1. A Portfolio Choice 54
1. C Risk and Risk Aversion 60
1. D Money Demand and Liquidity Traps 64
1. E Parameter Uncertainty 66
References 67

2 Arbitrage, Equilibrium, and Pricing 69
2.1 Introduction 69
2.2 The Static General Equilibrium in a Nutshell 71
2.2.1 Walras’s Law 72
2.2.2 Competitive Equilibrium 72
2.2.3 Optimality 73
2.3 The Role of Financial Securities in Markets with Uncertainty 77
2.3.1 Commodity Markets 77
2.3.2 Financial Securities and Rational Expectations 77
2.3.3 Laws of Large Numbers, Risk Aversion, and the Slicing of Risks 79
2.3.4 Arrow-Debreu Securities 81
2.4 Arbitrage and Replication: Examples 84
2.4.1 Rain and Sunshine 84
2.4.2 Replication and Pricing: The Role of Complete Markets 86
2.5 No-Arbitrage: Theory 87
2.5.1 Lands of Cockaigne 87
2.5.2 Enforced Asset Prices 89
2.6 Equivalent Martingales and Equilibrium 90
2.6.1 Equilibrium with Financial Markets: Definition 90
2.6.2 Rational Expectations 91
2.6.3 Pricing Kernels 92
2.6.4 Equilibrium, Risk Sharing, and Incomplete Markets 94
2.7 Consumption CAPM 100
2.7.1 Risk Neutral Pricing and Macroeconomic Risks 101
2.7.2 CCAPM versus CAPM 102
2. A Proof of Selected Results 102
References 104

3 Infinite Horizon Economies 107
3.1 Introduction 107
3.2 Consumption-Based Asset Evaluation 108
3.2.1 Recursive Plans: Introduction 108
3.2.2 Asset Pricing: The Marginalist Argument 110
3.2.3 Elasticity of Intertemporal Substitution 110
3.2.4 Lucas’s Model 111
3.3 Production: Foundational Issues 115
3.3.1 Decentralized Economy 115
3.3.2 The Social Planner Solution 117
3.3.3 Dynamics 118
3.3.4 Stochastic Economies 120
3.4 Production-Based Asset Pricing 124
3.4.1 Firms 125
3.4.2 Consumers 129
3.4.3 Equilibrium 130
3.5 Production, Money, and Asset Prices in Overlapping Generations Models 130
3.5.1 Introduction: Endowment Economies 131
3.5.2 Monetary Economies 134
3.5.3 Capital Accumulation and Bubbles 137
3.6 Dynamic Efficiency 140
3.6.1 Production Economies 140
3.6.2 Money 142
3.A Finite Difference Equations and Determinacy 142
3.B Neoclassical Growth in Continuous Time 146
3.C Optimization of Continuous Time Systems 151
References 154

4 Continuous Time Models 157
4.1 Introduction 157
4.2 An Introduction to No-Arbitrage and Equilibrium 159
4.2.1 Time 159
4.2.2 The Origins: Black–Scholes 159
4.2.3 Asset Prices As Feynman–Kac Representations 165
4.2.4 The Girsanov Theorem 167
4.2.5 The APT in Continuous Time 170
4.2.6 Example: No-Arbitrage in the Lucas Tree 173
4.3 Martingales and Arbitrage I: Viability 179
4.3.1 Trees 179
4.3.2 Martingale Restrictions 180
4.3.3 Market Completeness 181
4.4 Martingales and Arbitrage II: Optimization 183
4.4.1 Complete Markets and Single Budget Constraints 183
4.4.2 Optimization 184
4.4.3 Marginal Utility of Income 185
4.4.4 Example: Log Utility 186
4.4.5 Equilibrium 186
4.5 Martingales and Arbitrage III: Distortions and Numéraires 187
4.5.1 Leading Example: Consumption-Based Probabilities 188
4.5.2 Numéraire Pricing 190
4.6 Equilibrium with State Variables and a Representative Agent 193
4.6.1 Constant Investment Opportunity Sets 194
4.6.2 Stochastic Opportunity Sets 194
4.6.3 Arrow-Debreu Densities and Restrictions on Expected Returns 199
4.6.4 Interest Rates 203
Contents

