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# AN INTRODUCTION TO DERIVATIVE SECURITIES, FINANCIAL MARKETS, AND RISK MANAGEMENT

**Robert A. Jarrow and Arkadev Chatterjea**



AN INTRODUCTION TO

**Derivative Securities, Financial  
Markets, and Risk Management**





AN INTRODUCTION TO

# Derivative Securities, Financial Markets, and Risk Management

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THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL



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*Bob: To my wife Gail for her patience and understanding.*

*Arka: To my wife Sudeshna for her cheerful and steadfast support,  
and to our daughters Rushtri, Tvisha, and Roudra (all younger than the book!),  
who also cheerfully and proudly supported my writing.*

## About the Authors



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# Preface

“History has many cunning passages, contrived corridors,” wrote T. S. Eliot in the poem “Gerontion.” The history of options and futures can be so described. Derivatives have traded for centuries in small, over-the-counter markets in London, New York, and several cities of continental Europe. In 1688, a sophisticated rice futures market was established in Osaka, Japan, that thrived for 250 years. Modern commodity futures markets began in 1848 with the founding of the Chicago Board of Trade to help protect farmers from commodity price swings. After many placid decades, the calm was again broken with the inauguration of the world’s first financial futures market in 1972 at the Chicago Mercantile Exchange and in 1973 with the opening of the Chicago Board Options Exchange. Serendipitously, 1973 also saw the publication of the Nobel Prize–winning Black–Scholes–Merton (BSM) option pricing model, which further spurred market expansion by enabling better pricing and hedging.

Sometimes viewed as harmful and sometimes viewed as beneficial by the financial press and the public, derivatives have nonetheless played a significant role in financial markets across the centuries. Following the 2007 credit crisis, derivatives are most recently playing the role of the harmful security again, and new financial regulations have been proposed to rein them in. Although perhaps well intentioned, these attacks on derivatives are hurled by those unfamiliar with their proper use. Derivative securities, if used properly, reduce risk and facilitate real economic growth in the economy. In today’s complex world, modern financial institutions cannot succeed without the use of derivatives for managing the varied risks of their assets and liabilities. An understanding of their proper usage comes through a careful study of derivatives, which brings us to the purpose for writing this book.

*This book was written to be the first book read on derivatives and not the last. Our aim has been to design a book that is closely connected to real markets, examines the uses of derivatives but warns against their abuses, and presents only the necessary quantitative material in an easily digestible form—and no more!*

Given our purpose, this book differs from all existing derivatives textbooks in several important ways:

- First, it is an introduction. We wanted to create a textbook accessible to MBAs and undergraduates both in terms of the concepts and mathematics. Option pricing is normally thought of as a complex, mathematical, and difficult topic. Our experience is that this topic can be presented simply and intuitively.
- Second, it is about financial markets. We wanted to write an economics, not a quantitative, book on derivatives. Since the first textbooks on option pricing,<sup>1</sup>

<sup>1</sup> Jarrow and Rudd (1983) and Cox and Rubinstein (1984).

derivatives textbooks have taken a quantitative approach to the topic and are often encyclopedic in presentation. Little if any effort was spent on the underlying economics. In contrast, an economics perspective relates the market structure to the assumptions underlying the models. An understanding of when to use and when not to use a model based on its assumptions must be included. Our book does this.

