portfolio managers. The fair decomposition of portfolio outperformance must take into account the management structure of the portfolio. In addition, a good performance attribution model or system needs to successfully address multi-period compounding and have sufficient flexibility in order to meet the demands of modern portfolio management.

Multi-Period Attribution and Compounding

Generally speaking, a performance attribution model measures the exposure of a portfolio to various markets at the beginning of a period and then explains the contribution of each market to the performance of the portfolio over the period as the product of its exposure to the market times the market move. Since actively managed portfolios dynamically adjust exposures to various markets frequently, such performance attribution over a period of time will not capture the effect of active portfolio management.

For example, consider a portfolio that begins the attribution period with no exposure to a particular sector. During the period the sector rallied and in response the manager allocated positive exposure to the sector. Subsequently the sector lost all of its gains and ended the period flat. Since the portfolio had no exposure when the sector rallied but positive exposure when the sector retreated, the portfolio realizes losses over the period. An attribution system that looks at exposure at the beginning of the period (zero) and the return of the sector over the period (also zero) will not be able to explain the realized losses. A system using average exposure over the period will also fail to explain the losses since the return of the sector is zero over the period. On the other hand, a system that splits the attribution exercise in two (or more) subperiods and then combines the results of the subperiods to explain the total portfolio performance over the entire period will be able to identify the intra period exposure adjustment as the reason for the portfolio losses.

The length of the subperiods that an attribution system uses to explain performance over longer periods determines the frequency of the attribution system. Linking the returns of subperiods is called compounding. Timing affects investment performance, especially when intermediate cash flows occur. Since cash flows impact portfolio market value, the fundamental question is whether subperiod returns should be compounded without regard to the portfolio size during each subperiod (time-weighted compounding) or whether subperiod returns should be weighted by the portfolio market value in each period (money-weighted compounding). For example, consider a portfolio with a seed investment of \$1,000,000 that earns a rate of return of 100% doubling its value for the first half of the year. Because of its success, the portfolio attracts additional investments of \$100,000,000 and its market value becomes \$102,000,000. Unfortunately, in the second half of the year it has losses of 10% ending the year with a value of \$91,800,000. What is the annual return of the portfolio? Assuming the inflow occurred in the middle of the year, money-weighted rate of return estimates the annual return by solving for the internal rate of return:

$$1{,}000{,}000 \times (1+r) + 100{,}000{,}000 \times (1+r)^{0.5} = 91{,}800{,}000 \Rightarrow r = -17.24\%$$

Time-weighted rate of return ignores the portfolio size and reports an annual return of:

$$r = (1+100\%) \times (1-10\%) - 1 = 80\%$$

Given the dramatic differences between the two methods when portfolio flows are significant relative to its current size, the choice between the two methods is an important decision. Whether the timing of cash flows should be reflected in return measures depends on whether the portfolio manager is responsible for the timing of the cash flows. If she is responsible, then the money-weighted method should be used. In the case of mutual fund or pension fund managers who have no direct control of cash contributions and withdrawals, the time-weighted method is more appropriate. In the following three chapters we assume the time-weighted methodology.

Once the method for compounding returns is decided, the question of splitting multi-period returns into components (i.e., multi-period performance attribution) must be addressed. The difficulty arises from the fact that compounding is a nonlinear function and introduces interaction terms that must be allocated between different return components. For example, consider that the portfolio return is attributable to two components which both contribute 10% of return over two periods. The return of the first component is realized during the first period, and the return of the second component is realized over the second period. Time-weighted compounding will report total portfolio return of (1+10%) × (1+10%) – 1 = 21%. Each component contributes 10%, leaving 1% of total return that can be claimed by either component. A multi-period attribution system must adopt both return and outperformance compounding algorithms that retain the principles of additivity, completeness and fairness. Such algorithms are discussed in more detail in Chapter 72.

It is important that the frequency of the attribution system match the frequency of portfolio management decisions. If the attribution frequency is too low, as in the example above, part of the portfolio performance may remain unexplained. Conversely, if the attribution frequency is too high, the attribution model may attribute outperformance to portfolio management erroneously. Many fixed income portfolios are managed on a daily basis, especially with respect to their interest-rate exposures; therefore daily-frequency attribution models are commonly used for fixed income portfolios. Daily compounding generates the requirement for high-quality daily prices and analytics for all securities in a portfolio and its benchmark. Sophisticated attribution systems can be used as a magnifying glass for data quality. Any problems with the data are immediately shown in the quality of the results. An example of this is discussed later in the chapter.

Flexibility

A practical performance attribution system must reflect the decisions that a portfolio manager makes during the normal course of the investment process. With a wide diversity among portfolio managers also comes a wide diversity of styles that are often mutually exclusive. No single specification of a performance attribution can describe all managers' preferences. In order to be useful, the model must also satisfy the following requirements:

- Measure the risk factors corresponding to the portfolio managers' decisions
- Independently measure the contributions of each factor in the portfolio management process
- Closely follow the published returns of the fund, and its benchmark
- Be available in a timely manner

- Have sufficient adaptability to explain both short and long time periods

In short, it must be useful to the portfolio manager in explaining and refining her decisions, quantifying the effects of the investment process.

MATHEMATICS OF PERFORMANCE ATTRIBUTION

Performance attribution algorithms typically follow either a sector-based allocation or a factor-based allocation methodology. Both methods follow the same framework which expresses the total outperformance of the portfolio over a benchmark $R^P - R^B$ as the sum of several components. The contribution of each component is determined by a portfolio manager's decision to allocate a different exposure than the benchmark to a particular market or factor, and the performance of the market or the factor itself. In this section, we first discuss sector-based and factor-based attribution under this simple framework, and then introduce a hybrid model that blends the two and has the flexibility to support virtually all types of portfolios and portfolio management styles. We will develop the mathematical framework of performance attribution assuming a generic set of sectors and factors. In Chapters 71 and 72 we will see the application of this framework in the performance attribution of fixed income portfolios.

Sector-Based Attribution

In its simplest form, portfolio management versus a benchmark is modeled as a two-step process that consists of market weight allocation to various sectors and security selection within each sector. The classical performance attribution methodology is often referred as "Brinson model."[3] Portfolio return is the market value-weighted (w_s) sum of the individual sector returns, R_s:

$$R^P = \sum_s w_s^P R_s^P$$

Similarly, benchmark return is the weighted sum of benchmark sector returns:

$$R^B = \sum_s w_s^B R_s^B$$

This representation allows us to identify two key drivers of the total outperformance $R^P - R^B$: the differences in the sector allocations, $w_{s,}$ and the differences in the returns, R_s earned within each sector. The outperformance achieved by

3. Gary L. Brinson and Nimrod Fachler, "Measuring Non-U.S. Equity Portfolio Performance," *Journal of Portfolio Management*, 11, 3 (1985), pp. 73–76 and Gary L. Brinson Randolph. Hood and Gilbert Beebower "Determinants of Portfolio Performance," *Financial Analysis Journal*, 42, 4 4 (1986), pp. 39–44.

reweighting the sectors is called "Asset Allocation," and the outperformance due to the intrasector return differences is called "Security Selection." To make the decomposition of the total outperformance complete, we need to add a third term, the "Interaction" effect, the joint effect of asset allocation and security selection.

$$\text{Asset Allocation} \qquad \sum_s \left(w_s^P - w_s^B\right)\cdot R_s^B \tag{70-1}$$

$$\text{Security Selection} \qquad \sum_s w_s^B \cdot \left(R_s^P - R_s^B\right) \tag{70-2}$$

$$\text{Interaction} \qquad \sum_s \left(w_s^P - w_s^B\right)\cdot \left(R_s^P - R_s^B\right) \tag{70-3}$$

Interaction terms arise every time two factors contribute to outperformance through a non-additive function such as the product. Interaction terms are philosophically undesirable, since the stated goal of performance attribution is to credit agents separately for their contribution. Thus, we attempt to merge interaction terms into other outperformance components that can be uniquely attributed to a single agent. The criteria for consolidation are usually dictated by the order in which decisions are made, or the relative size of the interaction term.

The standard assumption is that asset allocation precedes security selection (i.e., the portfolio is managed in a top-down fashion), so it is common to fold the interaction term into the latter:

$$\text{Asset Allocation} \qquad \sum_s \left(w_s^P - w_s^B\right)\cdot R_s^B \tag{70-4}$$

$$\text{Security Selection} \qquad \sum_s w_s^P \cdot \left(R_s^P - R_s^B\right) \tag{70-5}$$

If, on the other hand, the expected returns of sectors in the portfolio are different than those in the benchmark (e.g., because of manager skill or leverage), then it might be more appropriate to fold the interaction term into asset allocation instead. As a result, asset allocation would be given by $\sum_s \left(w_s^P - w_s^B\right)\cdot R_s^P$ and security selection would be given by $\sum_s w_s^B \cdot \left(R_s^P - R_s^B\right)$. It is easy to see that in both cases, the outperformance breakdown is complete; i.e., the sum of the two components is equal to the total outperformance.

The above formulas would assign positive contribution to asset allocation outperformance to any overweighted sector with positive benchmark sector return. Thus, if all sectors have positive benchmark returns, overweighting the sector with the worst return would still be considered a good decision. This is intuitively wrong in most portfolios, as the weight allocated to such sector would be better used in sectors with higher returns. Therefore, instead of using the absolute benchmark sector return in the above asset allocation formula, one can use the sector return relative to the benchmark return (which represents the weighted average return of all benchmark sectors):

Asset Allocation $$\sum_s \left(w_s^P - w_s^B\right) \cdot \left(R_s^B - R^B\right) \qquad (70\text{-}6)$$

Security Selection $$\sum_s w_s^P \cdot \left(R_s^P - R_s^B\right) \qquad (70\text{-}7)$$

Notice that while the contribution of each sector to asset allocation changes, the total asset allocation outperformance remains the same as long as $\sum_s w_s^P = \sum_s w_s^B$.

The constraint that the sum of the portfolio and the benchmark sector weights are equal to one necessitates the comparison of the benchmark sector returns with the overall benchmark return. If leveraging is allowed, such that there is no constraint on each sector's weight, then each overweighted sector with a positive return should indeed have a positive contribution to outperformance. In such a case, we do not need to compare the return of each sector to the return of the benchmark and Eqs. (70-4) and (70-5) apply. In practice, however, leverage constraints do exist (usually dictated by risk constraints), and neither the benchmark return nor zero is a generally appropriate choice for the hurdle rate for each sector. In the following discussion, we will use the term R^H generically for the hurdle rate. This formulation describes both above models while allowing for extra flexibility. A choice of $R^H = 0$ gives the original Brinson model in Eqs. (70-4) and (70-5), while a choice of $R^H = R^B$ gives the model in Eqs. (70-6) and (70-7).

Recursive Allocation

Most large portfolios have many management layers by which allocation decisions are made successively. For example, the global strategist can specify the allocation into global markets, the U.S. strategist can determine the allocation to major asset classes in the United States (equities, bonds, commodities, etc.), the fixed income strategist can determine the allocations into the various sectors, and so forth.

In such a case, what we called security selection above contains not only security selection, but also further asset allocation, as well as security selection for each subsector. In fact, each sector can be considered as a smaller portfolio for which the above performance breakdown equations can be applied recursively. For this reason we will use the term "sector management" instead of "Security Selection," and we will reserve the term "security selection" for the last layer of management when no further sector decomposition occurs.

For each sector, its contribution to the sector management from the level above, $w_s^P \cdot \left(R_s^P - R_s^B\right)$, is recursively split into the following components:

Asset Allocation $$w_s^P \sum_r \left(\frac{w_r^P}{w_s^P} - \frac{w_r^B}{w_s^B}\right) \cdot \left(R_r^B - R_s^H\right) \qquad (70\text{-}8)$$

Sector Management $$\sum_r w_r^P \cdot \left(R_r^P - R_r^B\right) \qquad (70\text{-}9)$$

Typically, the benchmark sector return R_s^B is used as the hurdle rate as for the calculation of asset allocation to subsectors. In this fashion, we can keep decomposing sector management outperformance until we reach the last layer of portfolio management. Since at each level the decomposition is complete, the total outperformance decomposition is also complete. This algorithm has two of the three required properties of performance attribution: additivity and completeness. As we will see in the following discussion, it also has sufficient flexibility to be applied under different management structures such that it is considered to be fair, thereby satisfying all three requirements of performance attribution.

The fundamental advantage of the sector-based attribution methodology is its flexibility. The ability to analyze portfolio allocations along an arbitrarily specified market partition makes it possible to customize the model to fit many different types of portfolios and management styles. The main disadvantage of this approach is that it analyzes yield-curve and spread returns within the same market partition using market value weights, something that does not correspond to standard fixed income portfolio management practice.

Factor-Based Attribution

The "sector-based" attribution is gradually losing ground to a "factor-based" decomposition of the investment universe, where the return of the security in the portfolio/benchmark is decomposed into the contributions of common risk factors plus a residual. The residual represents the return not captured by the risk factors. The coefficients of the factors, α_k, are called loadings or sensitivities of the portfolio to each factor, f_k. Typically, the decomposition is linear and is represented as:

$$R^P = \sum_k \alpha_k^P f_k^P + \varepsilon^P$$

Such risk factors for fixed income securities include interest rates, implied volatility, spreads, etc., and the loadings are the corresponding sensitivities to the exposure of each factor (option-adjusted duration, partial (key-rate) durations, Vega, spread duration, and related measures). Factor-based attribution essentially entails the decomposition of outperformance to the contribution of each risk factor.

$$R^P - R^B = \sum_k \left(\alpha_k^P - \alpha_k^B\right) \cdot f_k^P + (\varepsilon^P - \varepsilon^B) \tag{70-10}$$

Pure factor-based attribution systems attempt to use a set of factors that can explain all of the systematic return of a portfolio. In this case the excess return is idiosyncratic and therefore quite small for a well-diversified portfolio. The disadvantages of this approach are that it does not attribute idiosyncratic returns of small portfolios to security selection decisions, and there is usually little flexibility in defining the risk factors. The latter shortcoming may be overcome with factor remapping,[4] which allows each portfolio manager to attain a personalized view of risk and return decomposition.

A Unified Framework for Performance Attribution

We will now combine the ideas we have developed in the preceding sections into a unified framework that blends the sector-based and the factor-based attribution. Models using this framework, such as the Barclays Capital Hybrid Performance Attribution model, are favored by portfolio managers since they can account for the complex management structures of large diversified portfolios. The framework offers enhanced flexibility in defining arbitrary hierarchical partitions along which sector allocation decisions are expressed. It allows the portfolio managers to achieve the best match to their investment decision-making process. It is a conceptually simple recursive algorithm that can be described in three steps: return splitting, factor return attribution, and recursive application. We explain these steps below.

Step 1: Return Splitting

The total return of the portfolio and the benchmark is split into the linear contributions of factors.[5]

$$R^P = \sum_k \alpha_k^P f_k^P \qquad R^B = \sum_k \alpha_k^B f_k^B$$

Note that residual is included here as one of the factors with a loading of one.

Step 2: Factor Return Attribution

The factors from step 1 are categorized as either common or allocated. We denote the set of common factors by C and the set of allocated factors by A and write the total outperformance as:

$$R^P - R^B = \left(\sum_{k \in C} \alpha_k^P f_k^P - \sum_{k \in C} \alpha_k^B f_k^B \right) + \left(\sum_{k \in A} \alpha_k^P f_k^P - \sum_{k \in A} \alpha_k^B f_k^B \right) \tag{70-11}$$

The outperformance from each factor is then handled separately. For each factor, we partition the investment universe into sectors[6] and decompose the outperformance from the factor.

$$\alpha_k^P f_k^P - \alpha_k^B f_k^B = \sum_s \alpha_{k,s}^P f_{k,s}^P - \sum_s \alpha_{k,s}^B f_{k,s}^B \tag{70-12}$$

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4. António Baldaque da Silva, "Risk Attribution with Custom-Defined Risk Factors," *Barclays Capital Publications*, August 2009.
5. Successive valuation used for the return splits is discussed in Chapter 71.
6. A different partition may be used for each factor.

Outperformance from common factors is explained using bottom-up aggregation, namely via net exposures to a factor at each level of the aggregation. Furthermore, if a factor is truly common, where the factor return in the portfolio is identical to the factor return in the benchmark, then the contribution of the factor to portfolio outperformance can be written as:

$$\alpha_k^P f_k^P - \alpha_k^B f_k^B = \sum_s \left(\alpha_{k,s}^P - \alpha_{k,s}^B\right) \cdot f_{k,s} \tag{70-13}$$

This breakdown allows the performance of the portfolio due to the common factors to be categorized and aggregated to the portfolio level. In this way, a more detailed explanation of the factor and its impact to the total portfolio is possible than if the return were split between sectors. For example, exposure to the yield-curve is typically managed at the portfolio level by determining first the overall duration over/underweight vs. the benchmark and then determining where on the yield-curve to take the extra exposure. The strategy may be designed to take advantage of flattening or steepening in the yield-curve, and only measurement of these effects at the portfolio or sub-portfolio level is meaningful.

Outperformance from allocated factors is explained using the following allocation methods: absolute allocation and relative allocation. We discuss each below.

Unlike common factors, allocated factors may have different realizations for different securities or sectors even if they broadly capture the same type of risk exposure. For example, credit-spread, whose level depends on the particular securities within a sector, is a factor of this type. In the absolute allocation framework, the total portfolio exposure to each factor is determined by all sector managers. Each sector manager may take a different view as to the expected direction of each factor. In this case, asset allocation is solely determined by the net sector exposure to a particular factor:

$$\text{Asset Allocation} \quad \sum_s \left(\alpha_{k,s}^P - \alpha_{k,s}^B\right) \cdot f_{k,s}^B \tag{70-14}$$

$$\text{Sector Management} \quad \sum_s \alpha_{k,s}^P \cdot \left(f_{k,s}^P - f_{k,s}^B\right) \tag{70-15}$$

In the relative allocation framework, the total exposure to each factor is determined at the portfolio level (or the higher hierarchical level). The asset allocator subsequently determines the sector exposures to the factor subject to the constraint imposed by the portfolio exposure. Each sector may take a different view as to the relative movement of each factor against the overall benchmark factor return.

$$\text{Asset Allocation} \quad \alpha_k^P \cdot \sum_s \left(\frac{\alpha_{k,s}^P}{\alpha_k^P} - \frac{\alpha_{k,s}^B}{\alpha_k^B}\right) \cdot \left(f_{k,s}^B - f_k^H\right) \tag{70-16}$$

$$\text{Sector Management} \quad \sum_s \alpha_{k,s}^P \cdot \left(f_{k,s}^P - f_{k,s}^B\right) \tag{70-17}$$

$$\text{Top-Level Exposure} \quad \left(\alpha_k^P - \alpha_k^B\right) \cdot f_k^H \tag{70-18}$$

Notice that in the relative allocation framework, the factor hurdle rate f_k^H essentially becomes a common factor.

Step 3: Recursive Application

The sector management terms from top-down allocations, $f_{k,s}^P - f_{k,s}^B$, can be now decomposed separately using the above algorithm recursively.

At the last stage of the decomposition, in which a sector is not decomposed further into subsectors, the sector management term becomes security selection. The top-down decomposition can be applied one last time to break down the security selection outperformance of a sector into the contributions of individual securities. In this case the management term is typically zero, since the factor driving the return of the same security in the portfolio and the benchmark is the same.

An Example of Hybrid Performance Attribution

To illustrate how this algorithm can be applied in practice, consider a very simple model in which the return of a security is split into two components: the time return that is measured by the yield of the security and a market return that is measured as the duration of the security times the negative of its yield change. This decomposition may not be complete, so it is reasonable to assume the presence of a residual.

$$R_i = Y_i \, \Delta t - D_i \, \Delta Y_i + \varepsilon_i \tag{70-19}$$

The portfolio (or benchmark) return is the weighted average return of the securities in the portfolio (or benchmark). The summation extends over a universe defined by the union of securities in the portfolio and benchmark. Securities not present in either get correspondingly zero weight.

$$\begin{aligned} R^P &= \sum_i w_i^P R_i = \sum_i w_i^P Y_i \, \Delta t - w_i^P D_i \, \Delta Y_i + w_i^P \varepsilon_i \\ R^B &= \sum_i w_i^B R_i = \sum_i w_i^B Y_i \, \Delta t - w_i^B D_i \, \Delta Y_i + w_i^B \varepsilon_i \end{aligned} \tag{70-20}$$

Aggregation of yield and duration is the usual weighted average; however, yield changes must be aggregated using duration contribution weights to retain their natural interpretation.

$$\begin{aligned} Y^P &= \sum_i w_i^P Y_i \qquad Y^B = \sum_i w_i^B Y_i \\ D^P &= \sum_i w_i^P D_i \qquad D^B = \sum_i w_i^B D_i \end{aligned} \tag{70-21}$$

$$\Delta \mathrm{Y}^P = \sum_i \frac{w_i^P D_i}{D^P} \Delta \mathrm{Y}_i \qquad \Delta \mathrm{Y}^B = \sum_i \frac{w_i^B D_i}{D^B} \Delta \mathrm{Y}_i \tag{70-22}$$

We can now rewrite the portfolio and benchmark returns using top-level analytics:

$$R^P = Y^P \Delta t - D^P \Delta Y^P + \sum_i w_i^P \varepsilon_i$$
$$R^B = Y^B \Delta t - D^B \Delta Y^B + \sum_i w_i^B \varepsilon_i \tag{70-23}$$

Let us assume that time return (carry) and residual are allocated as common factors.

$$\text{Carry} \qquad (Y^P - Y^B) \cdot \Delta t \tag{70-24}$$

$$\text{Residual} \qquad \sum_i \left(w_i^P - w_i^B\right) \cdot \varepsilon_i \tag{70-25}$$

Market return is managed by allocating duration exposure $w_s^P D_s^P$ to a set of sectors and allowing managers to pick securities within each sector.

If the top-level portfolio duration is not constrained and is completely determined by the choices of the sectors' net duration exposures, we should use the absolute allocation algorithm by setting $\alpha_k \leftarrow D$, $\alpha_{k,s} \leftarrow w_s D_s$, $f_{k,s} \leftarrow -\Delta Y_s$. The duration and yield change of each sector in the portfolio and the benchmark are calculated in the same weighted average fashion we discussed above. Since the asset allocation agent is free to determine the duration exposure of each sector, there is no hurdle rate and the total outperformance is solely distributed between asset allocation and security selection.

$$\text{Asset Allocation} \qquad -\sum_s \left(w_s^P D_s^P - w_s^B D_s^B\right) \cdot \Delta Y_s^B \tag{70-26}$$

$$\text{Security Selection} \qquad -\sum_s w_s^P D_s^P \cdot \left(\Delta Y_s^P - \Delta Y_s^B\right) \tag{70-27}$$

On the other hand, if the net duration of the portfolio is actively managed, we need to use the relative allocation method. In this case, we set the hurdle rate equal to the benchmark yield change.

$$\text{Asset Allocation} \qquad -D^P \cdot \sum_s \left(\frac{w_s^P D_s^P}{D^P} - \frac{w_s^B D_s^B}{D^B}\right) \cdot \left(\Delta Y_s^B - \Delta Y^B\right) \tag{70-28}$$

$$\text{Security Selection} \qquad -\sum_s w_s^P D_s^P \cdot \left(\Delta Y_s^P - \Delta Y_s^B\right) \tag{70-29}$$

$$\text{Top-Level Exposure} \qquad -(D^P - D^B) \cdot \Delta Y^B \tag{70-30}$$

APPLICATIONS OF PERFORMANCE ATTRIBUTION

Beyond its stated goal of attributing portfolio outperformance to the actions of agents, detailed and flexible performance attribution can bring clarity to the process of portfolio management by systematically exposing sources of risk and performance. By linking ex-post outperformance contributions to ex-ante views and management decisions, a manager can identify unanticipated sources of risk and return and adjust the management process accordingly. In addition, by providing the recursive decomposition of outperformance into the various contributing factors, it facilitates the discovery and correction of data errors that are not uncommon in large financial accounting systems. In the rest of this chapter we will illustrate such applications of performance attribution in the context of a particular portfolio.

Performance Attribution as a Portfolio Management Tool

Consider the following example. A portfolio manager has the mandate to track the Barclays Capital Global Aggregate G4 Index and has the latitude to implement certain market views in order to enhance the portfolio returns, as long as the standard deviation of portfolio minus benchmark returns (Tracking Error Volatility or TEV) stays below 40 bp per month. At a specific point in time, the manager is bullish on the Japanese yen, negative on the euro and neutral on the U.S. dollar and the British pound. She believes that global rates are falling. She has no sector views except in the U.S. markets, where she likes corporates but dislikes the securitized sector. According to her mandate and her views, she constructs a portfolio with the following characteristics:

- The portfolio has a 5% overweight (vs. the benchmark) in the yen, has a 5% underweight in the euro, and is flat in U.S. dollars and British pounds.
- The portfolio interest-rate option-adjusted duration (OAD) is about one year longer than that of the benchmark.
- Within the U.S. market, the portfolio has a 5% overweight in corporates, has a 5% underweight in securitized, and is flat in the U.S. Treasury and government-related sectors.

