Derivatives Markets Second Edition



化化学 化合金化合金

and the second for the

ROBERT L. MCDONALD

Northwestern University

Kellogg School of Management



Boston San Francisco New York London Toronto Sydney Tokyo Singapore Madrid Mexico City Munich Paris Cape Town Hong Kong Montreal

CONTENTS

Preface xxi

Chapter 1 Introduction to Derivatives 1

- 1.1 What Is a Derivative? 1
 Uses of Derivatives 2
 Perspectives on Derivatives 3
 Financial Engineering and Security
 Design 3
- 1.2 The Role of Financial Markets 4 Financial Markets and the Averages 4 Risk-Sharing 5
- 1.3 Derivatives in Practice 6 Growth in Derivatives Trading 7 How Are Derivatives Used? 10
- 1.4 Buying and Short-Selling Financial Assets 11 Buying an Asset 11 Short-Selling 12 The Lease Rate of an Asset 14 Risk and Scarcity in Short-Selling 15 Chapter Summary 16 Further Reading 16 Problems 17

PART ONE INSURANCE, HEDGING, AND SIMPLE STRATEGIES 19

Chapter 2 An Introduction to Forwards and Options 21

2.1 Forward Contracts 21 The Payoff on a Forward Contract 23 Graphing the Payoff on a Forward Contract 25

Comparing a Forward and Outright Purchase 26 Zero-Coupon Bonds in Payoff and Profit Diagrams 28 Cash Settlement Versus Delivery 30 Credit Risk 30 2.2 Call Options 31 Option Terminology 32 Payoff and Profit for a Purchased Call Option 33 Payoff and Profit for a Written Call Option 37 2.3 Put Options 38 Payoff and Profit for a Purchased Put Option 39 Pavoff and Profit for a Written Put Option 40 The "Moneyness" of an Option 43 2.4 Summary of Forward and Option Positions 43 Long Positions 44 Short Positions 44 2.5 **Options Are Insurance** 45 Homeowner's Insurance Is a Put Option 45 But I Thought Insurance Is Prudent and Put Options Are Risky ... 47 Call Options Are Also Insurance 47 Example: Equity-Linked CDs 48 2.6 Graphing the Payoff on the CD 49 Economics of the CD 50 Why Equity-Linked CDs? 51 Chapter Summary 52 Further Reading 53 Problems 54 Appendix 2.A: More on Buying a Stock Option 56 Dividends 56

Exercise 57 Margins for Written Options 57 Taxes 58

Chapter 3 Insurance, Collars, and Other Strategies 59

- Basic Insurance Strategies 59
 Insuring a Long Position:
 Floors 59
 Insuring a Short Position: Caps 62
 Selling Insurance 63
- 3.2 Synthetic Forwards 66 Put-Call Parity 68
- 3.3 Spreads and Collars 70 Bull and Bear Spreads 71 Box Spreads 72 Ratio Spreads 73 Collars 73
- 3.4 Speculating on Volatility 78 Straddles 78 Butterfly Spreads 81 Asymmetric Butterfly Spreads 82
- 3.5 Example: Another Equity-Linked Note 83 Chapter Summary 85 Further Reading 86 Problems 87

Chapter 4 Introduction to Risk Management 91

4.1 Basic Risk Management: The Producer's Perspective 91 Hedging with a Forward Contract 92 Insurance: Guaranteeing a Minimum Price with a Put Option 93 Insuring by Selling a Call 95 Adjusting the Amount of Insurance 96

4.2 Basic Risk Management: The Buyer's Perspective 98 Hedging with a Forward Contract 98 Insurance: Guaranteeing a Maximum Price with a Call Option 99

- 4.3 Why Do Firms Manage Risk? 100 An Example Where Hedging Adds Value 101 Reasons to Hedge 103 Reasons Not to Hedge 106 Empirical Evidence on Hedging 106
 4.4 Golddiggers Revisited 108
- Selling the Gain: Collars 108 Other Collar Strategies 112 Paylater Strategies 113
- 4.5 Selecting the Hedge Ratio 113 Cross-Hedging 114 Quantity Uncertainty 116 Chapter Summary 119 Further Reading 120 Problems 120

