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WILEY
John Wiley & Sons, Inc.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Whaley, Robert E.
Derivatives : markets, valuation, and risk management / Robert E. Whaley.
p. cm. — (Wiley finance series)
Includes index.
ISBN-13: 978-0-471-78632-0 (cloth/cd-rom)
ISBN-10: 0-471-78632-2 (cloth/cd-rom)
1. Derivative securities—Marketing. 2. Derivative securities—Valuation. 3. Financial risk management. I. Titile. II. Series.
HG6024.A3W475 2006
332.64′57—dc22

2006016190

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

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Preface

The book's title is *Derivatives: Markets, Valuation, and Risk Management*. In a nutshell, that is what it intends to provide—an understanding of derivatives markets, derivatives valuation, and risk management using derivative contracts. The first part of the book—*Markets*—sketches the landscape. What are derivative contracts? Where do they trade? Why do they exist? While a seemingly endless number of derivative contract structures will appear as we proceed through the chapters of the book, do not be misled. Only two basic contract structures exist—a forward and an option. All other product structures are nothing more than portfolios of forwards and options. Similarly, derivative products are offered by an almost endless number of firms and institutions in the marketplace—brokerages houses, banks, investment houses, commodity producers, importers, exporters, and so on. Again, do not be misled. Fundamentally there are only two types of derivatives markets—exchange-traded markets and over-the-counter (OTC) markets. Exchanges facilitate trading in standardized contracts. They offer deep and liquid markets, and the financial integrity of trades is guaranteed by the exchange's clearinghouse. OTC markets, on the other hand, can tailor contracts to meet customer needs, however, counterparties are left to their own devices to arrange protection from counterparty default. Finally, why do derivatives markets flourish, considering that they are *redundant securities*, that is, they derive their value from the price of the underlying security? The answer is plain and simple. They are generally less expensive to trade, or, in many instances, circumvent trading restrictions that impede trading in the underlying security market. Because derivative contracts are redundant means that they are effective risk management tools. Because they are cheaper to trade and may circumvent trading restrictions means that they are cost-effective.

The last two terms in the title—*Valuation* and *Risk Management*—are the other main focuses of the book. As we amply demonstrate throughout the book, derivative contracts are incredibly powerful tools for managing expected return and risk. In order to take full advantage of the opportunities they afford, we need to have a thorough understanding of how derivative contracts are valued. Without an understanding the economic factors that drive valuation, we cannot measure risk accurately, and, if we cannot measure risk accurately, we certainly cannot manage it effectively.

With this background in mind, we now outline the contents of the book. The sections of the book, and the chapters that comprise each section, are listed in Table 1. Here we provide a brief description of the each section's contents. As noted earlier, Part One sketches the derivatives landscape. Part Two, together

TABLE 1 Section outline for *Derivatives: Markets, Valuation, Risk Management*

I. DERIVATIVE MARKETS
- 1. Derivative contracts and markets

II. FUNDAMENTALS OF VALUATION
- 2. Assumptions and interest rate mechanics
- 3. Relation between expected return and risk

III. FORWARD/FUTURES/SWAP VALUATION
- 4. No-arbitrage price relations: Forwards, futures, swaps
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IV. OPTION VALUATION
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- 7. Valuing standard option analytically
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- 17. Interest rate products: Futures and options
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- 21. Commodity products

X. LESSONS LEARNED
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- A. Elementary statistics
- B. Regression analysis
- C. Statistical tables
- D. Glossary

with Appendixes A and B, review the basic principles of security valuation. The purpose of this section is to ensure that everyone is on the same page as we enter the discussions of derivative contract valuation and risk measurement. Parts Three and Four focus exclusively on derivatives valuation and risk measurement. These principles are developed in an environment in which the underlying asset is generic. We do this to emphasize the fact that the valuation and risk measurement principles are generally not asset-specific—the valuation equations/methods and risk management strategies for foreign currency derivatives are no different than those used for stock derivatives, stock index derivatives, interest rate derivatives, and commodity derivatives. With the general valuation/risk measurement framework in hand, we then focus in Parts Five through Nine on derivative contracts in specific asset categories. Aside from pointing out any asset market idiosyncrasies that may affect valuation, specific risk management strategies/practices, as they apply to the particular asset market, are discussed. Part Ten summarizes the key lessons contained in the chapters of the book and offers some general guidelines on derivatives use.

DERIVATIVE MARKETS

The first section of the book is devoted to providing a broad overview of derivative contracts and the markets within which they trade. We start by describing and illustrating the basic types of derivative contracts—a forward and an option. With these generic contract designs in mind, we then discuss the fundamental issues regarding derivatives markets—why they exist, how they originated, how they work, and how they are regulated.

