Handbooks in Operations Research and Management Science

Advisory Editors

M. Florian Université de Montréal A.M. Geoffrion

University of California at Los Angeles R.M. Karp

University of California at Berkeley

T.L. Magnanti Massachusetts Institute of Technology

D.G. Morrison University of California at Los Angeles

S.M. Pollock University of Michigan at Ann Arbor

A.F. Veinott, Jr. Stanford University

P. Whittle University of Cambridge Editors

J.K. Lenstra Centrum voor Wiskunde en Informatica, Amsterdam G.L. Nemhauser Georgia Institute of Technology J.G. Dai Georgia Institute of Technology

Volume 15



Amsterdam – Boston – Heidelberg – London – New York – Oxford Paris – San Diego – San Francisco – Singapore – Sydney – Tokyo North-Holland is an imprint of Elsevier



Financial Engineering

Edited by

John R. Birge University of Chicago, IL, USA

Vadim Linetsky Northwestern University, IL, USA



Amsterdam – Boston – Heidelberg – London – New York – Oxford Paris – San Diego – San Francisco – Singapore – Sydney – Tokyo North-Holland is an imprint of Elsevier



Contents

I. Introduction

Introduction to the Handbook of Financial Engineering	
John R. Birge and Vadim Linetsky	3
References	11
CHAPTER 1	
An Introduction to Financial Asset Pricing	
Robert A. Jarrow and Philip Protter	13
1 Introduction	13
2 Introduction to derivatives and arbitrage	14
3 The core of the theory	21
4 American type derivatives	60
Acknowledgements	67
References	67
II. Derivative Securities: Models and Methods	
CHAPTER 2	
Jump-Diffusion Models for Asset Pricing in Financial Engineering	
S.G. Kou	73
1 Introduction	73
2 Empirical stylized facts	75
3 Motivation for jump-diffusion models	84
4 Equilibrium for general jump-diffusion models	89
5 Basic setting for option pricing	92
6 Pricing call and put option via Laplace transforms	94
7 First passage times	96
8 Barrier and lookback options	100
9 Analytical approximations for American options	103
References	108
	110
CHAPTER 3	
Modeling Financial Security Returns Using Lévy Processes	
Liuren Wu	117
1 Introduction	117

Contents

2 Modeling return innovation distribution using Lévy processes	120
3 Generating stochastic volatility by applying stochastic time changes	127
4 Modeling financial security returns with time-changed Lévy processes	133
5 Option pricing under time-changed Lévy processes	144
6 Estimating Lévy processes with and without time changes	155
7 Concluding remarks	159
Acknowledgements	159
References	160

CHAPTER 4 Pricing with Wishart Risk Factors Christian Gourieroux and Razvan Sufana

1 Introduction	163
2 Wishart process	167
3 Pricing	172
4 Examples	175
5 Concluding remarks	181
References	181

163

CHAPTER 5

Volatility	
Federico M. Bandi and Jeffrey R. Russell	183
1 Introduction	183
2 A model of price formation with microstructure effects	184
3 The variance of the equilibrium price	186
4 Solutions to the inconsistency problem	191
5 Equilibrium price variance estimation: directions for future work	202
6 The variance of microstructure noise: a consistency result	210
7 The benefit of consistency: measuring market quality	210
8 Volatility and asset pricing	216
Acknowledgements	217
References	217

CHAPTER 6 Spectral Methods in Derivatives Pricing	
Vadim Linetsky	223
1 Introduction	224
2 Self-adjoint semigroups in Hilbert spaces	230
3 One-dimensional diffusions: general results	237
4 One-dimensional diffusions: a catalog of analytically tractable models	253
5 Symmetric multi-dimensional diffusions	285
6 Introducing jumps and stochastic volatility via time changes	288
7 Conclusion	294
References	294

vi

CHAPTER 7 Variational Methods in Derivatives Pricing Liming Feng, Pavlo Kovalov, Vadim Linetsky and Michael Marcozzi 301 1 Introduction 302 2 European and barrier options in the Black-Scholes-Merton model 305 3 American options in the Black-Scholes-Merton model 315 4 General multi-dimensional jump-diffusion models 320 5 Examples and applications 329 6 Summary 339 References 340

