OPTIONS, FUTURES, AND OTHER DERIVATIVES

NINTH EDITION

JOHN C. HULL

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To Michelle

CONTENTS IN BRIEF

List of Business Snapshots ..... *xvii*
List of Technical Notes ..... *xviii*
Preface ..... *xix*
1. Introduction 1
2. Mechanics of futures markets 24
3. Hedging strategies using futures 49
4. Interest rates 77
5. Determination of forward and futures prices 104
6. Interest rate futures 132
7. Swaps 152
8. Securitization and the credit crisis of 2007 185
9. OIS discounting, credit issues, and funding costs 200
10. Mechanics of options markets 213
11. Properties of stock options 234
12. Trading strategies involving options 254
13. Binomial trees 274
14. Wiener processes and Itô's lemma 302
15. The Black–Scholes–Merton model 321
16. Employee stock options 354
17. Options on stock indices and currencies 367
18. Futures options 383
19. The Greek letters 399
20. Volatility smiles 431
21. Basic numerical procedures 450
22. Value at risk 494
23. Estimating volatilities and correlations 521
24. Credit risk 544
25. Credit derivatives 571
26. Exotic options 598
27. More on models and numerical procedures 624
28. Martingales and measures 655
29. Interest rate derivatives: The standard market models 673
30. Convexity, timing, and quanto adjustments 693
31. Interest rate derivatives: Models of the short rate 706
32. HJM, LMM, and multiple zero curves 740
33. Swaps Revisited 760
34. Energy and commodity derivatives 775
35. Real options 792
36. Derivatives mishaps and what we can learn from them 806
Glossary of terms 818
DerivaGem software 840
Major exchanges trading futures and options 845
Tables for $N(x)$ 846
Author index 847
Subject index 852

Contents

List of Business Snapshots ..... **xvii**

List of Technical Notes ..... **xviii**

Preface ..... **xix**

Chapter 1. Introduction **1**

1.1 Exchange-traded markets 2
1.2 Over-the-counter markets 3
1.3 Forward contracts 6
1.4 Futures contracts 8
1.5 Options 8
1.6 Types of traders 11
1.7 Hedgers 11
1.8 Speculators 14
1.9 Arbitrageurs 16
1.10 Dangers 17
Summary 18
Further reading 19
Practice questions 19
Further questions 21

Chapter 2. Mechanics of futures markets **24**

2.1 Background 24
2.2 Specification of a futures contract 26
2.3 Convergence of futures price to spot price 28
2.4 The operation of margin accounts 29
2.5 OTC markets 32
2.6 Market quotes 35
2.7 Delivery 38
2.8 Types of traders and types of orders 39
2.9 Regulation 40
2.10 Accounting and tax 41
2.11 Forward vs. futures contracts 43
Summary 44
Further reading 45
Practice questions 45
Further questions 47

Chapter 3. Hedging strategies using futures **49**

3.1 Basic principles 49
3.2 Arguments for and against hedging 51
3.3 Basis risk 54
3.4 Cross hedging 58

3.5 Stock index futures ... 62
3.6 Stack and roll ... 68
Summary ... 70
Further reading ... 70
Practice questions ... 71
Further questions ... 73
Appendix: Capital asset pricing model ... 75

Chapter 4. Interest rates ... 77
4.1 Types of rates ... 77
4.2 Measuring interest rates ... 79
4.3 Zero rates ... 82
4.4 Bond pricing ... 82
4.5 Determining Treasury zero rates ... 84
4.6 Forward rates ... 86
4.7 Forward rate agreements ... 88
4.8 Duration ... 91
4.9 Convexity ... 95
4.10 Theories of the term structure of interest rates ... 96
Summary ... 98
Further reading ... 99
Practice questions ... 99
Further questions ... 102

Chapter 5. Determination of forward and futures prices ... 104
5.1 Investment assets vs. consumption assets ... 104
5.2 Short selling ... 105
5.3 Assumptions and notation ... 106
5.4 Forward price for an investment asset ... 107
5.5 Known income ... 110
5.6 Known yield ... 112
5.7 Valuing forward contracts ... 112
5.8 Are forward prices and futures prices equal? ... 114
5.9 Futures prices of stock indices ... 115
5.10 Forward and futures contracts on currencies ... 117
5.11 Futures on commodities ... 120
5.12 The cost of carry ... 123
5.13 Delivery options ... 124
5.14 Futures prices and expected future spot prices ... 124
Summary ... 126
Further reading ... 128
Practice questions ... 128
Further questions ... 130

Chapter 6. Interest rate futures ... 132
6.1 Day count and quotation conventions ... 132
6.2 Treasury bond futures ... 135
6.3 Eurodollar futures ... 140
6.4 Duration-based hedging strategies using futures ... 145
6.5 Hedging portfolios of assets and liabilities ... 147
Summary ... 147
Further reading ... 148
Practice questions ... 148
Further questions ... 150

Chapter 7. Swaps 152
7.1 Mechanics of interest rate swaps 153
7.2 Day count issues 158
7.3 Confirmations 159
7.4 The comparative-advantage argument 159
7.5 The nature of swap rates 163
7.6 Determining the LIBOR/swap zero rates 164
7.7 Valuation of interest rate swaps 164
7.8 Term structure effects 168
7.9 Fixed-for-fixed currency swaps 168
7.10 Valuation of fixed-for-fixed currency swaps 172
7.11 Other currency swaps 175
7.12 Credit risk 176
7.13 Other types of swaps 178
Summary 180
Further reading 181
Practice questions 181
Further questions 183

Chapter 8. Securitization and the credit crisis of 2007 185
8.1 Securitization 185
8.2 The US housing market 189
8.3 What went wrong? 193
8.4 The aftermath 195
Summary 196
Further reading 197
Practice questions 198
Further questions 198

Chapter 9. OIS discounting, credit issues, and funding costs 200
9.1 The risk-free rate 200
9.2 The OIS rate 202
9.3 Valuing swaps and FRAs with OIS discounting 205
9.4 OIS vs. LIBOR: Which is correct? 206
9.5 Credit risk: CVA and DVA 207
9.6 Funding costs 209
Summary 210
Further reading 211
Practice questions 211
Further questions 212