FUNDAMENTALS OF VALUATION

The second section of the book together with the two supporting end-of-book appendices—Appendix A: Elementary Statistics, and Appendix B: Regression Analysis—are not specific to derivative contract valuation. They focus on security valuation in general. The reason is simple. The problem is risk management. What risks? You name it. Corporations, institutions, governments, and governmental agencies incur all sorts of risks in their day-to-day operations. For corporate producers such as oil refiners, managing price risk of input costs (i.e., crude oil) as well as output prices (i.e., heating oil and unleaded gasoline) are relevant. For end-users such as airlines, managing its exposure to jet fuel prices is important. Depending upon user, some risks may be acceptable, while others may not. A gold company, for example, may have a thorough understanding of the world's supply and demand for gold production and, consequently, may be better able to predict gold price movements in the short- and long-run. On the other hand, it may have little or no awareness of probable movements in exchange rates. For this company to accept the gold price risk exposure and, at the same time, to hedge foreign currency risk exposure of sales commitments in a different currency is perfectly sensible.

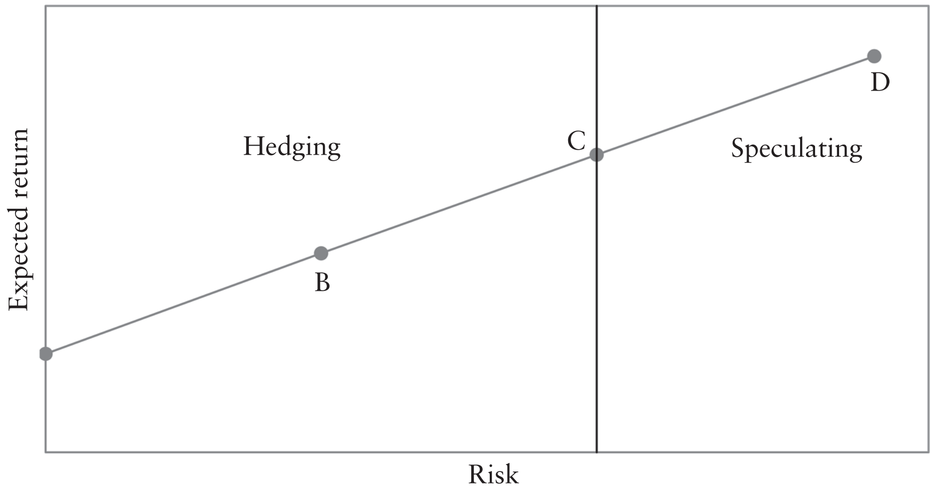
All of this is to say, we must begin at a more basic level. The key elements in financial decision making are the risk, return, and timing of cash flows. A security's value is driven by all three factors. A fundamental assumption that we will maintain throughout the book is the *absence of costless arbitrage opportunities*. If we identify two investments whose risk, return, and timing of cash flow properties are exactly the same, they must have the same price in the marketplace. Otherwise, market participants can make free money by simultaneously selling the more expensive one and buying the cheaper one. This economic premise was introduced nearly fifty years ago in the Nobel Prize-winning work of Modigliani and Miller (1958, 1961). We apply this premise again and again throughout the book in a context called *valuation-by-replication*. Suppose we are faced with the problem of valuing and measuring the risk of a seemingly complex security or derivative contract. If we can identify a set of securities/derivatives whose cash flow stream maps identically to the cash flow stream of the complex security, that security's value must be equal to the sum of the values of the constituent securities/derivatives. Then, since we know how to value the instrument, we can measure its risk.

After reviewing the no-arbitrage principles, we turn to reviewing the use of interest rate mechanics in moving expected future cash flows through time. To reenforce the relation between valuation and risk measurement, we examine simple security valuation problems such as bond valuation. After deriving the bond valuation formula, we show how to measure its risk. A bond's interest-rate price risk is called duration. We show how to measure it, and, then, how to hedge it.

Where Chapter 2 deals with projection of expected future cash flows and moving them back to the present at a specified rate of interest, Chapter 3 deals with the motivation for and the measurement of risk-adjusted rates of interest. In financial economics, the capital asset pricing model (CAPM) provides the structural relation between expected return and risk. Like the work of Modigliani and Miller, the precepts are not new. They begin with the work of Markowitz (1952, 1959) who demonstrates how risk-averse individuals should go about allocating their wealth among risky securities on a single-period model. Tobin (1958) extends the model to include risk-free borrowing and lending extends an individual's set of return/risk opportunities. Finally, Sharpe (1964) and Lintner (1965) show how individuals' security demands can be aggregated and identify the equilibrium expected return/risk relation for the marketplace. The continuous-time version of the CAPM, which we use repeatedly throughout the book, was derived by Merton (1973a). The central role that the CAPM plays in financial economics in general is attested to by the fact that five of the key players in its development—Harry Markowitz, James Tobin, William Sharpe, John Lintner, and Robert C. Merton—have received Nobel Prizes in Economics.