4.7 Portfolio Constraints 205
   4.7.1 Admissible Portfolio Choices 206
   4.7.2 Artificial Markets 207
4.8 Inaction: The Economics of American Options 209
   4.8.1 Early Exercise Premiums: An Introductory Example 209
   4.8.2 Risk Aversion 211
   4.8.3 Real Options Theory 212
   4.8.4 Perpetual Puts 213
   4.8.5 Perpetual Calls 215
   4.8.6 Further Topics on Real Options and Controlled Brownian Motions 217
4.9 Jumps 220
   4.9.1 Poisson Jumps 220
   4.9.2 A Rare Event Interpretation 221
   4.9.3 Properties and Related Distributions 222
   4.9.4 Cox Processes 223
   4.9.5 Asset Prices As Jump-Diffusion Processes 223
   4.9.6 An Option Pricing Formula 225
4.A Introduction to Stochastic Calculus for Finance 226
4.B Self-Financed Strategies 244
4.C Proof of Selected Results 246
4.D The Green’s Function 250
4.E Portfolio Constraints 252
4.F Jumps 254
References 257

5 Information, Security Design, and Financial Contracting 261
5.1 Introduction 261
5.2 Conceptual Challenges to Frictionless Markets: Information Problems 262
   5.2.1 The Economics of Information 262
   5.2.2 Information Problems in Financial Markets 263
5.3 Three Information Problems 265
   5.3.1 Adverse Selection and Trading 265
   5.3.2 Moral Hazard and Securitization 266
   5.3.3 Signaling: Callable Bonds, Equity, and Short-Term Debt 273
   5.3.4 Other Classical Problems: Short-Term Debt and Equity Sales 279
5.4 The Classics: Capital Structure and Modigliani-Miller Propositions 284
   5.4.1 Irrelevance of Capital Structure 284
   5.4.2 Dynamic Versions of Irrelevance 286
5.5 Debt and Moral Hazard 287
   5.5.1 Symmetric Information Again: Full Insurance 287
   5.5.2 Moral Hazard 288
5.6 Debt with Costly State Verification 291
   5.6.1 Symmetric Information 291
   5.6.2 Asymmetric Information 291
   5.6.3 Investments and Agency Costs 293
Contents

5.7 Liquidity Management and Dynamic Security Design 294
  5.7.1 Liquidity Constraints and Optimal Dividend Policy 294
  5.7.2 A Model of Continuous Time Contracting 299
5.A Proofs for Section 5.3 305
5.B Debt and Moral Hazard 307
5.C Dynamic Problems 308
References 310

6 Taking Models to Data 313
  6.1 Introduction 313
  6.2 Data Generating Processes 314
    6.2.1 Models: Specification and Identification 314
    6.2.2 Restrictions on the DGP 314
    6.2.3 Parameter Estimation 315
    6.2.4 Basic Properties of Density Functions 316
    6.2.5 The Cramer-Rao Lower Bound 316
  6.3 Maximum Likelihood Estimation 317
    6.3.1 Definition 317
    6.3.2 Factorizations 317
    6.3.3 Asymptotic Properties 317
  6.4 M-Estimators 319
  6.5 Pseudo- or Quasi-Maximum Likelihood 321
  6.6 Generalized Method of Moments 321
    6.6.1 Theory 322
    6.6.2 Early Asset Pricing Tests 324
  6.7 Simulation-Based Estimators 325
    6.7.1 Three Simulation-Based Estimators 326
    6.7.2 Asymptotic Normality 328
    6.7.3 A Fourth Estimator: Simulated Maximum Likelihood 331
    6.7.4 Progress 333
    6.7.5 In Practice? Latent Factors and Identification 333
  6.A Primers 334
  6.B Maximum Likelihood 337
  6.C Maximum Likelihood Estimator for Dependent Processes 338
References 340