PART TWO FORWARDS, FUTURES, AND SWAPS 125

Chapter 5 Financial Forwards and Futures 127

5.1 Alternative Ways to Buy a Stock 127

- 5.2 Prepaid Forward Contracts on Stock 128 Pricing the Prepaid Forward by Analogy 128 Pricing the Prepaid Forward by Discounted Present Value 129 Pricing the Prepaid Forward by Arbitrage 129 Pricing Prepaid Forwards with Dividends 131
 5.3 Forward Contracts on Stock 133
 - Creating a Synthetic Forward Contract 135

Synthetic Forwards in Market-Making and Arbitrage 136

No-Arbitrage Bounds with Transaction Costs 138

Quasi-Arbitrage 139

Does the Forward Price Predict the Future Price? 140

An Interpretation of the Forward Pricing Formula 141

5.4 Futures Contracts 142

The S&P 500 Futures Contract 143
Margins and Marking to Market 144
Comparing Futures and Forward Prices 146
Arbitrage in Practice: S&P 500 Index Arbitrage 147
Quanto Index Contracts 149

- 5.5 Uses of Index Futures 150
 Asset Allocation 150
 Cross-hedging with Index Futures 151
- 5.6 Currency Contracts 154 Currency Prepaid Forward 155 Currency Forward 156 Covered Interest Arbitrage 156
- 5.7 Eurodollar Futures 160 Chapter Summary 160 Further Reading 162 Problems 162 Appendix 5.A: Taxes and the Forward Price 166 Appendix 5.B: Equating Forwards and Futures 166

Chapter 6 Commodity Forwards and Futures 169

- 6.1 Introduction to Commodity Forwards 169
- 6.2 Equilibrium Pricing of Commodity Forwards 171
- 6.3 Nonstorability: Electricity 172
- 6.4 Pricing Commodity Forwards by Arbitrage: An Example 174

An Apparent Arbitrage and Resolution 175 Pencils Have a Positive Lease Rate 176 6.5 The Commodity Lease Rate 178 The Lease Market for a Commodity 178 Forward Prices and the Lease Rate 179 6.6 Carry Markets 181 Storage Costs and Forward Prices 181 Storage Costs and the Lease Rate 182 The Convenience Yield 182 6.7 Gold Futures 184 Gold Investments 187 Evaluation of Gold Production 187 6.8 Seasonality: The Corn Forward Market 188 6.9 Natural Gas 191 6.10 Oil 194 6.11 Commodity Spreads 195 6.12 Hedging Strategies 196

Basis Risk 197 Hedging Jet Fuel with Crude Oil 199 Weather Derivatives 199 Chapter Summary 200 Further Reading 201 Problems 201

Chapter 7 Interest Rate Forwards and Futures 205

7.1 Bond Basics 205

Zero-Coupon Bonds 206
Implied Forward Rates 208
Coupon Bonds 210
Zeros from Coupons 211
Interpreting the Coupon Rate 212
Continuously Compounded Yields 213

7.2 Forward Rate Agreements, Eurodollars, and Hedging 214

Forward Rate Agreements 214

Synthetic FRAs 216 Eurodollar Futures 218 Interest Rate Strips and Stacks 223

- 7.3 Duration and Convexity 223 Duration 224 Duration Matching 227 Convexity 228
- 7.4 Treasury-Bond and Treasury-Note Futures 230

7.5 Repurchase Agreements 233 Chapter Summary 235 Further Reading 237 Problems 237 Appendix 7.A: Interest Rate and Bond Price Conventions 241 Bonds 242 Bills 244