Chapter 10. Mechanics of options markets 213
10.1 Types of options 213
10.2 Option positions 215
10.3 Underlying assets 217
10.4 Specification of stock options 218
10.5 Trading 223
10.6 Commissions 223
10.7 Margin requirements 224
10.8 The options clearing corporation 226
10.9 Regulation 227
10.10 Taxation 227
10.11 Warrants, employee stock options, and convertibles 229
10.12 Over-the-counter options markets 229

Summary 230
Further reading 231
Practice questions 231
Further questions 232

Chapter 11. Properties of stock options 234
11.1 Factors affecting option prices 234
11.2 Assumptions and notation 238
11.3 Upper and lower bounds for option prices 238
11.4 Put–call parity 241
11.5 Calls on a non-dividend-paying stock 245
11.6 Puts on a non-dividend-paying stock 246
11.7 Effect of dividends 249
Summary 250
Further reading 251
Practice questions 251
Further questions 253

Chapter 12. Trading strategies involving options 254
12.1 Principal-protected notes 254
12.2 Trading an option and the underlying asset 256
12.3 Spreads 258
12.4 Combinations 266
12.5 Other payoffs 269
Summary 270
Further reading 271
Practice questions 271
Further questions 272

Chapter 13. Binomial trees 274
13.1 A one-step binomial model and a no-arbitrage argument 274
13.2 Risk-neutral valuation 278
13.3 Two-step binomial trees 280
13.4 A put example 283
13.5 American options 284
13.6 Delta 285
13.7 Matching volatility with u and d 286
13.8 The binomial tree formulas 288
13.9 Increasing the number of steps 288
13.10 Using DerivaGem 289
13.11 Options on other assets 290
Summary 293
Further reading 294
Practice questions 295
Further questions 296
Appendix: Derivation of the Black–Scholes–Merton option-pricing formula from a binomial tree 298

Chapter 14. Wiener processes and Itô's lemma 302
14.1 The Markov property 302
14.2 Continuous-time stochastic processes 303
14.3 The process for a stock price 308
14.4 The parameters 311
14.5 Correlated processes 312
14.6 Itô's lemma 313

14.7 The lognormal property 314
Summary 315
Further reading 316
Practice questions 316
Further questions 317
Appendix: Derivation of Itô's lemma 319

Chapter 15. The Black–Scholes–Merton model 321
15.1 Lognormal property of stock prices 322
15.2 The distribution of the rate of return 323
15.3 The expected return 324
15.4 Volatility 325
15.5 The idea underlying the Black–Scholes–Merton differential equation 329
15.6 Derivation of the Black–Scholes–Merton differential equation 331
15.7 Risk-neutral valuation 334
15.8 Black–Scholes–Merton pricing formulas 335
15.9 Cumulative normal distribution function 338
15.10 Warrants and employee stock options 339
15.11 Implied volatilities 341
15.12 Dividends 343
Summary 346
Further reading 347
Practice questions 348
Further questions 350
Appendix: Proof of Black–Scholes–Merton formula using risk-neutral valuation 352

Chapter 16. Employee stock options 354
16.1 Contractual arrangements 354
16.2 Do options align the interests of shareholders and managers? 356
16.3 Accounting issues 357
16.4 Valuation 358
16.5 Backdating scandals 363
Summary 364
Further reading 365
Practice questions 365
Further questions 366

Chapter 17. Options on stock indices and currencies 367
17.1 Options on stock indices 367
17.2 Currency options 369
17.3 Options on stocks paying known dividend yields 372
17.4 Valuation of European stock index options 374
17.5 Valuation of European currency options 377
17.6 American options 378
Summary 379
Further reading 379
Practice questions 380
Further questions 382

Chapter 18. Futures options 383
18.1 Nature of futures options 383
18.2 Reasons for the popularity of futures options 386
18.3 European spot and futures options 386
18.4 Put–call parity 387

18.5 Bounds for futures options 388
18.6 Valuation of futures options using binomial trees 389
18.7 Drift of a futures prices in a risk-neutral world 391
18.8 Black's model for valuing futures options 392
18.9 American futures options vs. American spot options 394
18.10 Futures-style options 394
Summary 395
Further reading 396
Practice questions 396
Further questions 397

Chapter 19. The Greek letters 399
19.1 Illustration 399
19.2 Naked and covered positions 400
19.3 A stop-loss strategy 400
19.4 Delta hedging 402
19.5 Theta 409
19.6 Gamma 411
19.7 Relationship between delta, theta, and gamma 414
19.8 Vega 415
19.9 Rho 417
19.10 The realities of hedging 418
19.11 Scenario analysis 419
19.12 Extension of formulas 419
19.13 Portfolio insurance 422
19.14 Stock market volatility 424
Summary 424
Further reading 426
Practice questions 426
Further questions 428
Appendix: Taylor series expansions and hedge parameters 430

Chapter 20. Volatility smiles 431
20.1 Why the volatility smile is the same for calls and puts 431
20.2 Foreign currency options 433
20.3 Equity options 436
20.4 Alternative ways of characterizing the volatility smile 437
20.5 The volatility term structure and volatility surfaces 438
20.6 Greek letters 439
20.7 The role of the model 440
20.8 When a single large jump is anticipated 440
Summary 442
Further reading 443
Practice questions 443
Further questions 445
Appendix: Determining implied risk-neutral distributions from volatility smiles 447

Chapter 21. Basic numerical procedures 450
21.1 Binomial trees 450
21.2 Using the binomial tree for options on indices, currencies, and futures contracts 458
21.3 Binomial model for a dividend-paying stock 460
21.4 Alternative procedures for constructing trees 465

21.5 Time-dependent parameters 468
21.6 Monte Carlo simulation 469
21.7 Variance reduction procedures 475
21.8 Finite difference methods 478
Summary 488
Further reading 489
Practice questions 490
Further questions 492

Chapter 22. Value at risk 494
22.1 The VaR measure 494
22.2 Historical simulation 497
22.3 Model-building approach 501
22.4 The linear model 504
22.5 The quadratic model 509
22.6 Monte Carlo simulation 511
22.7 Comparison of approaches 512
22.8 Stress testing and back testing 513
22.9 Principal components analysis 513
Summary 517
Further reading 517
Practice questions 518
Further questions 519

Chapter 23. Estimating volatilities and correlations 521
23.1 Estimating volatility 521
23.2 The exponentially weighted moving average model 523
23.3 The GARCH (1,1) model 525
23.4 Choosing between the models 526
23.5 Maximum likelihood methods 527
23.6 Using GARCH (1,1) to forecast future volatility 532
23.7 Correlations 535
23.8 Application of EWMA to four-index example 538
Summary 540
Further reading 540
Practice questions 540
Further questions 542