The expected return/risk relation is central to the understanding risk management using derivative contracts. Consider Figure 1. The vertical axis is expected return and the horizontal axis is risk. What derivatives risk management deals with is moving along the line by entering particular derivative contract positions. Point C on the figure might represent, for example, a farmer's current unhedged, expected return/risk profile. The coordinates of point C are determined by his assessment of the mean and the variance of the wheat price distribution. His decision about what to do depends on his risk preferences. He can engage in a risk-reducing strategy by committing to deliver part of his anticipated harvest of wheat

FIGURE 1 Expected return/risk tradeoff.



at a price that is fixed today. This short forward commitment would bring his return/risk profile toward the risk-free rate of return, say to point B, and would be referred to as *hedging*. On the other hand, if he is confident that wheat prices are going to be high as a result of poor weather during the summer and low yield in the fall, he may not hedge, keeping his risk profile at C, or he may attempt to profit from his directional view regarding wheat price movements and buy forward to increase his risk profile from C to, say, point D. All of this is to say that this book deals with moving along this line. There will be different types of risk to be managed, and we will handle each of them in turn. We should be clear, however, that risk management is synonymous with expected return/risk management. In equilibrium, we cannot move one without moving the other.

Appendices A and B to the book are intended to review the basic principles of elementary statistics and ordinary least squares regression. These are provided so as "… to leave no stone unturned." Having a basic understanding of statistics and regression analysis is a prerequisite for financial management. The implementation of the capital asset pricing model, for example, requires estimates of expected return, standard deviation of return, and covariance of returns of pairs of risky assets.

FORWARD/FUTURES/SWAP VALUATION

The third section of the book focuses on the valuation of forward contracts, and the fourth section focuses on the valuation of option contracts. In both cases, the underlying asset is generic and is characterized only by its net cost of carry rate. Section three has two parts. Chapter 4 focuses on the valuation of forward contracts. Futures and swaps are also mentioned in the section heading because they are simply different types of forward commitments. In Chapter 4, we demonstrate that the price of a futures contract is identical to the price of a forward contract in an environment in which short-term interest rates are known. In addition, we demonstrate that a swap contract is nothing more than a portfolio of forward contracts. Hence, if we can value a forward, we can value a swap. We show that the forward price and the underlying spot price are inextricably linked by the *net cost of carry relation*. The intuition underlying this relation is straightforward. Suppose we need 5,000 bushels of wheat on hand in three months. To lock in the purchase price of the wheat today, we can buy it in the marketplace, store it, and then use it in three months. Under this action, we forego the opportunity cost of the funds that we used to buy the wheat and pay storage costs such as warehouse rent and insurance. Collectively, these items are called *carry costs*. A second strategy is to buy wheat forward at the price agreed upon today. Since both alternatives provide wheat in three months at a price known today, the costs of the two strategies must be the same. Otherwise, someone can earn a *costless* arbitrage profit.

Assuming individuals are constantly monitoring the marketplace for free money opportunities, we can depend on the net cost of carry relation between a forward contract and the spot price to hold at any point in time, which implies that the price movements of the forward and the underlying asset are perfectly positively correlated. The correlation between forward and spot price movements is at the heart of the risk management strategies discussed in Chapter 5. We simply rework the mechanics of the CAPM to handle the problem. We show that we can alter the expected return/risk attributes of any commodity or financial asset position by entering forward positions. It is only a matter of deciding what exposures to hedge and what exposures to retain. If we have the ability to pick underpriced stocks but have no ability to pick the direction of the market, for example, an appropriate risk management strategy is to buy the underpriced stocks and sell stock index futures. In this way, we accept the stock's idiosyncratic risk about which we are expert and lay off the market risk about which we have little knowledge.

OPTION VALUATION

Section four is the longest of the book's ten sections.[1] But, it is arguably the most interesting and important. The ideas in this section have spawned an entire industry, which, as of December 2003, had more than USD 230 trillion in notional amount of contracts outstanding. Chapter 6 is the options counterpart to the no-arbitrage price relations for forward contracts provided in Chapter 4. The no-arbitrage price relations for options fall into one of three categories. First, because options are contingent claims (i.e., we have the right but not the obligation to engage in a future transaction), we can only develop lower bounds on call and put prices. Second, if we consider the call and put prices simultaneously, we can create a forward contract and, therefore, develop a net cost of carry relation for options. Called *put-call parity*, this relation resurfaces on many occasions throughout the chapters of the book. Finally, in countries such

[1] Much of the material for these chapters is drawn from Whaley (2003).

as the United States, options on assets as well as options on the futures written on those same assets are sometimes traded. When this happens, certain no-arbitrage price relations will govern prices in the adjacent markets.

Chapter 7 contains the development of the Black-Scholes (1973)/Merton (1973b) (hereafter, BSM) model. From the valuation of employee stock options to the dynamic risk management of securities/derivatives portfolios, this model plays a critical role in the valuation and risk management of hundreds of billions of dollars of derivatives transactions each day. A standard option contract, like any security, can be valued as the present value of its expected cash flows. For a European-style call option, the expected cash flow is at the option's expiration and equals the expected difference between the underlying asset price and the exercise price conditional upon the asset price being greater than the exercise price. Thus, the call's expected cash flow depends on, among other things, the expected risk-adjusted rate of price appreciation on the underlying asset between now and expiration. Once the call's expected terminal value is established, it must be discounted to the present. The discount rate applied to the expected terminal option value is the expected risk-adjusted rate of return for the option. The problem with this traditional approach to option valuation, provided by Samuelson (1965) eight years before BSM,[2] is that it is difficult, if not impossible, to estimate reliably the expected risk-adjusted return parameters.