We created this portfolio in the POINT system then offered by Barclays and used the Global Risk Model in POINT to estimate the portfolio tracking error volatility relative to its benchmark as 32 bp per month. Since this is below the 40 bp per month risk budget the portfolio is acceptable.

We subsequently ran the POINT hybrid performance attribution model over one month and produced a detailed performance attribution report. This report begins by reporting the total portfolio and benchmark returns over the month (+188.7 bp and +150.0 bp, respectively) as well as their difference, +38.7 bp, the total portfolio outperformance (Exhibit 70-1). The report then proceeds to decompose the total outperformance into the contributions of the various portfolio exposures and market performance. The decomposition is hierarchical to allow the portfolio manager to first get a broad understanding of the sources of outperformance and then dive into the specific details. In Exhibit 70-2, we see a first decomposition of the portfolio total outperformance on a global level into three components: FX Allocation and Hedging (+28.3 bp), Local Market Allocation (–8.7 bp), and Local Market Management (+19.1 bp). In Exhibit 70-3, the Local Market Management component is further decomposed into contributions from Yield-Curve exposures (+20.6 bp), Asset Allocation (+0.2 bp), and Security Selection (–1.7 bp).

EXHIBIT 70-1

Total Portfolio Outperformance

Global Outperformance (bp)	
Portfolio Return	188.7
Benchmark Return	150.0
Total Outperformance	**38.7**

Source: POINT

EXHIBIT 70-2

Global Outperformance Summary

Global Outperformance Summary (bp)	
FX Allocation and Hedging	28.3
Local Market Allocation	–8.7
Local Market Management	19.1
Total	**38.7**

Source: POINT

EXHIBIT 70-3

Local Market Management Details

Local Market Management Details (bp)	
Yield-Curve	20.6
Asset Allocation	0.2
Security Selection	–1.7
Total	**19.1**

Source: POINT

Outperformance from Currency Exposures

The +28.3 bp outperformance from FX allocation and hedges indicates that the manager's FX views were broadly correct. In Exhibit 70-4 we can see that, consistent to the manager's predictions, the yen rallied and the euro fell versus the U.S. dollar. The analysis also shows that the portfolio maintained a net exposure of +5% in the yen and –5% in the euro with little drift. In particular, the yen outperformed the U.S. dollar by 319.4 bp in the period, a figure that includes the change in the FX spot rate and the short-term interest rate differentials between the two currencies.[7] Since the yen is overweighted by 5% on average, a quick calculation estimates the outperformance contribution as 5% × 319.4 = +16.0 bp. This calculation is not exact, since the attribution model used in this example employs daily frequency and compounding as we have discussed previously. Such simple calculations are acceptable when the net exposure does not fluctuate significantly over the attribution period and will be used throughout this example. In this case the reported yen contribution of +16.1 bp in Exhibit 70-4 is within 1 bp of the result of simple calculation.

Similar analysis can be carried out for the underweight to weakening euro, which contributes outperformance of +12.0 bp. The fact that the British pound also weakened generates no outperformance because the portfolio net exposure to the British pound was designed to be zero. Finally, the completeness of FX outperformance decomposition is ensured by accounting for the interaction effect between FX and local returns. The cross-term is normally small. In this case, it is only +0.2 bp.

Outperformance from Allocation to Local Markets

Allocation to local markets evaluates a portfolio manager's decision to under-/overweight a local bond market. In this example its contribution is –8.7 bp. Exhibit 70-5 shows the major contributors to be the yen and euro markets. By attempting to overweight the yen and underweight the euro using cash instruments (i.e., without using FX forwards), the portfolio also took on an overweight in the yen local market and an underweight in the local euro-zone market. The yen market overweight is not a good decision since its local return over the deposit rate is only +64.2 bp, much lower than the benchmark local return over deposit of +164.1 bp. Therefore, it generates an underperformance that can be approximately calculated as (64.2 – 164.1) × 5% = –5.0 bp, as reported in the second to last column. The euro market underweight is not good either, since the local market had a return of +239.2 bp, significantly higher than the benchmark return of +164.1 bp. It results in an underperformance estimated as (239.2 – 164.1) × –5% = –3.8 bp. The actual contribution is –3.7 bp, as reported in the second to last column and together with the –5.0 bp of the yen market contribution fully explain the Local Markets Allocation outperformance component.

Separation of the FX and Local components of global markets allows the measurement of outperformance under several styles of management. In some portfolio management structures, the FX exposure of the portfolio is managed separately from the local market exposure of the portfolio using derivative instruments such as FX forwards. However, in our example, the exposures to the local markets might be thought as incidental to the manager's FX views and a result of

7. See Chapter 72 for a detailed discussion

EXHIBIT 70-4

FX Outperformance Breakdown

	FX Rate Begin	FX Rate End	Avg Depo Rate (%)	FX + Depo Return (bp)	Excess over Base Currency Depo	Portf Weight	Bmark Weight	P-B Mean	P-B Min	P-B Max	FX Allo-cation	FX / Local Cross Term
USD	1.0000	1.0000	0.23	2.1	0.0	45.5	45.6	–0.1	–0.2	0.0	0.0	0.0
EUR	1.3028	1.2710	0.28	–242.1	–244.1	23.2	28.1	–4.9	–5.0	–4.9	12.0	0.1
JPY	0.0115	0.0119	0.12	321.5	319.4	25.6	20.5	5.0	5.0	5.1	16.1	0.0
GBP	1.5661	1.5369	0.57	–181.5	–183.5	5.8	5.8	0.0	–0.1	0.0	0.0	0.1
Total						**100.0**	**100.0**				**28.1**	**0.2**

Source: POINT

EXHIBIT 70-5

Local Market Allocation Report

	Local Market Returns (bp)				Market Weight (%)						
	Benchmark Local Market Returns (bp)				Average		Overweight			Outperformance (bp)	
Currency Market	Total Return	Depo Rate Return	Return over Depo	Portfolio Local	Portf	Bmark	Mean	Min	Max	Local Market Allocation	Local Management
USD	129.8	2.1	127.8	161.6	45.5	45.6	–0.1	–0.2	0.0	0.0	14.6
EUR	241.7	2.5	239.2	269.0	23.2	28.1	–4.9	–5.0	–4.9	–3.7	6.3
JPY	65.3	1.1	64.2	74.8	25.6	20.5	5.0	5.0	5.1	–5.0	2.4
GBP	445.5	5.1	440.5	371.5	5.8	5.8	0.0	–0.1	0.0	0.0	–4.2
Total	**166.0**	**2.2**	**164.1**	**176.3**	**100.0**	**100.0**				**–8.7**	**19.1**

Source: POINT

EXHIBIT 70-6

Breakdown of Local Outperformance per Local Market

	U.S. Dollar	Euro	Japanese Yen	British Pound	Total
Portfolio Weight (%)	**45.5**	**23.2**	**25.6**	**5.8**	**100.0**
Local Management (bp)	**14.6**	**6.3**	**2.4**	**–4.2**	**19.1**
Yield-Curve	11.2	17.9	3.0	–11.5	20.6
Asset Allocation	–2.5	1.5	–0.1	1.3	0.2
Security Selection	5.9	–13.3	–0.5	6.2	–1.7

Source: POINT

not properly differentiating the views on FX versus the views on the local market performance. In this case, it might make sense to combine the two contributions and allocate 28.3 – 8.7 = +19.6 bp of outperformance to the views on the currency markets.

Outperformance from Management of Local Markets

Once the allocation into each local market is determined, local market management measures how well the portfolio performed versus its benchmark within the same local market. From Exhibit 70-3, we already know that the dominant contributor is yield-curve exposures with +20.6 bp. Exhibit 70-6 offers more details by each local market.

We can see that positive yield-curve outperformance came primarily from the U.S. dollar and the euro markets, whereas the British pound curve exposure resulted in a loss of –11.5 bp. We also see that asset allocation was not a significant driver of performance. Security selection decisions within each local market were significant, although the net result across all currencies was small at –1.7 bp. In particular, the selections within the U.S. dollar and British pound portion of the portfolio contributed positively, +5.9 bp and +6.2 bp, respectively, but the selections within the euro portion of the portfolio negated these gains by contributing –13.3 bp.

Outperformance Due to Yield-Curve Exposure

Focusing on the large yield-curve outperformance contribution, the manager wants to understand how her directive to go long duration by one year globally was implemented, and analyze the impact on each individual market. Exhibit 70-7 shows the yield-curve outperformance breakdown for the U.S. dollar portion of the portfolio.

EXHIBIT 70-7

Yield-Curve Outperformance Breakdown for U.S. Dollar

	Yield			Curve-Matched Market Weight (%)			Duration (yrs)			Outperformance (bp)		
	Level (%)		Change (bp)	Average		O/W	Average		O/W	Yield-Curve		
USD	Portf	Bmark		Portf	Bmark	Avg	Portf	Bmark	Avg	Carry	Change	Total
Parallel Shift												
Average	1.311	1.245	–31.6	99.7	100.0	–0.3	4.66	4.18	0.48	–0.3	14.6	14.3
Key Rates & Cash												
Cash	0.241	0.241	–1.3	–18.2	–11.2	–7.0	0.00	0.00	0.00	1.0	0.0	1.0
6m	0.179	0.179	1.3	35.3	32.4	2.8	0.18	0.16	0.01	–0.3	–0.5	–0.8
2y	0.534	0.534	–5.2	42.3	35.6	6.7	0.84	0.71	0.13	–0.5	–3.5	–4.0
5y	1.628	1.628	–26.1	19.8	24.9	–5.1	0.96	1.21	–0.25	–0.4	1.4	1.0
10y	3.055	3.055	–45.7	7.1	12.1	–5.0	0.64	1.09	–0.45	–1.0	–6.6	–7.6
20y	3.795	3.795	–48.7	12.3	3.2	9.1	1.83	0.47	1.36	1.6	23.8	25.3
30y	4.000	4.000	–42.1	1.1	2.9	–1.8	0.21	0.54	–0.33	–0.3	–3.8	–4.1
Rest of Curve & Convexity												
										0.0	–0.6	–0.6
Total Yield-Curve Levels & Shifts												
										–0.3	**24.9**	**24.6**

Source: POINT

Individual market reports are unscaled by the value of the holdings in each market in order to evaluate single-market managers on an equal basis. Looking at each market in absolute terms allows us to reveal useful information about the management within each market, even for markets that constitute a small portion of the overall portfolio and their contributions to total portfolio outperformance are not significant. To translate the absolute unscaled numbers contained in the local reports into their contributions to total portfolio outperformance, one has to multiply such numbers by the corresponding market weight in the portfolio. In this example, the currency weights can be found in the Global Outperformance by Currency report in Exhibit 70-6; they are 45.5% for the U.S. dollar, 23.2% for the euro, 25.6% for the yen, and 5.8% for the British pound market.

The yield-curve report in Exhibit 70-7 contains a lot of information, but the manager can quickly see that the U.S. Treasury curve experienced bull-flattening with long rates falling in excess of 40 bp (third column from the left). She can also see that the portfolio is generally long duration by about 0.5 years (4.66 vs. 4.18). This is consistent with the general desire to be long duration, and with rates generally falling, it creates outperformance. More precisely, the yield change at the average maturity point of the benchmark is –31.6 bp. Multiplied by the (negative of) the average duration overweight of 0.48 years results in approximately +15.2 bp of outperformance contribution. The daily algorithm calculates that this number is actually +14.6 bp (top of the second to last column) by taking into account that duration exposure fluctuated during the period. The total U.S. dollar curve outperformance, accounting for the re-shaping of the yield-curve and the contributions from carry, is calculated to be +24.6 bp. Most of the additional outperformance comes from a butterfly position on the curve, where an overweight of the 20 year point of about 1.36 years is partially offset with underweighting the 5-, 10-, and 30-year points. Since the 20-year point is the one with the largest yield drop (–48.7 bp), this butterfly position results in additional outperformance. The algorithm calculates and reports the excess contribution of each curve point separately.

The manager should be concerned that such a large component of total outperformance comes from an inadvertent position in the re-shaping of the U.S. curve (about +4.7 bp, estimated as the non-parallel U.S. curve outperformance 24.6 – 14.3 = +10.3 bp, times the U.S. dollar market weight of 45.5%) and should seek to control exposure to the various parts of yield curves more carefully.

Exhibit 70-8 displays the yield-curve reports for the other three currencies. The euro curve outperformance analysis is very similar to the U.S. dollar one. There is duration overweight of about 1 year, as well as a butterfly position. Like the U.S. dollar curve, the euro curve also bull-flattens, resulting in (unscaled) outperformance of +77.4 bp and a contribution to total outperformance of +17.9 bp (remember that the average portfolio weight of the euro market is 23.2%). The yen has an even bigger duration overweight, about 2.7 years, but the curve movement is not as dramatic, with average yields falling about 7 bp. The portfolio contains significant curve reshaping positions as well, with the 20-year

EXHIBIT 70-8

Yield-Curve Outperformance Breakdown for Euro, Japanese Yen, and the British Pound

	Yield			Curve-Matched Market Weight (%)			Duration (yrs)			Outperformance (bp)		
	Level (%)		Change (bp)	Average		O/W	Average		O/W	Yield-Curve		
EUR	**Portf**	**Bmark**		**Portf**	**Bmark**	**Avg**	**Portf**	**Bmark**	**Avg**	**Carry**	**Change**	**Total**
Parallel Shift												
Average	2.030	1.698	–50.2	100.0	100.0	0.0	6.68	5.62	1.05	2.9	54.2	57.1
Key Rates & Cash												
Cash	0.279	0.279	0.0	–13.1	–14.5	1.3	0.00	0.00	0.00	0.2	0.0	0.2
6m	0.381	0.381	0.6	4.0	16.2	–12.2	0.02	0.08	–0.06	1.8	3.1	5.0
2y	0.771	0.771	–22.6	39.5	37.4	2.2	0.79	0.74	0.04	–1.4	–1.3	–2.6
5y	1.726	1.726	–43.1	22.0	33.7	–11.7	1.07	1.64	–0.57	–1.2	4.0	2.8
10y	2.708	2.708	–57.3	40.1	18.5	21.6	3.65	1.68	1.97	0.8	14.1	14.9
20y	3.377	3.377	–64.7	7.5	5.8	1.7	1.16	0.89	0.26	–0.1	3.5	3.4
30y	3.324	3.324	–69.6	0.0	3.0	–3.0	0.00	0.59	–0.59	–0.1	–11.5	–11.6
Rest of Curve & Convexity												
										0.0	8.3	8.3
Total Yield-Curve Levels & Shifts												
										2.9	**74.4**	**77.4**

(Continued)

EXHIBIT 70-8

Yield-Curve Outperformance Breakdown for Euro, Japanese Yen, and the British Pound (*Continued*)

	Yield			Curve-Matched Market Weight (%)			Duration (yrs)			Outperformance (bp)		
	Level (%)		Change (bp)	Average		O/W	Average		O/W	Yield-Curve		
JPY	**Portf**	**Bmark**		**Portf**	**Bmark**	**Avg**	**Portf**	**Bmark**	**Avg**	**Carry**	**Change**	**Total**
Parallel Shift												
Average	0.822	0.617	–7.0	100.0	100.0	0.0	9.54	6.85	2.69	0.7	18.5	19.2
Key Rates & Cash												
Cash	0.126	0.126	–1.2	–6.6	–13.2	6.6	0.00	0.00	0.00	–0.5	0.0	–0.5
6m	0.124	0.124	–1.3	–0.3	15.3	–15.6	0.00	0.08	–0.08	1.2	0.4	1.6
2y	0.145	0.145	–3.3	19.2	33.9	–14.7	0.38	0.68	–0.29	1.0	1.3	2.3
5y	0.344	0.344	–5.3	51.8	19.7	32.1	2.58	0.98	1.59	–1.0	–3.0	–4.0
7y	0.616	0.616	–12.2	2.6	14.9	–12.3	0.18	1.03	–0.85	–0.6	–4.6	–5.1
10y	1.034	1.034	–5.1	–1.1	16.2	–17.3	–0.11	1.57	–1.67	–1.5	3.2	1.7
20y	1.776	1.776	–8.1	27.5	10.0	17.5	4.85	1.77	3.09	1.2	2.7	3.9
30y	1.876	1.876	–7.6	6.9	3.1	3.8	1.65	0.75	0.90	0.2	0.7	0.9
Rest of Curve & Convexity												
										0.0	–8.1	–8.1
Total Yield-Curve Levels & Shifts												
										0.7	**11.1**	**11.8**

(*Continued*)

EXHIBIT 70-8

Yield-Curve Outperformance Breakdown for Euro, Japanese Yen, and the British Pound (*Continued*)

	Yield			Curve-Matched Market Weight (%)			Duration (yrs)			Outperformance (bp)		
	Level (%)		Change (bp)	Average		O/W	Average		O/W	Yield-Curve		
GBP	**Portf**	**Bmark**		**Portf**	**Bmark**	**Avg**	**Portf**	**Bmark**	**Avg**	**Carry**	**Change**	**Total**
Parallel Shift												
Average	1.990	2.833	–44.9	100.0	100.0	0.0	4.78	8.58	–3.81	–5.0	–172.4	–177.4
Key Rates & Cash												
Cash	0.573	0.573	–0.4	–11.7	–10.5	–1.2	0.00	0.00	0.00	–0.3	0.0	–0.3
6m	0.579	0.579	–5.3	5.2	11.2	–5.9	0.03	0.06	–0.03	1.8	1.2	3.0
2y	0.936	0.936	–22.1	53.3	21.1	32.2	1.06	0.42	0.64	–2.9	–14.7	–17.7
5y	2.205	2.205	–43.4	24.7	24.8	–0.1	1.19	1.19	0.00	1.2	–0.1	1.2
10y	3.417	3.417	–46.7	28.4	23.0	5.4	2.51	2.03	0.48	1.9	0.9	2.7
20y	4.210	4.210	–49.5	0.0	14.9	–14.9	0.00	2.14	–2.14	–1.1	–10.1	–11.2
30y	4.277	4.277	–44.9	0.0	15.5	–15.5	0.00	2.74	–2.74	–0.6	0.1	–0.5
Rest of Curve & Convexity												
										0.0	0.9	0.9
Total Yield-Curve Levels & Shifts												
										–5.0	**–194.2**	**–199.2**

Source: POINT

point being overweighted by more than 3 years, while the 20-year point is underweighted by about 1.7 years. Nevertheless, the yen curve change is not sufficiently pronounced and generates only +11.8 bp of (unscaled) outperformance, contributing +3.0 bp to the total outperformance (the average portfolio weight of the yen market is 25.6%). The picture is completely different for the British pound. Here, the portfolio has a significant duration underweight of about 3.8 years, combined with a strong bull-flattening move of the British pound yield-curve (a yield change of –44.9 bp at the long end). This underweight results in a dramatic (unscaled) underperformance of –199.2 bp. The small average portfolio weight of the British pound market (5.8%) prevents this from being a major drag in the portfolio performance but even so its contribution to total outperformance is a significant –11.5 bp.

At this point, it should be clear to the portfolio manager that understanding and managing the detailed exposure to the yield-curve of each currency is of paramount importance for proper control of the portfolio performance. She may also decide that global curve management is so important that it has to be managed before any local allocation and management decisions are made. In this case, a different attribution algorithm must be used, one that excludes yield-curve outperformance from the Local Market Allocation and Local Management Components. A detailed discussion on this type of analysis can be found in Chapter 72.

Asset Allocation and Security Selection

The manager now shifts her attention to the remaining sources of outperformance. First, she wants to understand how her views on the performance of U.S. assets panned out. From the "Global Outperformance by Currency" report of Exhibit 70-6, she already knows that U.S. dollar asset allocation contributed –2.5 bp to total outperformance. Exhibit 70-9 displays the U.S. Dollar Asset Allocation report, where we can see that most of the underperformance is caused by the overweight to corporate bonds. Remember that all numbers in this page are un-weighted; that is, they have to be scaled by the 45.5% portfolio weight of the U.S. market allocation in order to convert them into contributions to total portfolio outperformance. In particular, the 5% overweight sought to U.S. corporate bonds during the portfolio construction is represented here as an overweight of 10.9% (30.9% – 19.8% = 11.1%, approximately equal to 5%/45.5%), and the –2.5 bp of underperformance is reported as –5.5 bp (approximately equal to –2.5 bp/45.5%). The corporate sector contributes –5.2 bp, something that can be explained by the significant underperformance of the corporate sector in the benchmark (–70.2 bp) relative to the benchmark itself (–22.0 bp). The approximate calculation results in 11.1% × (–70.2 + 22.0) = –5.35 bp, close to the –5.2 bp reported. The Treasury and government-related sectors have no contribution to asset allocation, as their weights are matched exactly between the portfolio and the benchmark, as designed. Finally, the securitized sector has minimal contribution to asset allocation, despite the significant underweight, because its performance (–19.0 bp) is close to that of the benchmark (–22.0 bp).

EXHIBIT 70-9

U.S. Asset Allocation Breakdown

	Market Weight (%)					Excess to Curve Return (bp)		Outperformance (bp)	
	Average		Overweight					Asset Alloc.	Security Select.
Partition Bucket	**Portf**	**Bmark**	**Average**	**Min**	**Max**	**Portf**	**Bmark**		
Total	**100.0**	**100.0**				**–14.6**	**–22.0**	**–5.5**	**13.0**
Treasury	31.7	31.7	0.1	–0.1	0.2	–4.7	–2.2	0.0	–0.8
Government-Related	14.3	14.3	0.0	0.0	0.1	17.6	–7.7	0.0	3.7
Corporate	30.7	19.8	10.9	10.7	11.0	–33.5	–70.2	–5.2	11.1
Securitized	22.8	33.4	–10.7	–10.9	–10.6	–23.3	–19.0	–0.3	–1.0
Cash	0.5	0.8	–0.3	–0.5	0.0	0.0	0.0	–0.1	0.0

Source: POINT

The same report also lists the contribution of each sector to security selection. We see that once again, the corporate sector is the dominant contributor with +11.1 bp out of the total +13.0 bp of security selection in the U.S. dollar market. To further understand the sources of security selection outperformance, the manager studies the detailed U.S. Dollar Security Selection report displayed in Exhibit 70-10. This report lists the chosen securities in each sector and their excess-of-curve return. We can see that the manager responsible for security picks in the U.S. corporate sector has indeed picked mostly securities whose excess returns beat the benchmark. One notable exception is the 6.45% 2037 Comcast bond, which represents 10.1% of the portfolio holdings in this sector (an overweight of 10% versus the benchmark) and which experienced –280.0 bp of excess return (much worse than the benchmark, which lost only 70.2 bp).

To estimate the contribution of the bond to the security selection outperformance coming from U.S. corporate bonds, one must take into account the weight of the corporate sector in the U.S. portfolio, which is 30.7%, to get 30.7% × 10% × (–280.0 + 70.2) = –6.4 bp. After scaling by the 45.5% weight of the U.S. portfolio, we calculate the contribution of the particular Comcast bond to global outperformance as 45.5% × –6.4 bp = –2.9 bp. This is quite significant and highlights the importance of name selection in a portfolio with a relatively small number of positions.

The manager also takes a look at the details of security selection in the euro market, which, as reported in Exhibit 70-6, reduces the total outperformance by a significant 13.3 bp. The report in Exhibit 70-11 lists the security selection outperformance as –57.4 bp (which scaled by the market weight of the euro market of 23.2% is equal to –13.3 bp) and identifies Italian government bonds as the main culprits. The fact that, absent any specific direction otherwise, the euro government sector was constructed by mostly Italian government bonds, leading to significant underperformance because of sovereign credit deterioration in Italy, indicates that the manager should attempt to take control of country exposure within the euro sector.

By now, the manager has a good understanding of most major contributors to the outperformance of the portfolio and has also reached some useful conclusions regarding the management of a small global portfolio.

- Yield-curve exposure is the dominant risk factor and must be managed explicitly in each currency.
- It is not sufficient to manage yield-curve exposure using just the duration. Exposure to curve re-shaping must also be controlled carefully.
- It may make sense to manage yield-curve exposure globally and not allow it to be determined by local allocation and management decisions.
- Name risk is very significant in a small portfolio; exposure to corporate issuers must be scrutinized and questionable names should be excluded.
- Country risk in certain areas such as the euro-zone must be managed separately.