Chapter 8 Swaps 247

8.1 An Example of a Commodity Swap 247 Physical Versus Financial Settlement 248 Why Is the Swap Price Not \$20.50? 250 The Swap Counterparty 250 The Market Value of a Swap 253
8.2 Interest Rate Swaps 254 A Simple Interest Rate Swap 254 Pricing and the Swap Counterparty 255 Computing the Swap Rate in General 257

The Swap Curve 258 The Swap's Implicit Loan Balance 260 Deferred Swaps 261 Why Swap Interest Rates? 262

- Amortizing and Accreting Swaps 263
- 8.3 Currency Swaps 264 Currency Swap Formulas 267 Other Currency Swaps 267
- 8.4 Commodity Swaps 268 The Commodity Swap Price 268 Swaps with Variable Quantity and Price 269
- 8.5 Swaptions 271
- 8.6 Total Return Swaps 272 Chapter Summary 274

Further Reading 275 Problems 275

PART THREE OPTIONS 279

Chapter 9 Parity and Other Option Relationships 281

- 9.1 Put-Call Parity 281 Options on Stocks 283 Options on Currencies 286 Options on Bonds 286
- 9.2 Generalized Parity and Exchange Options 287 Options to Exchange Stock 288 What Are Calls and Puts? 289 Currency Options 290

Comparing Options with Respect to 9.3 Style, Maturity, and Strike 292 European Versus American Options 293 Maximum and Minimum Option Prices 293 Early Exercise for American Options 294 Time to Expiration 297 Different Strike Prices 299 Exercise and Moneyness 304 Chapter Summary 305 Further Reading 306 Problems 306 Appendix 9.A: Parity Bounds for American Options 310 Appendix 9.B: Algebraic Proofs of Strike-Price Relations 311

Chapter 10 Binomial Option Pricing: | 313

 10.1 A One-Period Binomial Tree 313 Computing the Option Price 314 The Binomial Solution 315 Arbitraging a Mispriced Option 318

xi

A Graphical Interpretation of the Binomial Formula 319
Risk-Neutral Pricing 320
Constructing a Binomial Tree 321
Another One-Period Example 322
Summary 322
10.2 Two or More Binomial Periods 323
A Two-Period European Call 323
Many Binomial Periods 326

- 10.3 Put Options 328
- 10.4 American Options 329

10.5 Options on Other Assets 330 Option on a Stock Index 330 Options on Currencies 332 Options on Futures Contracts 332 Options on Commodities 334 Options on Bonds 335 Summary 336 Chapter Summary 337 Further Reading 337 Problems 338 Appendix 10.A: Taxes and Option Prices 341

Chapter 11 Binomial Option Pricing: II 343

- 11.1 Understanding Early Exercise 343
- 11.2 Understanding Risk-Neutral Pricing 346 The Risk-Neutral Probability 346 Pricing an Option Using Real Probabilities 347

11.3 The Binomial Tree and Lognormality 351 The Random Walk Model 351 Modeling Stock Prices as a Random Walk 352 Continuously Compounded Returns 353 The Standard Deviation of Returns 354 The Binomial Model 355 Lognormality and the Binomial Model 355

Alternative Binomial Trees 358 Is the Binomial Model Realistic? 3.59 11.4 Estimating Volatility 360 11.5 Stocks Paving Discrete Dividends 361 Modeling Discrete Dividends 361 Problems with the Discrete Dividend Tree 362 A Binomial Tree Using the Prepaid Forward 363 Chapter Summary 365 Further Reading 366 Problems 366 Appendix 11.A: Pricing Options with True Probabilities 369 Appendix 11.B: Why Does Risk-Neutral Pricing Work? 369 Utility-Based Valuation 369 Standard Discounted Cash Flow 371 Risk-Neutral Pricing 371 Example 372 Why Risk-Neutral Pricing Works 373

Chapter 12 The Black-Scholes Formula 375

- 12.1 Introduction to the Black-Scholes Formula 375 Call Options 375 Put Options 378 When Is the Black-Scholes Formula Valid? 379
 12.2 Applying the Formula to Other Assets 379 Options on Stocks with Discrete Dividends 380 Options on Currencies 381 Options on Futures 381
 12.3 Option Greeks 382
 - Definition of the Greeks 382 Greek Measures for Portfolios 388 Option Elasticity 389