A major theoretical breakthrough occurred in 1973 with the publication of research papers by Black and Scholes (1973) and Merton (1973b). They showed that, if a risk-free hedge between an option and its underlying asset can be formed, option valuation does not depend on individual risk preferences and therefore need not depend on estimating expected risk-adjusted returns.[3] Indeed, if option valuation does not depend on risk preferences, we are free to choose any type of individual risk behavior in valuing an option. An obvious choice is to assume individuals are risk-neutral. In a risk-neutral world, all assets are expected to have a rate of return equal to their risk-free rate of interest. Consequently, the need to estimate risk-adjusted rates of return is eliminated.

Chapter 7 begins by building the intuition underlying risk-neutral valuation using a simple, one-period binomial model. We show that BSM option values are the same as those obtained using risk-neutral individuals and risk-averse individuals. With the irrelevance of risk preferences established, we then turn to risk-neutral option valuation. The BSM model assumes that the price of the asset underlying the option is log-normally distributed. We develop the expressions for the expected value of the asset price given estimates of the mean and the variance of the normally distributed return distribution. With the expected terminal price of the option in hand, we present the valuation formulas for European-style call and put options. We then use the formulas to derive expressions to assess the option's risk characteristics.

Chapter 8 uses the BSM option valuation framework to value unusual or nonstandard types of option contracts. Many of these contracts emerged in the late 1980s and 1990s when the OTC markets were focused on designing new

[2] Interestingly enough, Paul Samuelson was also awarded the Nobel Prize in economics.

[3] If a risk-free hedge can be formed between two risky securities, the securities are *redundant*, and each can be priced in relation to the other as investors are risk neutral.

and ever more elaborate option contracts with wide-ranging payoff contingencies. For some contracts, the potential hedging properties are immediately obvious. For others, the contracts seem cleverly designed forms of speculation. Regardless of the purpose, all of the contracts discussed in this chapter have analytical valuation equations, that is, all of them are formulaic (rather than numerical) solutions to option valuation problems.

Where Chapter 7 and 8 focus on valuing options analytically, Chapter 9 focuses on numerical techniques that can be used to approximate the values of options with no analytical valuation equation. Here, the early contributors were Cox, Ross, and Rubinstein (1979) and Rendleman and Bartter (1979). What made the option valuation problem in Chapter 7 tractable is that we assumed the options were European style with only one exercise opportunity. For other types of options, the valuation problem is not so simple. With American-style options, for example, there are an infinite number of early exercise opportunities between now and the expiration date, and the decision to exercise early depends on a number of factors including all subsequent exercise opportunities. An analytical solution for the American-style option valuation problem (i.e., a valuation formula) has not been found. The same is true for many Asian-style options (e.g., options written on an arithmetic average) and many European-style options with multiple sources of underlying price risk (e.g., spread options). In such cases, options must be valued numerically. Moreover, even in instances where analytical solutions to option contract values are possible (e.g., accrual options), numerical methods are often easier to apply.

The numerical methods for valuing options described in Chapter 9 employ the BSM valuation assumptions. The underlying asset's price is assumed to follow a geometric Brownian motion (i.e., to be log-normally distributed at any future instant in time), and a risk-free hedge between the option and its underlying asset(s) is possible. Three of the methods involve replacing the continuous Brownian diffusion with a process that involves discrete jumps. The *binomial method*, for example, assumes that the asset price moves to one of two levels over the next increment in time. The size of the move and its likelihood are chosen in a manner so as to be consistent with the log-normal asset price distribution. In a similar fashion, the *trinomial method* allows the asset price to move to one of three levels over the next increment in time. The *Monte Carlo simulation* technique uses a discretized version of geometric Brownian motion to enumerate every possible path that the asset's price may take over the life of the option. A fourth method, called the *quadratic approximation method*, addresses the value of early exercise by modifying the BSM partial differential equation. As important as valuation, however, is risk measurement. The chapter concludes with a description of how the risk characteristics of options can be computed numerically.

Chapters 7 through 9 deal with option valuation. Knowing how to value options, in turn, provides a means for measuring risk. Chapter 10 focuses on option risk management strategies. Two major categories exist—dynamic strategies and passive strategies. Dynamic expected return/risk management, for example, attempts to manage changes in portfolio value caused by unexpected changes in the asset price, volatility, and interest rates, as well as the natural erosion of option's time value as it approaches expiration. These strategies are of particular importance to exchange-traded option market makers or OTC option dealers who, in the normal course of business, acquire option positions whose risks need to be managed on a day-to-day (minute-to-minute) basis.