EXHIBIT 70-10

U.S. Security Selection Breakdown

Bucket/Issue	Issuer	MV (%)		Excess to Curve Return (bp)*		Security Selection (bp)
		Portf	Bmark	Portf	Bmark	
USD		100.0	100.0	–14.6	–22.0	13.0
Treasury		31.7	31.7	–4.7	–2.2	–0.8
912828MQ	US TREASURY NOTES	54.9	0.9	–1.0	–1.0	0.2
912810FF	US TREASURY BONDS	19.5	0.2	–1.1	–1.1	0.1
912810FP	US TREASURY BONDS	25.6	0.4	–15.5	–15.5	–1.1
Bmark Securities	Not in Portfolio		98.5		–2.1	0.0
Govt-Related		14.3	14.3	17.6	–7.7	3.7
46513EFF	ISRAEL STATE OF	14.3	0.1	68.0	68.0	1.5
31359MRK	FEDERAL NATL MTG ASSN	62.0	0.1	9.0	9.0	1.5
31359MTP	FEDERAL NATL MTG ASSN	22.0	0.1	7.5	7.5	0.5
RUSSIA	RUSSIA GLOBAL	1.7	1.6	43.3	9.3	0.1
Bmark Securities	Not in Portfolio		98.2		–8.0	0.0

(Continued)

EXHIBIT 70-10

U.S. Security Selection Breakdown (*Continued*)

Bucket/Issue	Issuer	MV (%) Portf	MV (%) Bmark	Excess to Curve Return (bp)* Portf	Excess to Curve Return (bp)* Bmark	Security Selection (bp)
Corporate		30.7	19.8	–33.5	–70.2	11.1
MS	MORGAN STANLEY DEAN WITTER	10.0	1.8	57.7	–72.1	3.9
RABOBK	RABOBANK	11.5	0.5	39.0	47.5	3.7
JPM	JP MORGAN CHASE & CO	13.9	2.3	3.7	–108.6	3.4
UBS	UNION BANK OF SWITZERLAND	10.0	0.5	22.2	7.4	2.7
AXP	AMERICAN EXPRESS CO	10.4	0.8	9.7	–41.5	2.5
WDCAU	WESTFIELD CAPITAL CORP	5.8	0.2	59.9	–12.1	2.3
GS	GOLDMAN SACHS GROUP	9.7	2.3	–33.3	–104.9	1.3
DTV	DIRECTV HOLDINGS/FING	9.5	0.3	–76.9	–123.4	–0.3
WLP	WELLPOINT INC–GLOBAL	9.2	0.2	–133.8	–118.6	–1.8
CMCSA	COMCAST CORPORATION	10.1	1.0	–280.0	–143.7	–6.3
Bmark Securities	Not in Portfolio		90.1		–68.7	–0.4
Securitized		22.8	33.4	–23.3	–19.0	–1.0
FNA05003	FNMA Conventional Long T. 30yr	21.3	2.0	14.2	14.2	1.5
FNA04403	FNMA Conventional Long T. 30yr	11.2	0.4	6.0	6.0	0.6

(Continued)

EXHIBIT 70-10

U.S. Security Selection Breakdown (*Continued*)

Bucket/Issue	Issuer	MV (%) Portf	MV (%) Bmark	Excess to Curve Return (bp)* Portf	Excess to Curve Return (bp)* Bmark	Security Selection (bp)
FGB04403	FHLM Gold Guar Single F. 30yr	10.3	0.2	–21.0	–21.0	–0.1
FNA04409	FNMA Conventional Long T. 30yr	19.7	5.8	–26.5	–26.5	–0.2
GNA04403	GNMA I Single Family 30yr	8.6	0.0	–50.7	–50.7	–0.6
GNF04403	GNMA I Single Family 15yr	29.0	0.0	–52.7	–52.7	–2.2
Bmark Securities	Not in Portfolio		91.5		–19.4	0.1
Cash		0.5	0.8	0.0	0.0	0.0
USD-Unsettled	CASH-U.S. Dollar-Unsettled	52.3		0.0		0.0
USD-Settled	CASH-U.S. Dollar-Settled	47.7	62.0	0.0	0.0	0.0
Bmark Securities	Not in Portfolio		38.0		0.0	0.0

Source: POINT

In the Govt.-Related and Corporate sectors results are aggregated by ticker although calculations occur at the security level. Since each ticker might be represented by a different set of bonds in the portfolio vs. the benchmark, the Excess to Curve Return for each ticker differs between the portfolio and the benchmark.

EXHIBIT 70-11

Euro Security Selection Breakdown

Bucket/Issue	Issuer	MV (%) Portf	MV (%) Bmark	Excess to Curve Returns (bp) Portf	Excess to Curve Returns (bp) Bmark	Security Selection (bp)
EUR		100.0	100.0	–121.0	–69.7	–57.4
Treasury		44.0	55.4	–275.8	–122.4	–66.6
IT0003644769	ITALY (REPUBLIC OF)	4.7	0.5	–270.5	–270.5	–2.7
BE0000308172	BELGIUM (KINGDOM OF)	38.5	0.3	–149.7	–149.7	–3.9
IT0004594930	ITALY (REPUBLIC OF)	5.6	0.5	–321.9	–321.9	–4.5
IT0004513641	ITALY (REPUBLIC OF)	18.3	0.5	–253.7	–253.7	–10.5
IT0004009673	ITALY (REPUBLIC OF)	15.8	0.6	–433.4	–433.4	–20.7
IT0004356843	ITALY (REPUBLIC OF)	17.1	0.5	–420.6	–420.6	–21.6
Bmark Securities	Not in Portfolio		97.0		–116.2	–2.7
Government-Related		7.5	15.3	–119.4	–6.3	–8.2
POLAND	POLAND (REPUBLIC OF)	100.0	2.1	–119.4	–82.6	–8.1
Bmark Securities	Not in Portfolio		97.9		–4.7	–0.1
Corporate		43.8	17.6	18.4	–23.0	18.2
GE	GE CAPITAL CORP	24.0	2.4	54.4	–8.7	8.0
TELEFO	TELEFONICA EMISONES SAU	11.8	1.1	49.1	16.9	3.6
RBS	ROYAL BANK OF SCOTLAND	6.8	1.6	108.4	43.4	3.5

(Continued)

EXHIBIT 70-11

Euro Security Selection Breakdown (*Continued*)

Bucket/Issue	Issuer	MV (%)		Excess to Curve Returns (bp)		Security Selection (bp)
		Portf	Bmark	Portf	Bmark	
IBESM	IBERDROLA	22.7	0.7	1.1	10.6	2.2
BAC	MERRILL LYNCH & CO INC	13.2	1.7	5.5	–74.1	2.0
IMTLN	IMPERIAL TOBACCO FIN PLC	16.7	0.5	0.9	34.1	1.6
C	CITIGROUP INC	4.8	1.4	–181.4	–137.0	–2.7
Bmark Securities	Not in Portfolio		90.5		–22.8	–0.1
Securitized		4.4	11.7	11.3	26.3	–0.7
ES0312298237	AYT CEDULAS CAJAS GLOBAL	100.0	0.2	11.3	11.3	–0.7
Bmark Securities	Not in Portfolio		99.8		26.3	0.0
Cash		0.3	0.0	0.0	0.0	0.0
EUR-Unsettled	CASH-European Monetary Unit-Unsettled	0.0		0.0		0.0
EUR-Settled	CASH-European Monetary Unit-Settled	100.0	100.0	0.0	0.0	0.0

Source: POINT

Further insight can be gained by using a mode of performance attribution in which returns and outperformance are fully decomposed using all available analytics from pricing models. In this model, any part of outperformance that cannot be explained by analytics is reported as residual. This Fully Analytical model will be explained in detail in Chapter 71. Using this model, we get the local management details shown in Exhibit 70-12.

Comparing it with the report of Exhibit 70-3 we see that Local Market Management Details panel has changed. While the yield-curve contribution remains at +20.6 bp, asset allocation is now –0.9 bp instead of +0.2 bp, and security selection is now –2.2 bp instead of –1.7 bp. New terms have appeared, in particular Implied Volatility with +0.9 bp contribution, Mortgage with –3.7 bp contribution, and Residual with a prominent +4.4 bp. The Fully Analytical model also offers more clarity into sources of outperformance beyond the yield-curve, allowing users to understand the sources of the various types of outperformance; it will be discussed in detail in Chapter 71. In this example we will review only the Euro Security Selection report shown in Exhibit 70-13. We can see that not only is the portfolio concentrated on Italian government bonds, but that it also contains bonds of very long maturity, further overweighting the entire European government sector in terms of spread duration exposure. This may lead the manager to draw yet another conclusion: The spread duration exposure of sectors with credit risk must be carefully controlled.

Performance Attribution as a Data Quality Tool

A comprehensive and detailed performance attribution system serves as a magnifying lens for data quality problems and allows users to pinpoint and correct such issues quickly.

EXHIBIT 70-12

Local Market Management Details from a Fully Analytical Model

Local Market Management Details (bp)	
Yield-Curve	20.6
Implied Volatility	0.9
Asset Allocation	–0.9
Security Selection	–2.2
Mortgage	–3.7
Residual	4.4
Total	**19.1**

Source: POINT

EXHIBIT 70-13

Euro Security Selection Report

			Outperformance (bp)				
			Security Selection		Other		
Bucket/Issue	Issuer	MV (%) Portf	Spread Carry	Spread Change	Pricing	Residual	Total
EUR		100.0	2.9	–53.7	0.6	17.2	–33.0
Treasury		44.0	1.5	–59.3	0.6	16.9	–40.3
BE0000308172	BELGIUM	38.5	–0.2	6.2	0.0	0.0	6.1
IT0003644769	ITALY	4.7	0.1	–2.2	0.0	0.0	–2.0
IT0004594930	ITALY	5.6	0.1	–3.6	0.0	0.0	–3.5
IT0004513641	ITALY	18.3	0.6	–22.3	0.6	17.4	–3.7
IT0004356843	ITALY	17.1	0.5	–16.8	0.0	–0.1	–16.4
IT0004009673	ITALY	15.8	0.3	–17.1	0.0	–0.1	–16.9

Source: POINT

The report of Exhibit 70-13 shows that one particular Italian government bond (Issue IT0004513641) is almost single-handedly responsible for the entire reported residual. Indeed, it contributes +17.4 bp of residual to the euro portfolio, which, when scaled by the euro portfolio market weight of 23.2%, results in +4.0 bp of portfolio-level residual (out of the total of +4.4 bp reported in Exhibit 70-12). A diligent manager will promptly investigate such residuals. They may mean one of the following four things:

- Incorrect total returns. This can be caused by missing or incorrect prices, transaction errors, incorrect corporate actions, etc.
- Missing or inaccurate analytics produced in the security valuation process
- Attribution model deficiencies wherein certain contributing factors are not captured by the factor return decomposition
- Issues with the attribution algorithm or its implementation

All four are extremely important for the portfolio manager to know. Over time, model deficiencies will presumably be corrected, leaving data quality problems in the form of bad returns or bad analytics to be the primary cause of attribution residuals.

In the case of this portfolio, a quick investigation reveals that the offending bond had a coupon payment of 2.50% that has been recorded twice. The price of the bond on the coupon payment date was approximately 110; therefore, one would expect a residual of +227.3 bp at the bond level. Indeed, after taking into account the net weight of the bond, the residual contribution of the bond to the euro portfolio is 44.0% × (18.3% – 0.5%) × 227.3 = +17.8 bp, very close to the +17.4 bp of reported residual. Re-running the report after correcting the double entry produces a mostly identical report (Exhibit 70-14) to the one before (Exhibit 70-12), except that the return of the portfolio is lower by the correction amount (+4.2 bp), the outperformance is +34.5 bp instead of +38.7 bp, and the residual term has been reduced correspondingly from +4.4 bp to +0.2 bp.

Data problems have the potential to affect the quality of outperformance measurement of a portfolio significantly, as well as its breakdown to the various sources. Proper use of an analytics-based attribution platform can help identify and correct potential issues promptly.

KEY POINTS

- Performance measurement and attribution is an important function of the investment process. It helps bring clarity to the sources of portfolio risk and performance and identify the contributions of individual decision-makers.
- A successful performance attribution algorithm should satisfy three important requirements: additivity, completeness, and fairness.

EXHIBIT 70-14

Results from the Fully Analytical Model After the Data Correction

a. Total Portfolio Outperformance

Global Outperformance (bp)	
Portfolio Return	184.5
Benchmark Return	150.0
Outperformance	**34.5**

b. Global Outperformance Summary

Global Outperformance Summary (bp)	
FX Allocation & Hedging	28.3
Local Market Allocation	–8.7
Local Market Management	14.9
Total	**34.5**

c. Local Market Management Details

Local Market Management Details (bp)	
Yield-Curve	20.6
Implied Volatility	0.9
Asset Allocation	–0.9
Security Selection	–2.2
Mortgage	–3.7
Residual	0.2
Total	**14.9**

Source: POINT

- A good attribution system should have a calculation and compounding frequency that corresponds to the dynamics of modern portfolio management. This normally means daily frequency for an actively managed fixed income portfolio.
- A good attribution system should have the flexibility to accommodate the wide range of portfolio management styles. The best attribution is an analysis that best matches the portfolio management decision-making process.

- Performance attribution algorithms typically follow either a sector-based allocation or a factor-based allocation, but neither is sufficient to cope with the complexity of modern portfolio management.
- Algorithms that combine the sector-based and the factor-based attribution have the flexibility to adapt to the particular management structure of most fixed income and equity portfolios.

CHAPTER

SEVENTY-ONE

PERFORMANCE ATTRIBUTION FOR PORTFOLIOS OF FIXED INCOME SECURITIES

Barclays

In contrast to the simple and opaque nature of equities, fixed income securities can be thought of as structured investments that promise to pay a stream of cash flows. The magnitude of cash flows can be fixed, or may depend on observable variables (e.g., realized inflation, principal prepayments of mortgage loans, or the price of the security itself for securities with call/put features). This quasi-formulaic nature of fixed income securities allows their present value to be expressed as a (generally stochastic) function of economic variables—most prominently interest rates and credit spreads—which can be calibrated to observed market prices of reference securities to generate a "pricing model." In other words, a pricing model is a function that expresses the present value of a fixed income security (or derivative contract) as a function of economic variables. This function can be also used to estimate the sensitivities of the present value to changes in the underlying variables. Such sensitivities, generically called *analytics* and known as *greeks* in the options world or *duration/convexity* in the bond world, can and are being used as loadings to the pricing factors driving returns during performance decomposition and attribution of fixed income portfolios.

In this chapter we discuss in detail how the performance of a portfolio of fixed income securities relative to a benchmark can be analyzed using the hybrid performance attribution algorithm described in Chapter 70. The hybrid methodology that combines factor-based attribution with the traditional Brinson method is particularly appropriate for fixed income securities whose return usually includes a significant component driven by a common factor, interest rates. In this chapter, we will focus on attribution over a single period only. As discussed in Chapter 70, a single period is one business day for the majority of fixed income systems. Methods for compounding single period attribution results over longer periods of time will be discussed in detail in Chapter 72.

This chapter was coauthored by Anthony Lazanas, António Baldaque da Silva, Chris Sturhahn, Eric P. Wilson, and Pam Zhong when they were employees of Barclays.

We begin the discussion by using a generic pricing model in order to split the return of a fixed income security into the contributions of the various factors driving the security return. We discuss in detail the treatment of the most important factors such as interest rates, implied volatility, and credit spreads. Two important asset classes with special characteristics, mortgage-backed securities and inflation-linked bonds, are discussed separately. We then show how the flexible hybrid attribution framework can be applied in several ways to accommodate various types of fixed income portfolios and styles of portfolio management.

In this chapter we restrict the analysis to single-currency portfolios. The complications arising from investing in multiple currencies will be discussed in Chapter 72. All performance attribution reports have been generated using the Hybrid Performance Attribution (HPA) model[1] as implemented in POINT, the portfolio analytics and modeling platform then offered by Barclays.

RETURN SPLITTING

Securities with deterministic cash flows are priced by discounting the cash flows off a reference yield-curve. When future cash flows are not known but can be reasonably predicted by modeling them as functions of economic variables (most commonly interest rates) and security characteristics, more complex statistical diffusion models are used. Such models produce a set of projected interest rate paths that are consistent with the current yield-curve and the market implied volatility of liquid interest-rate options. Projected cash flows on each path are discounted at the corresponding discount factors, and the present value of the security is calculated as the average present value across all interest-rate paths. In this case, the present value of a security is a function of interest rates, their implied volatility and possibly other variables in the model.

A pricing model produces the "model value" of a security. In the case of securities such as derivatives that are traded over-the-counter, the model value is usually used to mark-to-market positions in the security. When a security is publicly traded, its market price generally does not agree with the model price. To make them equal, model parameters are calibrated to match the market price. For example, in the case of bonds, this usually entails additional discounting of cash flows at a flat rate across all maturities. In the majority of models, in which cash flows are discounted at a risk-free reference yield-curve (the government or swap yield-curve in a particular currency), this additional discounting rate is the well-known option-adjusted spread (OAS), which captures the extra discounting required to account for credit, liquidity, and other types of risks. Analytics produced by such a model are therefore known as option-adjusted analytics.

1. For details of the model, see Anthony Lazanas, Chris Sturhahn, and Pamela Zhong, *The Barclays Hybrid Performance Attribution (HPA) Model* (Barclays Publications, October 2010).

Generically, a pricing model can be expressed with the following formula:

$$MarketValue = f\,(Time,\ YC,\ Vol,\ Other,\ OAS)$$

Here, *YC* stands for yield-curve, *Vol* for implied volatility, and *Other* for any other market factors or parameters that the pricing model is using.

For a single-currency portfolio, the analysis begins with splitting the return of each portfolio position into the contributions of various factors. Most pricing systems provide the first-order sensitivity of the market value of a position to the underlying risk factors. Sometimes second-order sensitivities to particular factors (such as interest-rate convexity) are also reported. Using these sensitivities, the return of a particular position is approximated as a linear combination of the contributions of each pricing factor, for example:

$$R \approx \frac{\partial f}{\partial Time}\Delta Time + \frac{\partial f}{\partial YC}\Delta YC + \frac{1}{2}\frac{\partial^2 f}{\partial YC^2}\Delta YC^2 + \frac{\partial f}{\partial Vol}\Delta Vol + \frac{\partial f}{\partial OAS}\Delta OAS$$

Although some pricing systems do provide additional sensitivities (e.g., spread convexity, or sensitivities to some of the "other" pricing factors such as prepayment speed for mortgage securities) most of the time the difference between the actual return of a position (as reported in the accounting system of the portfolio) and the above approximation is non-negligible. Such difference, usually referred to as *Residual*, is attributable to sensitivities to unaccounted model inputs and parameters, higher-order terms, cross-terms between factors, and very often in practice, data and calculation errors. Analyzing the residual and understanding whether it is legitimate or a result of data or calculation error is an important function of a performance attribution system. To help achieve that, sophisticated performance attribution systems use an alternative scenario-based decomposition of returns, which by design is complete, i.e., has no residual. The return splitting exercise in such systems has two stages:

Stage I: Scenario-based return decomposition into broad categories

Stage II: Analytics-based return decomposition into fine categories

In Stage I, the scenario decomposition of one-period return[2] begins with the market value of the position at the beginning of the period and then moves one parameter at a time to the end-of-period value until all of the parameters have changed and the end-of-period market value is obtained. At each step, the market value of the security is obtained by fully recalculating its market value by

2. As discussed in Chapter 69, attribution over longer periods of time requires compounding attribution results over smaller periods. The length of a single period should be consistent with the management style of the portfolio. Actively managed portfolios should use a short period, typically one day. Buy and hold portfolios should use longer periods such as one month or even one year. The algorithm we describe here can be applied for arbitrary period lengths. Nevertheless, bear in mind that using pricing analytics to manage exposure typically indicates an active management style which more often than not requires daily portfolio actions and therefore daily compounding of attribution results.

EXHIBIT 71-1

Typical Scenario-Based Return Decomposition

Surprise Return	The difference of actual cash flows and notional changes from model predictions
Time Return	The effect of elapsing time
Yield-Curve Change Return	The effect of changes in the yield-curve
Implied Volatility Change Return	The effect of changes in the implied volatility surface
Other Market Return	The effect of changes in any other market parameters
Spread Change Return	The effect of changes in the option-adjusted spread

changing one input parameter at a time. This stage divides the return into broad categories, as described in Exhibit 71-1.

Of course, this is not the only possible decomposition. Coarser or finer decompositions are also possible, but this particular one is a good compromise between computational complexity and informational content for most fixed income portfolios. In Stage II, the sensitivities of the security to various pricing model inputs (analytics) are used to decompose the return further. The combination of the two decompositions allows the residual to be split among the major return constituents providing more insight about its potential sources.

We will now discuss in more detail the various return constituents in the typical decomposition of Exhibit 71-1.

Surprise Return

Surprise return is relevant to securities whose cash flows and amount outstanding are not deterministic. For example, for mortgage-backed securities, it is prepayments that generate the random behavior of cash flows and amount outstanding; for inflation-linked securities, it is the dependence of cash flows on the reference inflation index. Security valuation models make assumptions about inputs to pricing models and use such projections to value securities until realized values are known. The return explained by running scenarios or using model analytics is the return that would be realized if the uncertain parameters were consistent with the model predictions. If the realized values of the parameters are different from the projected ones, the difference between the actual return and the return explained by the model is captured as surprise return.

Mortgage Prepayments Surprise Return

As an example, consider a mortgage-backed security that is trading at a price of 105 and zero accrued. The prepayment model projects a 2.4% prepayment over the next month (25% CPR), thus predicting a return due to prepayments of –11.4 bp.[3] If the actual prepayment is lower, say 1.3% (15% CPR) resulting in a prepayment return of –6.2 bp, the difference of +5.2 bp will be registered as prepayment surprise return. The model-expected –11.4 bp of prepayment return will be part of the time return component.

Inflation Surprise Return

As another example, consider an inflation-linked security that is trading at a price consistent with projected inflation for next month of 3.0%. If the actual inflation announcement is 3.5% it will give +4.2 bp[4] of inflation surprise return to account for the larger inflation accretion accumulated over the month relative to the projected inflation rate. This return is separate from any return resulting from presumably increased future inflation expectations caused by the higher-versus-expectations announcement. Such return is captured separately as inflation spread change as will be described below.

Time Return

Time return is the deterministic component of the return, i.e., the return predicted by the pricing model if market parameters remain unchanged.[5] For most fixed income securities, time return can be decomposed into yield-curve carry, spread carry, and volatility decay. Inflation-linked securities also have inflation accretion and inflation spread carry. These time return components can be measured using analytics, as we will describe in detail in the following sections.

Yield-Curve Change Return

Changes of interest rates affect securities returns primarily through the change of discount factors. In addition, some securities have cash flows that are modeled as functions of interest rates (mortgage-backed, floating-rate securities). The component of return that is due to the fluctuation of the yield-curve is captured by the yield-curve change return component. The exposure of the security value to the yield-curve is captured by its sensitivity to parallel shifts of the yield-curve, the option-adjusted duration (OAD), movements of a specified set of points (key-rate points) representing the yield-curve, the key-rate durations (KRDs), and its second-order sensitivity, option-adjusted convexity (OAC). In daily frequency

3. −11.4 bp = (par-105) * 2.4% / 105.
4. The exact calculation is (3.5%/12 – 3.0%/12) / (1 + 3%/12) = 4.16 bp
5. We discuss the definition of “unchanged” for the yield-curve later in this chapter.

attribution models the potential daily change of yields is limited (moves above 15 bp are very uncommon); therefore, the convexity contribution is typically much smaller than the duration contribution. For this reason, the effect of yield-curve convexity does not need to be explicitly measured.[6]

Yield-Curve Change Return Decomposition

How total yield-curve change return is broken down between duration and convexity depends to a large extent on the frequency at which the duration exposure of a portfolio is managed. In this example a daily frequency is assumed, consistent with the practice of the majority of portfolio managers. To understand the frequency implications, consider a portfolio with interest-rate duration of 5 and an interest-rate convexity of –2. Assume that over the two weeks, interest rates keep falling at 10 bp per business day for a total of 100 bp. The duration-convexity formula explains portfolio returns caused by changes in interest rates:

$$R^{\Delta YC} = -OAD \cdot \Delta r + \frac{1}{2} \cdot (OAC/100) \cdot \Delta r^2$$

where both the returns and the rates change are expressed in basis points.