Chapter 24. Credit risk 544
24.1 Credit ratings 544
24.2 Historical default probabilities 545
24.3 Recovery rates 546
24.4 Estimating default probabilities from bond yield spreads 547
24.5 Comparison of default probability estimates 550
24.6 Using equity prices to estimate default probabilities 553
24.7 Credit risk in derivatives transactions 555
24.8 Default correlation 561
24.9 Credit VaR 564
Summary 567
Further reading 567
Practice questions 568
Further questions 569

Chapter 25. Credit derivatives 571
25.1 Credit default swaps 572
25.2 Valuation of credit default swaps 575
25.3 Credit indices 579
25.4 The use of fixed coupons 580
25.5 CDS forwards and options 581
25.6 Basket credit default swaps 581
25.7 Total return swaps 581
25.8 Collateralized debt obligations 583
25.9 Role of correlation in a basket CDS and CDO 585
25.10 Valuation of a synthetic CDO 585
25.11 Alternatives to the standard market model 592
Summary 594
Further reading 594
Practice questions 595
Further questions 596

Chapter 26. Exotic options 598
26.1 Packages 598
26.2 Perpetual American call and put options 599
26.3 Nonstandard American options 600
26.4 Gap options 601
26.5 Forward start options 602
26.6 Cliquet options 602
26.7 Compound options 602
26.8 Chooser options 603
26.9 Barrier options 604
26.10 Binary options 606
26.11 Lookback options 607
26.12 Shout options 609
26.13 Asian options 609
26.14 Options to exchange one asset for another 611
26.15 Options involving several assets 612
26.16 Volatility and variance swaps 613
26.17 Static options replication 616
Summary 618
Further reading 619
Practice questions 619
Further questions 621

Chapter 27. More on models and numerical procedures 624
27.1 Alternatives to Black–Scholes–Merton 625
27.2 Stochastic volatility models 630
27.3 The IVF model 632
27.4 Convertible bonds 633
27.5 Path-dependent derivatives 636
27.6 Barrier options 640
27.7 Options on two correlated assets 643
27.8 Monte Carlo simulation and American options 646
Summary 650
Further reading 651
Practice questions 652
Further questions 653

Chapter 28. Martingales and measures 655
28.1 The market price of risk 656
28.2 Several state variables 659
28.3 Martingales 660
28.4 Alternative choices for the numeraire 661
28.5 Extension to several factors 665
28.6 Black's model revisited 666
28.7 Option to exchange one asset for another 667
28.8 Change of numeraire 668
Summary 669
Further reading 670
Practice questions 670
Further questions 672

Chapter 29. Interest rate derivatives: The standard market models 673
29.1 Bond options 673
29.2 Interest rate caps and floors 678
29.3 European swap options 684
29.4 OIS discounting 688
29.5 Hedging interest rate derivatives 688
Summary 689
Further reading 690
Practice questions 690
Further questions 691

Chapter 30. Convexity, timing, and quanto adjustments 693
30.1 Convexity adjustments 693
30.2 Timing adjustments 697
30.3 Quantos 699
Summary 702
Further reading 702
Practice questions 702
Further questions 704
Appendix: Proof of the convexity adjustment formula 705

Chapter 31. Interest rate derivatives: models of the short rate 706
31.1 Background 706
31.2 Equilibrium models 707
31.3 No-arbitrage models 714
31.4 Options on bonds 719
31.5 Volatility structures 720
31.6 Interest rate trees 721
31.7 A general tree-building procedure 723
31.8 Calibration 732
31.9 Hedging using a one-factor model 734
Summary 735
Further reading 735
Practice questions 736
Further questions 738

Chapter 32. HJM, LMM, and multiple zero curves 740
32.1 The Heath, Jarrow, and Morton model 740
32.2 The LIBOR market model 743
32.3 Handling multiple zero curves 753
32.4 Agency mortgage-backed securities 755

Summary 757
Further reading 758
Practice questions 758
Further questions 759

Chapter 33. Swaps Revisited 760
33.1 Variations on the vanilla deal 760
33.2 Compounding swaps 762
33.3 Currency swaps 763
33.4 More complex swaps 764
33.5 Equity swaps 767
33.6 Swaps with embedded options 769
33.7 Other swaps 771
Summary 772
Further reading 773
Practice questions 773
Further questions 774

Chapter 34. Energy and commodity derivatives 775
34.1 Agricultural commodities 775
34.2 Metals 776
34.3 Energy products 777
34.4 Modeling commodity prices 779
34.5 Weather derivatives 785
34.6 Insurance derivatives 786
34.7 Pricing weather and insurance derivatives 786
34.8 How an energy producer can hedge risks 788
Summary 789
Further reading 789
Practice questions 790
Further question 791

Chapter 35. Real options 792
35.1 Capital investment appraisal 792
35.2 Extension of the risk-neutral valuation framework 793
35.3 Estimating the market price of risk 795
35.4 Application to the valuation of a business 796
35.5 Evaluating options in an investment opportunity 796
Summary 803
Further reading 803
Practice questions 804
Further questions 804

Chapter 36. Derivatives mishaps and what we can learn from them 806
36.1 Lessons for all users of derivatives 806
36.2 Lessons for financial institutions 810
36.3 Lessons for nonfinancial corporations 815
Summary 817
Further reading 817

Glossary of terms 818
DerivaGem software 840
Major exchanges trading futures and options 845
Tables for $N(x)$ 846
Author index 847
Subject index 852