Passive strategies, on the other hand, are those that involve holding an option over some discrete interval of time such as a week, a month, or even held to expiration. In this instance, the rates of return of the option and the asset are not perfectly correlated and the mechanics for analyzing the position are somewhat different. Specifically, we assess the expected return/risk characteristics of portfolios that are entered into and held to expiration. We discuss how to compute expected profits, expected returns, and risks under the assumption that the underlying asset price is log-normally distributed at the options' expiration. Finally, we show how to simulate the performance of option trading strategies using Monte Carlo simulation.

STOCK DERIVATIVES

The remaining sections of the book are arranged by the nature of the asset underlying the derivatives contract—stocks first, then stock indexes, currencies, interest rates or bonds, and, finally, commodities. In each section, we provide a flavor for the history of each derivatives market as well as any market idiosyncrasies that may affect the valuation principles developed in earlier chapters.

We begin with stock derivatives. Three chapters are warranted. Chapter 11 is focused on stock products. Options on common stocks have been traded in the United States since the 1790s. Originally, trading took place in the over-the-counter market. Put/call dealers would advertise their prices in the financial press, and interested buyers would call a dealer. These contracts were not standardized with respect to exercise prices or expiration dates. Without standardization, option positions were often difficult to unwind prior to expiration. An investor wanting to reverse his option position was forced to negotiate with the dealer with whom the original trade was made.

On April 26, 1973, the Chicago Board Options Exchange (CBOE) became the world's first organized secondary market for standardized stock options. The beginnings were modest. The "exchange" was in a small smokers' lounge off the main floor of the Chicago Board of Trade. The only options traded were calls, and calls were available only on 16 New York Stock Exchange stocks. Today, the CBOE, together with the American Stock Exchange, the Philadelphia Stock Exchange, the Pacific Coast Exchange, and the International Securities Exchange, list call and put options on over 2,200 hundred different stocks in the United States alone. Worldwide, stock options trade on over 50 exchanges in 38 different countries. Futures contracts on individual stocks also trade on a handful of exchanges worldwide, but their popularity pales by comparison.

Chapter 12 deals with the valuation of corporate securities, which can also be viewed as stock derivatives. Firms issue different types of securities to finance the assets of the firm—common stock preferred stock, discount bonds, coupon bonds, convertible bonds, warrants, convertible bonds, and so on. Some are issued to the public and are actively traded in the secondary markets. Others are placed publicly, but trade infrequently. Yet others are privately placed, and trade seldom if at all. The purpose of this chapter is to show how all of the firm's securities outstanding can be valued using only information regarding the firm's common stock price and volatility rate. This is possible because all of the firm's securities have the same source of uncertainty—the overall market value of the firm's assets. To develop the corporate security valuation framework, we rely of the BSM option valuation results from Chapter 7. The underlying source of uncertainty is the firm's overall market value, which we assume is log-normally distributed in the future. We also assume that a risk-free hedge may be formed between each of the firm's securities and the firm's overall value. As a practical matter, the firm's overall value (i.e., the sum of the market values of all of the firm's constituent securities) does not trade as a single asset, however, small changes in the value of the firm are perfectly correlated with the changes in the value of its stock. This means that, as long as the firm's common stock is actively traded, we can apply the risk-neutral valuation principles with no loss in generality. We value bonds with varying degrees of seniority, rights and warrants, and convertible bonds.

Chapter 13 deals with the valuation of options awarded by the firm to its employees. By providing employees with the shares of the firm, or claims on the shares of the firm, management aligns the interests of employees with those of owners (i.e., the shareholders). Two common contracts are an *employee stock option* (ESO) and an *employee stock purchase plan* (ESPP). Like a warrant, an ESO is a call option contract issued by the firm. Typically, ESOs are at-the-money at the time of issuance (i.e., the exercise price is set equal to the stock price) and have terms to expiration of ten years. Over the first few (usually three) years, the options cannot be exercised. This is called the *vesting period*. If the employee leaves the firm during the vesting period, the options are forfeit. After the vesting date, the options can be exercised at any time but are *non-transferable*. Because they are nontransferable, the only way for the employee to capitalize on its value is to exercise the option. An ESPP allows the employee to buy the company's stock at a discount, usually 15%, within a certain period of time, typically six months. Some the ESPP includes a lookback provision that allows its holder to apply the discount to either the end-of-period or the beginning-of-period stock price, whichever is less. Our standard approach to stock option valuation is modified to handle all of these special considerations.

STOCK INDEX DERIVATIVES

Arguably the most exciting financial innovation of the 1980s was the development of stock index derivative contracts. Although derivatives on the Dow were contemplated by the Chicago Board of Trade as early as the late 1960s, it was not until April 1982 that the Chicago Mercantile Exchange (CME) launched trading of the S&P 500 index futures contract. Options followed about a year later. Within a few years, stock index products appeared in most major financial centers worldwide. Included, for example, were contracts on the All Ordinaries index in Sydney, the FT-SE 100 index in London, and the Hang Seng index in Hong Kong. In spite of their relatively short history, billions of dollars in equities change hands every day through index derivatives trading in nearly 30 different countries.