- 12.4 Profit Diagrams Before Maturity 395 Purchased Call Option 396 Calendar Spreads 397
- 12.5 Implied Volatility 400 Computing Implied Volatility 400 Using Implied Volatility 402
- 12.6 Perpetual American Options 403 Barrier Present Values 403 Perpetual Calls 404 Perpetual Puts 404 Chapter Summary 405 Further Reading 405 Problems 406 Appendix 12.A: The Standard Normal Distribution 409 Appendix 12.B: Formulas for Option Greeks 410 Delta 410 Gamma 410 Theta 410 Vega 411 Rho 411 Psi 411

Chapter 13 Market-Making and Delta-Hedging 413

- 13.1 What Do Market-Makers Do? 413
- 13.2 Market-Maker Risk 414
 Option Risk in the Absence of Hedging 414

 Delta and Gamma as Measures of Exposure 416
- 13.3 Delta-Hedging 417

 An Example of Delta-Hedging for 2
 Days 417

 Interpreting the Profit Calculation 418
 Delta-Hedging for Several Days 420
 A Self-Financing Portfolio: The Stock Moves One σ 422

13.4 The Mathematics of Delta-Hedging 422

Using Gamma to Better Approximate the Change in the Option Price 423 Delta-Gamma Approximations 424 Theta: Accounting for Time 425 Understanding the Market-Maker's Profit 427

- 13.5 The Black-Scholes Analysis 429 The Black-Scholes Argument 429 Delta-Hedging of American Options 430 What Is the Advantage to Frequent Re-Hedging? 431 Delta-Hedging in Practice 432 Gamma-Neutrality 433
- 13.6 Market-Making as Insurance 436 Insurance 436 Market-Makers 437 Chapter Summary 438 Further Reading 438 Problems 438 Appendix 13.A: Taylor Series Approximations 441 Appendix 13.B: Greeks in the Binomial Model 441

Chapter 14 Exotic Options: | 443

- 14.1 Introduction 443
- 14.2 Asian Options 444
 XYZ's Hedging Problem 445
 Options on the Average 446
 Comparing Asian Options 447
 An Asian Solution for XYZ 448
- 14.3 Barrier Options 449 Types of Barrier Options 450 Currency Hedging 451
- 14.4 Compound Options 453

 Compound Option Parity 454
 Options on Dividend-Paying Stocks 455
 Currency Hedging with Compound
 Options 456
- 14.5 Gap Options 457
- 14.6 Exchange Options 459

 European Exchange Options 459
 Chapter Summary 461
 Further Reading 462

503

Problems 462
Appendix 14.A: Pricing Formulas for Exotic Options 466
Asian Options Based on the Geometric Average 466
Compound Options 467
Infinitely Lived Exchange Option 468

PART FOUR FINANCIAL ENGINEERING AND APPLICATIONS 471

Chapter 15 Financial Engineering and Security Design 473

- 15.1 The Modigliani-Miller Theorem 473
- 15.2 Pricing and Designing Structured Notes 474
 Zero-Coupon Bonds 474
 Coupon Bonds 475
 Equity-Linked Bonds 476
 Commodity-Linked Bonds 478
 Currency-Linked Bonds 481

15.3 Bonds with Embedded Options 482 Options in Coupon Bonds 482 Options in Equity-Linked Notes 483 Valuing and Structuring an Equity-Linked CD 483 Alternative Structures 485

15.4 Engineered Solutions for Golddiggers 486 Gold-Linked Notes 486 Notes with Embedded Options 488

15.5 Strategies Motivated by Tax and Regulatory Considerations 490 Capital Gains Deferral 490 Tax-Deductible Equity 495 Chapter Summary 498 Further Reading 498 Problems 498 Chapter 16 Corporate
Applications 503
16.1 Equity, Debt, and Warrants 5 Debt and Equity as Options 503