Applying this formula for the entire two weeks results in the following:

Duration Return:	$-5 \times (-100) =$	+500 bp
Convexity Return:	$0.5 \times (-2/100) \times (-100)^2 =$	−100 bp
Total Return:		+400 bp

On the other hand, applying the formula daily generates quite a different breakdown. The daily algorithm must take into account additional complexities such as the duration drift of the portfolio, as well as compounding. It is not sufficient to simply calculate the daily duration and convexity return as $-5 \times (-10) = +50$ bp and $0.5 \times (-2/100) \times (-10)^2 = -1$ bp, respectively, and just aggregate over 10 days to get +500 bp duration return and –10 bp convexity return, for a total return of +490 bp. Instead, the daily duration drift of the portfolio due to falling interest rates must be estimated first. Using the definitions of duration and convexity, the duration change due to a change in interest rates can be estimated as:

$$\Delta OAD = (OAD^2 - 100 \cdot OAC) \cdot \Delta r/10{,}000$$

where duration and convexity have the usual units and change of rates is measured in basis points. Due to the high convexity of the portfolio, over the course of the 10 days the duration of the portfolio shrinks by about two years. In addition, both the total return of the portfolio and the contributions of duration and

6. For currencies with high volatility of yields, convexity can become a significant determinant even for daily returns. In such a case, it is straightforward to include convexity as an explanatory variable to the algorithm.

convexity must be compounded daily (see Chapter 72 for details). After both adjustments, the total return calculation and breakdown are as follows:

Duration Return:	+408 bp
Convexity Return:	–10 bp
Total Return:	+398 bp

The total return is very close to the one estimated by analytics at the beginning of the period, but the breakdown between duration and convexity is dramatically different. In the daily model, the convexity contribution is much smaller than the duration contribution.

Daily attribution models typically use only the key-rate durations to explain the contribution of yield-curve changes. Any yield-curve change return (as estimated by the scenario-based total yield-curve change return) in excess of what can be explained by the key rates captures the contribution of the yield-curve movements between the key-rate points, as well as the convexity and other second-order terms and can be reported separately.

Implied Volatility Change Return

Securities with optionality require reference implied volatilities to calibrate the interest rate diffusion pricing model. In the fixed income world, most models use the Black swaption implied volatility surface[7] as input and calculate the sensitivity of the security value to the changes in implied volatility with a single analytic, Vega, which is the price change of the security for a 1% parallel shift in the Black implied volatility surface. Vega does not capture the effects of non-parallel movements of the implied volatility surface or the effect of yield-curve moves on the diffusion parameters of the interest-rate diffusion model.[8] Clearly, it does not sufficiently represent the sensitivity of the security value to changes in implied volatility surface. Some advanced models are capable of generating partial Vegas, e.g., sensitivities to exposures at multiple points of the volatility surface, or, alternatively, to a vector of parameters that can be used to parametrically fit the volatility surface. In such cases a more detailed decomposition of implied volatility change return is possible.

7. Swaptions are options on interest-rate swaps that are being priced using an extension of the classic Black-Scholes model, see Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 83 (1973), pp. 637-654. The volatility input in the Black-Scholes model that is consistent with the market price of such swaptions is commonly referred to as *Black volatility*. Swaptions are specified with two parameters, the tenor of the option and the maturity of the underlying swap. Therefore, the set of swaptions traded in the market is represented with a two-dimensional matrix, hence the term *volatility surface*.

8. In the simple lognormal model, the stochastic component of the relative interest rate changes is proportional to a scalar, the log-normal (Black) volatility; therefore no dependence on interest rates exists. Other models that better capture the true behavior of interest rates make the stochastic term a function of black volatilities, as well as the level of interest rates or other model parameters.

If only parallel Vega is available, capturing the total effect of implied volatility changes through scenarios is imperative. The scenario-based implied volatility change return can then be decomposed into a parallel shift component that is equal to the product of Vega and the average volatility shift, and a remainder that contains the effects of nonparallel volatility movements as well as the effects of changes of other inputs and parameters used in the volatility model.

Other Market Return

Although yield-curve and implied volatility are the most important factors in the pricing models of most fixed income instruments, they do not capture every aspect of the cash flows, and more factors may be required. Securities or derivatives with cash flows that depend on external factors, such as prepayments or inflation levels, may use additional inputs to the pricing model. Changes in such inputs will generate return that is not attributable to yield-curve or implied volatility surface changes. The effects of the changes of all others factors are captured together as Other Market Return.

For example, the model-projected cash flows of mortgage-backed securities may depend on market mortgage rates, as well as additional model-specific parameters such as home price appreciation expectations or swap spreads. All of these parameters contribute to Other Market Return. The breakdown to the various factors follows an instrument specific algorithm and depends on the availability of specific analytics.

Spread Change Return

The effect of OAS changes to return is captured in the spread change return component. Sensitivity to spread movements is measured directly using both spread duration (OASD) and spread convexity (OASC). The large spread moves often observed in the market make it necessary to use spread convexity. The difference between the sum of spread return captured by OASD and OASC and the scenario-based spread return contributes to the residual return component.

Reporting the return split of individual securities and sectors in a portfolio and a benchmark is very useful for the portfolio manager as it provides a detailed understanding of the sources of exposures and returns in the portfolio. When reporting return splits, attribution systems may re-organize the various components of returns. In particular, the Barclays HPA model which we use for illustrations in this chapter, re-groups the return components along risk-factors as shown in Exhibit 71-2. Sample return splits for a few securities can be found in Exhibit 71-3.

EXHIBIT 71-2

Return Splitting Components

Splits by Return Categories		Splits by Return Factors	
Surprise	Mortgage Prepay Surprise	Yield-Curve	Yield-Curve Carry
	Inflation Surprise		Key Rate Changes
			Rest of Yield Curve Change
Time Return	Yield-Curve Carry	Implied Volatility	Volatility Decay
	Spread Carry		Parallel Black Volatility Change
	Volatility Decay		Rest of Volatility Change
	Inflation Accretion	Spread	Spread Carry
	Inflation Spread Carry		Spread Duration
	Spread Carry		Spread Convexity
	Time Residual		
Yield-Curve Change	Key Rate Changes	Mortgage	Mortgage Prepay Surprise
	Rest of Yield-Curve Change		Mortgage Spread Change
Implied Volatility Change	Parallel Black Volatility Change		Other Mortgage Factors
	Rest of Volatility Change	Inflation	Inflation Surprise
Other Change	Mortgage Spread Change		Inflation Accretion
	Other Mortgage Factors		Inflation Spread Carry
	Inflation Spread Change		Inflation Spread Change
Spread Change	Spread Duration	Residual	Spread Residual
	Spread Convexity		Time Residual
	Spread Residual		

Source: POINT

EXHIBIT 71-3

Security Return Splits

Sector		Treasury	Govt-Related	Corporate	Securitized
Identifier		912810FP	XS0114288789	20030NAM	FNA04409
Coupon		5.4	7.5	6.5	4.5
Maturity		2/15/2031	3/31/2030	3/15/2037	2/1/2039
Ticker		US/T	RUSSIA	CMCSA	FNMA
Total Return		702.6	253.4	366.8	75.0
Yield-Curve	**Carry**	33.6	23.3	32.5	13.2
	Change	684.5	186.8	614.2	88.3
Volatility	**Decay**	0.0	0.0	0.0	6.7
	Parallel	0.0	0.0	0.0	–108.0
	Reshaping	0.0	0.0	0.0	61.3
OAS	**Carry**	0.2	16.8	17.0	1.8
	Change Duration	–12.1	27.0	–300.1	–34.4
	Change Convexity	0.1	5.3	2.8	1.5
Mortgage	**Prepayments**	0.0	0.0	0.0	6.2
	Mortgage Spread	0.0	0.0	0.0	45.8
Residual		–3.6	–5.7	0.3	–7.7

Source: POINT

OUTPERFORMANCE BREAKDOWN

Having split the returns in such detail based on analytical exposures to market factors, one might be tempted to proceed with bottom-up aggregation of outperformance per factor. However, neither does every portfolio manager use the factor approach to management, nor do all agree on which factors should represent portfolio risk. Many portfolios are managed by sectors or asset classes where top-down decomposition of outperformance is more appropriate, as the returns of the portfolio and the benchmark in each asset class or sector may differ. A flexible hybrid approach for performance attribution can be useful for both methods by allowing users to flexibly split total return into two parts: that driven by common factors for the entire portfolio and that in excess of common factors, which is further explained by asset allocation/security selection based on a user-defined hierarchical partition of the investment universe into sub-universes that we will refer to with the term "partition buckets."

Common components are explained by bottom-up aggregation as the difference of the exposure of the portfolio and the benchmark multiplied by the factor return. For example, yield-curve exposure is captured by duration, thus the outperformance explained by yield-curve movement would be the duration overweight of the portfolio (over the benchmark) multiplied by the negative of the yield-curve change. Excess of common or allocated components is explained by top-down decomposition using a user-defined hierarchical partition and the recursive algorithm discussed in Chapter 69, as will be detailed below.

This approach has the ability to accommodate different portfolio management styles. It also allows users to compare different ways of analyzing returns and outperformance and can lead to a better understanding of what drives portfolio outperformance. For example, many high-yield managers do not like to split total return into yield-curve, implied volatility, and spread components, citing the high negative correlation between yield-curve and implied volatility return versus spread return. Instead, they prefer to manage total return as a whole. And even when they do wish to separate out yield-curve return and manage the excess-to-yield-curve return, they usually do not rely on spread duration and spread convexity to measure their exposure. However, when spreads were very tight in 2005, many high-yield managers began experimenting with spread duration-based management.

While any return split component could be considered as a bottom-up common return component or as an excess return component that participates in the top-down allocation algorithm, the following three common configurations support most portfolio management decision-making structures: Total Return Model, Excess Return Model, and Fully Analytical Model.

The *Total Return Model* is the simplest model, where the total return is considered a single allocated factor. In other words, there is no common factor, and the total return is explained by top-down decomposition using market value weights and a user-defined security partition.

The *Excess Return Model* takes advantage of the return splitting algorithm to separate the factors contributing to return into common and allocated factors.

Returns from common factors are explained by bottom-up aggregation using appropriate analytic weights (e.g., OAD, Vega, market beta, and the like.). For fixed income portfolios yield-curve and/or implied volatility are typically considered as common factors. Returns from other factors (excess-over-common factor returns) are explained by top-down decomposition as in the Total Return Model.

The *Fully Analytical Model* is the most detailed model. It takes full advantage of the return splitting algorithm and the hybrid allocation algorithm, where each factor can be explained either by the top-down or the bottom-up aggregation using appropriate weights.

The following sections discuss these different types of models in more detail.

TOTAL RETURN MODEL

The Total Return model is the most basic performance attribution model and follows the classical, sector-based, asset allocation/security selection framework. It is appropriate for portfolios whose managers make decisions solely based on the total returns of the securities. A typical usage is a portfolio whose managers are allocating the capital based on their views of the sector and security returns, rather than risk factors. The model is generic in that the allocation buckets can be defined via a user-defined partition using any of the hundreds of security attributes available. Allocations such as geography, size, and momentum can be used, essentially mimicking factor-based allocation. The partition should be defined to mimic the management structure of the portfolio.

The Total Return model uses the relative allocation method of the top-down decomposition algorithm as explained in Chapter 70, where sector market value weight w_s is the allocation weight $\alpha_{k,s}$, total return of sector s is the only factor return $f_{k,s}$, and total return of the benchmark is the hurdle rate.

Asset Allocation $$w^P \cdot \sum_s \left(\frac{w_s^P}{w^P} - \frac{w_s^B}{w^B} \right) \cdot \left(TR_s^B - TR^B \right) \qquad (71\text{-}1)$$

Sector Management $$\sum_s w_s^P \cdot \left(TR_s^P - TR_s^B \right) \qquad (71\text{-}2)$$

Top-Level Exposure $$(w^P - w^B) \cdot TR^B \qquad (71\text{-}3)$$

Absent leverage, the top-level weights of the portfolio and the benchmark are both equal to one, so the top-level exposure term is always zero.

Let us now re-visit the attribution example of Chapter 69 to illustrate how results change according to the attribution model used. We remind the reader that in Chapter 69 we analyzed the outperformance of a multi-currency portfolio versus the Barclays Global Aggregate G4 Index over a period of one month. Here, we will focus only on the U.S. Dollar portion of the portfolio, which achieved a +32.1 bp outperformance[9] versus the U.S. Dollar portion of the index.

Using the Total Return model and assuming that the asset allocation universe consists of the major asset classes in the U.S. Dollar fixed income markets, the total portfolio outperformance is split into +18.9 bp of asset allocation and +13.2 bp of security selection as shown in Exhibit 71-4.

The contribution of each asset class to both asset allocation and security selection is calculated based on the total return of each asset class in the portfolio and the benchmark using Eqs. (71-1) and (71-2) and reported in Exhibit 71-5.

The corporate sector contributes +7.4 bp to the outperformance, since it has been overweighted by about 10.9% (portfolio average weight: 30.7%, benchmark average weight: 19.8%) and its performance in the benchmark (+196.1 bp) is much higher than the performance of the benchmark itself (+129.8 bp). The approximate[10] calculation yields 10.9% × (196.1 – 129.8) = +7.2 bp, close to the +7.4 bp reported. The contribution to security selection is also shown and captures the performance advantage of the portfolio versus the benchmark, weighted by the portfolio weight of each sector. For the corporate sector, this calculation yields 30.7% × (107.9 – 196.1) = –27.1 bp, close to the –27.3 bp reported.

The analysis above assumed that asset allocation occurs only at the major asset class level (Treasuries, Government-Related, Corporates, Securitized, and Cash). It is likely that within each major asset class a second level of allocation to asset class subsectors will occur. For example, within the Securitized sector further allocation to the Residential Mortgages (RMBS) sector, the Commercial

EXHIBIT 71-4

Outperformance Breakdown Using the Total Return Model

Outperformance (USD)		**Outperformance Details**	
Portfolio Return (bps)	161.6	Asset Allocation	18.9
Benchmark Return (bps)	129.5	Security Selection	13.2
Outperformance (bps)	**32.1**		

Source: POINT

9. This number can be approximated from the reported numbers in Exhibit 70-6 of Chapter 70 as the ratio of the outperformance contribution of the U.S. Dollar portfolio (+14.6 bp) divided by the U.S. Dollar portfolio weight (45.5%). The calculation is not exact because the weight of the dollar portfolio fluctuates over the monthly attribution period.

10. The calculation is approximate because the algorithm used by the Barclays HPA model that generated this report employs daily compounding. This calculation would be exact for single-day results.

EXHIBIT 71-5

Asset Allocation Using the Total Return Model

	Market Weight (%)		Return ex Common Factors		Outperformance (bps)	
	Average					
Partition Bucket	Port	Bench	Port	Bench	Asset Allocation	Security Selection
Total	100.0	100.0	161.6	129.8	18.9	13.2
Treasury	31.7	31.7	315.4	201.1	0.0	36.3
Government-Related	14.3	14.3	123.9	129.5	0.0	–0.8
Corporate	30.7	19.8	107.9	196.1	7.4	–27.3
Securitized	22.8	33.4	49.1	27.1	11.0	5.1
Cash	0.5	0.8	0.0	0.0	0.5	0.0

Source: POINT

Mortgages (CMBS) sector, the Asset-Backed (ABS) sector, and Covered Bonds may be desirable. As discussed in the previous chapter, a flexible attribution algorithm should support multiple decision levels. In our example, we introduce a second level of asset allocation by using asset class subsectors as defined by the Barclays Global Aggregate Index classification scheme. In this case the Total Return model applied recursively reports a dramatically different breakdown between asset allocation and security selection as reported in Exhibit 71-6. Asset allocation shrinks from +18.9 bp to +2.9 bp, while security selection grows from +13.2 bp to +29.2 bp.

Intuitively, the finer the partition used for asset allocation the more emphasis is put on asset allocation decisions versus security selection decisions. In the limit, if the buckets of the asset allocation partition are individual securities, then the entire outperformance is reported as asset allocation. Conversely, if the asset allocation partition contains only one bucket, the entire outperformance is reported as security selection. Notice though that the transition between the two limits is not monotonic since individual partition buckets may contribute positively or negatively to both asset allocation and security selection. Such flexibility to define the asset allocation levels used in the breakdown of total outperformance is an important characteristic of an attribution system as it can support multiple styles of portfolio management. It is important that the partition used for performance attribution corresponds to the decision structure used for the management of a particular portfolio.

To understand the differences between single-level and two-level asset allocation, examine the two-level asset allocation details shown in Exhibit 71-7. In the Level 1 report, there are two columns for asset allocation, a top-level one (labeled simply Asset Allocation) which is identical to the asset allocation from the simple partition (+18.9 bp) and a Further Allocation column that captures subsequent allocation decisions (–16.0 bp). Their sum is +2.9 bp, the asset allocation reported in the summary report. Level 2 reports illustrate the details of the asset allocation into subsectors within each of the major asset classes. Asset classes for which no subsectors are defined (such as Treasuries and Cash) do not get Level 2 reports and do not contribute to Further Allocation.

EXHIBIT 71-6

Outperformance Breakdown Using the Total Return Model (Two-Level Asset Allocation)

Outperformance (USD)		**Outperformance Details**	
Portfolio Return (bps)	161.6	Asset Allocation	2.9
Benchmark Return (bps)	129.5	Security Selection	29.2
Outperformance (bps)	**32.1**		

Source: POINT

EXHIBIT 71-7

Two-Level Asset Allocation Using the Total Return Model

Level 1: Portfolio Market Weight: 100.0

	Market Weight (%) Average		Return ex Common Factors		Outperformance (bps)		
Partition Bucket	**Port**	**Bench**	**Port**	**Bench**	**Asset Allocation**	**Further Allocation**	**Security Selection**
Total	100.0	100.0	161.6	129.8	18.9	–16.0	29.2
Treasury	31.7	31.7	315.4	201.1	0.0		36.3
Government-Related	14.3	14.3	123.9	129.5	0.0	–4.7	3.9
Corporate	30.7	19.8	107.9	196.1	7.4	–8.6	–18.7
Securitized	22.8	33.4	49.1	27.1	11.0	–2.6	7.6
Cash	0.5	0.8	0.0	0.0	0.5		0.0

Level 2: Government-Related: Portfolio Market Weight: 14.3

	Market Weight (%) Average		Return ex Common Factors		Outperformance (bps)		
Partition Bucket	**Port**	**Bench**	**Port**	**Bench**	**Asset Allocation**	**Further Allocation**	**Security Selection**
Government-Related	100.0	100.0	123.9	129.5	–4.7		3.9
Agency	98.3	70.5	121.7	94.3	–1.4		3.9
Local Authority		6.8		330.7	–2.0		0.0
Sovereign	1.7	12.6	253.4	232.7	–1.6		0.0
Supranational		10.0		113.5	0.2		0.0

(Continued)

EXHIBIT 71-7

Two-Level Asset Allocation Using the Total Return Model (*Continued*)

Level 2: Corporate: Portfolio Market Weight: 30.7

	Market Weight (%)		Return ex Common Factors		Outperformance (bps)		
	Average						
Partition Bucket	Port	Bench	Port	Bench	Asset Allocation	Further Allocation	Security Selection
Corporate	100.0	100.0	107.9	196.1	–8.6		–18.7
Industrial	19.6	51.1	171.3	214.6	–1.8		–2.6
Utility		10.4		251.2	–1.8		0.0
Financial Institutions	80.4	38.5	92.4	157.0	–5.1		–16.1

Level 2: Securitized: Portfolio Market Weight: 22.8

	Market Weight (%)		Return ex Common Factors		Outperformance (bps)		
	Average						
Partition Bucket	Port	Bench	Port	Bench	Asset Allocation	Further Allocation	Security Selection
Securitized	100.0	100.0	49.1	27.1	–2.6		7.6
RMBS	100.0	92.2	49.1	15.9	–0.2		7.6
ABS		0.6		101.2	–0.1		0.0
CMBS		6.4		181.3	–2.3		0.0
Covered		0.8		35.5	0.0		0.0

Source: POINT

Let us focus again on the corporate sector, which shows –8.6 bp of underperformance contribution from Further Allocation. Its Level 2 decomposition table explains why: the portfolio had a large overweight to financial institutions, an underweight to industrials, and no allocation to utilities. While both industrials and utilities outperformed the corporate benchmark, financials had a lower performance of +157.0 bp than the +196.1 bp of the aggregate corporate sector. Therefore, all three sectors have negative contribution to outperformance, with the largest (–5.1 bp) coming from financial institutions. Once again, this can be approximated with the recursive application of Eq. (71-1) as follows: 30.7% × (80.4% – 38.5%) × (157.0 – 196.1) = –5.0 bp close to the –5.1 bp reported. The security selection numbers represent security selection within each sub-sector.

EXCESS RETURN MODEL

The Excess Return model uses the return splitting algorithm to extract common factor returns from the total return and considers the remainder as excess return. In the fixed income world, portfolio managers like to manage their exposures to common factors such as the movement of the yield-curve and implied volatility surface separately from their other investment decision choices. For example, consider a manager who chooses to hedge the overall exposure to the yield-curve and makes investment decisions purely based on expectations of excess-to-curve returns. In this case, she would like to see the total outperformance breakdown into yield-curve and excess return so that she can assess the effectiveness of the hedge, as well as the asset allocation/security selection choices separately.

The outperformance due to exposure to common factors, which we will discuss in detail below, is explained by bottom-up aggregation. The excess return outperformance is explained by top-down decomposition using the relative allocation model of the the previous chapter, with sector excess returns and sector market value weights as in the Total Return model.

Asset Allocation $$w^P \cdot \sum_s \left(\frac{w_s^P}{w^P} - \frac{w_s^B}{w^B} \right) \cdot \left(ER_s^B - ER^B \right) \tag{71-4}$$

Sector Management $$\sum_s w_s^P \cdot \left(ER_s^P - ER_s^B \right) \tag{71-5}$$

Top-Level Exposure $$(w^P - w^B) \cdot ER^B \tag{71-6}$$

Once again, if neither the portfolio nor the benchmark is leveraged, the top-level weights are equal to one and the top-level exposure term is equal to zero.

Exhibit 71-8 shows the outperformance breakdown when using the Excess Return model and the two-level asset allocation in the previous example. The left-hand side table shows the results when only interest rates are treated as common return factors. Most of the outperformance (+24.6 bp) comes from the yield-curve exposure. Asset allocation is responsible for –2.2 bp and security selection for

EXHIBIT 71-8

Outperformance Breakdown Using the Excess Return Model

Excess of Yield-Curve		Excess of Yield-Curve and Implied Volatility	
Outperformance Details		**Outperformance Details**	
Yield-Curve	24.6	Yield-Curve	24.6
Asset Allocation	–2.2	Implied Volatility	1.9
Security Selection	9.7	Asset Allocation	–4.0
		Security Selection	9.6

Source: POINT

+9.7 bp. The right-hand side table shows the results when, in addition to interest rates, implied volatility is also treated as a common factor. The Implied Volatility term contributes +1.9 bp to outperformance, altering the asset allocation contribution to –4.0 bp and the security selection contribution to +9.6 bp.

Outperformance Due to Yield-Curve Exposure

As discussed at the beginning of this chapter, the pricing framework for most fixed income securities essentially amounts to projecting future cash flows and discounting them at projected paths of interest rates. Government, swap, or municipal AAA interest rate yield-curves can be used as the reference yield-curve, depending on the type of the security.

The yield-curve contribution to outperformance includes yield-curve change, the effect of interest rate changes, and yield-curve carry, the effect of the change of yield-curve discount factors or interest rate-related projected cash flows with the passage of time assuming that rates stay unchanged. There exist two different philosophies with respect to the definition of what constitutes a change in interest rates, and they result in different breakdowns between yield-curve carry and yield-curve change; however, the total yield-curve effect (their sum) is identical under both methodologies.

Methodology I: Rolling on Forwards

A yield-curve is deemed unchanged if the rates realize the values implied by the forward rates in the previous period. For example, if we look at an unchanged yield-curve one month into the future, the one-year rate is equal to the one-month forward one-year rate calculated from today's yield-curve. In this methodology, a yield-curve change is calculated with respect to the projected forward rates, and carry always accrues at the short rate.

This method is not very popular (particularly among cash investors) because it introduces significant complexity in the estimation of yield-curve change return—the most important component of fixed income returns. In addition, forward rates are not particularly good predictors of the realized path of interest rates, further reducing the appeal of this method.

Methodology II: Parallel Translation

A yield-curve is deemed unchanged if the level and shape of the yield-curve remains unchanged. For example, if we look at an unchanged yield-curve one month into the future, the one-year rate is equal to the one-year rate in today's yield-curve. In this methodology, a yield-curve change is calculated with respect to today's yield-curve, and carry accrues at a different rate for each cash flow.

Further, the representation of the yield-curve (e.g., par rates, zero rates, forward rates) is important and affects the breakdown of total yield-curve return between carry and change. If instantaneous forward rates are used to represent the yield-curve, then each cash flow accrues carry at a rate equal to the forward rate corresponding to the cash-flow date. Securities with deterministic cash flows accrue carry at a rate equal to the average of the forward rates corresponding to the date of each cash flow, weighted by the present value of each cash flow. Unfortunately, the forward rate representation is not very popular since forward rates are not directly observable in the market. Investors prefer the better understood zero or par rates to represent a yield-curve. Under both representations, the calculation of the curve carry of a set of cash flows is complicated. From the discussion above it is evident that the breakdown of yield-curve return and outperformance into curve carry and curve change is somewhat subjective. Portfolio managers should have the flexibility to choose a methodology that is consistent with their style of management.