Chapter 14 contains discussions of index derivatives markets and valuation. The primary focus is futures and option contracts. A return/risk management strategy discussed in detail in this chapter is the use of stock index futures to tailor the expected return-risk characteristics of a stock portfolio. This strategy is frequently in practice for purposes of market timing and asset allocation. Exchange-traded contracts are also used for structuring new and different products. Protected equity notes are one example. These notes allow individuals to protect the principal value of their investment, while, at the same time, share in the upside of a market index. We value protected equity notes using the valuation-by-replication principle and show that they are nothing more than a combination of risk-free bonds and a stock index call options.

A number of stock index products are based on trading strategies. These are the focus of Chapter 15. One such product is portfolio insurance. We examine several competing methods by which the value of stock portfolios may be insured against decline. These include passive insurance provided by index puts as well as dynamic insurance possible through continuous rebalancing of stocks and risk-free bonds, stocks and index futures, and index futures and risk-free bonds. Another product is funds based on particular option trading strategies. With options included in the mix, the properties of the return distribution can be dramatically altered, undermining conventional methods of portfolio performance. We examine this problem using the realized return/risk attributes of the BXM index—an index created from buying the S&P 500 index portfolio and selling one-month, at-the-money call options. The third set of products focus on stock market volatility. Two types exist—contracts on realized volatility and contracts on volatility implied by index option prices. We describe volatility contract specifications, valuation, and selected risk management strategies.

CURRENCY DERIVATIVES

Chapter 16 deals with currency products. Futures on foreign exchange (FX) rates were the first financial futures contract introduced by an exchange. On May 16, 1972, the Chicago Mercantile Exchange launched trading futures on three currencies—the British pound, the Deutschemark, and the Japanese yen. Before that time there was little need for derivatives markets on currencies. Exchange rates were essentially fixed as a result of the Bretton Woods Agreement, which required each country to fix the price of its currency in relation to gold. With the failure of the Bretton Woods Agreement and the removal of the gold standard in 1971, exchange rates began to fluctuate more freely, motivating a need for exchange rate risk management tools. Chapter 16 illustrates a number important currency risk management strategies. We show, for example, how to redenominate fixed-rate debt in one currency into another using a currency swap or a strip of currency forwards. We also show how forward/option contracts can be used to manage the price risks of single and multiple transactions and balance sheet risk.

INTEREST RATE DERIVATIVES

Where equity derivative products have the largest presence in exchange-traded markets, interest rate derivative products have the largest presence in the OTC market. Indeed, interest rate derivatives account for 72% of the USD 197.2 trillion in notional amount of OTC derivatives outstanding at the end of 2003. The popularity of these contracts is easy to imagine. Interest rate risk management is an important concern for most participants in the marketplace—corporations, agencies, municipalities, governments, and even individuals.

The interest rate derivatives section is divided into four chapters. Chapter 17 focuses on the interest rate derivative contracts traded on exchanges. For the most part, the principles and valuation methods of Chapters 4 through 10 can be applied directly to interest rate futures and options, with two notable exceptions. First, certain of the interest rate futures contracts have embedded delivery options that allow the short futures to deliver any one of a number of eligible bond issues. This "cheapest-to-deliver" option has value and affects the net cost of carry relation. Second, for options on short-term debt instruments, the log-normal price distribution assumption is inappropriate since the debt instrument cannot have a price that exceeds its par value. Consequently, we are required to develop a new methodology for valuing interest rate options. To do so, we invoke the assumption that the short-term interest rate is log-normally distributed, and then modify the valuation methods of Chapters 7 through 9. We then focus on some important interest rate risk management problems.

Chapter 18 focuses on interest rate swaps. The first interest rate swaps were consummated in the early 1980s. An early example occurred in 1982 when Sallie Mae swapped the interest payments on intermediate-term fixed rate debt for floating-rate payments indexed to the three-month T-bill yield. In the same year, a USD 300 million seven-year Deutsche Bank bond issue was swapped into USD LIBOR. While we discussed swaps on other types of assets in earlier chapters, interest rate swaps are far and away the largest asset category. As of year-end 2003, interest rate derivatives accounted for 72% of the notional amount of all OTC derivatives outstanding. Of this amount, more than 78% of interest rate derivatives were swaps. While plain vanilla swaps is certainly the largest category within this group, there are also a variety of other multiple-cash flow instruments including caps, collars, floors, and swaptions. We will address each in turn. A critical ingredient in the valuation of each of these contracts is the zero-coupon yield curve. The chapter, therefore, begins with a lengthy discussion of the zero-coupon yield curve and how it is estimated.

