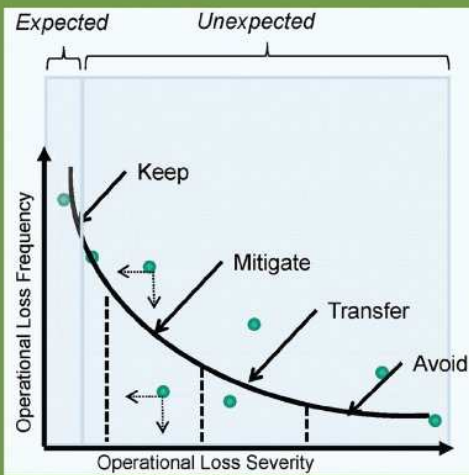
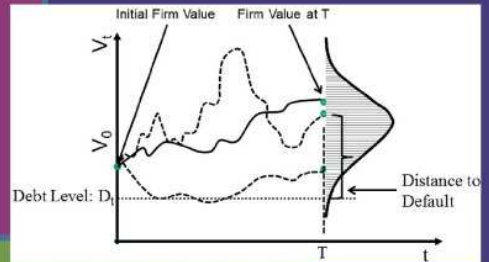
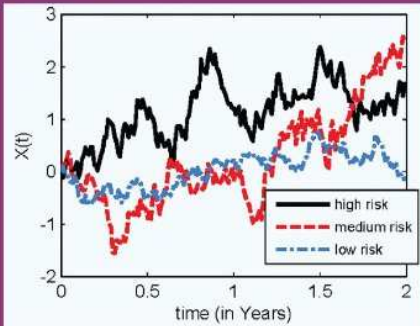


Risk Management *and Simulation*



Aparna Gupta

Risk Management *and* Simulation

Risk Management *and* Simulation

Aparna Gupta



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

A CHAPMAN & HALL BOOK

MATLAB® is a trademark of The MathWorks, Inc. and is used with permission. The MathWorks does not warrant the accuracy of the text or exercises in this book. This book's use or discussion of MATLAB® software or related products does not constitute endorsement or sponsorship by The MathWorks of a particular pedagogical approach or particular use of the MATLAB® software.

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2014 by Taylor & Francis Group, LLC
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper
Version Date: 20130509

International Standard Book Number-13: 978-1-4398-3594-4 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Library of Congress Cataloging-in-Publication Data

Gupta, Aparna.
Risk management and simulation / Aparna Gupta.
pages cm
Includes bibliographical references and index.
ISBN 978-1-4398-3594-4 (alk. paper)
1. Risk management. 2. Risk management--Simulation methods. I. Title.

HD61.G86 2013
338.5--dc23

2013007014

Visit the Taylor & Francis Web site at
<http://www.taylorandfrancis.com>

and the CRC Press Web site at
<http://www.crcpress.com>

To my parents, Amar-Sneh

Contents

I Risk and Regulation

1	Defining Risk	3
1.1	Types of Risk	5
1.1.0.1	Pure Risk	5
1.1.0.2	Speculative Risk	6
1.1.1	Classification of Pure Risk	7
1.1.2	Classification of Speculative Risk	8
1.2	Getting Started with Modeling Risk	12
1.2.1	Random Variable and Probability	12
1.2.1.1	Summarizing Random Variables	14
1.2.1.2	Several Random Variables and Correlation	16
1.2.1.3	Conditional Probability	17
1.2.2	Specific Models of Risk	19
1.2.2.1	Normal Distribution	19
1.2.2.2	Uniform Distribution	20
1.2.2.3	Central Limit Theorem	21
1.2.2.4	Binomial Distribution	23
1.2.2.5	Poisson Distribution	23
1.2.2.6	Exponential Distribution	24
1.2.2.7	Weibull Distribution	26
1.2.2.8	Lognormal Distribution	27
1.2.2.9	Chi-Square Distribution	27
1.2.2.10	Gamma Distribution	29
1.3	MATLAB [®] Tools for Distributions	30
1.4	Summary	30
1.5	Questions and Exercises	31
2	Framework for Risk Management	35
2.1	How to Handle Risk	36
2.1.1	The Risk Management Framework	37
2.1.2	Risk Preference vs. Risk Aversion	40
2.1.2.1	Normative vs. Behavioral Choice	43
2.1.3	Risk Measures	45
2.1.4	Risk Management	48
2.1.5	Elements of the Framework	50