II Empirical Lessons and Market Inefficiencies 343

7 Neoclassical Kernels and Puzzles 345
  7.1 Introduction 345
  7.2 The Equity Premium Puzzle 346
    7.2.1 A Single-Factor Model 346
    7.2.2 Equity Premium and Interest Rate Puzzles 349
  7.3 The Hansen-Jagannathan Cup 352
7.4 Multifactor Extensions: The Aggregate Equity Market 355
  7.4.1 Exponential Affine Pricing Kernels 355
  7.4.2 With Log-Normal Returns 357
7.5 Relations to the Classic Capital Asset Pricing Model 359
  7.5.1 Market Portfolios and Pricing Kernel Bounds 359
  7.5.2 A Semantic Digression on Market Portfolios 359
  7.5.3 The Maximum Correlation Portfolio 360
  7.5.4 Duality 362
7.6 The Conditional Capital Asset Pricing Model 363
7.A Proof of Selected Results 365
References 369

8 Aggregate Fluctuations in Equity Markets 371
  8.1 Introduction 371
  8.2 Empirical Evidence: A Bird’s Eye View 372
    8.2.1 Equity Markets and the Business Cycle 373
    8.2.2 Predictability 377
    8.2.3 Risk-Return Trade-offs 379
  8.3 Volatility: A Business Cycle Perspective 380
    8.3.1 Volatility Cycles 381
    8.3.2 Understanding the Empirical Evidence 383
    8.3.3 What to Do with Stock Market Volatility? 386
    8.3.4 What Did We Learn? 392
  8.4 Rational Market Fluctuations 392
    8.4.1 The Dynamics of Asset Returns 392
    8.4.2 Markov Pricing Kernels, Asset Returns, and Volatility 394
  8.5 Time-Varying Risk Premiums 396
    8.5.1 External Habit 397
    8.5.2 Countercyclical Statistics 398
    8.5.3 Some Additional Literature 402
    8.5.4 The Term Structure of Interest Rates 402
  8.6 Large Price Swings As a Learning-Induced Phenomenon 404
    8.6.1 Information 404
    8.6.2 An Introductory Model of Learning 405
    8.6.3 Convexity Again and Two Models of Learning 409
  8.7 Retained Earnings and Market-to-Book Ratios 413
    8.7.1 Plowbacks and Growth Opportunities 416
    8.7.2 Random Dividends Distribution 414
  8.A Estimation, Calibration, and Simulation Methods 416
  8.B A Multifactor Security Model 420
  8.C Arrow-Debreu Partial Differential Equations 420
  8.D Volatility, Options, and Convexity 421
  8.E Linearity-Generating Processes 431
  8.F Habit 433
8.G Learning 435
8.H Market-to-Book Ratios 437
References 437

9 Macrofinance 441
9.1 Introduction 441
9.2 Nonexpected Utility 444
  9.2.1 Recursive Formulations 444
  9.2.2 Preferences for Early Resolution of Uncertainty and Long-Run
      Risks 446
  9.2.3 Testable Restrictions 448
  9.2.4 Risk Premiums and Interest Rates 449
  9.2.5 The Campbell-Shiller Approximation 451
  9.2.6 Risks for the Long Run 451
9.3 Heterogeneous Agents and “Catching up with the Joneses” 453
9.4 Idiosyncratic Risk and Incomplete Markets 456
  9.4.1 A Static Model of Idiosyncratic Risk 456
  9.4.2 Idiosyncratic Shocks Unrelated to Aggregate Risk 458
  9.4.3 Self-Insurance and Persistence of Idiosyncratic Shocks 459
  9.4.4 Countercyclical Income Inequality 459
  9.4.5 A Model with Restricted Market Participation 461
9.5 Disagreement and Learning 464
  9.5.1 Learning with Multiple Signals 465
  9.5.2 Overconfidence and Bubbles 465
  9.5.3 General Equilibrium Without Frictions 470
9.6 Coping with Knightian Uncertainty 479
  9.6.1 Prelude 479
  9.6.2 Uncertainty Aversion and the Ellsberg Paradox 480
  9.6.3 Portfolio Selection and Market Participation 483
  9.6.4 A Model of Multiple Likelihoods 487
9.7 Government Spending and Asset Prices 492
  9.7.1 Assumptions 492
  9.7.2 Government Debt 492
  9.7.3 Ricardian Equivalence 493
  9.7.4 Government Size and Asset Prices 494
9.8 Leverage and Volatility 495
  9.8.1 Primitives 496
  9.8.2 Equity Volatility and Leverage 497
  9.8.3 Bankruptcy 498
9.9 Multiple Trees and the Cross-Section of Asset Returns 499
  9.9.1 A Model of the Cross-Section of Expected Returns 499
  9.9.2 Exogenous Aggregate Output and Habit
      Formation 504
  9.9.3 Discussion: Predictability 506
  9.9.4 Stochastic Strings 506
## Contents