Multiple Debt Issues 511 Warrants 512 Convertible Bonds 513 Callable Bonds 516 Bond Valuation Based on the Stock Price 520 Other Bond Features 520 Put Warrants 522

- 16.2 Compensation Options 523 Whose Valuation? 525 Valuation Inputs 527 An Alternative Approach to Expensing Option Grants 528 Repricing of Compensation Options 531 Reload Options 532 Level 3 Communications 534
- 16.3 The Use of Collars in Acquisitions 538 The Northrop Grumman–TRV Merger 538 Chapter Summary 542 Further Reading 542 Problems 543

Chapter 17 Real Options 547

17.1 Investment and the NPV Rule 548 Static NPV 548 The Correct Use of NPV 549 The Project as an Option 550

17.2 Investment under Uncertainty 551

A Simple DCF Problem 551
Valuing Derivatives on the Cash Flow 552
Evaluating a Project with a 2-Year Investment Horizon 554
Evaluating the Project with an Infinite Investment Horizon 558

- 17.3 Real Options in Practice 558 Peak-Load Electricity Generation 559 Research and Development 563
- 17.4 Commodity Extraction as an Option 565 Single-Barrel Extraction under Certainty 565 Single-Barrel Extraction under Uncertainty 569 Valuing an Infinite Oil Reserve 570

Commodity Extraction with 17.5 Shut-Down and Restart Options 572 Permanent Shutting Down 574Investment When Shutdown Is Possible 576 Restarting Production 578 Additional Options 578 Chapter Summary 579 Further Reading 580 Problems 580 Appendix 17.A: Calculation of Optimal Time to Drill an Oil Well 583 Appendix 17.B: The Solution with Shutting Down and Restarting 583

PART FIVE ADVANCED PRICING

PART FIVE ADVANCED PRICING THEORY 585

Chapter 18 The Lognormal Distribution 587

- 18.1 The Normal Distribution 587
 Converting a Normal Random Variable to Standard Normal 590
 Sums of Normal Random Variables 591
- 18.2 The Lognormal Distribution 593
- 18.3 A Lognormal Model of Stock Prices 595
- 18.4 Lognormal Probability Calculations 598 Probabilities 599

Lognormal Confidence Intervals 600 The Conditional Expected Price 602 The Black-Scholes Formula 604 18.5 Estimating the Parameters of a Lognormal Distribution 605 18.6 How Are Asset Prices Distributed? 608 Histograms 608 Normal Probability Plots 609 Chapter Summary 613 Further Reading 613 Problems 614 Appendix 18.A: The Expectation of a Lognormal Variable 615 Appendix 18.B: Constructing a Normal Probability Plot 616

Chapter 19 Monte Carlo Valuation 617

19.1 Computing the Option Price as a Discounted Expected Value 617 Valuation with Risk-Neutral Probabilities 618 Valuation with True Probabilities 619

- 19.2 Computing Random Numbers 621
 Using Sums of Uniformly Distributed
 Random Variables 622

 Using the Inverse Cumulative Normal
 Distribution 622
- 19.3 Simulating Lognormal Stock Prices 623 Simulating a Sequence of Stock Prices 623
- **19.4 Monte Carlo Valuation 624** Monte Carlo Valuation of a European Call 625

Accuracy of Monte Carlo 626 Arithmetic Asian Option 627

- 19.5 Efficient Monte Carlo Valuation 630 Control Variate Method 630 Other Monte Carlo Methods 632
- 19.6 Valuation of American Options 633

- 19.7 The Poisson Distribution 636
- 19.8 Simulating Jumps with the Poisson Distribution 639 Multiple Jumps 643
- 19.9 Simulating Correlated Stock Prices 643

Generating *n* Correlated Lognormal Random Variables 644 *Chapter Summary* 645

Further Reading 645 Problems 646 Appendix 19.A: Formulas for Geometric Average Options 648