- Third, it is a book about risk management. Generally speaking, there are four risks to be managed: (1) market risk, which includes commodity (including equity) price risk, interest rate risk, and foreign currency price risk; (2) credit risk; (3) liquidity risk; and (4) operational risk. We walk you through these different risks, with an emphasis on market risk, and discuss how they can be managed in business as well as in one's personal life.
- Fourth, not only do governments regulate the markets, but many government entities use derivatives to promote the public's welfare. The book often discusses the relevant issues from a regulator's point of view and from a public policy perspective.
- Fifth, another unique feature of this book is an intuitive and accessible presentation of the Heath–Jarrow–Morton (HJM) model, which is the most advanced as well as a widely used derivatives pricing model. To make this model accessible, we first present the classical option pricing theory centering on the BSM model in a user-friendly fashion. Our presentation of the BSM model, however, is done with an eye toward the HJM model, emphasizing those aspects of the BSM model that are needed later. Then, when we study the HJM model, less development is needed. This approach enables us to present the HJM model in a parallel fashion to that of the BSM model, so if you see one, you see them both!
- Sixth, option pricing has a fascinating history, filled with colorful people and events. We share this history with the reader. This history is obtained from century-old books (now, uniquely available via the Internet), recent books, newspaper and magazine articles, websites, and personal experiences.
- Seventh, we have included enrichment material for the advanced reader through the use of inserts and appendixes. Many of these inserts include current research insights not available in existing textbooks.

The organization of this book is purposely designed to facilitate its use in many courses relating to options, futures, derivatives, risk management, investments, fixed income securities, and financial institutions. Three major courses that can be taught from this book are: (1) derivatives, (2) futures and commodities, and (3) fixed income securities and interest rate derivatives. In a sense, there are many books within this one cover.

- **Derivatives.** This is a standard course on basic derivatives that gives an introduction to forwards, futures, options, and swaps but excludes interest rate derivatives for the most part. For this, use chapters 1–20 and most of chapter 22. This would be for first-year MBAs and masters of financial engineering and for upper-level undergraduates in business schools, engineering schools, and economics departments.



- **Futures and commodities.** This is a course on futures and commodities, excluding option pricing. For this, use chapters 1–6 and 8–13. The target audience is as for the prior item.
- **Fixed-income securities and interest rate derivatives.** This would be a models-based approach to teaching this material. Integrating ongoing research developments, Jarrow has been teaching such a course at Cornell University for over twenty years. For this, use chapters 1, 2, 4, 6, 9, and 15–26. This course can be taught to MBAs and more mathematically inclined upper level undergraduates.
- **Case-based courses.** We have also recommended cases at the end of each chapter so that instructors can easily develop a case study–oriented derivatives course.
- **Spreadsheet-based courses.** Unlike other textbooks, we do not provide black boxes in which you input data and get a derivative price! In line with current teaching trends, we have woven spreadsheet applications throughout the text. Our aim is for students to achieve self-sufficiency so that they can generate all the models and graphs in this book via Excel. In addition, spreadsheet software—called Priced!—especially designed for this textbook is available to facilitate learning and to teach the course material.
- **Use in courses in other areas.** Courses in accounting and law can use this as background material.

This book is a “download” of our understandings of markets and derivatives obtained from decades of research, teaching, and consulting. The material has been class tested at the Cornell University, Helsinki School of Economics and Business Administration, Hong Kong University of Science and Technology, the Indian Institutes of Management at Ahmedabad and at Calcutta, Indiana University (Bloomington), University of Colorado at Boulder, and the University of North Carolina at Chapel Hill. We hope that the reader will have a better understanding of derivative securities and risk management models after reading this book. Although we have tried to make this textbook error free, please notify us if you discover any errors.

## The Ancillaries

This text is accompanied by a number of important ancillaries, each intended to enhance the learning experience for the student and the teaching experience for the instructor.

### For Students and Instructors

*Online only on [www.norton.com/studyspace](http://www.norton.com/studyspace)*

**PRICED!** Developed by a Cornell computer science Ph.D. Tibor János specifically for this text and in collaboration with book authors Robert Jarrow and Arkadev Chatterjea, Priced! is Excel-based software that makes the models real rather than hypothetical.

The software computes prices and hedge ratios for the four key derivative security models contained in the book: (1) the binomial model, (2) the Black–Scholes–Merton (BSM) model, (3) the discrete time Heath–Jarrow–Morton (HJM) model, and (4) the HJM Libor model.