2.1.5.1	Avoid	51
2.1.5.2	Mitigate	51
2.1.5.3	Transfer	53
2.1.5.4	Keep	54
2.2	Example Contexts to Apply the Framework	54
2.2.1	Analysis Using Central Measures	55
2.2.2	Tail Analysis	56
2.2.3	Scenario Analysis	58
2.2.4	Stress Testing	59
2.3	MATLAB Tools for Risk Measures	60
2.4	Summary	61
2.5	Questions and Exercises	61
3	Regulations and Risk Management	65
3.1	Regulations Overview	66
3.1.1	Regulatory Evolution for Banking	67
3.1.2	Regulatory Evolution for Investment Banking	71
3.1.3	Regulatory Evolution for Insurance	73
3.2	Regulations and Banking	74
3.3	Regulations and Investment Banking	80
3.4	Regulations and Insurance	84
3.5	Summary	86
3.6	Questions and Exercises	86
 II Modeling and Simulation of Risk		
4	Principles of Simulation and Generating Random Variates	93
4.1	Principles of Simulation	93
4.1.1	What Is Simulation?	94
4.2	Random Number Generation	96
4.2.1	Linear Congruential Generator	97
4.2.2	Lagged Fibonacci Generator	97
4.3	Generation of Discrete Random Variates	98
4.3.1	n-Outcome Random Variate	98
4.3.2	Poisson Random Variate	99
4.4	Generation of Continuous Random Variates	100
4.4.1	Inverse Transform Method	100
4.4.2	Acceptance-Rejection Method	101
4.4.3	Normal Random Variate	103
4.4.3.1	Box-Muller Method	104
4.4.3.2	Polar-Marsaglia Method	104
4.4.3.3	Generation of Multi-Variate Normal	106
4.4.4	Chi-Square and Other Random Variates	107
4.5	Testing Random Variates	107
4.5.1	Testing for Independence of Random Numbers	108

4.5.1.1	Shuffling Procedure	109
4.5.2	Testing for Correctness of Distribution	110
4.5.2.1	The χ^2 Goodness of Fit Test	110
4.5.2.2	Kolmogorov-Smirnov Test	112
4.6	Validation of Model	113
4.6.1	Techniques for Model Verification	114
4.6.2	Techniques for Model Validation	115
4.7	Output Analysis	117
4.7.1	Descriptive Output Analysis	118
4.7.1.1	Designing Simulation Run by Properties of Estimators	119
4.7.2	Inferential Output Analysis	120
4.8	MATLAB Tools for Simulation	121
4.9	Summary	122
4.10	Questions and Exercises	122
5	Modeling Risk Evolving over Time	127
5.1	Stochastic Processes	127
5.2	Discrete-Time Evolution of Risk	128
5.2.1	Discrete-Time Markov Chains	129
5.2.2	Simple Random Walk	133
5.2.3	Geometric Random Walk	135
5.3	Continuous-Time Evolution of Risk	136
5.3.1	Continuous-Time Markov Chains	136
5.3.2	Poisson Process	138
5.3.3	Birth-Death Process	140
5.3.4	Markov Process	141
5.3.5	Gaussian Process	142
5.3.6	Brownian Motion	144
5.3.6.1	Approximating Brownian Motion by a Random Walk	145
5.3.6.2	Convergence of Random Variables	146
5.3.6.3	Properties of the Wiener Process	147
5.3.7	Brownian Motion with Drift and Geometric Brownian Motion	149
5.3.8	Additional Concepts for Stochastic Processes	150
5.4	Modeling Correlation	152
5.4.1	Correlated Brownian Motion	152
5.4.2	Copulas for Correlation	153
5.5	MATLAB Tools for Modeling Risk Evolving over Time	156
5.6	Summary	156
5.7	Questions and Exercises	157