CHAPTER 8

Discrete Barrier and Lookback Options

S.G. Kou	343
1 Introduction	343
2 A representation of barrier options via the change of numeraire argument	348
3 Convolution, Broadie-Yamamoto method via the fast Gaussian transform, and	
Feng–Linetsky method via Hilbert transform	350
4 Continuity corrections	355
5 Perturbation method	361
6 A Laplace transform method via Spitzer's identity	363
7 Which method to use	365
Appendix A. Proof of (1)	366
Appendix B. Calculation of the constant β	368
References	370

III. Interest Rate and Credit Risk Models and Derivatives

CHAPTER 9

Topics in Interest Rate Theory	
Tomas Björk	377
1 Introduction	377
2 Basics	378
3 Forward rate models	381
4 Change of numeraire	387
5 LIBOR market models	390
6 Notes	400
7 Geometric interest rate theory	400
8 Consistency and invariant manifolds	401
9 Existence of nonlinear realizations	411
10 Potentials and positive interest	419
References	434

CHAPTER 10	
Calculating Portfolio Credit Risk	
Paul Glasserman	437
1 Introduction	437
2 Problem setting	439
3 Models of dependence	444
4 Conditional loss distributions	451
5 Unconditional loss distributions	457
6 Importance sampling	462
7 Summary	467
References	468
CHAPTER 11	
Valuation of Packet Credit Derivatives in the Cred	it Migratians Envi

Valuation of Basket Credit Derivatives in the Credit Migrations Envi-	
ronment	
Tomasz R. Bielecki, Stéphane Crépey, Monique Jeanblanc and Marek	
Rutkowski	471
1 Introduction	472
2 Notation and preliminary results	476
3 Markovian market model	481
4 Changes of measures and Markovian numeraires	485
5 Valuation of single name credit derivatives	492
6 Valuation of basket credit derivatives	497
7 Model implementation	500
References	507

IV. Incomplete Markets

CHAPTER 12 Incomplete Markets Jeremy Staum 511 1 Introduction 511 2 The over-the-counter market 513 3 Causes of incompleteness 516 4 Pricing and optimization 518 5 Issues in pricing and expected utility examples 528 6 Quadratics 533 7 Entropy and exponential utility 536 8 Loss, quantiles, and prediction 537 9 Pricing kernel restrictions 540 10 Ambiguity and robustness 544 11 Calibration 550 12 Conclusion 551 Acknowledgements 554 Appendix A. Definition of incompleteness and fundamental theorems 554 Appendix B. Financial perspectives on incompleteness 556 References 558

viii

CHAPTER 13

Option Pricing: Real and Risk-Neutral Distributions

George M. Constantinides, Jens Carsten Jackwerth and Stylianos Per	rrakis 565
1 Introduction	566
2 Implications of the absence of arbitrage	567
3 Additional restrictions implied by utility maximization	570
4 Special case: one period without transaction costs	574
5 Special case: one period with transaction costs and general payoffs	578
6 Special case: two periods without transaction costs and general payoffs	579
7 Special case: two periods with transaction costs and general payoffs	580
8 Multiple periods without transaction costs and with convex payoffs	581
9 Multiple periods with transaction costs and with convex payoffs	583
10 Empirical results	585
11 Concluding remarks	588
Acknowledgements	589
References	589

CHAPTER 14

Total Risk Minimization Using Monte Carlo Simulations	
Thomas F. Coleman, Yuying Li and Maria-Cristina Patron	593
1 Introduction	593
2 Discrete hedging criteria	599
3 Total risk minimization in the Black–Scholes framework	603
4 Total risk minimization in a stochastic volatility framework	618
5 Shortfall risk minimization	625
6 Conclusions	632
References	634