BUSINESS SNAPSHOTS

1.1 The Lehman Bankruptcy 4
1.2 Systemic Risk 5
1.3 Hedge Funds 12
1.4 SocGen's Big Loss in 2008 18
2.1 The Unanticipated Delivery of a Futures Contract 25
2.2 Long-Term Capital Management's Big Loss 34
3.1 Hedging by Gold Mining Companies 54
3.2 Metallgesellschaft: Hedging Gone Awry 69
4.1 Orange County's Yield Curve Plays 89
4.2 Liquidity and the 2007–2009 Financial Crisis 98
5.1 Kidder Peabody's Embarrassing Mistake 109
5.2 A Systems Error? 114
5.3 The CME Nikkei 225 Futures Contract 116
5.4 Index Arbitrage in October 1987 117
6.1 Day Counts Can Be Deceptive 133
6.2 The Wild Card Play 139
6.3 Asset–Liability Management by Banks 147
7.1 Extract from Hypothetical Swap Confirmation 160
7.2 The Hammersmith and Fulham Story 177
8.1 The Basel Committee 196
9.1 What Is the Risk-Free Rate? 201
10.1 Gucci Group's Large Dividend 222
10.2 Tax Planning Using Options 228
11.1 Put–Call Parity and Capital Structure 244
12.1 Losing Money with Box Spreads 263
12.2 How to Make Money from Trading Straddles 268
15.1 Mutual Fund Returns Can be Misleading 326
15.2 What Causes Volatility? 329
15.3 Warrants, Employee Stock Options, and Dilution 340
17.1 Can We Guarantee that Stocks Will Beat Bonds in the Long Run? 376
19.1 Dynamic Hedging in Practice 418
19.2 Was Portfolio Insurance to Blame for the Crash of 1987? 425
20.1 Making Money from Foreign Currency Options 435
20.2 Crashophobia 438
21.1 Calculating Pi with Monte Carlo Simulation 469
21.2 Checking Black–Scholes–Merton in Excel 472
22.1 How Bank Regulators Use VaR 495
24.1 Downgrade Triggers and Enron's Bankruptcy 559
25.1 Who Bears the Credit Risk? 572
25.2 The CDS Market 574
26.1 Is Delta Hedging Easier or More Difficult for Exotics? 617
29.1 Put–Call Parity for Caps and Floors 680
29.2 Swaptions and Bond Options 685
30.1 Siegel's Paradox 701
32.1 IOs and POs 757
33.1 Hypothetical Confirmation for Nonstandard Swap 761
33.2 Hypothetical Confirmation for Compounding Swap 762
33.3 Hypothetical Confirmation for an Equity Swap 768
33.4 Procter and Gamble's Bizarre Deal 772
35.1 Valuing Amazon.com 797
36.1 Big Losses by Financial Institutions 807
36.2 Big Losses by Nonfinancial Organizations 808

TECHNICAL NOTES

Available on the Author's Website
www-2.rotman.utoronto.ca/~hull/technicalnotes

1. Convexity Adjustments to Eurodollar Futures
2. Properties of the Lognormal Distribution
3. Warrant Valuation When Value of Equity plus Warrants Is Lognormal
4. Exact Procedure for Valuing American Calls on Stocks Paying a Single Dividend
5. Calculation of the Cumulative Probability in a Bivariate Normal Distribution
6. Differential Equation for Price of a Derivative on a Stock Paying a Known Dividend Yield
7. Differential Equation for Price of a Derivative on a Futures Price
8. Analytic Approximation for Valuing American Options
9. Generalized Tree-Building Procedure
10. The Cornish–Fisher Expansion to Estimate VaR
11. Manipulation of Credit Transition Matrices
12. Calculation of Cumulative Noncentral Chi-Square Distribution
13. Efficient Procedure for Valuing American-Style Lookback Options
14. The Hull–White Two-Factor Model
15. Valuing Options on Coupon-Bearing Bonds in a One-Factor Interest Rate Model
16. Construction of an Interest Rate Tree with Nonconstant Time Steps and Nonconstant Parameters
17. The Process for the Short Rate in an HJM Term Structure Model
18. Valuation of a Compounding Swap
19. Valuation of an Equity Swap
20. Changing the Market Price of Risk for Variables That Are Not the Prices of Traded Securities
21. Hermite Polynomials and Their Use for Integration
22. Valuation of a Variance Swap
23. The Black, Derman, Toy Model
24. Proof that Forward and Futures Prices are Equal When Interest Rates Are Constant
25. A Cash-Flow Mapping Procedure
26. A Binomial Measure of Credit Correlation
27. Calculation of Moments for Valuing Asian Options
28. Calculation of Moments for Valuing Basket Options
29. Proof of Extensions to Itô's Lemma
30. The Return of a Security Dependent on Multiple Sources of Uncertainty
31. Properties of Ho–Lee and Hull–White Interest Rate Models

Preface

It is sometimes hard for me to believe that the first edition of this book, published in 1988, was only 330 pages and 13 chapters long. The book has grown and been adapted to keep up with the fast pace of change in derivatives markets.

Like earlier editions, this book serves several markets. It is appropriate for graduate courses in business, economics, and financial engineering. It can be used on advanced undergraduate courses when students have good quantitative skills. Many practitioners who are involved in derivatives markets also find the book useful. I am delighted that half the purchasers of the book are analysts, traders, and other professionals who work in derivatives and risk management.

One of the key decisions that must be made by an author who is writing in the area of derivatives concerns the use of mathematics. If the level of mathematical sophistication is too high, the material is likely to be inaccessible to many students and practitioners. If it is too low, some important issues will inevitably be treated in a rather superficial way. I have tried to be particularly careful about the way I use both mathematics and notation in the book. Nonessential mathematical material has been either eliminated or included in end-of-chapter appendices and the technical notes on my website. Concepts that are likely to be new to many readers have been explained carefully and many numerical examples have been included.

Options, Futures, and Other Derivatives can be used for a first course in derivatives or for a more advanced course. There are many different ways it can be used in the classroom. Instructors teaching a first course in derivatives are likely to want to spend most classroom time on the first half of the book. Instructors teaching a more advanced course will find that many different combinations of chapters in the second half of the book can be used. I find that the material in Chapter 36 works well at the end of either an introductory or an advanced course.

What's New in the Ninth Edition?

Material has been updated and improved throughout the book. The changes in the ninth edition include:

1. New material at various points in the book on the industry's use of overnight indexed swap (OIS) rates for discounting.
2. A new chapter early in the book discussing discount rates, credit risk, and funding costs.
3. New material on the regulation of over-the-counter derivatives markets.
4. More discussion of central clearing, margin requirements, and swap execution facilities.

5. Coverage of products such as DOOM options and CEBOs offered by the CBOE.
6. New nontechnical explanation of the terms in the Black–Scholes–Merton formulas.
7. Coverage of perpetual options and other perpetual derivatives.
8. Expansion and updating of the material on credit risk and credit derivatives with the key products and key issues being introduced early in the book.
9. More complete coverage of one-factor equilibrium models of the term structure
10. New release of DerivaGem with many new features (see below).
11. Improvements to the Test Bank, which is available to adopting instructors.
12. Many new end-of-chapter problems.