Since interest rate yield curves are infinite-dimension objects, we need to represent them with a finite set of parameters. The simplest method is to choose a small discrete set of yield-curve points (key-rate points) dispersed along the yield-curve. The premise is that the dynamics of the yield-curve can be represented with the dynamics of the key rates with a high degree of accuracy. Intermediate yield-curve points are assumed to move as a linear combination of the moves of adjacent key rates. A typical set of key rates used includes the 6-month, 2-year, 5-year, 10-year, 20-year, and 30-year points for most currencies. Other curve points that also appear are the 1-month, 3-month, 1-year, 3-year, 7-year, 12-year, 15-year, 25-year, and 40-year points. Some managers prefer to represent the curve using factors that are defined as linear combinations of curve points. The prototype for such representation is the level-slope-butterfly set of factors, a representation implied by the principal component analysis of yield-curves. The choice of yield-curve representation depends on the type of yield-curve exposure a portfolio is taking as well as the capabilities of the underlying analytics system.

Although the key rates or level-slope-butterfly representation of the yield-curve is highly accurate from a risk perspective (captures more than 99% of its variance), there may be deviations from a return perspective, especially if a small number of points are used. Indeed, there are periods where, for example, the three-year U.S, Treasury rate moves very differently than what is implied from the two-year and five-year rates. Analytics (key-rate durations) explain the bulk of yield-curve outperformance. Scenario-based outperformance calculations are used to capture any residual outperformance from intermediate yield-curve points and convexity.

Yield-Curve Carry

As discussed above, yield-curve carry calculations are complex even for bullet securities under par- or zero-rate representation of yield-curves. An approximation method for the calculation of yield-curve carry, called the Curve Matching Portfolio (CMP) method, can be used to simplify these calculations.

The basic idea is to define a set of par and/or zero-coupon reference bonds whose yield-curve carry can be easily computed analytically, and then construct a carry-matching portfolio of such bonds for each portfolio or benchmark security. The matching algorithm attempts to create a portfolio that earns the same yield-curve carry as the security.

Matching par bonds are made to have a coupon equal to the par key rate of the corresponding maturity and a price of par (100). The payment frequency and day count convention match those used for yield-curve construction. As a result, all matching par bonds on the day of construction have an option-adjusted spread of zero by construction. Zero-coupon bonds do not pay coupons, but have yields matching the zero rates for maturities matching each point.

A curve matching portfolio consisting of reference bonds and cash is created for each security in the portfolio and benchmark such that the cash-flow profile of the portfolio matches the one for the bond. Since dealing with bond cash flows (which are often nondeterministic) is generally difficult, some algorithms use key-rate durations to represent the concentration of cash flows around each key-rate point. Therefore matching the key-rate durations of the curve-matching portfolio and the bond is an approximate way to match their cash-flow profiles and thus the curve carry. Cash is added or subtracted from the matching portfolio to make sure that it has the same present value with the bond. The amount of cash needed to replicate any particular bond can vary according to the duration profile and price of the bond. For example, if only par bonds are used in the matching portfolio of a bond with a higher coupon than the current par rate, leverage must be used in the matching portfolio (borrowing at the short rate to fund the future cash flows) to match the cash-flow profile of the bond. This leads to a negative amount of cash in the matching portfolio.

A common choice for the set of matching reference bonds is to use one par or zero bond per key-rate point. The weights of each reference bond (and cash) are aggregated over all positions in the portfolio and benchmark. Let us represent with ω_j^P and ω_j^B weights allocated to reference bond and cash in the curve-matching portfolio of the portfolio and benchmark, respectively, with j spanning all key-rate points and cash. If we approximate the carry return of each reference bond and cash as its yield (by definition the corresponding key rate level) multiplied by the attribution period length $y_j \Delta t$, the yield-curve carry outperformance can be broken down per key-rate point contribution as $\sum_j \left(\omega_j^P - \omega_j^B\right) \cdot y_j \cdot \Delta t$. If we define the average portfolio or benchmark yield as the average of all key rates using the CMP portfolio weights, the above formula can be re-written as $\left(y_{avg}^P - y_{avg}^B\right) \cdot \Delta t$. The excess yield-curve carry contribution of each key rate over the average carry can be defined, but the sum over all key rates will be zero.

Generally, yield-curve carry can be broken down using the following equations:

Outperformance from average carry $$\left(y_{avg}^P - y_{avg}^B\right) \cdot \Delta t \tag{71-7}$$

Key rate contributions $$\sum_j \left(\omega_j^P \left(y_j - y_{avg}^P\right) - \omega_j^B \left(y_j - y_{avg}^B\right)\right) \cdot \Delta t \tag{71-8}$$

If the average yield is set to zero for both portfolio and benchmark, then the average carry term is zero and the yield-curve carry outperformance is attributed to each key rate. If the average yield is calculated using the CMP weights for portfolio and benchmark, then the average carry is equal to the total carry contribution and the sum of the excess key rate contributions is equal to zero. Other choices for the average yield are also possible.

Yield-Curve Change

Yield-curve change outperformance is a result of duration profile differences between the portfolio and the benchmark and the change in the yield-curve. The scenario-based return decomposition described earlier is used to compute the total yield-curve change return and hence the outperformance. Then, by using the analytics (OAD and KRDs), the total yield-curve change outperformance is decomposed further into a parallel shift component, a curve reshaping (at the key-rate points) component, the rest of yield-curve contribution, and the effects of convexity.

The outperformance from parallel yield-curve shift is computed by applying the bottom-up aggregation, using key-rate durations as loadings and key rate changes as factors. Similar to yield-curve carry, the notion of an average yield change (parallel shift) can be used to control how the yield-curve change outperformance is distributed between the key rate contributions and the parallel shift term.

Outperformance from avg. parallel shifts $$-(OAD^P - OAD^B) \cdot \Delta y_{avg} \tag{71-9}$$

Outperformance from reshaping $$-\sum_j \left(KRD_j^P - KRD_j^B\right) \cdot (\Delta y_j - \Delta y_{avg}) \tag{71-10}$$

If the average yield change is set to zero, the yield-curve change outperformance will be attributed to each key rate separately. If the average yield change is set equal to an appropriately defined parallel shift, the key rate terms capture the outperformance in excess of the parallel shift, i.e., the yield-curve reshaping effect on outperformance.

Since we represent the shape of the yield-curve by key-rate points, there will always be a small fraction of yield-curve change outperformance not captured by the above methodology, as explained at the beginning of this section. Exhibit 71-9 illustrates the change not captured by the key rates.

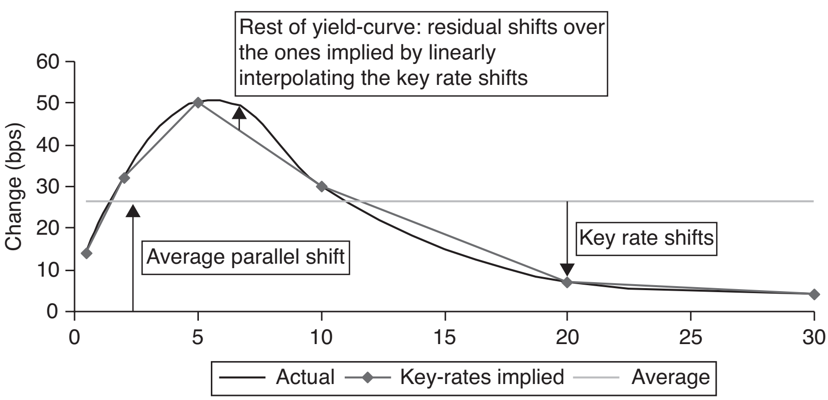
This final piece of the yield-curve change outperformance, calculated as the difference between total yield-curve change return from the scenario-based decomposition and the sum of the average parallel shift and reshaping return, includes the change in excess of key rates as well as return from convexity and other higher-order terms.

Exhibit 71-10 displays a yield-curve attribution report as produced by the Barclays HPA model.[11] The total yield-curve outperformance of +77.4 bp is broken into +2.9 bp of curve carry and +74.4 bp of curve change. Each is further broken down into an average curve contribution, the excess-to-average contributions of each key-rate point and the rest of the curve and convexity effect. The key rate levels and their changes over the attribution period (one month in this example) as well as the portfolio exposures in terms of curve matching portfolio weights and key-rate durations are displayed to help users better understand the reported outperformance breakdown.

To illustrate how this can be done we will focus on curve carry. The average yield of the portfolio and the benchmark are calculated as the yield of the corresponding yield-curve–matching portfolios. Since the portfolio is longer than the benchmark (as indicated by its higher duration) in an upward sloping yield-curve, its average yield is higher than the benchmark (2.030% versus 1.698%).

EXHIBIT 71-9

Approximation of Yield-Curve Change by Key Rates



Source: POINT

11. The portfolio and benchmark used in this report are the Euro-denominated portions of the global portfolio used in the example in the previous chapter.

EXHIBIT 71-10

Yield-Curve Report

	Yield				Yield-Curve–Matched Market Weight (%)		Duration (yrs)		Outperformance (bps)		
	Level (%)		Change		Average		Average		Explained by Yield-Curve		
	Port	Bench	Port	Bench	Port	Bench	Port	Bench	Carry	Change	Total
Total									**2.9**	**74.4**	**77.4**
Average	2.030	1.698	–50.2	–50.2	100.0	100.0	6.7	5.6	2.9	54.2	57.1
Key Rates & Cash									0.0	12.0	12.0
Cash	0.279	0.279	0.0	0.0	–13.1	–14.5	0.0	0.0	0.2	0.0	0.2
6m	0.381	0.381	0.6	0.6	4.0	16.2	0.0	0.1	1.8	3.1	5.0
2y	0.771	0.771	–22.6	–22.6	39.5	37.4	0.8	0.7	–1.4	–1.3	–2.6
5y	1.726	1.726	–43.1	–43.1	22.0	33.7	1.1	1.6	–1.2	4.0	2.8
10y	2.708	2.708	–57.3	–57.3	40.1	18.5	3.6	1.7	0.8	14.1	14.9
20y	3.377	3.377	–64.7	–64.7	7.5	5.8	1.2	0.9	–0.1	3.5	3.4
30y	3.324	3.324	–69.6	–69.6	0.0	3.0	0.0	0.6	–0.1	–11.5	–11.6
Rest of Yield-Curve and Convexity									0.0	8.3	8.3

Source: POINT

The corresponding average yield-curve carry contribution can be approximated[12] using Eq. (71-7) as the excess yield of the portfolio times the elapsed time of one month, (2.030% – 1.698%) × (1/12) = +2.8 bp, close to the +2.9 bp shown. The additional contributions of key-rate points can be estimated using Eq. (71-8). For example, the 2-year point contributes approximately [39.5% × (0.771% – 2.030%) – 37.4% × (0.771% – 1.698%)] × (1/12) = –1.3 bp, close to the –1.4 bp shown.

Outperformance Due to Implied Volatility Exposure

For fixed income securities with optionality, pricing models are typically calibrated to reflect the Black swaption implied volatility surface prevailing in the market. Therefore, changes in implied volatility create returns on the embedded option that must be attributed correctly in performance attribution. Similar to how the contribution of yield-curve changes are measured, both scenario- and analytics-based calculations are used to break down the contribution of implied volatility changes to outperformance. The outperformance due to exposure to implied volatility is typically calculated in terms of volatility decay, parallel shift of the implied volatility surface, and surface reshaping.

Volatility Decay

Volatility decay captures the change in option value due to the lapse of time. The return from volatility decay is difficult to capture exactly, as it requires re-simulating interest rate paths and pricing securities using two separate time variables (one for diffusion and the other for discounting). However, volatility decay return can be approximated by subtracting all other components of the total time return, such as yield-curve and spread carry. Outperformance due to volatility decay is the difference between the weighted average volatility decay return of the portfolio and the benchmark.

Implied Volatility Change

The outperformance due to implied volatility change is a result of the difference in volatility exposures of the portfolio and the benchmark and the change in the implied volatility surface. The exposure to parallel shift is measured by Vega, and the parallel shift return is equal to Vega multiplied by the average implied volatility change over the entire surface. The implied volatility surface reshaping return, as well as additional terms that represent other parameters entering the fitting of the implied volatility surface can be calculated as the scenario-based total implied volatility return minus the return from the parallel shift.

Exhibit 71-11 shows a sample implied volatility report[13] produced by the Barclays HPA model. Volatility outperformance is broken down into the contributions of the major asset classes in the portfolio and benchmark.

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12. Remember that these formulas hold for attribution over a single period while the example goes over a month using a daily compounding attribution algorithm.

13. The portfolio and benchmark in this report are the U.S. dollar portions of the global portfolio used in the example in the previous chapter.

EXHIBIT 71-11

Implied Volatility Report

	Volatility		Market Weight (%)		Parallel Vol Exposure		Outperformance (bps)			
			Average		Average		Explained by Volatility			
	Initial Level (%)	Total Change (%)	Port	Bench	Port	Bench	Decay	Parallel	Reshaping	Total
Total							**–0.5**	**6.2**	**–3.8**	**1.9**
Treasury	30.6	5.71	31.72	31.66	0.00	0.00	0.0	0.0	0.0	0.0
Government-Related	30.6	5.71	14.32	14.29	0.00	–0.03	0.0	0.2	–0.2	0.0
Corporate	30.6	5.71	30.71	19.85	–0.12	–0.01	0.1	–0.6	0.9	0.3
Securitized	30.6	5.71	22.76	33.42	–2.49	–3.60	–0.6	6.6	–4.5	1.5
Cash	0.0	0.00	0.49	0.78	0.00	0.00	0.0	0.0	0.0	0.0

Source: POINT

The report contains the initial implied volatility level and its change over the attribution period for each asset class.[14] In this example, implied volatility exposure occurs only in the government-related, corporate, and securitized sectors. The ability of an issuer to call a bond and the prepayment option of mortgage-backed securities give issuers of such bonds optionality, therefore long exposure to implied volatility. Conversely, holders of such bonds are short volatility, as the negative exposure numbers indicate. By being long the corporate and short the securitized sector, the portfolio is implicitly underweighted volatility in the corporate sector and overweighted volatility in the securitized. Since on average implied volatilities increased 5.71% during this month, the corporate sector contributes negatively to parallel volatility outperformance (–0.6 bp), and the securitized sector contributes positively (+6.6 bp). Overall, the portfolio is long volatility since the volatility exposure of the securitized sector is much bigger than that of the corporate and government-related sectors. The total parallel volatility change outperformance contribution is +6.2 bp. The total contribution of changes in the implied volatility surface is calculated from the return splits scenarios, as described above. From that, the surface reshaping (net of the parallel shift) contribution as well as the effects of other parameters and factor of the volatility model are calculated as –3.8 bp. Finally, a net long volatility portfolio will suffer loss of return because of volatility decay. In this case, it has been calculated to be –0.5 bp. Putting it all together, the total contribution of implied volatility to the outperformance of the dollar portfolio is calculated to be +1.9 bp.

FULLY ANALYTICAL MODEL

The Fully Analytical model offers the flexibility to match the increasing diversity in portfolio management structures. It takes full advantage of the return splits by isolating returns from each factor individually. The model can accommodate either bottom-up aggregation or top-down decomposition, depending on how the factor exposures are managed in the portfolio. It is suitable for portfolios with multiple asset classes, as they often have exposures to different market risk factors. For example, consider a portfolio consisting of corporate bonds, mortgage-backed securities, and inflation-linked bonds. While all of these securities are exposed to changes in interest rates and possibly implied volatility, mortgage securities have additional exposure to prepayment risk and mortgage spreads, and inflation-linked securities have additional exposure to their reference

14. Although in this report the average volatility of each bucket is reported to be the same, generally each security is exposed to different points of the volatility surface. It is difficult to estimate a single point representing the reference point for each security hence this report is using the simplistic approach where all securities are exposed to the same point for parallel shift calculations. Since the total effect of implied volatility changes is captured using scenario-based returns breakdown this choice only affects the breakdown between the average volatility change and the reshaping components.

inflation indices. Similar to how the yield-curve risk is managed, managers of mortgage and inflation-linked securities tend to manage these additional risk factors separately. The ability to break down outperformance due to specific factor exposure can be very valuable to the managers for explaining the impact of their portfolio decisions.

Furthermore, the Fully Analytical model allows portfolio managers to use measures other than market value as allocation weight. This is particularly useful for managers who allocate their capital to various sectors based on risk exposures rather than market values. For instance, a manager taking views on sector spread movement may think of over/underweight in terms of option-adjusted spread duration (OASD). In the credit space, the concept of duration-times-spread (DTS) has been gaining traction in recent years as an alternative measure of spread risk exposure.[15] As a result, credit portfolio managers may prefer to use OASD or DTS as allocation weight in performance attribution.

For illustrative purposes here, we will use the Fully Analytical model with the following choices: Yield-curve and implied volatility are considered common factors and their outperformance contribution is explained using bottom-up aggregation as previously described. The outperformance from mortgage and inflation factors as well as residuals are also explained using bottom-up aggregation and the details of their decomposition is described in the following sections. These factors are calculated per security and can be aggregated to buckets of the selected partition. Outperformance from spread is calculated in a top-down fashion using analytics-based exposure weights for spread change outperformance but market value weights for spread carry outperformance, as described in detail below.

Outperformance Due to Spread

Outperformance from spread is explained using top-down decomposition into asset allocation and security selection per user-defined hierarchical partition or sector. All three components of spread outperformance (carry, spread duration, and spread convexity) are decomposed separately using the top-down decomposition algorithm. Spread carry outperformance is decomposed by applying the absolute allocation algorithm using market value weights and carry returns. We consider two different methods for the decomposition of the spread change outperformance: top-level and sector-level.

Top-Level Spread Model

The top-level spread model assumes that there is a decision to over/underweight the spread duration exposure of the portfolio against the benchmark at the portfolio

15. See Arik Ben Dor, Lev Dynkin, Patrick Houweling, Jay Hyman, Erik van Leeuwen, and Olaf Penninga, *A New Measure of Spread Exposure in Credit Portfolios* (Barclays Publications, February 2010).

level (top level). Subsequent decisions to allocate spread duration exposure to various sectors are made relative to the portfolio spread duration. This implies that allocation weight is measured by the ratio of the spread duration contribution of each sector ($w_s OASD_s$) over the portfolio spread duration. In other words, we apply the relative allocation method of the top-down algorithm of Chapter 69 using $\alpha_k \leftarrow OASD$, $\alpha_{k,s} \leftarrow w_s OASD_s$, $f_{k,s} \leftarrow -\Delta OAS_s$ and $-\Delta OAS^B$ as hurdle rate.

$$\text{Asset Allocation} \quad -OASD^P \cdot \sum_s \left(\frac{w_s^P OASD_s^P}{OASD^P} - \frac{w_s^B OASD_s^B}{OASD^B} \right) \cdot \left(\Delta OAS_s^B - \Delta OAS^B \right) \tag{71-11}$$

$$\text{Security Selection} \quad -\sum_s w_s^P OASD_s^P \cdot \left(\Delta OAS_s^P - \Delta OAS_s^B \right) \tag{71-12}$$

$$\text{Spread Duration Mismatch} \quad -(OASD^P - OASD^B) \cdot \Delta OAS^B \tag{71-13}$$

Here, the Top-Level Exposure term has been renamed Spread Duration Mismatch.

Sector-Level Spread Model

In contrast to the top-level model, the sector-level model assumes no such spread duration decision at the portfolio level. Instead, each asset allocation decision is made without any top-level restriction. In this case, the appropriate allocation weight is the absolute, rather than relative, spread duration contribution. Furthermore, the hurdle rate is set to zero, as sector views are expressed on the absolute (rather than relative) changes in sector spreads. In other words, the absolute top-down decomposition is applied using $\alpha_{k,s} \leftarrow w_s OASD_s$ and $f_{k,s} \leftarrow -\Delta OAS_s$.

$$\text{Asset Allocation} \quad -\sum_s \left(w_s^P OASD_s^P - w_s^B OASD_s^B \right) \cdot \Delta OAS_s^B \tag{71-14}$$

$$\text{Security Selection} \quad -\sum_s w_s^P OASD_s^P \cdot \left(\Delta OAS_s^P - \Delta OAS_s^B \right) \tag{71-15}$$

Exhibit 71-12 shows the USD Local Management outperformance decomposition of the U.S. Dollar portfolio discussed earlier in this chapter using the Fully Analytical model with either top-level or sector-level spread duration management. We assume two-level allocation of spread exposure, first to major asset classes and then to subsectors of each asset class. In both models a new category, Mortgage,[16] has appeared and is responsible for –8.2 bp of outperformance. In both models, the security selection contribution is +9.3 bp. The difference comes from the treatment of spread duration exposure. The top-level model treats it as a portfolio-level decision (essentially a common return factor) contributing –1.8 bp of outperformance under the label Spread Duration Mismatch, while asset allocation is listed as +5.0 bp. The sector-level model makes spread duration exposure

16. We will discuss this term in more detail below.

part of the allocation decision and essentially combines the two terms, reporting asset allocation of +3.2 bp.

Exhibit 71-13 contains the Asset Allocation report to major asset classes (first level of allocation) using the sector-level model. Outperformance from asset allocation and security selection from each partition bucket is displayed, along with other useful information such as OAS and the changes in OAS, OASD, OASC, and market value weights.

The asset classes with the biggest contribution to spread change asset allocation outperformance are securitized with +4.4 bp and corporate with –1.7 bp. These numbers can be explained as follows. The securitized sector has an underweight of –0.3 years in terms of spread duration (0.8 years versus 1.1 years as seen in the top panel), while benchmark spreads in this sector widened 15.9 bp. Note that since we use the sector-level model, the hurdle rate is zero; therefore, we do not need to compare the spread widening of each sector with that of the benchmark. The approximate calculation estimates the contribution as –0.3 × –15.9 = +4.8 bp, relatively close to the +4.4 bp shown.

Spread carry contributes +1.5 bp to asset allocation, coming mostly from the corporate sector, which has high spread (+186.5 bp versus +57.1 bp for the benchmark) and is market value overweighted (30.7% versus 19.8%). The approximate calculation is (30.7% – 19.8%) × (186.5 – 57.1) × (1/12) = +1.2 bp.

EXHIBIT 71-12

Outperformance Breakdown Using the Fully Analytical Model

Fully Analytical Model (Top-Level) Outperformance Details		Fully Analytical Model (Sector-Level) Outperformance Details	
Yield-Curve	24.6	Yield-Curve	24.6
Implied Volatility	1.9	Implied Volatility	1.9
Asset Allocation	5.0	Asset Allocation	3.2
Security Selection	9.3	Security Selection	9.3
Spread Duration Mismatch	–1.8	Mortgage	–8.2
Mortgage	–8.2	Residual	1.3
Residual	1.3		

Source: POINT

Columns for further allocation[17] representing the contribution of spread exposure allocation to subsectors are also included.

Exhibit 71-13 also provides information to confirm the USD spread duration mismatch term from the top-level model (Exhibit 71-12, left panel). Indeed, the portfolio is slightly longer than the benchmark in terms of spread duration (4.7 versus 4.5 years), and benchmark spreads widened by 8.3 bp on average. Multiplying the spread overweight by the negative of the benchmark spread change yields $+0.2 \times (-8.3) = -1.7$ bp close to the –1.8 bp shown in Exhibit 71-12.

Mortgage Factors

The present value of mortgage-related securities depends on additional factors such as prepayments and mortgage rates. Some common additional factors are described below.

Prepayment Surprise Outperformance

Securities involving prepayments are priced using model predictions of future cash flows. Over a month, the realized prepayment rate is generally different from the one predicted by the model. The difference gives rise to a return component that is not captured by analytics; this return can be computed separately as Prepayment Surprise return. In the Global Aggregate G4 index, which is the benchmark in this example, prepayments are recognized on the first of the month based on a predicted rate (which, if different from the model-predicted one, will generate surprise return). Over the course of the month, the actual prepayment rate can be more accurately predicted and used to adjust the returns, leading to more days where the surprise return is non-zero. Once the actual rate is known and returns are adjusted to reflect it, no more surprise return for that particular month will occur. Note that portfolio accounting conventions with respect to recognizing realized prepayments may vary. If they are different from the benchmark conventions, the attribution system will report prepayment surprise outperformance that is not economic but accounting in nature.

Mortgage Spread Change Return

A common factor that affects the cash flows of all mortgage securities is the difference between the model-implied mortgage rate and the actual mortgage rate observed in the market. This difference is called the mortgage spread and the

17. It is interesting to note that further allocation must use the relative spread duration allocation model, since the spread duration of each major asset class has been determined at the first level of allocation. The spread duration allocation to subsectors must be consistent with the pre-determined spread duration of the asset class.