CHAPTER 15 Queuing Theoretic Approaches to Financial Price Fluctuations	
Erhan Bayraktar, Ulrich Horst and Ronnie Sircar	637
1 Introduction	638
2 Agent-based models of financial markets	639
3 Microstructure models with inert investors	649
4 Outlook and conclusion	671
Acknowledgements	674
References	674

V. Risk Management

CHAPTER 16	
Economic Credit Capital Allocation and Risk Contributions	
Helmut Mausser and Dan Rosen	681
1 Introduction	682
2 Credit portfolio models and general framework	684

0		
Con	ten	ts

 3 Capital allocation and risk contributions 4 Credit risk contributions in analytical models 5 Numerical methods to compute risk contributions 6 Case studies 7 Summary and further research Appendix A References 	688 693 701 706 717 721 724
CHAPTER 17 Liquidity Risk and Option Pricing Theory Robert A. Jarrow and Philip Protter	727
 Introduction The model The extended first fundamental theorem The extended second fundamental theorem Example (extended Black–Scholes economy) Economies with supply curves for derivatives Transaction costs Examples of supply curves Conclusion Acknowledgement Appendix A 	727 729 733 735 741 743 745 747 751 751 751
References	761

CHAPTER 18 Financial Engineering: Applications in Insurance Phelim Boyle and Mary Hardy

1 Introduction	763
2 Insurance products and markets	765
3 Premium principles and risk measures	768
4 Risk management for life insurance	770
5 Variable annuities	775
6 Guaranteed annuity options	781
7 Conclusions	784
Acknowledgements	784
References	785

763

VI. Portfolio Optimization

CHAPTER 19	
Dynamic Portfolio Choice and Risk Aversion	
Costis Skiadas	789
1 Introduction	789
2 Optimality and state pricing	793
3 Recursive utility	804
4 Modeling risk aversion	814

х

Cor	nter	nts
001	ww	220

5 Scale-invariant solutions	821
6 Extensions	833
Acknowledgements	839
References	839

CHAPTER 20

Optimization Methods in Dynamic Portfolio Manage	ement
John R. Birge	845
1 Introduction	845
2 Formulation	846
3 Approximation methods	849
4 Solution methods	857
5 Extensions and conclusions	860
Acknowledgements	861
References	861

CHAPTER 21

Simulation Methods for Optimal Portfolios	
Jérôme Detemple, René Garcia and Marcel Rindisbacher	867
1 Introduction	867
2 The consumption-portfolio choice problem	869
3 Simulation methods for portfolio computation	878
4 Asymptotic properties of portfolio estimators	887
5 Performance evaluation: a numerical study	903
6 Conclusion	907
Acknowledgement	909
Appendix A. An introduction to Malliavin calculus	909
Appendix B. Proofs	915
References	922

CHAPTER 22

Duality Theory and Approximate Dynamic Programming for Pricing American Options and Portfolio Optimization Martin B. Haugh and Leonid Kogan

1 Introduction	925
2 Pricing American options	927
3 Portfolio optimization	937
References	947

CHAPTER 23

Asset Allocation with Multivariate Non-Gaussian Returns	
Dilip B. Madan and Ju-Yi J. Yen	949
1 Introduction	949
2 Non-Gaussian investment	951
3 Modeling distributions	953

xi

925

Content	s
Conton	v

4 Exponential utility and investment in zero cost VG cash flows	955
5 Identifying the joint distribution of returns	958
6 Non-Gaussian and Gaussian investment compared	960
7 Conclusion	962
Appendix A. Formal analysis of skewness preference and kurtosis aversion	963
Appendix B. Proof of Theorem 4.1	964
Appendix C. Proof of Theorem 4.2	966
References	968
 CHAPTER 24 Large Deviation Techniques and Financial Applications Phelim Boyle, Shui Feng and Weidong Tian Introduction Large deviation techniques Applications to portfolio management Tail risk of portfolios 	971 971 972 979 986
5 Application to simulation	987
6 Incomplete markets	992
7 Conclusions and potential topics for future research	997
Acknowledgements	998
References	998

Subject Index

1001

xii