Chapter 20 Brownian Motion and Itô's Lemma 649

- 20.1 The Black-Scholes Assumption about Stock Prices 649
- 20.2 Brownian Motion 650 Definition of Brownian Motion 650 Properties of Brownian Motion 652 Arithmetic Brownian Motion 653 The Ornstein-Uhlenbeck Process 654
- 20.3 Geometric Brownian Motion 655 Lognormality 655 Relative Importance of the Drift and Noise Terms 656 Correlated Itô Processes 657 Multiplication Rules 658
- 20.4 The Sharpe Ratio 659
- 20.5 The Risk-Neutral Process 660
- 20.6 Itô's Lemma 663 Functions of an Itô Process 663 Multivariate Itô's Lemma 665
- 20.7 Valuing a Claim on S^a 666 The Process Followed by S^a 667 Proving the Proposition 668 Specific Examples 669 Valuing a Claim on $S^a Q^b$ 670
- 20.8 Jumps in the Stock Price 672 Chapter Summary 674

Further Reading 674 Problems 675

Chapter 21 The Black-Scholes Equation 679

- 21.1 Differential Equations and Valuation under Certainty 679 The Valuation Equation 680 Bonds 680 Dividend-Paying Stocks 681 The General Structure 681
- 21.2 The Black-Scholes Equation 681 Verifying the Formula for a Derivative 683

The Black-Scholes Equation and Equilibrium Returns 686

What If the Underlying Asset Is Not an Investment Asset? 688

21.3 Risk-Neutral Pricing 690 Interpreting the Black-Scholes Equation 690 The Backward Equation 691

Derivative Prices as Discounted Expected Cash Flows 692

21.4 Changing the Numeraire 693

21.5 Option Pricing When the Stock Price Can Jump 696 Merton's Solution for Diversifiable Jumps 697 Chapter Summary 698 Further Reading 698 Problems 699 Appendix 21.A: Multivariate Black-Scholes Analysis 700 Appendix 21.B: Proof of Proposition 21.1 701

Chapter 22 Exotic Options: II 703

22.1 All-or-Nothing Options 703 Terminology 703 Cash-or-Nothing Options 704 Asset-or-Nothing Options 706 Ordinary Options and Gap Options 706 Delta-Hedging All-or-Nothing Options 707

- 22.2 All-or-Nothing Barrier Options 710 Cash-or-Nothing Barrier Options 710 Asset-or-Nothing Barrier Options 715 Rebate Options 716
- 22.3 Barrier Options 717

22.4 Quantos 718

The Yen Perspective 720
The Dollar Perspective 721
A Binomial Model for the
Dollar-Denominated Investor 724

22.5 Currency-Linked Options 727

Foreign Equity Call Struck in Foreign Currency 728

Foreign Equity Call Struck in Domestic Currency 729

Fixed Exchange Rate Foreign Equity Call 730

Equity-Linked Foreign Exchange Call 731

22.6 Other Multivariate Options 732 Exchange Options 732 Options on the Best of Two Assets 733 Basket Options 735 Chapter Summary 736 Further Reading 736 Problems 737

Chapter 23 Volatility 741

- 23.1 Implied Volatility 741
- 23.2 Measurement and Behavior of Volatility 744 Historical Volatility 744 Exponentially Weighted Moving Average 746 Time-Varying Volatility: ARCH 747 The GARCH Model 751
 - Realized Quadratic Variation 755

- 23.3 Hedging and Pricing Volatility 757 Variance and Volatility Swaps 758 Pricing Volatility 759
- 23.4 Extending the Black-Scholes Model 763 Jump Risk and Implied Volatility 764 Constant Elasticity of Variance 766 The Heston Model 768 Evidence 771 Chapter Summary 773 Further Reading 773 Problems 774 Appendix 23.A 777