6 Building and Solving Models of Risk 161

- 6.1 Deterministic Financial Modeling 161
- 6.2 Introducing Stochasticity in the Modeling 164
- 6.3 Defining New Integrals 166
 - 6.3.1 Ito Integral 166
 - 6.3.2 Properties of the Ito Integral 168
 - 6.3.3 Chain Rule of Ito Calculus - The Ito Formula 170
- 6.4 Analytical Solutions 171
 - 6.4.1 Solving the Model Exactly 172
- 6.5 Solving Models Using Simulation 175
 - 6.5.1 The Euler Method for Solving Differential Equations 175
 - 6.5.2 Evaluating Simulation Solutions 180
 - 6.5.2.1 Convergence Properties of Solutions 181
 - 6.5.2.2 Error Analysis - Absolute Error Criterion 181
 - 6.5.2.3 Error Analysis - Mean Error Criterion 183
 - 6.5.3 Higher Order Methods 186
 - 6.5.3.1 Trapezoidal Method 186
- 6.6 Estimating Parameters 188
 - 6.6.1 Geometric Brownian Motion 188
 - 6.6.2 Method of Maximum Likelihood 189
 - 6.6.3 Method of Quasi-Maximum Likelihood 191
 - 6.6.4 Method of Moments 192
 - 6.6.4.1 Ornstein-Uhlenbeck Process 192
- 6.7 MATLAB Tools for Building and Solving Models of Risk 193
- 6.8 Summary 194
- 6.9 Questions and Exercises 194

III Risk Management

7 Managing Equity Market Risk 199

- 7.1 Mitigating Equity Risk 200
 - 7.1.1 Portfolio Diversification 200
 - 7.1.1.1 Classical Mean-Variance Reward-Risk Measures 201
 - 7.1.1.2 Dynamic Investment Strategy 203
 - 7.1.2 Portfolio Optimization 205
 - 7.1.2.1 Optimum Risk-Return Trade-Off 205
 - 7.1.2.2 Simulation Analysis for Portfolio Decisions 208
- 7.2 Transferring Equity Risk 210
 - 7.2.1 Option Pricing - Black-Scholes-Merton Approach 211
 - 7.2.1.1 Solving Black-Scholes Partial Differential Equation 216
 - 7.2.1.2 Estimating Option Price by Simulation 219
 - 7.2.1.3 Making Model Simpler - Binomial Tree Approach 220

7.2.2	Implied Volatility and Calibration for Risk-Neutral Pricing	223
7.2.3	Sensitivity to the Parameters	225
7.2.4	Exotic Options	229
7.2.5	American Options	233
7.2.6	Generalizing the Models in Black-Scholes-Merton . . .	235
7.2.6.1	Constant Elasticity of Variance (CEV) Model	236
7.2.6.2	Model for Several Correlated Stocks	237
7.2.6.3	Extensions in Option Pricing - Stochastic Volatility	239
7.2.6.4	Large Sudden Changes in Prices - Jump Diffusion Model	244
7.3	Equity Hedging Strategies	246
7.3.1	Static Hedging Strategies	247
7.3.2	Optimal Hedge Problem	253
7.3.3	Dynamic Hedging Strategies	254
7.4	MATLAB Tools for Equity and Portfolios	258
7.5	Summary	258
7.6	Questions and Exercises	259
8	Managing Interest Rates and Other Market Risks	265
8.1	Pricing Fixed Income Instruments	266
8.1.1	Bond Pricing	266
8.1.2	Stochastic Interest Rate Models	270
8.1.2.1	Short Rate Models	270
8.1.2.2	Multi-Factor Interest Rate Models	276
8.1.2.3	Other Fixed-Income Instruments	277
8.1.3	Simulation of Interest Rate Models	279
8.2	Interest-Rate Risk Management	280
8.2.1	Interest-Rate Sensitivity in Fixed-Income Instruments	281
8.2.1.1	Bond Portfolio Immunization	285
8.2.2	Interest-Rate Derivatives	287
8.2.3	Interest-Rate Hedging Strategies	291
8.3	Managing Commodities Risk	294
8.3.1	Modeling Commodity Spot Prices	297
8.3.1.1	Energy, Electricity, and Weather Risk	299
8.3.2	Management of Commodity Risk	301
8.3.2.1	Commodity Futures and Other Derivatives	304
8.4	Managing Foreign Exchange Risk	306
8.4.1	Models for Spot and Forward Exchange Rates	309
8.4.2	Currency Derivatives	310
8.5	Value-at-Risk and Stress Testing for Market Risk Management	312
8.6	MATLAB Tools for Fixed Income, Commodities, and Exchange Rates	317
8.7	Summary	318