The prices and hedge ratios are represented visually—both graphically and in trees—for easy analysis by students and instructors. For quick recognition and clarity, the software’s inputs and outputs are color-coded. Priced! is also completely dynamic; when changes are made to inputs, outputs are updated instantaneously.

This software can be used to illustrate all of the key concepts associated with the derivative models discussed in the course. Instructors can illustrate how a model’s prices and hedge ratios change when inputs are changed. Students can even use Priced! and current market prices from the financial press to compute actual prices.

### For Students

**SOLUTIONS MANUAL** Written entirely by the text’s authors, Robert Jarrow and Arkadev Chatterjea, the solutions manual provides completely worked solutions for all the problems included with the book. ISBN: 978-0-393-92094-9

### For Instructors

**POWERPOINTS** Created by coauthor Arkadev Chatterjea. The slides include lecture slides and all art from the book. There is also a separate set of PowerPoints created by Robert Jarrow for a fixed income course based on selected chapters in the book. *Downloadable from [wnnorton.com/instructors](http://wnnorton.com/instructors).*

**TEST BANK** Written by the text’s authors, Robert Jarrow and Arkadev Chatterjea. *Downloadable formats available on [wnnorton.com/instructors](http://wnnorton.com/instructors).*

- *PDF*
- *Word*
- *ExamView® Assessment Suite*

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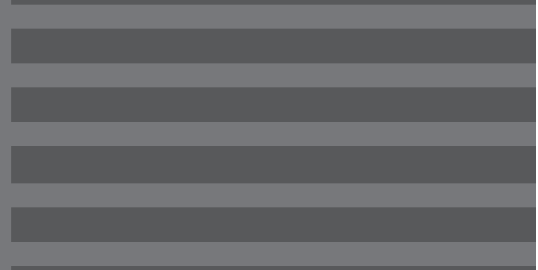
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# Introduction



**CHAPTER 1**  
Derivatives and  
Risk Management

**CHAPTER 2**  
Interest Rates

**CHAPTER 3**  
Stocks

**CHAPTER 6**  
Arbitrage and  
Trading

**CHAPTER 7**  
Financial  
Engineering and  
Swaps

**CHAPTER 4**  
Forwards and  
Futures

**CHAPTER 5**  
Options



# 1

## Derivatives and Risk Management

- 1.1 Introduction**
- 1.2 Financial Innovation**
  - Expanding Derivatives Markets
  - Two Economic Motives
- 1.3 Traded Derivative Securities**
  - EXTENSION 1.1** The Influence of Regulations, Taxes, and Transaction Costs on Financial Innovation
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  - Risk Management in a Blue Chip Company
- 1.8 Risk Management Perspectives in This Book**
- 1.9 Summary**
- 1.10 Cases**
- 1.11 Questions and Problems**