EXHIBIT 71–13

Asset Allocation Report for the Sector-Level Fully Analytical Model

	OAS (bps)				OASD (yrs)		Market Weight (%)		OASD Contr. (yrs)	
	Average		Change		Average		Average		Average	
Partition Bucket	**Port**	**Bench**	**Port**	**Bench**	**Port**	**Bench**	**Port**	**Bench**	**Port**	**Bench**
Total	74.2	57.1	5.5	8.3	4.7	4.5	100.0	100.0	4.7	4.5
Treasury	0.8	–1.3	0.5	0.5	6.5	5.2	31.7	31.7	2.1	1.6
Government-Related	80.4	65.1	–2.4	3.7	3.7	4.0	14.3	14.3	0.5	0.6
Corporate	182.5	186.5	11.8	14.1	4.4	6.2	30.7	19.8	1.4	1.2
Securitized	28.1	33.4	13.1	15.9	3.4	3.2	22.8	33.4	0.8	1.1
Cash	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0	0.0

(Continued)

EXHIBIT 71-13

Asset Allocation Report for the Sector-Level Fully Analytical Model (*Continued*)

	Outperformance (bps)					
	Asset Allocation			Further Allocation		
Partition Bucket	Spread Carry	Spread Change	Total	Spread Carry	Spread Change	Total
Total	1.5	2.6	4.1	0.3	–1.2	–0.9
Treasury	0.0	–0.3	–0.3			
Government-Related	0.0	0.1	0.1	–0.2	0.1	0.0
Corporate	1.2	–1.7	–0.4	0.9	0.1	1.0
Securitized	0.2	4.4	4.6	–0.4	–1.5	–1.9
Cash	0.0	0.0	0.0			

Source: POINT

price sensitivity of a security to this spread is the mortgage spread duration. The return due to mortgage spread change is usually estimated with a first order approximation as the product of the mortgage spread duration and the negative of the change in the mortgage spread, i.e., $-MtgRtDur \cdot \Delta MtgSpread$. The outperformance is the difference between the weighted average mortgage spread return of the portfolio and the benchmark.

Other Mortgage Factors

A number of other parameters such as home price appreciation projections and swap spreads may also be used in mortgage pricing models. In the scenario-based return splits, all such parameters are accounted for in Other Market Return scenario. For mortgage securities, the difference between the other market return and the mortgage spread return captures the return from factors for which no analytics are available. If this difference is significant, it is an indication that additional analytics are required to better understand the sources of risk and performance of mortgage securities under the particular valuation model.

Exhibit 71-14 displays a portion of a detailed position-level outperformance contribution report for the U.S. Dollar portfolio discussed earlier in this chapter. The contribution of each position is broken down per factor. Outperformance components that are allocated in a top-down fashion such as spread carry and spread change are listed under "Security Selection." Components aggregated in a bottom-up fashion such as mortgage factors and residual are listed under "Other." Exhibit 71-14 is focused on the securitized sector, which is solely responsible for the –8.2 bp of underperformance attributable to mortgage factors. This report can be very useful to help managers drill down to the position level and understand the drivers of outperformance per individual factor.

Inflation Factors

Inflation-linked securities have cash flows linked to a specified price index. For example, the principal and interest payment of U.S. Government Inflation-Linked bonds (TIPS) are linked to the Consumer Price Index for All Urban Consumers (CPI-U), non–seasonally adjusted. The value and the return of inflation-linked securities depend on realized inflation as well as on expectations of future inflation during the lifetime of the security.

The analysis of the risk and performance of inflation-linked securities is subject to debate. One school of thought prefers to treat them as independent of nominal interest rates and express risk and performance as a function of real rates (nominal rates minus inflation expectations). In this type of analysis, the return of inflation-linked securities comes from changes of real rates, as well as time return, which is a combination of real rate carry and realized inflation accretion.

Another school of thought prefers to decompose real rates into the difference of nominal interest rates and inflation expectations such that nominal interest rate risk and contribution to outperformance is accounted consistently

EXHIBIT 71-14

Position-Level Report Using the Fully Analytical Model

	Outperformance					
	Security Selection		Other			
Bucket/Issue	Spread Carry	Spread Change	Prepayments	Mortgage Spread	Residual	Total
Securitized	0.3	3.7	–1.2	–7.0	1.4	–2.7
RMBS	0.3	3.7	–1.2	–7.0	1.6	–2.5
FNA05003	0.0	1.2	0.6	2.6	–0.3	3.8
FNA04403	0.0	1.1	0.2	1.3	–0.2	2.4
FNA04409	0.0	1.0	0.2	1.2	–0.2	2.1
FGB04403	0.0	0.7	0.1	1.1	–0.1	1.7
GNA04403	0.0	0.5	0.0	0.7	0.0	1.2
GNF04403	0.2	–1.3	0.1	0.3	0.7	–0.1

Source: POINT

across all types of bonds. The numbers shown below are calculated following the latter approach.[18] Inflation expectations are captured by a negative discounting spread (similar to OAS), which is called inflation spread. The return of inflation-linked securities is explained by changes in nominal interest rates and inflation spreads. The time return is captured by the nominal interest rate carry reduced by the negative inflation spread carry and increased by realized inflation accretion. Since realized inflation is announced only once a month, an assumption about the projected inflation of the current month is required to ensure smooth daily inflation accretion. When realized inflation is announced, it is generally different from projected inflation, producing a return that cannot be otherwise accounted for. This kind of return of inflation-linked securities is called inflation surprise and is accounted separately. Inflation surprise return is also present when current month inflation projections change.

Exhibit 71-15 shows the Fully Analytical model's security return splits for the Barclays Inflation Linked US TIPS index for the period from July 16, 2010, to August 13, 2010. These dates correspond to the CPI-U announcement dates for the index level as of the end of June and July, respectively; therefore, the index should show a realized inflation return equal to the rate of inflation realized during July (but only becoming known on August 13).

The total return of the index was +169.9 bp, with the majority coming from nominal interest rates exposure (+27.7 bp carry and +184.6 bp of yield-curve change). Inflation related return was negative at –40.6 bp, most of it coming from falling inflation expectations (captured under inflation spread change as –29.7 bp). Inflation accretion during July was –3.0 bp, indicating that at the beginning of the month, the market actually expected a small amount of deflation at an annualized rate of $-0.03\% \times 12 = -0.36\%$. The positive inflation surprise of +5.3 bp indicates that the realized inflation was actually positive, although quite low. The total realized inflation return is +2.3 bp, the sum of inflation accretion (at the market expected rate) and inflation surprise. From that, July realized annualized inflation can be calculated to be approximately $+0.023\% \times 12 = +0.28\%$. Indeed, the CPI reading for June was 217.965 and the one for July 218.011, implying an inflation rate for July of $218.011/217.965 - 1 = 2.11$ bp or +0.25%. The inflation spread carry term of –13.1 bp reduces the yield-curve carry of +27.7 bp that was credited to the index due to exposure to nominal rates. The difference of the two can be thought of as the carry earned by the index due to exposure to real rates, i.e., nominal rates reduced by inflation expectations.

Another interesting thing to note is that inflation expectations did not fall uniformly across all maturities. Indeed, short bonds exhibited positive inflation spread return, indicating increasing inflation expectations over the next three years or so. This is also the case for very long bonds, with the 30-year bond showing increasing inflation expectations. Inflation expectations fell only for bonds

18. This approach is detailed in Anthony Lazanas and Jeremy Rosten, *Risk Modelling and Performance Attribution for Inflation-Linked Securities* (Lehman Brothers Publications, October 2005).

EXHIBIT 71-15

Return Splits of Inflation-Linked Securities

		Yield-Curve		Inflation					
Bucket/Issue	Maturity	Carry	Change	Accretion	Carry	Surprise	Spread Change	Residual	Total Return
Total		27.7	184.6	–3.0	–13.1	5.3	–29.7	–1.9	169.9
9128277J	1/15/2012	6.4	5.9	–3.0	–6.5	5.2	30.4	–1.0	37.5
912828GN	4/15/2012	7.1	8.9	–3.0	–6.1	5.2	31.5	–0.6	43
912828AF	7/15/2012	7.8	12.5	–3.0	–7.5	5.2	34.4	–0.2	49.2
912828HW	4/15/2013	11.5	29.6	–3.0	–8.7	5.2	19.4	1.1	55
912828BD	7/15/2013	12.7	36.6	–3.0	–8.5	5.2	26.4	1.7	71.1
912828BW	1/15/2014	15.7	55.1	–3.0	–8.5	5.2	14.5	2.7	81.8
912828KM	4/15/2014	17.4	66.7	–3.0	–10.0	5.2	–7.7	2.9	71.6
912828CP	7/15/2014	19	77.3	–3.0	–9.6	5.2	–0.2	2.8	91.5
912828DH	1/15/2015	22.9	103.4	–3.0	–9.9	5.3	–6.6	2	114
912828MY	4/15/2015	25.5	120	–3.0	–12.2	5.2	–31.5	1.4	105.3
912828EA	7/15/2015	26.8	128.6	–3.0	–11.0	5.3	–21.2	0.4	125.8
912828ET	1/15/2016	28.6	154.3	–3.0	–11.5	5.3	–29.4	0.6	144.9
912828FL	7/15/2016	29.8	176	–3.0	–12.5	5.3	–49.4	0.7	146.8
912828GD	1/15/2017	31.4	199.3	–3.0	–12.6	5.3	–63.7	0.3	156.9
912828GX	7/15/2017	32.4	217.5	–3.0	–13.7	5.3	–66.4	0.1	172.1

(Continued)

EXHIBIT 71-15

Return Splits of Inflation-Linked Securities (*Continued*)

		Yield-Curve		Inflation					
Bucket/Issue	Maturity	Carry	Change	Accretion	Carry	Surprise	Spread Change	Residual	Total Return
Total		27.7	184.6	–3.0	–13.1	5.3	–29.7	–1.9	169.9
912828HN	1/15/2018	34.5	245	–3.0	–14.2	5.3	–80.5	0.1	187.1
912828JE	7/15/2018	35.7	265.4	–3.0	–15.2	5.3	–88.9	–0.1	199.3
912828JX	1/15/2019	35.8	272.4	–3.0	–15.2	5.3	–88.9	–0.4	205.9
912828LA	7/15/2019	36.7	289.4	–3.0	–16.0	5.3	–93.2	–0.7	218.5
912828MF	1/15/2020	37.8	309	–3.0	–16.4	5.3	–105.6	–0.9	226.3
912810FR	1/15/2025	39.9	337	–3.0	–17.4	5.4	–66.1	–8.1	287.7
912810FS	1/15/2026	39.9	335.1	–3.0	–17.6	5.3	–89.8	–8.7	261.3
912810PS	1/15/2027	38.7	320.3	–3.0	–17.6	5.4	–62.0	–8.4	273.3
912810PV	1/15/2028	38.2	315.7	–3.0	–17.9	5.4	–33.9	–8.3	296.2
912810FD	4/15/2028	36	292.1	–3.1	–16.8	5.3	–34.6	–7.5	271.5
912810PZ	1/15/2029	36	292.8	–3.0	–17.7	5.3	–30.9	–7.3	275.3
912810FH	4/15/2029	34.7	279	–3.1	–16.9	5.4	–14.2	–6.6	278.3
912810FQ	4/15/2032	33.6	237.5	–3.0	–17.7	5.3	11.5	–7.0	260.1
912810QF	2/15/2040	35.5	107.3	–3.0	–19.1	5.2	59.6	–9.0	176.4

Source: POINT

with maturities between 3.5 and 20 years. This indicates that inflation portfolio managers need to pay more attention to the term structure of expected inflation exposure and use more detailed analytics that provide partial sensitivities to the inflation term structure.

SELECTING AN APPROPRIATE ATTRIBUTION MODEL

From the above discussion, it should be clear that many variants of attribution models exist and that a portfolio manager must choose one that best corresponds to the decision structure during portfolio management. The results from several models applied to the U.S. dollar–denominated portion of the portfolio/benchmark from the previous chapter are summarized in Exhibit 71-16. All models assume two-level asset allocation, first to major asset classes and then to subsectors of each asset class.

Essentially, models differ with respect to what factors of return are managed at the portfolio level via allocations of appropriate exposures (factor-based management) and which component of return is managed via allocation to sectors and security selection within each sector (sector-based management).

Each successive model brings one additional common factor. The Excess of Yield-Curve model introduces yield-curve exposure as a common factor; the Excess of Yield-Curve and Implied Volatility model introduces implied volatilities; the Fully Analytical model with sector-level allocation of spread exposure

EXHIBIT 71-16

Outperformance Contributions Using Various Models

	Total Return	Excess of Yield-Curve	Excess of Yield-Curve and Vol	Fully Analytical (Sector-Level)	Fully Analytical (Top-Level)
Total	32.1	32.1	32.1	32.1	32.1
Yield-Curve		24.6	24.6	24.6	24.6
Implied Volatility			1.9	1.9	1.9
Spread Duration Mismatch					–1.8
Asset Allocation	2.9	–2.2	–4.0	3.2	5.0
Security Selection	29.2	9.7	9.6	9.3	9.3
Mortgage				–8.2	–8.2
Residual				1.3	1.3

Source: POINT

introduces all other factors for which there exist explanatory analytics (mortgage factors only, in this particular portfolio) as well as residual; and the Fully Analytical model with top-level allocation of spread exposure introduces top-level spread duration as a common factor.

Flexibility is a very important feature of attribution algorithms. Portfolio management styles differ, and an attribution platform must have sufficient richness so that a model representing each management style can be chosen. In addition, running multiple versions of the performance attribution algorithm may help portfolio managers reveal exposures that they have been implicitly taking and help them improve their management process.

KEY POINTS

- The total return of a security can be broken down to the contributions of various risk factors such as yield-curve, volatility, spread, mortgage, and inflation—based on the variables used in the pricing model for that security type.
- Various models can be applied to allocate these components of return in different ways to correspond to the management structure of a portfolio.
- The Total Return Model considers all return as a single allocated factor and divides the difference in performance versus a benchmark into allocation to sectors and sector performance using market value weightings.
- The Excess Return Model extracts common factors, such as yield-curve and volatility, and allocates outperformance from excess return using a top-down algorithm into asset allocation and security selection. Relative performance from common factors is determined using bottom-up aggregation.
- The Fully Analytical model allows any return split component to be extracted as a common factor for bottom-up aggregation. Alternative weights, such as spread duration, can be used in allocation calculations to provide a risk-weighted view.
- It is most effective to choose a primary performance attribution model that matches the management structure of the portfolio. This provides a more effective evaluation of the performance due to exposure to the factors used in the decision-making process.

CHAPTER

SEVENTY-TWO

ADVANCED TOPICS IN PERFORMANCE ATTRIBUTION

Barclays

The principles of performance attribution are outlined in Chapter 70 and a detailed attribution analysis for fixed income portfolios is discussed in Chapter 71. This chapter explores topics that more complex portfolios or analysis may encounter in practice. In particular, we start looking at the attribution exercise in a multicurrency context. Given the fact that the majority of multicurrency portfolios have some type of foreign exchange (FX) hedging overlay, being able to accurately separate the performance due to active FX positions from that due to hedging is a complex but important exercise. Another important topic discussed in this chapter concerns the treatment of returns and outperformance due to the use of derivatives or leverage in the portfolio. Their presence may change the nature of the basis used to define returns, so we discuss in more detail how to change the analysis in order to maintain the integrity of the performance attribution. This chapter finishes with the discussion of other practical considerations that performance attribution exercises often encounter. These include issues such as multi-period compounding, transaction handling, and missing or incorrect input data.

MULTICURRENCY ATTRIBUTION

In the previous chapter, we used performance attribution to examine the portfolio at the local market level, that is, associated with a particular currency market. Multicurrency portfolios add an additional layer of complexity to the portfolio management structure. For instance, there may be decisions made at the global level to determine capital allocation across different local markets or the FX exposures to those markets. In this section, we describe in more detail how one can decompose total global outperformance in terms of FX allocation, local market allocation, and local market management.

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To study the FX component of the portfolio's return, we need to define first the base currency of analysis, the currency in which we define the portfolio's return. Note that by definition, securities denominated in the base currency do not have FX exposure or return.

FX Return Splitting

Since most portfolio managers prefer to manage FX risk separately from all other risk exposures, the first step in return splitting of non-base-currency-denominated securities is to separate the FX component of return from the local component of return. The base currency total return of security i (${}^{b}R_i$) can be expressed in terms of its local currency return (R_i) and the spot FX return of the currency in which the security is denominated, F_i.[1]

$$ {}^{b}R_i = F_i + R_i F_i + R_i \tag{72-1} $$

Here, we assume that all positions with cash flows or dependencies on interest rates in multiple currencies (such as FX swaps, FX forwards) have been decomposed into legs that have exposure only to the market parameters of a single currency. Note the presence of a cross-term that is the product of the FX return and the local currency return. This can be accounted separately, but in most cases it is combined with the FX return under the assumption that the FX return is typically much larger than local currency returns. While this is generally true for fixed income securities, it may not be true for portfolios that invest in asset classes with higher volatility, such as equities or commodities.

To separate the performance due to FX exposures from the performance due to local management, we need to include the cash deposit return of each currency in the FX return.[2] Indeed, a cash investment in any foreign currency will earn the FX return plus the local cash deposit return over the attribution period, R_i^{depo}, without incurring any local risk.

$$ {}^{b}R_i = \left(F_i + R_i^{depo}\right) + R_i F_i + \left(R_i - R_i^{depo}\right) \tag{72-2} $$

The total return of the portfolio can then be written as the sum of returns from "local markets" that correspond to the first allocation layer of a multicurrency portfolio. Although single-currency markets provide the natural breakdown

1. This formula is applicable to fully funded securities only. When leverage is present, such as in derivatives, it needs to be adjusted appropriately.
2. Brian D. Singer, and Denis S. Karnosky, "The General Framework for Global Investment Management and Performance Attribution," *Journal of Portfolio Management* (Winter 1995), pp. 84–92.

for FX returns, there is no reason to impose the same breakdown for local returns. In fact many managers allocate local return exposure to markets based on geography, asset class, or industry, rather than currency. We will denote the local return allocation markets with *m* and we will generally assume that they are not necessarily single-currency markets. Single-currency markets will be denoted with *c* and will be used for the allocation of the FX component of return, as well as the cross term.

$$ {}^{b}R^{P} = \sum_{c} {}^{b}w_{c}^{P} \cdot \left(F_{c} + R_{c}^{depo}\right) + \sum_{c} {}^{b}w_{c}^{P} R_{c}^{P} F_{c} + \sum_{m} {}^{b}w_{m}^{P} \cdot \left(R_{m}^{P} - R_{m}^{depo,P}\right) \quad (72\text{-}3) $$

The three terms in Eq. (72-3) correspond to FX, FX/local cross-term, and local returns, respectively. Here, ${}^{b}w_{c}^{P}$ and ${}^{b}w_{m}^{P}$ represent the "base-currency portfolio market value weights," i.e., the market value of positions in currency *c* or market *m* over the market value of the portfolio, both expressed in base currency units. Note that within single-currency markets the cash deposit rate return and the FX return are the same for all securities and therefore the same for the portfolio and the benchmark. However for a generic market *m* that may span several currencies, the cash deposit rate return $R_{m}^{depo,P}$ is defined as the weighted average return over all market securities. Since the composition of the market generally differs across portfolios and benchmarks we need to use the designation *P* to identify a specific portfolio.

FX Hedging

FX hedging—the overlay of FX derivatives with the intent to change the FX exposure profile of a portfolio without affecting its local markets exposures—is a common practice in multicurrency portfolios. It enables managers to disentangle the portfolio construction process between the FX experts and the local market managers. The most common instruments used for hedging are FX forwards, typically with short tenors (e.g., one month) and rolled regularly. Longer tenors are sometimes used to reduce rolling costs.

Despite the intent to leave the local exposures unchanged, in practice FX hedging instruments have side effects that must be accounted for in a complete attribution framework. In what follows we detail two such effects.

Exposure to Local Interest Rates

Ideal FX hedges earn the cash rate in each currency and have zero interest rate duration. In practice, FX hedging instruments do have exposure to the short end of local interest rate curves. This effect is highlighted during market crises, when short rates exhibit significant volatility. Typically, this return is considered part of the hedging return, as it comes from an unintended exposure to local rates through the instruments used to hedge the portfolio and is not part of the local rates strategy decisions.

Cash Balance Effect

As FX rates fluctuate, the mark-to-market of FX forwards becomes nonzero, essentially representing a cash balance (positive or negative). Unless such cash balance is reinvested regularly, it represents an unintended allocation to cash (which is equivalent to leveraging if the balance is negative). This effect can be significant and needs to be highlighted in performance attribution. To that end, one possible solution is to capture this effect explicitly as the difference of the actual portfolio return minus the hypothetical return that would be achieved if the FX hedges cash balance were reinvested daily in the portfolio. Similar to the exposures to local rates, this effect should also be reported as part of the hedging return.

Once these side effects have been accounted for, the effect of FX hedges is restricted to the FX component of the total return and the cross-term; the local component of return remains unchanged.

Outperformance from FX Allocation and Hedging

FX outperformance is defined as the part of total outperformance that is due to fluctuations of the exchange rates between the base currency and all non-base currencies present in the portfolio or the benchmark. The first two terms of Eq. (72-3), pure FX and the FX/local cross-term, contribute to FX outperformance. We look at them separately in what follows.

Let's denote the effective portfolio exposure to each spot FX rate after hedging with ${}^{b}h_c^P$ and the benchmark one with ${}^{b}h_c^B$. Then, we can represent the *pure FX outperformance* contribution to the portfolio outperformance as follows:

$$^{FX}R^P - {}^{FX}R^B = \sum_c {}^{b}h_c^P \cdot \left(F_c + R_c^{depo}\right) - \sum_c {}^{b}h_c^B \cdot \left(F_c + R_c^{depo}\right)$$

We can now apply the relative allocation model of the top-down decomposition algorithm described in Chapter 70 to get the hedged FX allocation as:

$$\sum_c \left({}^{b}h_c^P - {}^{b}h_c^B\right) \cdot \left(F_c + R_c^{depo} - R_b^{depo}\right) \tag{72-4}$$

To derive Eq. (72-4), we specifically set the following variables using the notation from Chapter 70: $\alpha_{k,s} = {}^{b}h_c$, $\alpha_k = \sum_c {}^{b}h_c = 1$, $f_{k,c} = F_c + R_c^{depo}$ and $f_k^H = R_b^{depo}$. The allocation in Eq. (72-4) is typically used to measure pure FX allocation. However, a similar decomposition can be made to the FX outperformance without the hedges. The unhedged FX allocation would be:

$$\sum_c \left({}^{b}w_c^P - {}^{b}w_c^B\right) \cdot \left(F + R_c^{depo} - R_b^{depo}\right) \tag{72-5}$$

Let's now discuss the *FX-local cross-term return*. For simplicity, let's focus only on the portfolio and split it into the original portfolio (P, with weights w) and the portfolio of hedges (H, with weights w–h). As per Eq. (72-3), we know that the portfolio cross-term return is $\sum_c {}^b w_c^P R_c^P F_c^P$. However, the hedge portfolio H pays the deposit rate R_c^{depo} in each currency. Therefore, the net return for the hedged portfolio ($P + H$) is:

$$\sum_c \left({}^b w_c^P R_c^P - \left({}^b w_c^P - {}^b h_c^P\right) \cdot R_c^{depo}\right) \cdot F_c^P$$

We can therefore see that hedges do contribute to the cross-term between FX and local returns. The contribution of the FX-local cross-term return to the outperformance of a portfolio versus a benchmark is calculated as:

$$\sum_c \left({}^b w_c^P R_c^P - {}^b w_c^B R_c^B\right) \cdot F_c^B + \left(\left({}^b w_c^P - {}^b h_c^P\right) - \left({}^b w_c^B - {}^b h_c^B\right)\right) \cdot R_c^{depo} \cdot F_c^B \qquad (72\text{-}6)$$

Since this term is the product of two returns, its size is usually smaller than either of the two. However over time, the contributions of the cross-term can accumulate (similar to a convexity term) and become significant relative to the local and FX returns. Moreover, the FX cross-term can be a significant component of total return when FX and local returns have opposite signs and similar magnitudes. For example, if FX return is +5% and local return is –4%, the total return is 5% – 4% + 5% × –4% = 0.80%. Without the cross-term the total return would have been 1.00%, so the cross-term of –0.20% reduces total return by 25%. In the extreme, if the two returns are opposite but equal in magnitude, the entire total return is due to the cross-term. While in the majority of the cases the FX/local cross-term is insignificant, it is preferable to account for it explicitly.

In addition to the first two terms of Eq. (72-3) we just explored, the local return and market value effects of the hedging instruments, as well as their trading returns, should be accounted for separately. This allows us to separate any returns from the hedging instruments from the local returns and outperformance that we explore in the next stage of attribution.