- 8.8 Questions and Exercises 318
- 9 Credit Risk Management 325**
 - 9.1 Retail Credit Risk 326
 - 9.1.1 Measuring Retail Credit Risk 329
 - 9.1.1.1 Credit Scoring Methods 332
 - 9.1.2 Retail Credit Risk Management 336
 - 9.2 Commercial Credit Risk 340
 - 9.2.1 Credit Rating System 341
 - 9.2.1.1 Risk Assessment by Credit Rating Migration 342
 - 9.2.2 Models for Credit Risk 347
 - 9.2.2.1 Structural Model of Credit Risk 348
 - 9.2.2.2 Reduced-Form Model of Credit Risk 350
 - 9.3 Credit Risk Hedging Instruments 351
 - 9.3.1 Single-Name Credit Derivatives 354
 - 9.3.1.1 Credit Default Swaps 355
 - 9.3.1.2 Spread Options 357
 - 9.3.2 Multi-Name Credit Derivatives 357
 - 9.3.2.1 Collateralized Debt Obligations 358
 - 9.4 Portfolio Credit Risk Management 361
 - 9.5 MATLAB Tools for Credit Risk 364
 - 9.6 Summary 364
 - 9.7 Questions and Exercises 365
- 10 Strategic, Business, and Operational Risk Management 371**
 - 10.1 Strategic Risk Management 371
 - 10.1.1 Objective of Strategic Risk Management 373
 - 10.1.2 Approaches for Strategic Risk Management 374
 - 10.2 Business Risk Management 378
 - 10.3 Asset-Liability Management 380
 - 10.3.1 Components of Asset-Liability Management 382
 - 10.3.2 Risk Management in ALM 385
 - 10.3.2.1 Gap Analysis 385
 - 10.3.2.2 Cumulative Gap Analysis 387
 - 10.3.2.3 Duration Gap Analysis and Gap Convexity . 387
 - 10.3.2.4 Dynamic Gap and Long-Term Value at Risk Analysis 388
 - 10.3.2.5 Scenario Analysis and Stress Testing 390
 - 10.4 Operational Risk Management 391
 - 10.4.1 Assessing Operational Risk 393
 - 10.4.2 Managing Operational Risk 395
 - 10.4.2.1 Risk Measures for Operational Risk 396
 - 10.4.2.2 Operational Risk Management Strategy . . . 397
 - 10.5 Summary 399
 - 10.6 Questions and Exercises 399

11 Risk Management Using Insurance	405
11.1 Basic Concepts of Insurance	407
11.2 Principle behind Insurance	409
11.2.1 Characteristics of Insurance and Insurable Risk	410
11.2.1.1 Law of Large Numbers	410
11.2.1.2 Requirement of Insurable Risk	413
11.3 Types of Insurance	414
11.3.1 Benefits and Cost of Insurance to Society	416
11.4 Risk Management Framework for Pure Risk	417
11.4.1 Pure Risk Evaluation	420
11.4.2 Risk Management Strategies for Pure Risk	423
11.4.3 Modeling Individual Mortality Risk	426
11.5 Risk Management by Insurers	427
11.5.1 Pricing, Investment, and Asset-Liability Management	427
11.5.2 Risk Management, Securitization, and Reinsurance	431
11.6 Summary	433
11.7 Questions and Exercises	434