The first two interest rate derivatives chapters focus almost exclusively on interest-rate risk. Chapter 19 introduces a second source of risk often present in interest rate instruments—credit risk. For corporate bonds, credit risk is sometimes called default risk; for foreign bonds, it is called sovereign risk. Under either label, it refers to the fact that receiving the bond's promised interest payments and repayment of principal is uncertain. Credit derivatives come in a variety forms. We discuss three—credit default swaps, total return swaps, and credit-linked notes. In a credit default swap, the protection seller agrees, for an upfront fee or a continuing premium, to compensate the protection buyer upon a defined credit event. Since the buyer retains ownership of the underlying asset, a credit default swap isolates the credit risk inherent in the asset (e.g., the default risk of a corporate bond) from market risk (e.g., the interest rate risk of a corporate bond). With total return swaps, however, the buyer transfers all of the risks of the asset (e.g., the market risk and default risk of a corporate bond) to the seller in return for a risk-free interest payment. A credit-linked note is a corporate bond-like security structured by a bank to behave like a particular corporate or sovereign bond. This is done by buying risk-free bonds and selling credit default options. The success of this market is driven by the fact that the corporate bond is illiquid, at least relative to the stock market, and that many firms and institutions do not have authorization to trade derivative contracts or to engage in off-balance sheet transactions.

Chapter 20 focuses on the no-arbitrage valuation of interest rate options. The modeling is more intricate than it is the case for other asset categories for two reasons. The first is, as noted earlier, while an asset such as a stock price, an exchange rate or a commodity price can roam freely through time without constraint, fixed income security prices must converge to their par values as the security approaches its maturity. Second, in the fixed income markets, there is often a wide range of securities available on the *same* underlying source of uncertainty. The U.S. Treasury, for example, has T-bills, T-notes and T-bonds with a wide range of maturities. In modeling interest rate dynamics, care must be taken to ensure that all of these securities are simultaneously valued at levels consistent with observed market prices. Chapter 20 develops a binomial procedure for valuing interest rate derivative contracts where the short-term interest rate ("short rate") is the single underlying source of interest rate uncertainty and zero-coupon bond values are consistent with observed market prices. With the mechanics of no-arbitrage pricing in hand, we then turn to valuing coupon-bearing bonds, callable bonds, putable bonds, and bond options. Be forewarned, however. While the valuation framework provided in this chapter is intuitive and commonly applied in practice, it only begins to scratch the surface of the literature focused on no-arbitrage interest rate models. This literature is deep in multifactor theoretical models of interest rate movements and sophisticated numerical procedures for calibrating the models to observed market prices. Such technical discussions, however, are beyond the scope of this book.

COMMODITY DERIVATIVES

Commodities are physical assets. Examples include precious metals, base metals, energy stores (e.g., crude oil and natural gas), refined products (e.g., heating oil and gasoline), and food (e.g., wheat, and livestock). Commodity derivatives have been traded in over-the-counter markets for centuries. The first modern-day commodity futures exchange began operation in 1865, when the Chicago Board of Trade launched trading of standardized futures contracts calling for the delivery of grain. With the passage of time, nonagricultural commodities were introduced—precious metal (silver) futures in 1933, livestock in 1961, petroleum and petroleum products in the late 1970s and early 1980s, liquefied propane in 1987, natural gas in 1990, and electricity in 1996. Chapter 21 focuses on derivatives contracts written on commodities. This chapter is organized by underlying commodity. The reason is that the price relations of commodity derivatives are influenced by idiosyncrasies in the underlying commodity market. Understanding commodity derivatives price behavior, therefore, involves understanding the factors that influence commodity price behavior. We discuss the fundamental differences between pricing commodity derivatives and pricing financial derivatives. Commodity derivatives require that we consider the storage costs such as warehouse rent and insurance as well as the convenience of having an inventory of the commodity on hand. Neither of these factors played an important role in the pricing of stock, stock index, currency, and interest rate derivatives products. We focus on the three major commodity categories—energy, agricultural, and metals—and on common types of commodity price risk management problems.

LESSONS LEARNED

Chapter 22 summarizes the key lessons contained in the book. In spite of the book's length, the lessons are few.

1. Derivatives markets exist because of high trading costs and/or trading restrictions/regulations in the underlying asset market.
2. The expected return/risk relation for derivative contracts, like risky assets, is governed by the capital asset pricing model.
3. The absence of costless arbitrage opportunities (i.e., the law of one price) ensures that derivative contract price is inextricably linked to the prices of the underlying asset and risk-free bonds.
4. The no-arbitrage price relation between a derivative contract and its underlying asset ensures that derivative contracts are effective risk management tools.
5. The key insight into derivative contract valuation is that a risk-free hedge can be formed between a derivatives contract and its underlying asset.
6. Only two basic types of derivatives exist—a forward and an option.
7. Valuing and measuring the risk of complex derivatives is made possible by valuation by replication.
8. Derivatives valuation and risk measurement principles are not asset-specific.
9. Accurate parameter estimation is critical in applying derivative contract valuation models.
10. So-called "derivative disasters" reported in the financial press did not arise from a failing in the performance of a derivative contract or the market in which it traded.