DerivaGem Software

DerivaGem 3.00 is included with this book. This consists of two Excel applications: the Options Calculator and the Applications Builder. The Options Calculator consists of easy-to-use software for valuing a wide range of options. The Applications Builder consists of a number of Excel functions from which users can build their own applications. A number of sample applications enabling students to explore the properties of options and use different numerical procedures are included. The Applications Builder software allows more interesting assignments to be designed. Students have access to the code for the functions.

DerivaGem 3.00 includes many new features. European options can be valued using the CEV, Merton mixed-jump diffusion, and variance gamma models, which are discussed in Chapter 27. Monte Carlo experiments can be run. LIBOR and OIS zero curves can be calculated from market data. Swaps and bonds can be valued. When swaps, caps, and swaptions are valued, either OIS or LIBOR discounting can be used.

The software is described more fully at the end of the book. The software is available for download from `www.pearsonhighered.com/hull` with a Pearson access code, included with the book.

Slides

Several hundred PowerPoint slides can be downloaded from Pearson's Instructor Resource Center or from my website. Instructors who adopt the text are welcome to adapt the slides to meet their own needs.

Solutions Manual

End-of-chapter problems are divided into two groups: "Practice Questions" and "Further Questions." Solutions to the Practice Questions are in *Options, Futures, and Other Derivatives 9e: Solutions Manual* (ISBN: 978-0-133-45741-4), which is published by Pearson and can be purchased by students.

Instructor's Manual

The Instructor's Manual is made available online to adopting instructors by Pearson. It contains solutions to all questions (both Further Questions and Practice Questions), notes on the teaching of each chapter, Test Bank questions, notes on course organization, and some relevant Excel worksheets.

Technical Notes

Technical Notes are used to elaborate on points made in the text. They are referred to in the text and can be downloaded from my website:

www-2.rotman.utoronto.ca/~hull/technicalnotes

By not including the Technical Notes in the book, I am able to streamline the presentation of material so that it is more student-friendly.

Acknowledgments

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CHAPTER 1

Introduction

In the last 40 years, derivatives have become increasingly important in finance. Futures and options are actively traded on many exchanges throughout the world. Many different types of forward contracts, swaps, options, and other derivatives are entered into by financial institutions, fund managers, and corporate treasurers in the over-the-counter market. Derivatives are added to bond issues, used in executive compensation plans, embedded in capital investment opportunities, used to transfer risks in mortgages from the original lenders to investors, and so on. We have now reached the stage where those who work in finance, and many who work outside finance, need to understand how derivatives work, how they are used, and how they are priced.

Whether you love derivatives or hate them, you cannot ignore them! The derivatives market is huge—much bigger than the stock market when measured in terms of underlying assets. The value of the assets underlying outstanding derivatives transactions is several times the world gross domestic product. As we shall see in this chapter, derivatives can be used for hedging or speculation or arbitrage. They play a key role in transferring a wide range of risks in the economy from one entity to another.

A *derivative* can be defined as a financial instrument whose value depends on (or derives from) the values of other, more basic, underlying variables. Very often the variables underlying derivatives are the prices of traded assets. A stock option, for example, is a derivative whose value is dependent on the price of a stock. However, derivatives can be dependent on almost any variable, from the price of hogs to the amount of snow falling at a certain ski resort.

Since the first edition of this book was published in 1988 there have been many developments in derivatives markets. There is now active trading in credit derivatives, electricity derivatives, weather derivatives, and insurance derivatives. Many new types of interest rate, foreign exchange, and equity derivative products have been created. There have been many new ideas in risk management and risk measurement. Capital investment appraisal now often involves the evaluation of what are known as *real options*. Many new regulations have been introduced covering over-the-counter derivatives markets. The book has kept up with all these developments.

Derivatives markets have come under a great deal of criticism because of their role in the credit crisis that started in 2007. Derivative products were created from portfolios of risky mortgages in the United States using a procedure known as securitization. Many of the products that were created became worthless when house prices declined.

Financial institutions, and investors throughout the world, lost a huge amount of money and the world was plunged into the worst recession it had experienced in 75 years. Chapter 8 explains how securitization works and why such big losses occurred. As a result of the credit crisis, derivatives markets are now more heavily regulated than they used to be. For example, banks are required to keep more capital for the risks they are taking and to pay more attention to liquidity.

The way banks value derivatives has evolved through time. Collateral arrangements and credit issues are now given much more attention than in the past. Although it cannot be justified theoretically, many banks have changed the proxies they use for the "risk-free" interest rate to reflect their funding costs. Chapter 9, new to this edition, discusses these developments. Credit and collateral issues are considered in greater detail in Chapter 24.

In this opening chapter, we take a first look at derivatives markets and how they are changing. We describe forward, futures, and options markets and provide an overview of how they are used by hedgers, speculators, and arbitrageurs. Later chapters will give more details and elaborate on many of the points made here.

1.1 EXCHANGE-TRADED MARKETS

A derivatives exchange is a market where individuals trade standardized contracts that have been defined by the exchange. Derivatives exchanges have existed for a long time. The Chicago Board of Trade (CBOT) was established in 1848 to bring farmers and merchants together. Initially its main task was to standardize the quantities and qualities of the grains that were traded. Within a few years, the first futures-type contract was developed. It was known as a *to-arrive contract*. Speculators soon became interested in the contract and found trading the contract to be an attractive alternative to trading the grain itself. A rival futures exchange, the Chicago Mercantile Exchange (CME), was established in 1919. Now futures exchanges exist all over the world. (See table at the end of the book.) The CME and CBOT have merged to form the CME Group (www.cmegroup.com), which also includes the New York Mercantile Exchange, the commodity exchange (COMEX), and the Kansas City Board of Trade (KCBT).

The Chicago Board Options Exchange (CBOE, www.cboe.com) started trading call option contracts on 16 stocks in 1973. Options had traded prior to 1973, but the CBOE succeeded in creating an orderly market with well-defined contracts. Put option contracts started trading on the exchange in 1977. The CBOE now trades options on over 2,500 stocks and many different stock indices. Like futures, options have proved to be very popular contracts. Many other exchanges throughout the world now trade options. (See table at the end of the book.) The underlying assets include foreign currencies and futures contracts as well as stocks and stock indices.