IV Advanced Simulation

12 Advanced Simulation Topics	441
12.1 Variance Reduction Techniques	442
12.1.1 Control Variates	444
12.1.2 Antithetic Variables	447
12.1.3 Stratified Sampling	450
12.1.4 Latin Hypercube Sampling	453
12.1.5 Importance Sampling	454
12.2 Simulation-Based Optimization	455
12.2.1 Challenges of Simulation-Based Optimization	458
12.2.2 Simulation Optimization Methodologies	460
12.2.2.1 Gradient-Based Methods	463
12.2.2.2 Simulated Annealing	464
12.2.2.3 Tabu Search	466
12.2.2.4 Scatter Search	467
12.2.2.5 Evolutionary Strategies	467
12.2.2.6 Particle Swarm Optimization	469
12.3 MATLAB Tools for Variance Reduction and Optimization	471
12.4 Summary	471
12.5 Questions and Exercises	472

Bibliography	479
---------------------	------------

Index	485
--------------	------------

List of Figures

1.1	Classification structure for types of risk.	7
1.2	(a) Probability density function for normal distribution. (b) Cumulative distribution function for normal distribution. . .	20
1.3	(a) Probability density function for uniform distribution. (b) Cumulative distribution function for uniform distribution. . .	21
1.4	Display of Central Limit Theorem. (a) $N = 1,000$ (b) $N = 5,000$ (c) $N = 10,000$ (d) $N = 100,000$	22
1.5	(a) Probability mass function for binomial distribution. (b) Cumulative distribution function for binomial distribution. . . .	23
1.6	(a) Probability mass function for Poisson distribution. (b) Cumulative distribution function for Poisson distribution.	24
1.7	(a) Probability density function for exponential distribution. (b) Cumulative distribution function for exponential distribution.	25
1.8	(a) Probability density function for Weibull distribution. (b) Cumulative distribution function for Weibull distribution. . .	26
1.9	(a) Probability density function for lognormal distribution. (b) Cumulative distribution function for lognormal distribution. .	27
1.10	(a) Probability density function for Chi-square distribution. (b) Cumulative distribution function for Chi-square distribution.	28
1.11	(a) Probability density function for gamma distribution. (b) Cumulative distribution function for gamma distribution. . .	29
2.1	The overall flowchart for the Risk Management Process. . . .	38
2.2	(a) Plot of the exponential, constant absolute risk aversion (CARA) utility function. (b) Plot of the power, constant relative risk aversion (CRRA) utility function.	42
2.3	Plot of the loss-aversion utility, an example of behavioral utility function.	44
2.4	Display of Value-at-Risk and Conditional Value-at-Risk. . . .	47
2.5	(a) Plot of mean and standard deviation of combined risk for a range of weights on two individual risks. (b) Plot of mean and first percentile of combined risk for a range of weights on two individual risks, assuming normal distribution of combined risk.	52

2.6 (a) Unimodal distribution of risk and its central tendencies. (b) Bimodal distribution of risk. 55

2.7 Probability density plot displaying light-tail and heavy-tail. 57

2.8 (a) Probability plot for a dataset that matches the light-tailed normal distribution model. (b) Probability plot for a dataset that displays heavy-tail deviations from the normal distribution model. 58

3.1 The table shows the main regulatory agencies for the Group of Eight (G8) countries for banking, investment banking, and insurance industry, as of 2012. 67

4.1 The guideline for how to structure a simulation study. 95

4.2 The stages to build the simulation model. 96

4.3 N-outcome discrete random variate generation. 99

4.4 A pictorial depiction of the principle behind the inverse transform method. 101

4.5 A pictorial depiction of the principle behind the acceptance-rejection method. 102

4.6 A pictorial depiction of the construction of the Polar-Marsaglia method. 105

4.7 Display of output from a linear congruential generator. (a) 1000 numbers generated lie on three parallel lines. (b) The 1000 numbers after implementing shuffling. 108