Outperformance from Allocation to Local Markets

After the contributions of FX exposure and hedging are taken out, the remaining outperformance is given by:

$${}^L R^P - {}^L R^B = \sum_m {}^b w_m^P \cdot \left(R_m^P - R_m^{depo,P}\right) - \sum_m {}^b w_m^B \cdot \left(R_m^B - R_m^{depo,B}\right) \qquad (72\text{-}7)$$

There are many different ways to decompose this outperformance into the contributions of the various decision-makers. The most straightforward is to assume that the first decision layer is the allocation of market value exposure to various local markets. After this, each local market is managed separately versus a corresponding benchmark. We can apply the top-down decomposition algorithm from Chapter 70 to define the local market allocation outperformance as:

$$\sum_{m}\left({}^{b}w_{m}^{P}-{}^{b}w_{m}^{B}\right)\cdot\left(\left(R_{m}^{B}-R_{m}^{depo,B}\right)-\left(R^{B}-R^{depo,B}\right)\right) \tag{72-8}$$

And the local market management outperformance as:

$$\sum_{m}{}^{b}w_{m}^{P}\cdot\left(\left(R_{m}^{P}-R_{m}^{depo,P}\right)-\left(R_{m}^{B}-R_{m}^{depo,B}\right)\right) \tag{72-9}$$

Specifically, we use the following notation from Chapter 70 to construct the equations above $\alpha_{k,s}={}^{b}w_{m}$, $\alpha_{k}=\sum_{c}{}^{b}w_{m}=1$, $f_{k,s}=R_{m}-R_{m}^{depo}$ and $f_{k}^{H}=R^{B}-R^{depo,B}$. Note that this breakdown is equivalent to the *Total Return model* presented in the previous chapter.

If each local market contains securities denominated in the same currency then Eq. (72-9) is simplified to $\sum_{c}{}^{b}w_{c}^{P}\cdot\left(R_{c}^{P}-R_{c}^{B}\right)$. The local outperformance within each currency $R_{c}^{P}-R_{c}^{B}$ can then be decomposed using the general methodology and any of the models described in the previous chapter. If on the other hand local markets span across currencies, then only the *Total Return Model* (see Chapter 71) is directly applicable for the analysis of local market management outperformance. The use of models that require a reference interest-rate curve for the analysis is not straightforward.

Factor-Based Local Markets Allocation

Market value-weighted allocation to markets hides many of the complexities of the decision process of investing across markets. Indeed, allocation of exposure to local markets consists of the aggregation of exposure to each risk factor that drives market returns, such as yield-curve, implied volatility, spreads, and so forth. To better quantify how much risk is taken in a particular local market, we can describe the allocation decision using the appropriate exposure to each risk factor, e.g., interest rate duration for yield-curve, Vega for implied volatility, and spread duration for spreads, etc.

Following the methodology described in Chapter 70, we can rewrite Eq. (72-7) by decomposing local returns into the contributions of risk factors as follows:

$$\begin{aligned}{}^{L}R^{P}-{}^{L}R^{B}=&\sum_{k}\sum_{m_k}{}^{b}w_{m_k}^{P}\alpha_{k,m_k}^{P}f_{k,m_k}^{P}-\sum_{m}{}^{b}w_{m}^{P}R_{m}^{depo,P}\\&-\left(\sum_{k}\sum_{m_k}{}^{b}w_{m_k}^{B}\alpha_{k,m_k}^{B}f_{k,m_k}^{B}-\sum_{m}{}^{b}w_{m}^{B}R_{m}^{depo,B}\right)\end{aligned} \tag{72-10}$$

As implied by the notation m_k, each factor may use a different set of local markets. We can now separate local outperformance into allocation, management, and leverage using different weights for each factor. Specifically, the outperformance due to allocation is:

$$\sum_k \left(\sum_{m_k} \left({}^b w^P_{m_k} \alpha^P_{k,m_k} - {}^b w^B_{m_k} \alpha^B_{k,m_k} \right) \cdot \left(f^B_{k,m_k} - f^H_k \right) \right) - \sum_m \left({}^b w^P_m - {}^b w^B_m \right) \cdot R^{depo,B}_m \tag{72-11}$$

While the one due to management is:

$$\sum_k \left(\sum_{m_k} {}^b w^P_{m_k} \alpha^P_{k,m_k} \cdot \left(f^P_{k,m_k} - f^B_{k,m_k} \right) \right) - \sum_m {}^b w^P_m \cdot \left(R^{depo,P}_m - R^{depo,B}_m \right) \tag{72-12}$$

Finally, the top-level allocation, or leverage, can be represented as:

$$\sum_k \left(\sum_{m_k} {}^b w^P_{m_k} \alpha^P_{k,m_k} - \sum_{m_k} {}^b w^B_{m_k} \alpha^B_{k,m_k} \right) \cdot f^H_k \tag{72-13}$$

Example: Curve Allocation to Local Markets

As an example of the decomposition we just described, consider a portfolio manager that centrally manages the global interest-rate positioning of the portfolio. In this context, we can use the above methodology to separate the local performance of a portfolio into a global curve allocation and excess (of global curve) outperformance. The portfolio manager can use key rate durations to control her exposure to the former and market value weight to control exposure to the latter. We will select the local markets for the decomposition of global interest rates outperformance in a way that each market c corresponds to a unique interest-rate curve. Most of the time this decomposition is equivalent to single currency markets decomposition, yet occasionally this is not the case. For example, it might be preferable to use individual country government curves when analyzing a portfolio of euro-denominated bonds. This methodology allows us to answer successively:

- What was the contribution of the global duration position of the entire portfolio (Global Duration Mismatch)?
- What was the contribution of taking interest rate exposure (sovereign exposure) outside of our reference currency (Local Curve Advantage)?
- What was the contribution of taking other risk exposure in each currency (Excess of Curve Allocation)?

In this example, we will further separate the curve return into two components, a *curve carry* and a *curve change* return. To account for *curve carry* in a way that is consistent with Eq. (72-7), we subtract the deposit return from the outperformance of curve carry. The carry exposure to each individual key-rate point i in each curve c is constructed using the curve-matching portfolio (CMP) weights $\omega_{c,j}$ as described in the previous chapter. The idea behind the CMP is to represent each bond in the portfolio or benchmark as a portfolio of "par bonds" whose curve carry is easy to compute analytically. We can then calculate the carry associated with the portfolio or benchmark using the carry of the corresponding CMP. Let us also denote the curve carry return from each individual key-rate point with $R_{c,j}^{carry} = y_{c,j}\Delta t$. From Eqs. (72-11) to (72-13), using the transformations $\alpha_{k,m_k} = \omega_{c,j}$, $f_{k,m_k} = R_{c,j}^{carry} - R_c^{depo}$ and setting the hurdle rate equal to the excess carry return of a reference currency (typically the base currency of the analysis) $f_k^H = R_{ref,j}^{carry} - R_{ref}^{depo}$, we get the following decomposition.

The local curve carry allocation is given by

$$\sum_c \sum_j \left({}^b w_c^P \omega_{c,j}^P - {}^b w_c^B \omega_{c,j}^B \right) \cdot \left(\left(R_{c,j}^{carry} - R_c^{depo} \right) - \left(R_{ref,j}^{carry} - R_{ref}^{depo} \right) \right) \tag{72-14}$$

The local curve carry management by

$$\sum_c \sum_j {}^b w_c^P \omega_{c,j}^P \cdot \left(\left(R_{c,j}^{carry} - R_c^{depo} \right) - \left(R_{c,j}^{carry} - R_c^{depo} \right) \right) = 0 \tag{72-15}$$

And the global curve carry over deposit as

$$\sum_c \sum_j \left({}^b w_c^P \omega_{c,j}^P - {}^b w_c^B \omega_{c,j}^B \right) \cdot \left(R_{ref,j}^{carry} - R_{ref}^{depo} \right) \tag{72-16}$$

Note that since c represents a single interest-rate curve, the carry return at each key-rate point and the deposit rate return are uniform across all securities and therefore the same for the portfolio or the benchmark. In this case the curve carry management is zero by construction. Further, if we do not use a reference curve, then the global curve carry term also becomes zero and the global curve carry outperformance is simply broken down per curve and key-rate point as follows:

$$\sum_c \sum_j \left({}^b w_c^P \omega_{c,j}^P - {}^b w_c^B \omega_{c,j}^B \right) \cdot \left(R_{c,j}^{carry} - R_c^{depo} \right) \tag{72-17}$$

We now turn to the second component of the curve return, the *curve change* return. The outperformance due to curve change is decomposed similarly using key-rate durations as allocation weights and the negative of the key-rate yield change as return, i.e., $\alpha_{k,m_k} = KRD_{c,j}$, $f_{k,m_k} = -\Delta y_{c,j}$ and $f_k^H = -\Delta y_{ref,j}$.

Under this setting the local yield-curve change allocation is

$$-\sum_c \sum_j \left({}^b w_c^P KRD_{c,j}^P - {}^b w_c^B KRD_{c,j}^B \right) \cdot \left(\Delta y_{c,j} - \Delta y_{ref,j} \right) \tag{72-18}$$

And the local yield-curve change management is

$$-\sum_c \sum_j {}^b w_c^P KRD_{c,j}^P \cdot \left(\Delta y_{c,j} - \Delta y_{c,j} \right) = 0 \tag{72-19}$$

Finally, the global duration mismatch is

$$-\sum_c \sum_j \left({}^b w_c^P KRD_{c,j}^P - {}^b w_c^B KRD_{c,j}^B \right) \cdot \Delta y_{ref,j} \tag{72-20}$$

Once again, within a specific curve interest rate changes are the same for all securities and therefore for the portfolio and the benchmark. This causes the management term to be zero. In addition, if no reference curve is specified, then the global duration mismatch becomes zero as well and the global curve change outperformance is simply broken down per curve and key-rate point as follows:

$$-\sum_c \sum_j \left({}^b w_c^P KRD_{c,j}^P - {}^b w_c^B KRD_{c,j}^B \right) \cdot \Delta y_{c,j} \tag{72-21}$$

Once outperformance from interest-rate curve exposures has been accounted for, the remaining return, i.e., the return in excess of FX and curve return can be explained using a different set of local markets using the same methodology discussed above in the "Outperformance from Allocation to Local Markets" section.

Global Curve Allocation in Practice

To illustrate the concepts just developed, let's consider the following example. A U.S. dollar-denominated portfolio is managed against the Barclays Global G4 Treasury Index, an index consisting of government bonds from four currencies, U.S. dollar, euro, Japanese yen, and British pound. The manager is allowed to make the portfolio deviate from the index in order to express views that in her opinion will produce superior returns. In this case, the manager believes that the euro will strengthen versus the U.S. dollar and at the same time U.S. rates will rise while euro rates will fall. She wants no active exposure to the yen market. Finally, to minimize sovereign risk she prefers to concentrate exposure within the euro-zone to the strongest economies in the region.

The portfolio is constructed in line with the above views as follows:

- The portfolio is long euro (against the U.S. dollar, the base currency of the portfolio).
- The portfolio uses six-month FX forwards selling Japanese yen against the U.S. dollar to bring the portfolio yen exposure in line with that in the benchmark.

- The portfolio is net long interest-rate duration in euro-denominated securities and net short interest-rate duration in U.S. dollar–denominated securities.
- The portfolio overall interest rate duration is neutral against the benchmark.
- In the euro-zone, only bonds from AAA-rated countries are included in the portfolio.

The major portfolio exposures are summarized in Exhibit 72-1.

Exhibit 72-2 shows the breakdown of the portfolio outperformance versus the benchmark for a period of one month. The total outperformance is +10.5 bp. It is broken down by currency, with U.S. dollar being the top contributor at +15.5 bp. It is also broken down by type of exposures, where we see that FX positioning contributed +14.3 bp, and allocation to local markets (including interest rate exposures) contributed +6.5 bp, while local management within each currency market had a negative contribution of –10.3 bp. As expected, most of the FX Allocation outperformance came from the exposure to the euro (+14.4 bp), indicating that the manager's view regarding a strengthening euro was correct. The breakdown also shows a small contribution from hedging effects under Japanese yen, +0.1 bp. As discussed previously, the six-month JPY/USD FX forwards contributed to non-FX return in two ways: (1) They were exposed to the short end of the yen and U.S. dollar yield-curve movements; and (2) over the attribution period they accumulated nonzero market value and therefore created a cash balance effect. Both effects are captured in the non-zero hedging effects outperformance. The yield-curve allocation outperformance is +3.1 bp, with U.S. and the euro-zone contributing +14.9 bp and –12.0 bp, respectively. From this perspective and for this

EXHIBIT 72-1

Portfolio Major Characteristics by Currency

Currency Buckets	Market Value [%]			OAD Contribution		
	Portfolio	Benchmark	Net	Portfolio	Benchmark	Net
Total	100	100	0.0	6.46	6.47	–0.01
U.S. Dollar	24.1	28.6	–4.5	1.05	1.50	–0.45
Euro	34.4	29.8	4.6	2.33	1.88	0.45
Japanese Yen	34.5	34.5	0.0	2.45	2.46	–0.01
British Pound	7.0	7.1	–0.1	0.63	0.63	0.00

Source: POINT

EXHIBIT 72-2

Total Outperformance Breakdown by Currency

	Total	U.S. Dollar	Euro	Japanese Yen	British Pound
Outperformance	10.5	15.5	–5.1	0.5	–0.4
FX Allocation & Hedging	14.3	0.0	14.4	0.0	–0.1
Hedged FX Allocation	14.6	0.0	14.8	–0.1	–0.2
FX / Local Cross Term	–0.4	0.0	–0.4	0.0	0.0
Hedging Effects	0.1			0.1	
Local Market Allocation	6.5	16.5	–9.7	–0.3	0.0
Local Yield-Curve	3.1	14.9	–12.0	0.2	0.0
Local Market Allocation Over Curve	3.4	1.6	2.3	–0.5	0.0
Local Management	–10.3	–1.0	–9.8	0.8	–0.3
Asset Allocation	0.6	–1.1	1.3	0.4	0.0
Security Selection	–10.9	0.1	–11.1	0.4	–0.3

Source: POINT

period, the views the manager had regarding the movements on the yield-curve played well for him regarding the U.S. dollar, but against him regarding the euro. The local market allocation in excess of the yield-curve totals +3.4 bp. Finally, local management pulled back the overall outperformance. Security selection in the euro-zone, in particular, contributed –11.1 bp to total outperformance.

Let us first look into the FX allocation outperformance in detail (Exhibit 72-3). In line with the fund manager's view, the euro strengthened, producing +306.1 bp of FX plus cash deposit return in excess of the base currency (U.S. dollar) cash deposit return. Since the euro had an average overweight of 4.6% during this period, it contributed +14.8 bp of FX outperformance. This number can be approximated as the product of the average overweight times the excess return of the currency, i.e., $4.6\% \times 306.1 = +14.1$ bp. The number does not tie out exactly with the +14.8 bp outperformance reported in Exhibit 72-3 because in the attribution system it is calculated daily and then compounded taking account of any fluctuations in the exposure. In Exhibit 72-3 one can also observe that FX hedging of the yen exposure cost +8.5 bp of outperformance since the yen also appreciated during this period. However, the reverse could be true should the yen weaken against the U.S. dollar. The return coming from the hedged FX Allocation outperformance for the Japanese yen is close to zero. This shows that the manager was able to implement into the portfolio one of his goals: reduce significantly any volatility related to exposure to the yen.

EXHIBIT 72-3

FX Allocation Outperformance Breakdown by Currency[3]

Currency Market	FX Rate Begin	FX Rate End	Excess over Base Depo	Average Market Value (%)			Unhedged FX Allocation	Hedged FX Allocation	FX / Local Cross Term
				Portf	Bmark	Over-weight			
U.S. Dollar	1.0000	1.0000	0.0	24.1	28.6	–4.5	0.0	0.0	0.0
Euro	1.3018	1.3416	306.1	34.4	29.8	4.6	14.8	14.8	–0.4
Japanese Yen	0.0119	0.0123	327.4	34.5	34.5	0.0	8.4	–0.1	0.0
British Pound	1.5574	1.5657	56.3	7.0	7.1	–0.1	–0.1	–0.1	0.0
Total				**100**	**100**		**23.1**	**14.6**	**–0.4**

[3]The hedging effects category is not included here as it has been discussed in the Exhibit 72-2.

Source: POINT

Next, we look more carefully into the global yield-curve outperformance (see Exhibit 72-4). The portfolio curve carry outperformance is almost flat at –0.1 bp. Most of the outperformance comes from portfolio duration positioning. During the period, yields rose for all G4 curves. However, on a relative basis, euro yields rose less than U.S. dollar yields. Without changing the portfolio overall interest rate duration, the portfolio picked up +3.2 bp of outperformance. This was achieved by going short the interest-rate duration in the U.S. (+16.3 bp) while long duration in the euro-zone (–13.1 bp). Overall, the duration decisions played in favor of the manager. Japanese yen and British pound markets contributed little as their durations have been purposely kept neutral to the benchmark.

The outperformance contributions in Exhibit 72-4 have been calculated using Eqs. (72-17) and (72-21) and taking into account the detailed key-rate exposures of the portfolio in each currency. For the purposes of this example we simplify these equations assuming that the portfolio curve exposure is distributed evenly across all key-rate points. In this case the following simplifications can be made:

$$\sum_c \sum_j \left({}^b w_c^P \omega_{c,j}^P - {}^b w_c^B \omega_{c,j}^B \right) \cdot \left(R_{c,j}^{carry} - R_c^{depo} \right) \approx \sum_c \left({}^b w_c^P - {}^b w_c^B \right) \cdot \left(\overline{R_c^{carry}} - R_c^{depo} \right), \text{ and}$$

$$-\sum_c \sum_j \left({}^b w_c^P KRD_{c,j}^P - {}^b w_c^B KRD_{c,j}^B \right) \cdot \Delta y_{c,j} \approx -\sum_c \left({}^b w_c^P OAD_c^P - {}^b w_c^B OAD_c^B \right) \cdot \overline{\Delta y_c}$$

Here $\overline{R_c^{carry}}$ and $\overline{\Delta y_c}$ represent the average curve carry return and average yield change in each curve.

For example, the average euro yield is about 3.1%, which implies a carry-over deposit return[4] of 23.4 bp over the attribution period (one month). The contribution of the euro market value overweight to curve carry outperformance can be estimated as the market value overweight times the average carry over deposit return, i.e., (34.4% – 29.8%) × 23.4 bp = +1.1 bp. The contribution of the euro duration overweight to curve change outperformance can be estimated as the product of the duration overweight times the negative of the average yield change, i.e., (2.33 – 1.88) × (–28 bp) = –12.6 bp. This is close but not equal to the reported –13.1 bp because of the simplification above as well as the compounding effects over the attribution period. A detailed key-rate level report can be used to gain more insight into the numbers. It is interesting to note that the portfolio market weights in some currencies reported here are different than the ones reported in Exhibit 72-3. In particular, the U.S. dollar weight was 24.1% in Exhibit 72-3 but is now reported as 21.6%; the yen weight was 34.5% but is now reported as 37.0%; the euro and British pound weights are unchanged. This is because the market value of the JPY/USD forwards has been excluded from the local analysis

4. Euro deposit rate is about 0.3% during the period. Its monthly carry over deposit return can be estimated as (3.1% – 0.3%) / 12.

EXHIBIT 72-4

Global Yield-Curve Allocation Outperformance

Currency Market	Average Yield Level (%)	Carry Over Deposit (bp)	Curve-Matched Market Weight (%)		Average Yield Change (bp)	Duration (years)		Curve Outperformance (bp)		
			Portf	Bmark		Portf	Bmark	Carry	Change	Total
U.S. Dollar	2.7	20.4	21.6	28.6	35.0	1.05	1.50	–1.4	16.3	14.9
Euro	3.1	23.4	34.4	29.8	28.0	2.33	1.88	1.1	–13.1	–12.0
Japanese Yen	1.2	9.1	37.0	34.5	5.0	2.45	2.46	0.2	0.0	0.2
British Pound	3.6	25.0	7.0	7.1	20.0	0.63	0.63	0.0	0.0	0.0
Total			**100.0**	**100.0**		**6.46**	**6.47**	**–0.1**	**3.2**	**3.1**

Source: POINT

since such positions are considered FX hedges. The contribution of the cash balance effect is captured in the *hedging effects* category of outperformance as discussed above.

If we analyze the performance by currency as in Exhibit 72-4, we may penalize the fund manager unfairly for the large negative outperformance coming from the Euro exposure. An alternative way to analyze the global curve outperformance is to use a reference curve, as presented in Eqs. (72-14), (72-16), (72-18), and (72-20). This is done in Exhibit 72-5, using the U.S. dollar yield-curve as the reference curve. Although the total curve outperformance remains the same, the breakdown among currencies has changed.

For example, Japanese yen now contributes negatively to the curve carry outperformance. Although the yen has a positive carry over deposit return of +9.1 bp over the month, this return is lower than the U.S. dollar (reference) carry over deposit return of +20.4 bp. Therefore, an overweight in a relatively underperforming currency results in an underperformance. The global carry outperformance can be approximated with the formula

$$\left(\sum_c {}^b w_c^P - \sum_c {}^b w_c^B\right)\cdot\left(\overline{R_{ref}^{carry}} - R_{ref}^{depo}\right)$$

This approximation is always zero since the sum of the weights over all curves of an (unleveraged) portfolio or benchmark is equal to 1. However, since the actual calculation is using exposures at each key-rate point, the exact global carry outperformance may be non-zero.

The euro shows now a *positive* contribution to the curve change outperformance due to better performance relative to the U.S. curve. Its contribution to curve change outperformance is now estimated as – (2.33 – 1.88) × (28 bp – 35 bp) = +3.2 bp, close to the +3.1 bp reported. As concluded before, the manager decision regarding global curve positioning had an overall positive performance for the portfolio during this period. The U.S. curve—being the reference curve—does not contribute to outperformance. The global duration contribution can be estimated using the formula $-(OAD^P - OAD^B)\cdot\overline{\Delta y_{ref}}$, i.e., – (6.46 – 6.47) × 35 bp = +0.3 bp, close to the +0.1 bp reported.

After the yield-curve outperformance has been accounted for, the excess of yield-curve return is split into allocation and management components. Although in general a different set of markets can be used, in this example we will use the same G4 markets used for the curve decomposition. Exhibit 72-6 shows the details of this breakdown. Overall, the allocation of exposure to the four markets has contributed positively (+3.4 bp) with the exposure to the euro market contributing most of it (+2.3 bp). This number can be approximated as the overweight of the euro market times the excess return of the euro market in the benchmark relative to the overall benchmark, i.e., 4.6% × (67.9 bp – 22.5 bp) = +2.1 bp. On the other hand, the local management of excess to curve return in the euro market has not been successful, contributing –9.8 bp to outperformance. The approximate calcu-

EXHIBIT 72-5

Global Yield-Curve Outperformance with U.S. as Reference Curve

Currency Market	Avg Yield Level (%)	Carry Over Deposit (bp)	Curve-Matched Market Weight (%)		Average Yield Change (bp)	Duration (years)		Curve Outperformance (bp)		
			Portf	Bmark		Portf	Bmark	Carry	Change	Total
Global Carry/ Duration			100.0	100.0		6.46	6.47	0.0	0.1	0.1
U.S. Dollar (Ref)	2.7	20.4	21.6	28.6	35.0	1.05	1.50	0.0	0.0	0.0
Euro	3.1	23.4	34.4	29.8	28.0	2.33	1.88	0.1	3.1	3.2
Japanese Yen	1.2	9.1	37.0	34.5	5.0	2.45	2.46	–0.2	0.0	–0.2
British Pound	3.6	25.0	7.0	7.1	20.0	0.63	0.63	0.0	0.0	0.0
Total			**100.0**	**100.0**		**6.46**	**6.47**	**–0.1**	**3.2**	**3.1**

Source: POINT

EXHIBIT 72-6

Excess of Yield-Curve Outperformance

	Return Over Curve		Market Weight (%)			Outperformance	
Currency Market	Portf	Bmark	Portf	Bmark	Overweight	Local Market Allocation Over Curve	Local Management
U.S. Dollar	–2.0	0.5	21.6	28.6	–7.0	1.6	–1.0
Euro	40.5	67.9	34.4	29.8	4.6	2.3	–9.8
Japanese Yen	6.3	4.7	37.0	34.5	2.5	–0.5	0.8
British Pound	2.0	7.5	7.0	7.1	–0.1	0.0	–0.3
Total	**16.0**	**22.5**	**100.0**	**100.0**	**0.0**	**3.4**	**–10.3**

Source: POINT

lation yields 34.4% × (40.5 bp − 67.9 bp) = –9.4 bp. This underperformance can be understood by looking at more detailed issuer-level reports as presented in the previous chapter,. In this example, it turns out that the lower-rated EU countries experienced much bigger spread tightening during the period. The concentration in the strongest economies in the region may reduce the portfolio long-term risk, but during this particular period contributed to loss of performance.

DERIVATIVES AND LEVERAGE

Derivative instruments are widely used across asset classes as both hedges and means to express market views. Their payoffs are tied to changes in the values of underlying securities, and their market values do not generally represent the size of the actual exposure to risk factors. In this section, we discuss how a performance attribution model may handle derivative instruments in order to maintain the intuitive and meaningful nature of the results.