9.10 Prices, Quantities, and the Separation Hypothesis 508
9.10.1 Production Puzzles 509
9.10.2 Risk-Sensitive Models 510
9.10.3 Irrelevance 512
9.10.4 Preferences for Robustness and Detection Error Probabilities 513

9.11 Procyclicality and the Financial Accelerator Doctrine 515
9.11.1 Procyclicality 515
9.11.2 Introduction: Credit Rationing 517
9.11.3 Credit Cycles I: Propagation 518
9.11.4 Credit Cycles II: Amplification 524
9.11.5 Financial Intermediation and Business Cycles: Additional Mechanisms 529
9.11.6 The State of Current Research 537

9.A Nonexpected Utility 538
9.B Economies with Heterogeneous Agents 546
9.C Knightian Uncertainty 553
9.D Credit Rationing 554

References 558

10 Information and Other Market Frictions 563
10.1 Introduction 563
10.2 Prelude: Imperfect Information in Macroeconomics 565
10.3 Informational Efficiency: A Road Map 568
10.4 Walrasian Equilibria as Informationally Inefficient Outcomes 569
10.5 Rational Expectations Equilibrium 571
10.6 Noisy Rational Expectations Equilibrium 574
10.6.1 Asymmetric Information: Information Transmission 575
10.6.2 Differential Information: Information Aggregation 582
10.6.3 Higher Order Beliefs and Beauty Contests 585
10.7 Dealers Markets: Introduction 587
10.7.1 Markets with Symmetric Information 588
10.7.2 With Asymmetric Information: Bid-Ask Spreads 589
10.7.3 Inventory Risk and Bid-Ask Spreads 592
10.7.4 Empirical Measures of Liquidity 594
10.8 Markets with Strategic Players 595
10.8.1 Kyle's Baseline Model 596
10.8.2 Markets with Multiple Traders and Dealers 598
10.8.3 Dynamic Markets 604
10.8.4 Gravitational Pull Problems 609
10.8.5 Mandatory Disclosure 611
10.9 Limits of Arbitrage and Further Frictions 614
10.9.1 A Simple Model of Risky Arbitrage 615
10.9.2 Funding and Early Liquidation Constraints 617
10.9.3 Market Segmentation and Bond Supply Shocks 622
10.9.4 Liquidity and Runs 625
10.10 Over-the-Counter Markets 630
  10.10.1 Background 630
  10.10.2 Search 631
  10.10.3 A Model with Symmetric Information 631
10.A The Projection Theorem 635
10.B Proof of Selected Results 636
10.C Market Segmentation 641
10.D Search 642
10.E Introduction to Pricing Behavior in Macroeconomics 643
References 647