## 1.1 Introduction

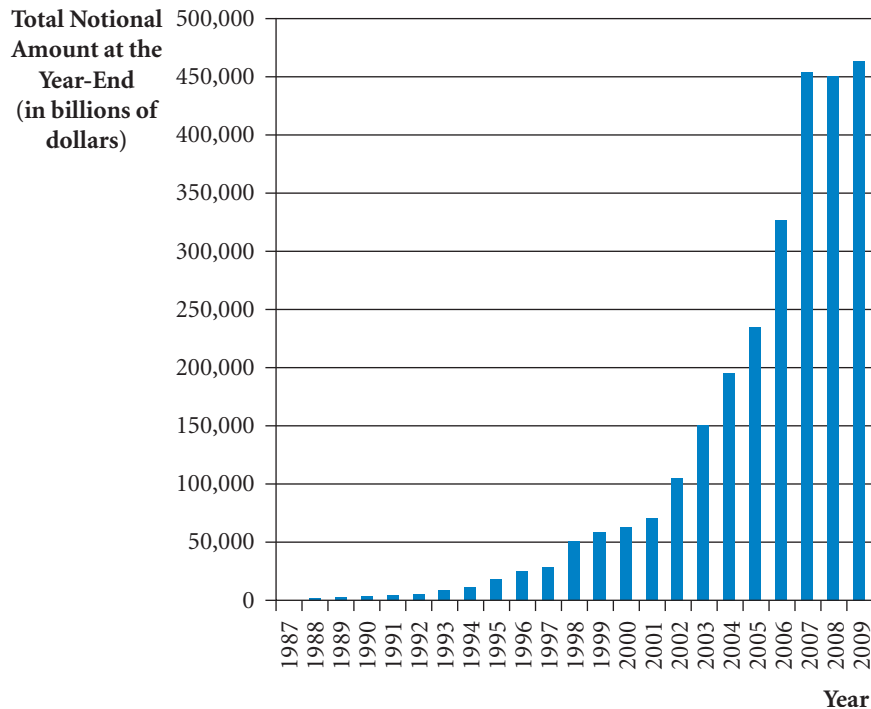
The bursting of the housing price bubble, the credit crisis of 2007, the resulting losses of hundreds of billions of dollars on credit default swaps and credit debt obligations, and the failure of prominent financial institutions have forever changed the way the world views derivatives. Today derivatives are of interest not only to Wall Street but also to Main Street. Credit derivatives are cursed as one of the causes of the Great Recession of 2007–9, a period of decreased economic output and high unemployment.

But what are derivatives? A **derivative security** or a **derivative** is a financial contract that derives its value from an underlying asset's price, such as a stock or a commodity, or even from an underlying financial index like an interest rate. A derivative can both reduce risk, by providing insurance (which, in financial parlance, is referred to as *hedging*), and magnify risk, by speculating on future events. Derivatives provide unique and different ways of investing and managing wealth that ordinary securities do not.

Derivatives have a long and checkered past. In the 1960s, only a handful of individuals studied derivatives. No academic books covered the topic, and no college or university courses were available. Derivatives markets were small, located mostly in the United States and Western Europe. Derivative users included only a limited number of traders in futures markets and on Wall Street. The options market existed as trading between professional traders (called the *over-the-counter [OTC] market*) with little activity. In addition, cheating charges often gave the options market disrepute. Derivatives discussion did not add sparkle to cocktail conversations, nor did it generate the allegations and condemnations that it does today. Brash young derivatives traders who drive exotic cars and move millions of dollars with the touch of a computer key didn't exist. Although Einstein had developed the theory of relativity and astronauts had landed on the moon, no one knew how to price an option. That's because in the 1960s, nobody cared, and derivatives were unimportant.

What a difference the following decades have made! Beginning in the early 1970s, derivatives have undergone explosive growth in the types of contracts traded and in their importance to the financial and real economy. Figure 1.1 shows that after 2006, the total notional value of outstanding derivatives contracts exceeded \$450 trillion. The markets are now global and measured in trillions of dollars. Hundreds of academics study derivatives, and thousands of articles have been written on the topic of pricing derivatives. Colleges and universities now offer numerous derivatives courses using textbooks written on the subject. Derivatives experts are in great demand. In fact, Wall Street firms hire PhDs in mathematics, engineering, and the natural sciences to understand derivatives—these folks are admirably called “rocket scientists” (“quants” is another name). If you understand derivatives, then you know cool stuff; you are hot and possibly dangerous. Today understanding derivatives is an integral part of the knowledge needed in the risk management of financial institutions.

Markets have changed to accommodate derivatives trading in three related ways: the introduction of new contracts and new exchanges, the consolidation and linking of exchanges, and the introduction of computer technology. Sometimes these changes happened with astounding quickness. For example, when twelve European nations replaced their currencies with the euro in 2002, financial

**FIGURE 1.1: Global Derivatives Market**

Source: ISDA Market Survey of notional amounts outstanding at year-end of all surveyed derivative contracts, 1987–2009. This includes interest rate, currency, equity, and credit derivatives.

markets for euro-denominated interest rate derivatives sprang up almost overnight, and in some cases, they quickly overtook the dollar-denominated market for similar interest rate derivatives.