Returns and Basis

Returns of derivative instruments can be difficult to measure. The market value of a contract is typically small (or sometimes zero) compared with its notional exposure, and the standard definition of return—profit/loss (P&L) divided by market value—can result in extremely large (or even infinite) values. For example, the market value of instruments that are marked-to-market daily, such as Treasury futures, is guaranteed to be zero at the end of the day, resulting in a theoretically infinite return. To maintain the notion of return as a P&L per unit of investment, we seek to use a denominator that represents the size of the position in terms of its exposure. We refer to this quantity as the "return basis" or simply "basis." One should define an appropriate return basis for each derivative type of interest. Usually, the basis is set equal to the notional amount, although in many cases special rules are used to define the basis in a bond-equivalent way.

To complicate the issue of derivatives further, the standard methodology of multi-period return compounding cannot be applied. Consider the following definition of single- and multi-period returns, where PL_t and R_t are the P&L and return over the period (t–1, t). The portfolio return is given by

$$R_t = \frac{PL_t}{MV_{t-1}}$$

And the multi-period return is:

$$R = \left(\prod_{t=1}^{T} \left(1 + R_t\right) \right) - 1$$

By using market value as a basis for the return and compounding it with the above formula, we get an intuitive relationship between the market values at t = 0 and t = T, and the return over the period (0, T).[5]

$$MV_T = MV_0\left(1+R\right)$$

Changing the basis to a quantity that is not proportional to the market value will annul this property. This is more evident when returns are large. As an exaggerated example, consider a futures contract that is marked-to-market daily and therefore always has zero market value. A reasonable basis for returns for a position in this contract is the notional amount invested. Suppose the notional amount is \$1,000 and that over two days, the contract produces a mark-to-market P&L of –\$500 and \$1,000, respectively. Using the notional amount as the basis of returns, the returns for the two days are –50% and +100%, respectively. Using the chain rule to compound returns yields zero return over the two days: $(1-50\%)\times(1+100\%)-1=0\%$. Obviously, this is not consistent with the positive P&L of \$500 produced over the two days. Such effects are always present when compounding returns using a basis that is different from the market value of the position; however, their effect is much smaller when the magnitude of returns is small. To avoid such nonintuitive results, one should make appropriate adjustments to the compounding of returns of derivative securities—something out of the scope of this chapter.

Returns for Portfolios and Sectors Containing Derivatives

The return of each individual derivative contract is defined using its basis as described above. However, in typical portfolios, these contracts coexist with cash securities. When we analyze partitions of the portfolio, such as sector or rating, that contain both cash and derivative securities, it is still typical to use market value as the denominator for all returns and weights.[6] Nevertheless, the presence of the derivatives imposes some changes into the analysis.

Let's define the leverage ratio for each security, β_i, to be the basis divided by the market value of the security. Then the leveraged weight of the security is the product of the market value weight and the leverage ratio, $w_i\,\beta_i$. The return of the portfolio or sector can then be written as the leveraged weighted sum of the deleveraged return of each security:

$$R^P = \sum_i \frac{PL_i^P}{MV^P} = \sum_i \frac{MV_i^P}{MV^P}\frac{basis_i^P}{MV_i^P}\frac{PL_i^P}{basis_i^P} = \sum_i w_i^P \beta_i^P R_i^P$$

5. We assume that the portfolio has no significant cash flows. When such cash flows do occur, the above formula does not hold.

6. Net (or gross) basis and gross market value could also be used as the denominator for the entire portfolio when analyzing highly leveraged or long-short strategy funds.

Although this transformation does not change the return, notice that the leveraged weights are no longer constrained to sum to 1 when derivatives are present in the portfolio.

$$\sum_i w_i \beta_i \neq 1$$

Therefore, when we seek to explain the contribution of each instrument to the security selection outperformance of each bucket (the last step of the top-down decomposition—see the previous chapter.), derivatives give rise to an additional term of outperformance that comes from the implicit leverage they introduce. The example below illustrates this issue.

Example: Leverage from Derivatives and Security Selection Outperformance
Consider a bucket with a single credit security A experiencing excess of curve return of +10%, while the corresponding benchmark bucket has two equally weighted securities, the one in the portfolio A and another one B returning 0%. The total return for that bucket in the benchmark is therefore +5%. Let us also assume that the market value weight of this bucket in the portfolio is 20%; therefore, its contribution to security selection would typically be calculated as 20% × (10% – 5%) = 1.0%. The contribution of security A to security selection is calculated as 20% × (100% – 50%) × (10% – 5%) = 0.5%, and the one of security B is 20% × (0% – 50%) × (0% – 5%) = 0.5%.

Now assume that the portfolio also contained a short protection credit default swap on the issuer of bond A with a return basis equal to the market value of A, essentially doubling the exposure to the issuer of A. Let us assume that the default swap is at-the-money, i.e., its market value is zero, and that it also experiences a return of +10% (using notional as the return basis). Since the market value of the portfolio bucket remains the same but its P&L doubles, the return of the sector is now reported as +20%, and the security selection term becomes 20% × (20% – 5%) = 3.0%. Notice that the market value weight of the bond remains 100% and that the default swap also has a weight of 100% (return basis over market value of the bucket). Bonds A and B contribute to security selection 0.5% exactly as before. The default swap contributes 20% × (100% – 0%) × (10% – 5%) = 1.0%. The contributions of the three securities to security selection sum to 2.0%, leaving 1.0% of security selection unexplained.

This comes from the leverage introduced to the bucket. Indeed, the sum of securities weights in the portfolio is 200%, whereas in the benchmark it is 100%. This causes an outperformance of 20% × (200% – 100%) × 5% = 1.0%, completing the decomposition of security selection. This term was introduced as the "top-level exposure" for the excess return model in Chapter 71 (see Eq. (71-6)).

Typically, in the presence of derivatives, this top-level term can be reported as a separate line item for each bucket–bucket leverage, and folded into the security selection term. Alternatively, it can be reported as leverage at the portfolio level.

A General Framework for Leverage

Leverage complicates portfolio returns calculations and comparison to the benchmark. Furthermore, there are different means to achieve leverage, and the decision to employ it can occur at any level of the portfolio management decision structure. For instance, cash borrowing can be used to leverage the entire portfolio, while derivatives can be used to leverage specific sectors. The latter case can be further distinguished into a decision made by an asset allocator or by a sector manager. Below, we outline an analytical way to account for leverage in a consistent framework with the one discussed in Chapter 70.

We expand the concept of leverage ratio as introduced before and apply it to the entire portfolio. We assume that a "funded" market value—generally different from the actual market value—can be defined for the portfolio, partition buckets, and individual securities, and serve as the *basis* for the calculation of unleveraged returns. The ratio of the returns basis to actual market value is the leverage ratio of the portfolio.

$$R^P_{leveraged} = \frac{basis^P}{MV^P} \cdot \frac{PL^P}{basis^P} = \beta^P R^P$$

We can also recursively break down the portfolio return into the contributions of its various sectors by appropriately defining the leverage ratio of each sector:

$$R^P_{leveraged} = \sum_s \frac{PL^P_s}{MV^P} = \sum_s \frac{MV^P_s}{MV^P} \cdot \frac{basis^P_s}{MV^P_s} \cdot \frac{PL^P_s}{basis^P_s} = \sum_s w^P_s \beta^P_s R^P_s$$

Using similar terminology for the benchmark, the total leveraged outperformance can be expressed as a function of leverage ratios and unleveraged returns as:

$$R^P_{leveraged} - R^B_{leveraged} = \beta^P R^P - \beta^B R^B = \sum_s w^P_s \beta^P_s R^P_s - \sum_s w^B_s \beta^B_s R^B_s$$

We will now consider the different ways to break down the total outperformance into contributions from asset allocators and sector managers. It is worthwhile to note that when leverage is allowed, there is no limit to how much exposure managers can allocate to sectors or securities. Consequently, it no longer makes sense to compare sector returns against a hurdle rate (as discussed in Chapter 70) to determine the contribution from asset allocation decisions.

Separate Allocation of Market Weight and Leverage of Each Sector

In this case, each sector is given a market value budget, but sector managers are free to take leverage within their sectors. Separate agents determine the market value allocation and the leverage in each sector. The simple asset allocation/sector management equations can be readily applied in this case. The comparison of sector returns of the portfolio and the benchmark occurs on a leveraged basis. In this case, the outperformance from leverage decisions is embedded in the sector management term. Specifically, the asset allocation would come as

$$\sum_s \left(w_s^P - w_s^B\right) \cdot \beta_s^B R_s^B \tag{72-22}$$

And the sector management as

$$\sum_s w_s^P \cdot \left(\beta_s^P R_s^P - \beta_s^B R_s^B\right) \tag{72-23}$$

Allocation of Total Exposure to Sectors

Alternatively, leverage can be determined by the asset allocator instead of the sector managers. In this case, a single agent decides the total exposure[7] to the unleveraged return of each sector. Once again, the asset allocation/sector management equations can be applied, but we now need to use total exposure instead of market value as the allocation weight. In this case, the outperformance from leverage decisions is embedded in the asset allocation term. The asset allocation is

$$\sum_s \left(w_s^P \beta_s^P - w_s^B \beta_s^B\right) \cdot R_s^B \tag{72-24}$$

While the sector management comes as

$$\sum_s w_s^P \beta_s^P \cdot \left(R_s^P - R_s^B\right) \tag{72-25}$$

In general, we can assume that leverage decisions are made at both the portfolio and the sector levels. A top-level manager may determine the total portfolio leverage (relative to the benchmark), and an asset allocator may subsequently determine the total exposure to each sector. Therefore, if total leverage is determined at the portfolio level, then the allocation of total exposure to each sector is constrained by the portfolio leverage decision and must be measured relative to that. Instead of using the absolute total exposure as the allocation weight, we now need to use the relative total exposure (total exposure divided by the portfolio/benchmark leverage). We also need to use a hurdle return, as exposure at the sector level is partially constrained.

In this scenario the outperformance decomposition has some extra terms, as shown below. The asset allocation outperformance can be derived as

$$\beta^P \sum_s \left(\frac{w_s^P \beta_s^P}{\beta^P} - \frac{w_s^B \beta_s^B}{\beta^B}\right) \cdot \left(R_s^B - R^H\right) \tag{72-26}$$

7. The total exposure is defined here as market weight times leverage.

While the sector management comes as

$$\sum_s w_s^P \beta_s^P \cdot \left(R_s^P - R_s^B\right) \tag{72-27}$$

The top-level leverage is

$$\left(\beta^P - \beta^B\right) \cdot R^H \tag{72-28}$$

If we do not assume that leverage aggregates linearly, i.e., generally $\beta^P \neq \sum_s w_s^P \beta_s^P$ and $\beta^B \neq \sum_s w_s^B \beta_s^B$ in order to keep the decomposition complete we need to add an additional term, that we call "diversification."

$$\left(\sum_s w_s^P \beta_s^P - \beta^P \frac{\sum_s w_s^B \beta_s^B}{\beta^B}\right) \cdot R^H \tag{72-29}$$

If we assume no leverage in the benchmark, the diversification term becomes

$$\left(\sum_s w_s^P \beta_s^P - \beta^P\right) \cdot R^H$$

Moreover, this term is zero if the leverage is aggregated linearly; that is,

$$\beta^P = \sum_s w_s^P \beta_s^P, \quad \beta^B = \sum_s w_s^B \beta_s^B$$

However, there are situations where we may not want the leverage to aggregate linearly. As an example, suppose that betas are defined based on risk. Then, if the different sectors are not perfectly correlated, the beta of the portfolio would tend to be smaller than the sum of the individual sector betas. This is due to the well-known risk diversification effect, hence the name for this term. In this case, the leverage creates a diversification effect with positive returns for our portfolio as long as the hurdle rate return is positive.

Handling leverage is a generalization of the top-down decomposition algorithm described in Chapter 70, where unleveraged returns are the factor returns, leveraged weights are the factor loadings, and we assume linear aggregation of leverage (so that the diversification term vanishes). This analysis is also similar to the one regarding the decomposition of the spread related outperformance, described in Chapter 71.

Special Handling of Certain Derivative Types

Often, derivatives are used to manage a specific type of risk exposure and are not meant to participate in the general asset allocation/security selection portfolio management framework. We already encountered this issue earlier in this chapter, while discussing how to handle the role of currency derivatives as FX hedging instruments. A similar situation arises with interest-rate derivatives as instruments of managing interest-rate risk only. In both cases we have to account for the return that is not tied to their primary hedging function and for the implicit cash allocation that occurs when derivative instruments used as hedges acquire market value between rebalancing dates. On the other hand, credit derivatives are typically used along with cash instruments to manage exposures to sectors and issuers; therefore, they do participate in asset allocation and security selection. Depending on the portfolio and level of analysis, we may want all these different effects to be captured and reported separately. Below, we discuss in more detail issues arising from the handling of common derivatives and the treatment typically adopted.

Currency Derivatives

FX forwards are typically used as FX hedging instruments. In this case, their return and outperformance contributions should not be allowed to affect the local (excess of FX) outperformance analysis. As discussed previously in this chapter, the easiest way to achieve this is to remove them completely from the analysis of non-FX outperformance. However, removing FX hedges from the local analysis introduces two side effects that have to be explicitly accounted for. First, the non-FX return of FX hedges must be recorded. Such return can be non-negligible in periods of market crisis or whenever hedges with longer tenors are being used. Second, since FX hedges are not being rolled daily, they accumulate market value, which represents an allocation to cash, if positive, or leverage, if negative. This effect—called earlier the "FX hedging cash balance effect"—contributes to outperformance and should be appropriately recorded.

Interest Rate Derivatives

Derivatives designed to hedge or gain exposure to interest rate factors are typically overlays onto a portfolio after the core positions are chosen. These instruments, such as government bond futures and interest rate swaps, typically affect the curve return of the portfolio but have little effect on the excess return over the yield-curve. Typically, they are used in portfolios that lend themselves to attribution models that treat curve outperformance separately (e.g., the excess return model discussed in Chapter 71). In these models, interest rate derivatives should only contribute to the curve outperformance, which is a common factor, and they should be removed entirely from the decomposition of the allocated factors. Two portfolios identical except for the use of interest rate derivatives should have the same asset allocation and security selection returns.

Similar to currency hedges, the removal of interest rate derivatives from the asset allocation/security selection outperformance analysis introduces a cash-balance effect if the market value of such derivatives is non-zero. Indeed, a positive market value indicates an implicit allocation to cash, whereas a negative market value indicates implicit borrowing and, therefore, leverage. Further, exchange-traded derivative instruments may incur return that cannot be explained by their curve exposures. For example, Treasury futures frequently trade at a spread to their theoretical fair value. Changes in this spread result in return that cannot be explained by interest rate movements. However, this return should be accounted for and reported as a side effect of interest rate hedging.

Credit Derivatives

In contrast to currency and interest rate derivatives, credit default swaps (CDS), credit index default swaps (CDX or iTraxx), and total return swaps (TRS) are primarily used to manipulate exposure to excess (over curve) return factors. Typically, these instruments are included in the regular asset allocation/security selection decomposition. Single issuer credit default swap instruments have small interest-rate exposure that does contribute to the yield-curve outperformance, but their primary exposure is to the credit factor of the underlying issuer. The performance of credit default swap indices should be explained by exploding them into their single-issuer constituents. The constituents are then included in the asset allocation/security selection decomposition, ensuring that the correct weights and returns are used to reflect the actual exposure to each partition bucket. The basis of returns for credit derivatives is not their market value. As a result, they generate bucket leverage, as discussed previously.

FROM THEORY TO PRACTICE

In order to be of any practical use, a performance attribution system must deal with a significant number of special situations that arise in day-to-day portfolio management. Such issues include missing security prices or analytics, bad prices or analytics, intra-period transactions, settlement conventions, pricing discrepancies between the portfolio and its benchmark, and so on. Below, we discuss some of these issues.

Return and Outperformance Compounding[8]

Multi-period arithmetic total return is compounded by taking the product of the single-period total returns:

$$R = \left(\prod_{t=1}^{T} \left(1 + R_t\right) \right) - 1$$

As discussed in Chapter 70, a general framework of performance attribution begins with the splitting of a single-period total return into the contributions

8. For an introduction to multi-period attribution and compounding see Chapter 70.

of various factors, $R_t = \sum_k \alpha_{k,t} f_{k,t}$. This leads to the question of how the return splits should be compounded so that the sum of the compounded return splits remains equal to the compounded total return. This is necessary to satisfy the additivity and completeness requirements of attribution.

One way to accomplish this is the following: Let us designate with $\hat{R}_k$ the multi-period compounded factor return. Setting $\hat{R}_k$ equal to the single-period factor return, $f_{k,t}$, scaled by the compounded portfolio value at the beginning of the period, i.e.,

$$\hat{R}_k = \sum_{t=1}^{T} \alpha_{k,t} f_{k,t} \prod_{s=1}^{t-1} \left(1 + R_s\right), \qquad \text{where} \qquad \prod_{s=1}^{0} \left(1 + R_s\right) \equiv 1 \tag{72-30}$$

guarantees the additive decomposition of total multi-period return, i.e., $R = \sum_k \hat{R}_k$. This decomposition algorithm is fairly straightforward and has the properties of additivity and completeness, but what about fairness?

Consider a simple example with two factors and two periods. Let us assume that both factors contribute 20% return, but factor A does so in the first period and has zero return in the second period, while factor B has zero return in the first period and 20% return in the second period. The total portfolio return is therefore (1 + 20%) × (1 + 20%) – 1 = 44%. According to the algorithm above, the contribution of the first factor is not scaled because it occurs in the first period and remains at 20%; the contribution of the second factor is scaled by the portfolio value at the end of the first period (1.20) so it becomes 24%. Although one could argue that the decomposition is unfair—as it favors the second factor which contributed returns after the first factor—the notion that later returns and contributions can be affected by the earlier performance of the portfolio as a whole is generally accepted as a fair practice.

In addition to the total return and return splits compounding, any multi-period attribution algorithm also needs to address the compounding of outperformance. In the context of simple factor-based performance attribution models the above algorithm can be readily applied:

$$R^P - R^B = \sum_k \left(\hat{R}_k^P - \hat{R}_k^B\right)$$

However, in the context of a general attribution model where the categories to which outperformance is decomposed to may depend both on the portfolio and the benchmark (e.g., asset allocation or security selection), such simple decomposition is not possible and more complex algorithms must be used.

Since single-period performance attribution provides a complete, additive, and fair decomposition of single-period outperformance, most compounding algorithms seek to define scaling coefficients for each period, such that the sum of the scaled single-period outperformance is equal to the total multi-period outperformance.[9]

$$R^P - R^B = \sum_t \beta_t \left(R_t^P - R_t^B\right)$$

Once β_t is determined, it can be used to scale every outperformance component (e.g., yield-curve, asset allocation, security selection, etc.) because of the additivity and completeness properties of single-period performance attribution.

One commonly used approach in practice is the optimized linking coefficient approach.[10] The basic idea behind this approach is to seek coefficients that avoid extreme values under most scenarios. Indeed, if not carefully defined, such coefficients can become zero or attain very high values distorting the outperformance decomposition and making it unfair. The value of β_t in the optimized-linked method is determined as follows:

$$A = \frac{\left(R^P - R^B\right)/T}{\left(1 + R^P\right)^{1/T} - \left(1 + R^B\right)^{1/T}}$$

$$C = \frac{R^P - R^B - A\sum_{t=1}^{T}\left(R_t^P - R_t^B\right)}{\sum_{t=1}^{T}\left(R_t^P - R_t^B\right)^2}$$

$$\beta_t = A + C\left(R_t^P - R_t^B\right)$$

Transactions

Return and outperformance calculations require special treatment of transactions. Security transactions that usually settle on a forward basis create “intra-period” returns as well as “unsettled” positions. It is important to recognize intra-period return separately because it does not participate in the decompositions previously discussed. It is also important to make the distinction between settled and unsettled positions because only the settled positions earn carry.

Intra-Day Return

Daily attribution models compound returns and outperformance using end-of-day market-closing prices. However, the models should allow users to enter transactions that occur during the day at the actual transaction prices, which can be quite

9. The exact nature of the algorithm that should be used to link the results of a multi-period attribution has been the subject of intense debate in the performance attribution literature. The entire Fall 2002 issue of the *Journal of Performance Measurement* was devoted to this topic.

10. Jose Menchero, “An Optimized Approach to Linking Attribution Effects over Time,” *Journal of Performance Measurement* (Fall 2000), pp. 36–42.

different from the closing prices of the traded security used to calculate daily returns. This flexibility guarantees that the returns of the portfolio, including trading activities, are captured accurately. The difference between the trade price and the closing price should be captured and reported separately as "Trading" return. Further, the return contribution from intra-day trading activities, which is not captured by the end-of-day portfolio snapshots, must also be accounted for and reported as "Intra-Day Trading" outperformance.

Unsettled Positions

Most security transactions settle on a forward basis, i.e., both cash and the security are exchanged some days in the future. For example, corporate securities transactions settle after three business days (T+3), while most government securities settle after one day (T+1). Certain mortgage-backed securities (TBAs) have special settlement rules as they settle on a specific day each month. A comprehensive attribution model should allow transactions to settle on any forward date.

While buyers of a security are exposed to its clean price fluctuations (market risk) immediately after the transaction, they do not begin earning the coupon return of the security (more accurately, the yield or time return of the security r^{carry}) until after the settlement date. Instead, they keep earning the yield on the cash (r^{cash}) that they have promised to pay on the settlement date. Therefore, an unsettled position in a portfolio is earning a return equal to $r^{cash} + r^{price}$, while the same security in an index, always settled, is earning $r^{yield} + r^{price}$. The return $(r^{cash} - r^{yield}) \cdot \Delta t$, where Δt is the time to settlement, constitutes real outperformance (usually negative) that must be accounted for. Conversely, when the portfolio sells the position, it is earning the security yield (instead of cash) until the sell settlement date, making back any yield lost when the security was bought. These effects should be captured by the outperformance algorithm and reported for each model as carry outperformance.

Handling Inconsistent or Missing Data

Security prices used to compute returns of benchmark indices may be different from what portfolio managers use to mark their positions.[11] For any outperformance decomposition to be meaningful, it is important for the price and, hence, the return of the same security to be consistent in both universes. In most cases, managers would want to use their own prices to compute their portfolio returns. In general, we should use the security returns from the portfolio by default. However, since the total return of the benchmark index typically needs to be consistent with the published number, the algorithm should allow for the pricing difference effect to be reported as a separate source of outperformance.

When there are missing prices during the attribution period, the system can either exclude the securities from the analysis entirely or imply prices if that is

11. This is not uncommon for less liquid securities.

deemed reasonable. During the period with missing prices, one can use last available analytics and market changes to imply prices so that daily outperformance can be computed. This approach is particularly useful if prices for the beginning and end of the period are available so that the correct return over the attribution period is known.

KEY POINTS

- Multi-currency portfolios add an additional layer of complexity to the portfolio management structure. An attribution algorithm normally needs to decompose the global total outperformance into FX and local market allocations, as well as local management.
- Being able to accurately separate the performance due to active foreign-exchange (FX) positions from that due to the hedging effects is a complex but particularly important task in any multi-currency attribution system.
- Factor-based local market allocation, such as duration-based global curve allocation, quantifies better the risk and return in a particular market than the market-value weighted local markets allocation.
- Derivatives change the nature of the basis used to define returns. They often require special treatment in order to obtain intuitive and meaningful attribution results.
- Return and outperformance compounding is an important task in order to ensure the additivity and completeness properties for any multi-period attribution.
- A complete attribution system should be able to handle intra-day transactions, unsettled positions as well as missing and inconsistent prices.

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Frank J. Fabozzi is editor of *The Journal of Portfolio Management* and co-editor/cofounder of *The Journal of Financial Data Science*. He is Professor of Finance at EDHEC Business School. Over the past 35 years, he has held various professorial positions at MIT, Yale, Princeton, Carnegie Mellon University, and New York University. He is a trustee of the BlackRock fixed income complex. He has authored more than 120 books and more than 200 articles in peer-reviewed journals. He is the CFA Institute's 2007 recipient of the C. Stewart Sheppard Award and the CFA Institute's 2015 recipient of the James R. Vertin Award. He was inducted into the Fixed Income Analysts Society Hall of Fame in November 2002. He has earned the designations of Chartered Financial Analyst (CFA) and Certified Public Accountant (CPA). His *Conversations with Frank Fabozzi* for Portfolio Management Research is a fortnightly series of interviews of some of the investment industry's most renowned practitioners. He received his BA and MA in economics in 1970 from The City College of New York where he was elected to Phi Beta Kappa and received a PhD in economics in 1972 from the City University of New York. In 1994 he was awarded an Honorary Doctorate of Humane Letters from Nova Southwestern University.

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