III Asset Pricing and Reality 651
11 Options and Volatility 653
  11.1 Introduction 653
  11.2 Forwards and Futures 655
    11.2.1 Forwards: Definition and Pricing in Frictionless Markets 656
    11.2.2 Forwards As a Means to Borrow Money, and Pricing Again 657
    11.2.3 Marking to Market 657
    11.2.4 Futures 657
    11.2.5 Backwardation and Contango 659
  11.3 Optionality and No-Arbitrage Bounds 663
    11.3.1 Model-Free Properties 664
    11.3.2 Limiting Behavior and Arbitrage Bounds 666
    11.3.3 Wasting Assets and Convexity 667
    11.3.4 Hedging 667
    11.3.5 A Case Study: Accumulators and Decumulators 669
  11.4 Classical Evaluation and Properties 670
    11.4.1 A Pricing Formula 670
    11.4.2 Black–Scholes 671
    11.4.3 Future Options and Black’s Formula 674
    11.4.4 Surprising Cancellations and “Preference-Free” Formulae 675
    11.4.5 Properties of Options in Diffusive Models 675
  11.5 Stochastic Volatility 678
    11.5.1 Statistical Models of Changing Volatility 678
    11.5.2 Implied Volatility, Smiles, and Skews 680
    11.5.3 Option Pricing under Stochastic Volatility 686
  11.6 Trading Volatility with Options 696
    11.6.1 Option Portfolios and a Taxonomy 696
    11.6.2 Delta-Neutral Portfolios 698
    11.6.3 Delta-Hedged Strategies and Variance Risk Premiums 702
    11.6.4 Perfect Hedging: Price Independence 707
  11.7 Local Volatility 708
    11.7.1 Issues 709
    11.7.2 Implied Binomial Trees 710
11.7.3 The Perfect Fit in Continuous Time 713
11.7.4 Relations with Implied Volatility 715
11.8 The Price of (Equity) Volatility 717
11.8.1 One Introductory Example: Range-Based Volatility 717
11.8.2 “Fear Gauge” Contracts 719
11.8.3 Hedging Variance Swaps 723
11.8.4 Forward Volatility Trading 724
11.8.5 Marking to Market 725
11.8.6 Stochastic Interest Rates 726
11.8.7 A Digression on Skewness 726
11.9 VIX Derivatives 728
11.9.1 Model-Free Future Pricing 728
11.9.2 A Simple VIX Future Pricing Model 730
11.9.3 Options and the Volatility of Volatility 732
11.9.4 Replicating Variance Futures 733
11.10 Endogenous Risk and Market Dysfunctionalities 735
11.10.1 Cyclical Hedging 737
11.10.2 Market Crashes 738
11.A The Original Formulation of Black–Scholes 746
11.B Black 1976 746
11.C Stochastic Volatility 747
11.D Local Volatility 750
11.E Spanning and Variance Contracts 752
References 755