OPTVAL™

The book makes extensive use of OPTVAL™, a library of Microsoft Excel Visual Basic Add-Ins design to perform a wide range of valuation, risk measurement, and statistical computations. The logic in doing so is simple. By facilitating the computation of value/risk, the OPTVAL functions allow the reader to focus on the economic understanding of solving the valuation and risk management problems rather than the computational mechanics of valuation and risk measurement.

More specifically, accurate and reliable valuation/risk measurement has two important computational steps. The first is performing all of the computations that go into generating a model value conditional on knowing the values of the model's parameters. In some instances such as valuing a simple forward or futures contract, the numbers of intermediate computations are hundreds, perhaps, thousands. In other instances such as valuing an option on a dividend-paying stock, they are many. The second is estimating model parameters. All valuation models are function analytical or numerical functions of a set of parameters. Reliably estimating many of these parameters such as expected future return volatility involves collecting histories of price data and then applying statistical techniques. OPTVAL also contains a host of statistical functions to supplement what is already available in Microsoft Excel.

The add-in functions contained in OPTVAL are introduced and applied in each chapter's illustrations. In the early chapters of the book, the illustrations show all of the intermediate computations involved in addressing the valuation/risk measurement problem at hand as well as the OPTVAL function that allows the reader to find the solution without seeing the intermediate computations. This two-step procedure is designed to allow the reader to develop confidence that OPTVAL functions are not merely a "black box" but rather a set of computational routines that the reader can verify, if he or she chooses to do so. As the chapters progress, less emphasis is placed on showing intermediate steps and more emphasis is placed on addressing important, everyday valuation/risk management problems.

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Acknowledgments

Writing a comprehensive book on derivatives is an impossible task. Derivatives markets continue to grow at rapid rate, with thousands of new products or product variations being introduced every year. At best, all a derivatives book can hope to provide is a framework for understanding derivatives contract valuation and risk management as well as the structure of the markets within which they trade. My thinking about these issues has been influenced in many important ways by coauthors, professional colleagues, teachers, and students. Among those who deserve special recognition and gratitude are David Alexander, Fred Arditti, Lynn Bai, Giovanni Barone-Adesi, Messod D. Beneish, Fischer Black, Nicolas P. B. Bollen, Michael Bradley, Michael W. Brandt, Alon Brav, Alan Brudner, Pat Catania, Alger "Duke" Chapman, Joseph K. Cheung, Jeff Fleming, Theodore E. Day, Paul Dengel, Bernard Dumas, Frank J. Fabozzi, Myron J. Gordon, John Graham, Dwight Grant, Stephen Gray, Campbell R. Harvey, Edward Joyce, Runeet Kishore, T.E. "Rick" Kilcollin, Chris Kirby, Alan W. Kleidon, Albert "Pete" Kyle, Joseph Levin, Craig Lewis, Ravi Mattu, Robert C. Merton, Merton H. Miller, Matt Moran, Jay Muthuswamy, Barbara Ostdiek, Todd Petzel, Emma Rasiel, Ray Rezner, David T. Robinson, Mark Rubinstein, Eileen Smith, Bill Speth, Hans R. Stoll, René M. Stulz, Joseph R. Sweeney, and Guofu Zhou. I am especially indebted to Tom Smith of Australian National University in Canberra who carefully read and commented on all of the chapters of the book in preparation for final submission. Megan Orem provided professional and accurate typesetting. Finally, I would like to dedicate this book to my family, who have supported me during this long writing process—my wife, Sondra, and my children, Ryan, Justin, and Heather. Without their support and encouragement, this project would never have been completed.

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Professor Whaley's current research interests are in the areas of market microstructure, market volatility, hedge fund performance, index construction, and employee compensation. Much of his past work focused on investigations of the effects of program trading on stock prices, the expiration day effects of index futures and options, and the valuation of option and futures option contracts and the efficiency of the markets in which they trade. His research has been published in the top academic and practitioner journals, and he is a frequent presenter at major conferences and seminars. He has also published six books, including a textbook on the theory and applications of futures and option contracts.

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During his career, Professor Whaley received a number of grants and awards including the 1989 Richard and Hinda Rosenthal Foundation Award for innovation in finance research, the 1991 NCNB Faculty Award for contributions in research, teaching and service at the Fuqua School of Business, and the 1993 Earl M. Combs, Jr. Award for contributions to the futures industry. Many of his research papers have received awards, including Graham and Dodd Scrolls for Excellence in Financial Writing from the *Financial Analysts Journal* in 1986 and 1987, the Bernstein Fabozzi/Jacobs Levy Award for Outstanding Article published in *Journal of Portfolio Management* during the volume year 1999–2000, the E. Yetton Award for Best Paper in *Australian Journal of Management*, 1997 for his work on program trading and futures option valuation, the CBOT Award for Best Paper on Futures at the Western Finance Association meetings in 1993 for his work on dual trading, the Canadian Securities Institute Award for Best Paper in Investments at the Northern Finance Association meetings in 1989 for his work on market volatility prediction, and an EOE Prize from the Institute for Quantitative Investment Research—Europe in 1995 for his work on deterministic volatility functions.