Once two traders have agreed on a trade, it is handled by the exchange clearing house. This stands between the two traders and manages the risks. Suppose, for example, that trader A agrees to buy 100 ounces of gold from trader B at a future time for $1,450 per ounce. The result of this trade will be that A has a contract to buy 100 ounces of gold from the clearing house at $1,450 per ounce and B has a contract to sell 100 ounces of gold to the clearing house for $1,450 per ounce. The advantage of this arrangement is that traders do not have to worry about the creditworthiness of the

people they are trading with. The clearing house takes care of credit risk by requiring each of the two traders to deposit funds (known as margin) with the clearing house to ensure that they will live up to their obligations. Margin requirements and the operation of clearing houses are discussed in more detail in Chapter 2.

Electronic Markets

Traditionally derivatives exchanges have used what is known as the *open outcry system*. This involves traders physically meeting on the floor of the exchange, shouting, and using a complicated set of hand signals to indicate the trades they would like to carry out. Exchanges have largely replaced the open outcry system by *electronic trading*. This involves traders entering their desired trades at a keyboard and a computer being used to match buyers and sellers. The open outcry system has its advocates, but, as time passes, it is becoming less and less used.

Electronic trading has led to a growth in high-frequency and algorithmic trading. This involves the use of computer programs to initiate trades, often without human intervention, and has become an important feature of derivatives markets.

1.2 OVER-THE-COUNTER MARKETS

Not all derivatives trading is on exchanges. Many trades take place in the *over-the-counter* (OTC) market. Banks, other large financial institutions, fund managers, and corporations are the main participants in OTC derivatives markets. Once an OTC trade has been agreed, the two parties can either present it to a central counterparty (CCP) or clear the trade bilaterally. A CCP is like an exchange clearing house. It stands between the two parties to the derivatives transaction so that one party does not have to bear the risk that the other party will default. When trades are cleared bilaterally, the two parties have usually signed an agreement covering all their transactions with each other. The issues covered in the agreement include the circumstances under which outstanding transactions can be terminated, how settlement amounts are calculated in the event of a termination, and how the collateral (if any) that must be posted by each side is calculated. CCPs and bilateral clearing are discussed in more detail in Chapter 2.

Traditionally, participants in the OTC derivatives markets have contacted each other directly by phone and email, or have found counterparties for their trades using an interdealer broker. Banks often act as market makers for the more commonly traded instruments. This means that they are always prepared to quote a bid price (at which they are prepared to take one side of a derivatives transaction) and an offer price (at which they are prepared to take the other side).

Prior to the credit crisis, which started in 2007 and is discussed in some detail in Chapter 8, OTC derivatives markets were largely unregulated. Following the credit crisis and the failure of Lehman Brothers (see Business Snapshot 1.1), we have seen the development many new regulations affecting the operation of OTC markets. The purpose of the regulations is to improve the transparency of OTC markets, improve market efficiency, and reduce systemic risk (see Business Snapshot 1.2). The over-the-counter market in some respects is being forced to become more like the exchange-

Business Snapshot 1.1 The Lehman Bankruptcy

On September 15, 2008, Lehman Brothers filed for bankruptcy. This was the largest bankruptcy in US history and its ramifications were felt throughout derivatives markets. Almost until the end, it seemed as though there was a good chance that Lehman would survive. A number of companies (e.g., the Korean Development Bank, Barclays Bank in the UK, and Bank of America) expressed interest in buying it, but none of these was able to close a deal. Many people thought that Lehman was "too big to fail" and that the US government would have to bail it out if no purchaser could be found. This proved not to be the case.

How did this happen? It was a combination of high leverage, risky investments, and liquidity problems. Commercial banks that take deposits are subject to regulations on the amount of capital they must keep. Lehman was an investment bank and not subject to these regulations. By 2007, its leverage ratio had increased to 31:1, which means that a 3–4% decline in the value of its assets would wipe out its capital. Dick Fuld, Lehman's Chairman and Chief Executive Officer, encouraged an aggressive deal-making, risk-taking culture. He is reported to have told his executives: "Every day is a battle. You have to kill the enemy." The Chief Risk Officer at Lehman was competent, but did not have much influence and was even removed from the executive committee in 2007. The risks taken by Lehman included large positions in the instruments created from subprime mortgages, which will be described in Chapter 8. Lehman funded much of its operations with short-term debt. When there was a loss of confidence in the company, lenders refused to roll over this funding, forcing it into bankruptcy.

Lehman was very active in the over-the-counter derivatives markets. It had over a million transactions outstanding with about 8,000 different counterparties. Lehman's counterparties were often required to post collateral and this collateral had in many cases been used by Lehman for various purposes. It is easy to see that sorting out who owes what to whom in this type of situation is a nightmare!

traded market. Three important changes are:

1. Standardized OTC derivatives in the United States must, whenever possible, be traded on what are referred to a *swap execution facilities* (SEFs). These are platforms where market participants can post bid and offer quotes and where market participants can choose to trade by accepting the quotes of other market participants.
2. There is a requirement in most parts of the world that a CCP be used for most standardized derivatives transactions.
3. All trades must be reported to a central registry.

Market Size

Both the over-the-counter and the exchange-traded market for derivatives are huge. The number of derivatives transactions per year in OTC markets is smaller than in exchange-traded markets, but the average size of the transactions is much greater. Although the statistics that are collected for the two markets are not exactly comparable, it is clear that

Business Snapshot 1.2 Systemic Risk

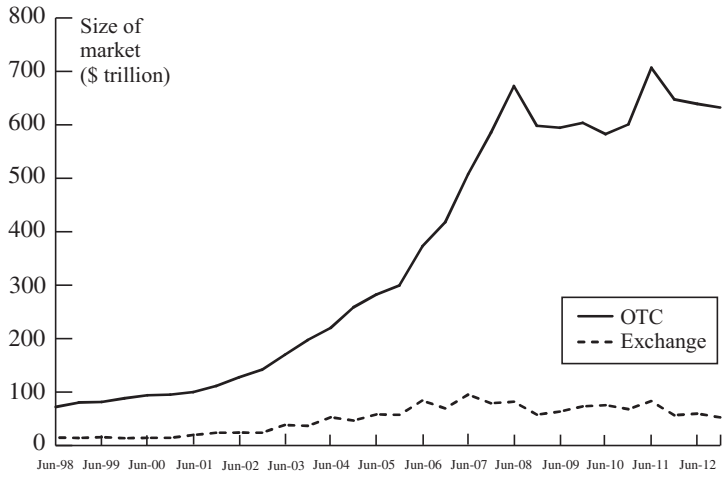
Systemic risk is the risk that a default by one financial institution will create a "ripple effect" that leads to defaults by other financial institutions and threatens the stability of the financial system. There are huge numbers of over-the-counter transactions between banks. If Bank A fails, Bank B may take a huge loss on the transactions it has with Bank A. This in turn could lead to Bank B failing. Bank C that has many outstanding transactions with both Bank A and Bank B might then take a large loss and experience severe financial difficulties; and so on.