12 Engineering of Fixed Income Securities 759
12.1 Introduction 759
12.1.1 No-Arbitrage Models 760
12.1.2 Relative Pricing in Fixed Income Markets 760
12.1.3 Many Evaluation Paradigms 761
12.1.4 Plan of the Chapter 762
12.2 Markets and Interest Rate Conventions 762
12.2.1 Markets for Interest Rates 762
12.2.2 Mathematical Definitions of Interest Rates 765
12.2.3 Yields to Maturity on Coupon-Bearing Bonds 767
12.2.4 Accruals, Invoice, and Clean Prices on Coupon-Bearing Bonds 768
12.3 Duration, Convexity Hedging, and Trading 770
12.3.1 Duration 770
12.3.2 Convexity 772
12.3.3 Asset-Liability Management 772
12.4 Foundational Issues in Interest Rate Modeling 781
12.4.1 Tree Representation of the Short-Term Rate 782
12.4.2 Tree Pricing 787
12.4.3 Introduction to Calibration 788
12.4.4 Calibrating Probabilities Through Derivative Data 800
12.4.5 Extensions to Trinomial Trees 807
<table>
<thead>
<tr>
<th>12.5 The Ho–Lee Model</th>
<th>807</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5.1 The Tree</td>
<td>808</td>
</tr>
<tr>
<td>12.5.2 Price Movements and the Martingale Restriction</td>
<td>809</td>
</tr>
<tr>
<td>12.5.3 The Recombining Condition and Interest Rate Volatility</td>
<td>810</td>
</tr>
<tr>
<td>12.5.4 Model Solution</td>
<td>811</td>
</tr>
<tr>
<td>12.5.5 Model Calibration</td>
<td>813</td>
</tr>
<tr>
<td>12.5.6 An Example</td>
<td>813</td>
</tr>
<tr>
<td>12.5.7 Continuous Time Approximations with an Application to Barbell Trading</td>
<td>816</td>
</tr>
<tr>
<td>12.6 Beyond Ho–Lee: Calibration Through Arrow-Debreu Securities</td>
<td>821</td>
</tr>
<tr>
<td>12.6.1 Extracting Arrow-Debreu Securities from the Yield Curve</td>
<td>822</td>
</tr>
<tr>
<td>12.6.2 Implementation with Two Model Examples</td>
<td>825</td>
</tr>
<tr>
<td>12.6.3 Numerical Examples</td>
<td>827</td>
</tr>
<tr>
<td>12.7 Callables, Puttables, and Convertibles with Trees</td>
<td>835</td>
</tr>
<tr>
<td>12.7.1 Foundational Issues</td>
<td>835</td>
</tr>
<tr>
<td>12.7.2 Callable Bonds</td>
<td>838</td>
</tr>
<tr>
<td>12.7.3 Convertible Bonds</td>
<td>842</td>
</tr>
<tr>
<td>12.8 Probabilities of Fed Funds Target Changes</td>
<td>845</td>
</tr>
<tr>
<td>12.A Bootstrapping and No-Arbitrage Restrictions</td>
<td>847</td>
</tr>
<tr>
<td>12.B Bond Sharpe Ratios</td>
<td>852</td>
</tr>
<tr>
<td>12.C Ho-Lee Representations</td>
<td>853</td>
</tr>
<tr>
<td>References</td>
<td>855</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>13 Interest Rates</th>
<th>857</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.1 Introduction</td>
<td>857</td>
</tr>
<tr>
<td>13.2 Bond Prices and Interest Rates</td>
<td>859</td>
</tr>
<tr>
<td>13.2.1 A First Representation of Bond Prices</td>
<td>859</td>
</tr>
<tr>
<td>13.2.2 Forward Rates</td>
<td>861</td>
</tr>
<tr>
<td>13.2.3 A Second Representation of Bond Prices</td>
<td>862</td>
</tr>
<tr>
<td>13.3 Stylized Facts</td>
<td>862</td>
</tr>
<tr>
<td>13.3.1 The Expectation Hypothesis</td>
<td>862</td>
</tr>
<tr>
<td>13.3.2 Bond Returns Predictability</td>
<td>864</td>
</tr>
<tr>
<td>13.3.3 The Yield Curve and the Business Cycle</td>
<td>865</td>
</tr>
<tr>
<td>13.3.4 Additional Stylized Facts about the US Yield Curve</td>
<td>868</td>
</tr>
<tr>
<td>13.3.5 Common Factors Affecting the Yield Curve</td>
<td>868</td>
</tr>
<tr>
<td>13.4 Models of the Short-Term Rate: Introduction</td>
<td>872</td>
</tr>
<tr>
<td>13.4.1 Models versus Representations</td>
<td>873</td>
</tr>
<tr>
<td>13.4.2 The Bond Pricing Equation</td>
<td>874</td>
</tr>
<tr>
<td>13.4.3 Stochastic Duration</td>
<td>878</td>
</tr>
<tr>
<td>13.4.4 Some Famous Models</td>
<td>879</td>
</tr>
<tr>
<td>13.4.5 Interest Rate Volatility and the Business Cycle</td>
<td>887</td>
</tr>
<tr>
<td>13.4.6 Jumps, Volatility, and Default</td>
<td>890</td>
</tr>
<tr>
<td>13.5 Multifactor Models of the Short-Term Rate</td>
<td>896</td>
</tr>
<tr>
<td>13.5.1 Stochastic Volatility</td>
<td>896</td>
</tr>
<tr>
<td>13.5.2 Three-Factor Models</td>
<td>901</td>
</tr>
</tbody>
</table>
13.5.3 Affine and Quadratic Term Structure Models 902
13.5.4 Unspanned Stochastic Volatility 904
13.5.5 Topics Regarding Estimation and Trading Strategies 905
13.6 No-Arbitrage Models: Early Formulations 908
13.6.1 Fitting the Yield-Curve, Perfectly 908
13.6.2 Ho and Lee 909
13.6.3 Hull and White 910
13.7 The Heath-Jarrow-Morton Framework 911
13.7.1 The Framework 911
13.7.2 The Model 913
13.7.3 The Dynamics of the Short-Term Rate 913
13.7.4 Embedding 914
13.7.5 Stochastic String Shocks Models 915
13.8 Interest Rate Derivatives 918
13.8.1 Persistence and Volatility in Fixed Income Markets 918
13.8.2 Hypothetical Continuous Payoffs 921
13.8.3 Forward Martingale Probabilities 922
13.8.4 European Options on Bonds 923
13.8.5 Callable Bonds and Convexity Risks 926
13.8.6 Options on Fixed Coupon Bonds 932
13.8.7 Interest Rate Swaps 934
13.8.8 Caps and Floors 938
13.8.9 Swaptions 939
13.9 Market Models 940
13.9.1 Models and Market Practice 940
13.9.2 No-Arbitrage Restrictions 941
13.9.3 Applications to Derivatives Evaluation 943
13.9.4 Multiple Curves 947
13.10 Volatility Surfaces 950
13.10.1 Implied Volatilities 950
13.10.2 Local Volatilities and SABR Models 951
13.A Bond Prices and Arbitrage Restrictions 954
13.B Forward Probabilities 955
13.C Factors and Components 957
13.D Jumps 958
13.E Exponential-Affine Models 961
13.F Expectation Theory and Embedding 963
13.G Strings 965
13.H Changes of Numéraire 965
13.I Convexity Risks in Gaussian Markets 966
References 967