4.8 Display of Probability Plots. (a) Lognormal probability plot. (b) Weibull probability plot. 110

4.9 Display of Validation Cost vs. Risk Cost Curve. 116

5.1 (a) A typical sample realization for a discrete-time stochastic process. (b) The binomial tree example of a discrete time stochastic process. 129

5.2 A pictorial depiction of states of a Markov chain, transitions following Markovian property, and transition probabilities. 130

5.3 (a) Three realizations of a simple random walk. (b) Three realizations of simple symmetric random walk. (c) Three realizations of general random walk. (d) Three realizations of simple random walk with upper barrier set at 10. 134

5.4 Three sample path realizations of a Poisson process with varied levels of λ 139

5.5 (a) Three sample path realizations of an Ornstein-Uhlenbeck process. (b) Three sample path realizations of Ornstein-Uhlenbeck process with different risk levels. 143

5.6 Three sample path realizations for the standard Brownian motion or the Wiener process. 145

5.7	(a) Three sample path realizations for the standard Brownian motion or Wiener process with drift. (b) Three sample path realizations for geometric Brownian motion.	150
5.8	(a) Marginal CDF for first random variable, chosen to be beta distribution with parameters, $a=2$, $b=2$. (b) Marginal CDF for second random variable, chosen to be Weibull distribution with parameters, $a=0.15$, $b=0.8$. (c) Scatter plot of 1000 random variates generated by Gaussian copula with $\rho = 0.7$. (d) Scatter plot of 100 random variates generated using t-copula with $\rho = 0.7$, $\nu = 1$	155
6.1	Applying different frequency of interest rate accrual for a risk-free investment. (a) Annual accrual applied for five years. (b) Monthly accrual applied for five years. (c) Daily accrual applied for five years. (d) Hourly accrual applied for five years.	163
6.2	Comparison of exact and numerical solutions for an example ordinary differential equation.	176
6.3	Comparison of exact and numerical solution for an example stochastic differential equation.	178
6.4	Comparison of distributional properties of the exact solution (in left panel) and numerical solution (in the right panel) for the example stochastic differential equation.	179
7.1	Plot of risk-reward trade-off of individual stocks. The combination of the individual stock helps mitigate the risk in the frontier.	201
7.2	Plot of mean and standard deviation of two stock returns. The correlation of $\rho = 1$ and -1 define the right and left extents of the region, respectively.	204
7.3	Plot of mean and standard deviation space spanned by return on portfolio of stocks. For a choice of expected portfolio return threshold, the optimum risk-return trade-off is made on the left most feasible points. The dashed curve is the efficient risk-return trade-off points, or the efficient frontier.	207
7.4	Simulation analysis of risk-reward of a portfolio based on equity returns scenarios and parametric scenarios.	209
7.5	(a) Display of pay-off and profit curve for a plain-vanilla European call option with strike price, $K=\$80$. (b) Display of pay-off and profit curve for a plain-vanilla European put option with strike price, $K=\$80$	212
7.6	(a) Display of pay-off and profit curve for a short position in a plain-vanilla European call option with strike price, $K=\$80$. (b) Display of pay-off and profit curve for a short position in a plain-vanilla European put option with strike price, $K=\$80$	213

7.7 (a) Display of pay-off and price curve for a plain-vanilla European call option with strike price, $K=\$35$, $\sigma = 23\%$, $T-t = 1/2$ year, and short-term interest rate of $r = 2\%$. (b) Display of pay-off and price curve for a plain-vanilla European put option with the same set of parameters as the call option. 218

7.8 (a) Single period binomial tree model for stock price evolution. (b) Multi-period binomial tree model for stock price evolution. 221

7.9 Implied volatility obtained from the Black-Scholes option pricing formula for plain-vanilla European call option with stock price, $S_t =\$35$, $\sigma = 23\%$, $T - t = 1/2$ year, and short-term interest rate of $r = 2\%$ 225