The financial system has survived defaults such as Drexel in 1990 and Lehman Brothers in 2008, but regulators continue to be concerned. During the market turmoil of 2007 and 2008, many large financial institutions were bailed out, rather than being allowed to fail, because governments were concerned about systemic risk.

the over-the-counter market is much larger than the exchange-traded market. The Bank for International Settlements (www.bis.org) started collecting statistics on the markets in 1998. Figure 1.1 compares (a) the estimated total principal amounts underlying transactions that were outstanding in the over-the counter markets between June 1998 and December 2012 and (b) the estimated total value of the assets underlying exchange-traded contracts during the same period. Using these measures, by December 2012 the over-the-counter market had grown to $632.6 trillion and the exchange-traded market had grown to $52.6 trillion.[1]

In interpreting these numbers, we should bear in mind that the principal underlying an over-the-counter transaction is not the same as its value. An example of an over-the-counter transaction is an agreement to buy 100 million US dollars with British pounds

Figure 1.1 Size of over-the-counter and exchange-traded derivatives markets.



[1] When a CCP stands between two sides in an OTC transaction, two transactions are considered to have been created for the purposes of the BIS statistics.

at a predetermined exchange rate in 1 year. The total principal amount underlying this transaction is $100 million. However, the value of the transaction might be only $1 million. The Bank for International Settlements estimates the gross market value of all over-the-counter transactions outstanding in December 2012 to be about $24.7 trillion.[2]

1.3 FORWARD CONTRACTS

A relatively simple derivative is a *forward contract*. It is an agreement to buy or sell an asset at a certain future time for a certain price. It can be contrasted with a *spot contract*, which is an agreement to buy or sell an asset almost immediately. A forward contract is traded in the over-the-counter market—usually between two financial institutions or between a financial institution and one of its clients.

One of the parties to a forward contract assumes a *long position* and agrees to buy the underlying asset on a certain specified future date for a certain specified price. The other party assumes a *short position* and agrees to sell the asset on the same date for the same price.

Forward contracts on foreign exchange are very popular. Most large banks employ both spot and forward foreign-exchange traders. As we shall see in a later chapter, there is a relationship between forward prices, spot prices, and interest rates in the two currencies. Table 1.1 provides quotes for the exchange rate between the British pound (GBP) and the US dollar (USD) that might be made by a large international bank on May 6, 2013. The quote is for the number of USD per GBP. The first row indicates that the bank is prepared to buy GBP (also known as sterling) in the spot market (i.e., for virtually immediate delivery) at the rate of $1.5541 per GBP and sell sterling in the spot market at $1.5545 per GBP. The second, third, and fourth rows indicate that the bank is prepared to buy sterling in 1, 3, and 6 months at $1.5538, $1.5533, and $1.5526 per GBP, respectively, and to sell sterling in 1, 3, and 6 months at $1.5543, $1.5538, and $1.5532 per GBP, respectively.

Forward contracts can be used to hedge foreign currency risk. Suppose that, on May 6, 2013, the treasurer of a US corporation knows that the corporation will pay £1 million in 6 months (i.e., on November 6, 2013) and wants to hedge against exchange rate moves. Using the quotes in Table 1.1, the treasurer can agree to buy £1 million

Table 1.1 Spot and forward quotes for the USD/GBP exchange rate, May 6, 2013 (GBP = British pound; USD = US dollar; quote is number of USD per GBP).

	Bid	*Offer*
Spot	1.5541	1.5545
1-month forward	1.5538	1.5543
3-month forward	1.5533	1.5538
6-month forward	1.5526	1.5532

[2] A contract that is worth $1 million to one side and −$1 million to the other side would be counted as having a gross market value of $1 million.

6 months forward at an exchange rate of 1.5532. The corporation then has a long forward contract on GBP. It has agreed that on November 6, 2013, it will buy £1 million from the bank for $1.5532 million. The bank has a short forward contract on GBP. It has agreed that on November 6, 2013, it will sell £1 million for $1.5532 million. Both sides have made a binding commitment.

Payoffs from Forward Contracts

Consider the position of the corporation in the trade we have just described. What are the possible outcomes? The forward contract obligates the corporation to buy £1 million for $1,553,200. If the spot exchange rate rose to, say, 1.6000, at the end of the 6 months, the forward contract would be worth $46,800 (= $1,600,000 − $1,553,200) to the corporation. It would enable £1 million to be purchased at an exchange rate of 1.5532 rather than 1.6000. Similarly, if the spot exchange rate fell to 1.5000 at the end of the 6 months, the forward contract would have a negative value to the corporation of $53,200 because it would lead to the corporation paying $53,200 more than the market price for the sterling.