14 Risky Debt and Credit Derivatives 973
14.1 Introduction 973
14.1.1 A Brief History of Credit Risk and Financial Innovation 973
14.1.2 Plan of the Chapter 976
14.2 Conceptual Approaches to the Evaluation of Defaultable Securities  
14.2.1 Firm Value, or Structural, Approach  
14.2.2 The Structural Approach in Theory: Strategic Defaulting  
14.2.3 In Practice: The Pricing ofConvertible Bonds  
14.2.4 Sovereign Risk  
14.2.5 Reduced Form Approaches: Rare Events or Intensity Models  
14.2.6 Ratings  
14.3 Credit Derivatives and Structured Products Based Thereon  
14.3.1 Options and Spreads  
14.3.2 Credit Default Swaps  
14.3.3 Evaluation with Random Intensity Rates  
14.3.4 The Pricing ofCredit Products  
14.3.5 Collateralized Debt Obligations  
14.4 Managing Loan Losses  
14.4.1 Regulatory Framework  
14.4.2 Foundations of Risk Management  
14.4.3 Measures of Systemic Risk  
14.4.4 Credit Risk, Correlation, and Loss Probabilities  
14.5 The Global Financial Crisis of the Late 2000s  
14.5.1 Credit Bubbles, Procyclicality, and “Quantitative Easing”  
14.5.2 The 2007 Subprime Crisis  
14.5.3 Procyclicality  
14.5.4 Credit Crunches and Quantitative Easing  
14.5.5 Where Did Quantitative Easing go?  
14.A Strategic Defaulting  
14.B Proof of Selected Results  
14.C Transition Probability Matrices and Pricing  
14.D Stochastic Default Intensity and Bond Spreads  
14.E Bond and Credit Default Swap spreads  
14.F Conditional Probabilities of Survival  
14.G CDS Index Swaps and Swaptions  
14.H Copulae  
14.I Pricing CDOs with Imperfect Correlation  
References  
Index