7.10 The chart marks the dependence of European and American vanilla call and put option prices on parameters that determine the price. 226

7.11 Trajectories for valuation of a compound option. 229

7.12 Pay-offs of an up-and-out barrier call option and a down-and-in barrier call option. 230

7.13 Pictorial display of algorithm to determine the price of an American option using the binomial tree model. 234

7.14 Monthly observations of VIX index from January 2005 through mid-2012. The variability in the stock market is captured in this index through the financial crises of 2008 and euro crisis evolving through 2011-2012. 240

7.15 (a) Profit and individual positions of a protective put. (b) Profit and individual positions of a reverse protective put. 248

7.16 (a) Profit and individual positions of a covered call. (b) Profit and individual positions of a reverse covered call. 248

7.17 (a) Profit and individual positions of a bull spread using call options. (b) Profit and individual positions of a bear spread using put options. 249

7.18 (a) Profit and individual positions of a butterfly spread. . . . 251

7.19 (a) Profit and individual positions of a straddle. (b) Profit and individual positions of a strangle. 252

7.20 (a) Profit and individual positions of a strip. (b) Profit and individual positions of a strap. 252

7.21 The points of time along the life of an option when trades must be made to cover the naked short call position. A margin around the strike, K , is created of width 2ϵ to avoid rapid trades when the option is near at-the-money range. 255

7.22 Delta hedge strategy takes advantage of the fact that the slope of the option price curve will converge to the terminal pay-off level as option reaches its maturity. 256

8.1 Cash flow from a bond with maturity, T years, and annual coupon of $c\%$ 266

8.2	Different shapes of the term structure of interest rate by maturity. (a) Constant (b) Upward sloping (c) Inverted.	267
8.3	Relation of the forward curve to the spot curve for different shapes of the term structure of interest rates.	270
8.4	Bond price as a function of increasing yield.	282
8.5	Value at Risk (VaR) and Conditional Value at Risk (CVaR) display for bond price.	285
8.6	Volume of over-the-counter (OTC) interest rate derivatives in 2008-2010 period (Courtesy <i>Bank for International Settlements (BIS) Report</i>).	288
8.7	Prices for some commodities of different type, from January 2002 through 2012.	295
8.8	Level of volatility in commodity indices (Courtesy <i>Reserve Bank for Australia (RBA) Bulletin</i> , June 2011).	296
8.9	Participation in commodities markets for diversification benefits (Courtesy <i>Reserve Bank for Australia (RBA) Bulletin</i> , June 2011).	302
8.10	Sample of key exchanges for developed and emerging economy countries from all continents, as of March 2012.	307
8.11	United States turnover of foreign exchange, all currencies. (Courtesy <i>Federal Reserve Bank of New York (FRB NY) Report</i> , April 2010).	308
8.12	USD and euro daily foreign exchange volume by currency. (Courtesy <i>Federal Reserve Bank of New York (FRB NY) Report</i> , April 2010).	309
8.13	Spot and forward exchange rates hold a key relationship. . . .	310
8.14	Daily turnover comparison for foreign exchange spot, forward and swaps. (Courtesy <i>Federal Reserve Bank of New York (FRB NY) Report</i> , April 2010).	311
8.15	Distribution of the change in portfolio value, $\Delta\Pi$, in order to compute Market Value-at-Risk.	312
8.16	Histogram and normal probability plot of two years of equity return for Microsoft (MSFT) and Exxon-Mobil (XOM). . . .	315
9.1	Distribution of the population by their credit score, as well as distribution of individuals who have defaulted and who have not defaulted on their loans by their credit score. The figure also indicates a selected cut-off score, with its implication on false 'bads' and false 'goods.'	335
9.2	Level of accuracy in a specific credit scoring model relative to a perfect and a random model. This is summarized in the accuracy ratio, which is the area under the curve below the actual model profile relative to the perfect model profile. . . .	338