Preface

[A book] is a node within a network.
Michel Foucault (1926–1984), *The Archaeology of Knowledge*

Intended Audience

As the title of this book suggests, a modern book on financial engineering has to cover investment theory, financial mathematics, and computer science evenly. This interdisciplinary emphasis is tuned more to the capital markets wherever quantitative analysis is being practiced. After all, even economics has moved away from a time when "the bulk of [Alfred Marshall's] potential readers were both unable and unwilling to read economics in mathematical form" according to Viner (1892–1970) [860] toward the new standard of which Markowitz wrote in 1987, "more than half my students cannot write down the formal definition of [the limit of a sequence]" [642].

This text is written mainly for students of engineering and the natural sciences who want to study quantitative finance for academic or professional reasons. No background in finance is assumed. Years of teaching students of business administration convince me that technically oriented MBA students will benefit from the book's emphasis on computation. With a sizable bibliography, the book can serve as a reference for researchers.

This text is also written for practitioners. System analysts will find many compact and useful algorithms. Portfolio managers and traders can obtain the quantitative underpinnings for their daily activities. This work also serves financial engineers in their design of financial instruments by expounding the underlying principles and the computational means to pricing them.

The marketplace has already offered several excellent books on derivatives (e.g., [236, 470, 514, 746, 878]), financial engineering (e.g., [369, 646, 647]), financial theory (e.g., [290, 492]), econometrics (e.g., [147]), numerical techniques (e.g., [62, 215]), and financial mathematics (e.g., [59, 575, 692, 725]). There are, however, few books that come near to integrating the wide-ranging disciplines. I hope this text succeeds at least partially in that direction and, as a result, one no longer has to buy four or five books to get good coverage of the topics.

Presentation

This book is self-contained. Technically sophisticated undergraduates and graduates should be able to read it on their own. Mathematical materials are added where they are needed. In many instances, they provide the coupling between earlier chapters and upcoming themes. Applications to finance are generally added to set the stage. Numerical techniques are presented algorithmically and clearly; programming them should therefore be straightforward. The underlying financial theory is adequately covered, as understanding the theory underlying the calculations is critical to financial innovations.

The large number of exercises is an integral part of the text. Exercises are placed right after the relevant materials. Hints are provided for the more challenging ones. There are also numerous programming assignments. Those readers who aspire to become software developers can learn a lot by implementing the programming assignments. Thoroughly test your programs. The famous adage of Hamming (1916–1998), "The purpose of computing is insight, not numbers," does not apply to erroneous codes. Answers to all nontrivial exercises and some programming assignments can be found near the end of the book.

Most of the graphics were produced with *Mathematica* [882]. The programs that generate the data for the plots have been written in various languages, including C, C++, Java, JavaScript, Basic, and Visual Basic. It is a remarkable fact that most – if not all – of the programming works could have been done with spreadsheet software [221, 708]. Some computing platforms admit the integration of the spreadsheet's familiar graphical user interface and programs written in more efficient high-level programming languages [265]. Although such a level of integration requires certain sophistication, it is a common industry practice. Freehand graphics were created with Canvas and Visio.

The manuscript was typeset in LaTeX [580], which is ideal for a work of this size and complexity. I thank Knuth and Lamport for their gifts to technical writers.

Software

Many algorithms in the book have been programmed. However, instead of being bundled with the book in disk, my software is Web-centric and platform-independent [412]. Any machine running a World Wide Web browser can serve as a host for those programs on *The Capitals* page at

www.csie.ntu.edu.tw/~lyuu/capitals.html

There is no more need for the (rare) author to mail the upgraded software to the reader because the one on the Web page is always up to date. This new way of software development and distribution, made possible by the Web, has turned software into an Internet service.

Organization

Here is a grand tour of the book:

Chapter 1 sets the stage and surveys the evolution of computer technology.

Chapter 2 introduces algorithm analysis and measures of complexity. My convention for expressing algorithms is outlined here.

Chapter 3 contains a relatively complete treatment of standard financial mathematics, starting from the time value of money.

Chapter 4 covers the important concepts of duration and convexity.

Chapter 5 goes over the static term structure of interest rates. The coverage of classic, static finance theory ends here.

Chapter 6 marks the transition to stochastic models with coverage of statistical inference.

Chapters 7–12 are about options and derivatives. Chapter 7 presents options and basic strategies with options. Chapter 8 introduces the arbitrage argument and derives general pricing relations. Chapter 9 is a key chapter. It covers option pricing under the discrete-time binomial option pricing model. The celebrated Black–Scholes formulas are derived here, and algorithms for pricing basic options are presented. Chapter 10 presents sensitivity measures for options. Chapter 11 covers the diverse applications and kinds of options. Additional derivative securities such as forwards and futures are treated in Chap. 12.

Chapters 13–15 introduce the essential ideas in continuous-time financial mathematics. Chapter 13 covers martingale pricing and Brownian motion, and Chap. 14 moves on to stochastic integration and the Ito process. Together they give a fairly complete treatment of the subjects at an accessible level. From time to time, we go back to discrete-time models and establish the linkage. Chapter 15 focuses on the partial differential equations that derivative securities obey.

Chapter 16 covers hedging by use of derivatives.

Chapters 17–20 probe deeper into various technical issues. Chapter 17 investigates binomial and trinomial trees. One of the motives here is to demonstrate the use of combinatorics in designing highly efficient algorithms. Chapter 18 covers numerical methods for partial differential equations, Monte Carlo simulation, and quasi–Monte Carlo methods. Chapter 19 treats computational linear algebra, least-squares problems, and splines. Factor models are presented as an application. Chapter 20 introduces financial time series analysis as well as popular time-series models.

Chapters 21–27 are related to interest-rate-sensitive securities. Chapter 21 surveys the wide varieties of interest rate derivatives. Chapter 22 discusses yield curve fitting. Chapter 23 introduces interest rate modeling and derivative pricing with the elementary, yet important, binomial interest rate tree. Chapter 24 lays the mathematical foundations for interest rate models, and Chaps. 25 and 26 sample models from the literature. Finally, Chap. 27 covers fixed-income securities, particularly those with embedded options.

Chapters 28–30 are concerned with mortgage-backed securities. Chapter 28 introduces the basic ideas, institutions, and challenging issues. Chapter 29 investigates the difficult problem of prepayment and pricing. Chapter 30 surveys collateralized mortgage obligations.

Chapter 31 discusses the theory and practice of portfolio management. In particular, it presents modern portfolio theory, the Capital Asset Pricing Model, the Arbitrage Pricing Theory, and value at risk.

Chapter 32 documents the Web software developed for this book.

Chapter 33 contains answers or pointers to all nontrivial exercises.

This book ends with an extensive index. There are two guiding principles behind its structure. First, related concepts should be grouped together. Second, the index should facilitate search. An entry containing parentheses indicates that the term within should be consulted instead, first at the current level and, if not found, at the outermost level.

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