This chapter tells the fascinating story of this expansion in derivatives trading and the controversy surrounding its growth. An understanding of the meaning of financial risk is essential in fully understanding this story. Hence a discussion of financial *risk* comes next, from the regulator's, the portfolio manager's, and the corporate financial manager's points of view. We explain each of these unique perspectives, using them throughout the book to increase our understanding of the uses and abuses of derivatives. A summary completes the chapter.

## 1.2 Financial Innovation

Derivatives are at the core of financial innovation, for better or for worse. They are the innovations to which columnist David Wessel's *Wall Street Journal* article titled "A Source of Our Bubble Trouble," dated January 17, 2008, alludes:

Modern finance is, truly, as powerful and innovative as modern science. More people own homes—many of them still making their mortgage payments—



because mortgages were turned into securities sold around the globe. More workers enjoy stable jobs because finance shields their employers from the ups and downs of commodity prices. More genius inventors see dreams realized because of venture capital. More consumers get better, cheaper insurance or fatter retirement checks because of Wall Street wizardry.

Expressed at a time when most of the world was in the Great Recession, this view is challenged by those who blame derivatives for the crisis. Indeed, this article goes on to say that “tens of billions of dollars of losses in new-fangled investments [in derivatives and other complex securities] at the largest US financial institutions—and the belated realization that some of those Ph.D.-wielding, computer-enhanced geniuses were overconfident in the extreme—strongly suggests some of the brainpower drawn to Wall Street would have been more productively employed elsewhere in the economy.”

But derivatives have been trading in various guises for over two thousand years. They have continued to trade because, when used properly, they enable market participants to reduce risk from their portfolios and to earn financial rewards from trading on special skills and information. Indeed, derivatives help to advance or postpone cash flows (**borrowing and lending**), to accumulate wealth (**saving**), to protect against unfavorable outcomes (**insurance or hedging**), to commit funds to earn a financial return (**investment**), and to accept high risks in the hope of big returns (**speculation or gambling**), which often goes along with magnifying the scale of one’s financial returns (**leverage**). Financial markets grow and real economic activity prospers because derivatives make financial markets more efficient. This is a theme to which we return repeatedly throughout the book.

## Expanding Derivatives Markets

Many factors have fueled the growth of derivatives markets. These include regulatory reforms, an increase in international commerce, population growth, political changes, the integration of the world’s economy, and revolutionary strides in information technology (IT). The interrelated financial markets are now more susceptible to global shocks and financial crises. The financial world has become a mad, bad, and dangerous place—financially speaking! More pronounced business cycles, default by sovereign nations, high-risk leveraged bets by hedge funds, imprudent investment in complicated securities by unsophisticated investors, and fraudulent actions by rogue traders have the potential to shake financial markets to their core. Financial regulators exist to help prevent these catastrophes from happening. And if used properly, derivatives can also help to mitigate their effects on aggregate wealth.

To help achieve this economic stability, the central bank of the United States, the **Federal Reserve System** (often referred to as the **Federal Reserve** or simply the **Fed**), historically used monetary policy tools to keep interest rates stable.<sup>1</sup> In 1979, the Fed also began targeting money supply growth. Despite this oversight, oil

<sup>1</sup> Courses in macroeconomics, money and finance, banking, or financial markets and institutions study how central banks fine-tune the economy using the tools of monetary policy: (1) setting the rate at which member banks can borrow from it (called the **discount rate** in the United States), (2) fixing bank **reserve requirements** (which is the percentage of money that a member bank must keep in its vault to support the loans it has made), and (3) buying and selling of government debts/bonds (**open market operations**).