Chapter 24 Interest Rate Models 779

24.1 Market-Making and Bond Pricing 779

The Behavior of Bonds and Interest Rates 780 An Impossible Bond Pricing Model 780 An Equilibrium Equation for Bonds 781 Delta-Gamma Approximations for Bonds 784

24.2 Equilibrium Short-Rate Bond Price Models 785 The Rendelman-Bartter Model 785 The Vasicek Model 786 The Cox-Ingersoll-Ross Model 787

Comparing Vasicek and CIR 788

- 24.3 Bond Options, Caps, and the Black Model 790
- 24.4 A Binomial Interest Rate Model 793 Zero-Coupon Bond Prices 794 Yields and Expected Interest Rates 796 Option Pricing 797
- 24.5 The Black-Derman-Toy Model 798 Verifying Yields 802 Verifying Volatilities 803 Constructing a Black-Derman-Toy Tree 804 Pricing Examples 805

Chapter Summary 808 Further Reading 808 Problems 809 Appendix 24.A: The Heath-Jarrow-Morton Model 811

Chapter 25 Value at Risk 813

25.1 Value at Risk 813
Value at Risk for One Stock 815
VaR for Two or More Stocks 817
VaR for Nonlinear Portfolios 819
VaR for Bonds 826
Estimating Volatility 830
Bootstrapping Return Distributions 831

25.2 Issues with VaR 832

Alternative Risk Measures 832
VaR and the Risk-Neutral Distribution 835
Subadditive Risk Measures 837
Chapter Summary 838
Further Reading 839
Problems 839

- Chapter 26 Credit Risk 841
- 26.1 Default Concepts and Terminology 841
- 26.2 The Merton Default Model 843 Default at Maturity 843 Related Models 845
- 26.3 Bond Ratings and Default Experience 847

Using Ratings to Assess Bankruptcy Probability 847

Recovery Rates 850

Reduced Form Bankruptcy Models 852

- 26.4 Credit Instruments 853
 - Collateralized Debt Obligations 853 Credit Default Swaps and Related Structures 858 Pricing a Default Swap 862 CDS Indices 864

Chapter Summary 866 Further Reading 867 Problems 867

PART SIX APPENDIXES 871

Appendix A The Greek Alphabet 873

Appendix B Continuous Compounding 875 B.1 The Language of Interest Rates 875

- B.2 The Logarithmic and Exponential
 - Functions 876
 Changing Interest Rates 877
 Symmetry for Increases and Decreases 878
 Problems 878

Appendix C Jensen's Inequality 881

- C.1 Example: The Exponential Function 881
- C.2 Example: The Price of a Call 882
- C.3 Proof of Jensen's Inequality 884 Problems 884

Appendix D An Introduction to Visual Basic for Applications 885

- D.1 Calculations without VBA 885
- D.2 How to Learn VBA 886
- D.3 Calculations with VBA 886 Creating a Simple Function 886 A Simple Example of a Subroutine 888 Creating a Button to Invoke a Subroutine 888

Functions Can Call Functions889Illegal Function Names889Differences between Functions and

Subroutines 890

D.4	Storing and Retrieving Variables in a
	Worksheet 890
	Using a Named Range to Read and Write Numbers from a Spreadsheet 891
	Reading and Writing to Cells That Are Not Named 892
	Using the Cells Functions to Read and Write to Cells 892
	Reading from within a Function 893
D.5	Using Excel Functions from within
	VBĂ 893
	Using VBA to Compute the Black-Scholes Formula 894
	The Object Browser 895
D.6	Checking for Conditions 896
D.7	Arrays 897

- Defining Arrays 897
- D.8 Iteration 899 A Simple for Loop 899

Creating a Binomial Tree 900 Other Kinds of Loops 901

- D.9 Reading and Writing Arrays 901 Arrays as Outputs 901 Arrays as Inputs 903
- D.10 Miscellany 904 Getting Excel to Generate Macros for You 904 Using Multiple Modules 905 Recalculation Speed 905 Debugging 906 Creating an Add-In 906

Glossary 907

Bibliography 921 Index 935