In general, the payoff from a long position in a forward contract on one unit of an asset is

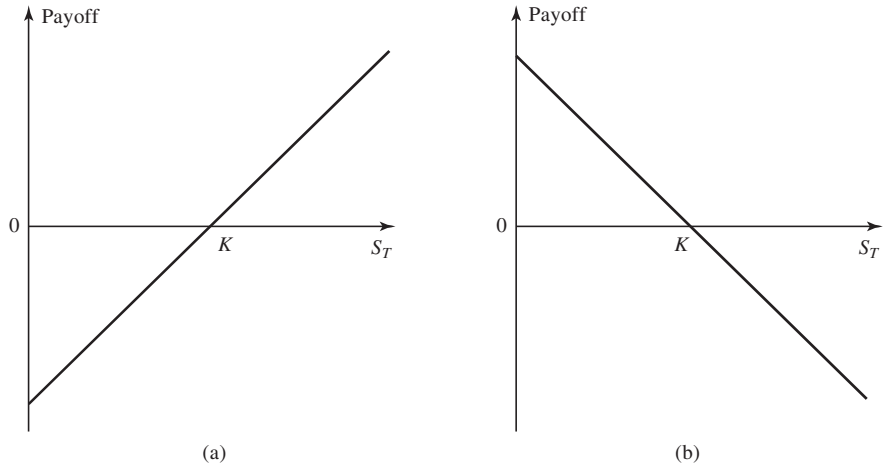
$$S_T - K$$

where K is the delivery price and S_T is the spot price of the asset at maturity of the contract. This is because the holder of the contract is obligated to buy an asset worth S_T for K. Similarly, the payoff from a short position in a forward contract on one unit of an asset is

$$K - S_T$$

These payoffs can be positive or negative. They are illustrated in Figure 1.2. Because it costs nothing to enter into a forward contract, the payoff from the contract is also the trader's total gain or loss from the contract.

Figure 1.2 Payoffs from forward contracts: (a) long position, (b) short position. Delivery price = K; price of asset at contract maturity = S_T.



In the example just considered, $K = 1.5532$ and the corporation has a long contract. When $S_T = 1.6000$, the payoff is \$0.0468 per £1; when $S_T = 1.5000$, it is −\$0.0532 per £1.

Forward Prices and Spot Prices

We shall be discussing in some detail the relationship between spot and forward prices in Chapter 5. For a quick preview of why the two are related, consider a stock that pays no dividend and is worth \$60. You can borrow or lend money for 1 year at 5%. What should the 1-year forward price of the stock be?

The answer is \$60 grossed up at 5% for 1 year, or \$63. If the forward price is more than this, say \$67, you could borrow \$60, buy one share of the stock, and sell it forward for \$67. After paying off the loan, you would net a profit of \$4 in 1 year. If the forward price is less than \$63, say \$58, an investor owning the stock as part of a portfolio would sell the stock for \$60 and enter into a forward contract to buy it back for \$58 in 1 year. The proceeds of investment would be invested at 5% to earn \$3. The investor would end up \$5 better off than if the stock were kept in the portfolio for the year.

1.4 FUTURES CONTRACTS

Like a forward contract, a futures contract is an agreement between two parties to buy or sell an asset at a certain time in the future for a certain price. Unlike forward contracts, futures contracts are normally traded on an exchange. To make trading possible, the exchange specifies certain standardized features of the contract. As the two parties to the contract do not necessarily know each other, the exchange also provides a mechanism that gives the two parties a guarantee that the contract will be honored.

The largest exchanges on which futures contracts are traded are the Chicago Board of Trade (CBOT) and the Chicago Mercantile Exchange (CME), which have now merged to form the CME Group. On these and other exchanges throughout the world, a very wide range of commodities and financial assets form the underlying assets in the various contracts. The commodities include pork bellies, live cattle, sugar, wool, lumber, copper, aluminum, gold, and tin. The financial assets include stock indices, currencies, and Treasury bonds. Futures prices are regularly reported in the financial press. Suppose that, on September 1, the December futures price of gold is quoted as \$1,380. This is the price, exclusive of commissions, at which traders can agree to buy or sell gold for December delivery. It is determined in the same way as other prices (i.e., by the laws of supply and demand). If more traders want to go long than to go short, the price goes up; if the reverse is true, then the price goes down.

Further details on issues such as margin requirements, daily settlement procedures, delivery procedures, bid–offer spreads, and the role of the exchange clearing house are given in Chapter 2.

1.5 OPTIONS

Options are traded both on exchanges and in the over-the-counter market. There are two types of option. A *call option* gives the holder the right to buy the underlying asset by a certain date for a certain price. A *put option* gives the holder the right to sell the

Table 1.2 Prices of call options on Google, May 8, 2013, from quotes provided by CBOE; stock price: bid \$871.23, offer \$871.37.

Strike price	*June 2013*		*September 2013*		*December 2013*	
(*\$*)	*Bid*	*Offer*	*Bid*	*Offer*	*Bid*	*Offer*
820	56.00	57.50	76.00	77.80	88.00	90.30
840	39.50	40.70	62.90	63.90	75.70	78.00
860	25.70	26.50	51.20	52.30	65.10	66.40
880	15.00	15.60	41.00	41.60	55.00	56.30
900	7.90	8.40	32.10	32.80	45.90	47.20
920	n.a.	n.a.	24.80	25.60	37.90	39.40

underlying asset by a certain date for a certain price. The price in the contract is known as the *exercise price* or *strike price*; the date in the contract is known as the *expiration date* or *maturity*. *American options* can be exercised at any time up to the expiration date. *European options* can be exercised only on the expiration date itself.[3] Most of the options that are traded on exchanges are American. In the exchange-traded equity option market, one contract is usually an agreement to buy or sell 100 shares. European options are generally easier to analyze than American options, and some of the properties of an American option are frequently deduced from those of its European counterpart.

It should be emphasized that an option gives the holder the right to do something. The holder does not have to exercise this right. This is what distinguishes options from forwards and futures, where the holder is obligated to buy or sell the underlying asset. Whereas it costs nothing to enter into a forward or futures contract, there is a cost to acquiring an option.

The largest exchange in the world for trading stock options is the Chicago Board Options Exchange (CBOE; www.cboe.com). Table 1.2 gives the bid and offer quotes for some of the call options trading on Google (ticker symbol: GOOG) on May 8, 2013. Table 1.3 does the same for put options trading on Google on that date. The quotes are

Table 1.3 Prices of put options on Google, May 8, 2013, from quotes provided by CBOE; stock price: bid \$871.23, offer \$871.37.

Strike price	*June 2013*		*September 2013*		*December 2013*	
(*\$*)	*Bid*	*Offer*	*Bid*	*Offer*	*Bid*	*Offer*
820	5.00	5.50	24.20	24.90	36.20	37.50
840	8.40	8.90	31.00	31.80	43.90	45.10
860	14.30	14.80	39.20	40.10	52.60	53.90
880	23.40	24.40	48.80	49.80	62.40	63.70
900	36.20	37.30	59.20	60.90	73.40	75.00
920	n.a.	n.a.	71.60	73.50	85.50	87.40

[3] Note that the terms *American* and *European* do not refer to the location of the option or the exchange. Some options trading on North American exchanges are European.