## CONTENTS

	eface xiz knowledgments xxxii			xix xxiii
			PART I BASICS	
1	AN I	NTROD	UCTION TO FIXED INCOME MARKETS	3
	1.1	Introdu	uction	3
		1.1.1	The Complexity of Fixed Income Markets	6
		1.1.2	No Arbitrage and the Law of One Price	7
	1.2	The Go	overnment Debt Markets	9
		1.2.1	Zero Coupon Bonds	11
		1.2.2	Floating Rate Coupon Bonds	11
		1.2.3	The Municipal Debt Market	14
	1.3	The M	oney Market	14
		1.3.1	Federal Funds Rate	14
		1.3.2	Eurodollar Rate	14
		1.3.3	LIBOR	14
	1.4	The Re	epo Market	15
		1.4.1	General Collateral Rate and Special Repos	16
		1.4.2	What if the T-bond Is Not Delivered?	18
	1.5	The M	ortgage Backed Securities Market and Asset-Backed Securities	
		Marke	t	21

	1.6	The De	erivatives Market	23
		1.6.1	Swaps	23
		1.6.2	Futures and Forwards	25
		1.6.3	Options	25
	1.7	Roadm	ap of Future Chapters	26
	1.8	Summa	ary	28
2	BAS	ICS OF	FIXED INCOME SECURITIES	29
	2.1	Discou	int Factors	29
		2.1.1	Discount Factors across Maturities	30
		2.1.2	Discount Factors over Time	31
	2.2	Interes	t Rates	32
		2.2.1	Discount Factors, Interest Rates, and Compounding	
			Frequencies	34
		2.2.2	The Relation between Discounts Factors and	
			Interest Rates	38
	2.3	The Te	rm Structure of Interest Rates	38
		2.3.1	The Term Structure of Interest Rates over Time	40
	2.4	Coupo	n Bonds	42
		2.4.1	From Zero Coupon Bonds to Coupon Bonds	43
		2.4.2	From Coupon Bonds to Zero Coupon Bonds	45
		2.4.3	Expected Return and the Yield to Maturity	47
		2.4.4	Quoting Conventions	50
	2.5	Floatin	g Rate Bonds	52
		2.5.1	The Pricing of Floating Rate Bonds	52
		2.5.2	Complications	54
	2.6	Summa	агу	57
	2.7	Exercis	ses	57
	2.8	Case S	tudy: Orange County Inverse Floaters	61
		2.8.1	Decomposing Inverse Floaters into a Portfolio of Basic	
			Securities	61
		2.8.2	Calculating the Term Structure of Interest Rates from Coupon	
			Bonds	62
		2.8.3	Calculating the Price of the Inverse Floater	62
		2.8.4	Leveraged Inverse Floaters	64
	2.9	Appen	dix: Extracting the Discount Factors $Z(0,T)$ from Coupon	
		Bonds		65
		2.9.1	Bootstrap Again	66
		2.9.2	Regressions	67
		2.9.3	Curve Fitting	67
		2.9.4	Curve Fitting with Splines	70

3	BAS	ICS OF	INTEREST RATE RISK MANAGEMENT	73
	3.1	The Va	ariation in Interest Rates	73
		3.1.1	The Savings and Loan Debacle	75
		3.1.2	The Bankruptcy of Orange County	75
	3.2	Duratio	on	75
		3.2.1	Duration of a Zero Coupon Bond	77
		3.2.2	Duration of a Portfolio	78
		3.2.3	Duration of a Coupon Bond	79
		3.2.4	Duration and Average Time of Cash Flow Payments	80
		3.2.5	Properties of Duration	82
		3.2.6	Traditional Definitions of Duration	83
		3.2.7	The Duration of Zero Investment Portfolios: Dollar Duration	84
		3.2.8	Duration and Value-at-Risk	86
		3.2.9	Duration and Expected Shortfall	89
	3.3	Interes	t Rate Risk Management	90
		3.3.1	Cash Flow Matching and Immunization	91
		3.3.2	Immunization versus Simpler Investment Strategies	93
		3.3.3	Why Does the Immunization Strategy Work?	96
	3.4	Asset-l	Liability Management	97
	3.5	Summa	ary	98
	3.6	Exercis	ses	99
	3.7	Case S	tudy: The 1994 Bankruptcy of Orange County	103
		3.7.1	Benchmark: What if Orange County was Invested in Zero	
			Coupon Bonds Only?	104
		3.7.2	The Risk in Leverage	105
		3.7.3	The Risk in Inverse Floaters	105
		3.7.4	The Risk in Leveraged Inverse Floaters	106
		3.7.5	What Can We Infer about the Orange County Portfolio?	107
		3.7.6	Conclusion	108
	3.8	Case A	Analysis: The Ex-Ante Risk in Orange County's Portfolio	108
		3.8.1	The Importance of the Sampling Period	109
		3.8.2	Conclusion	110
	3.9	Appen	dix: Expected Shortfall under the Normal Distribution	111
4	BAS	IC REFI	NEMENTS IN INTEREST RATE RISK MANAGEMENT	113
	4.1	Conve	xity	113
		4.1.1	The Convexity of Zero Coupon Bonds	116
		4.1.2	The Convexity of a Portfolio of Securities	118
		4.1.3	The Convexity of a Coupon Bond	118
		4.1.4	Positive Convexity: Good News for Average Returns	120
		4.1.5	A Common Pitfall	121

		4.1.6	Convexity and Risk Management	122
		4.1.7	Convexity Trading and the Passage of Time	126
	4.2	Slope	and Curvature	127
		4.2.1	Implications for Risk Management	129
		4.2.2	Factor Models and Factor Neutrality	130
		4.2.3	Factor Duration	132
		4.2.4	Factor Neutrality	134
		4.2.5	Estimation of the Factor Model	136
	4.3	Summ	ary	137
	4.4	Exerci	ses	138
	4.5	Case S	Study: Factor Structure in Orange County's Portfolio	142
		4.5.1	Factor Estimation	142
		4.5.2	Factor Duration of the Orange County Portfolio	142
		4.5.3	The Value-at-Risk of the Orange County Portfolio with	
			Multiple Factors	144
	4.6	Appen	dix: Principal Component Analysis	145
		4.6.1	Benefits from PCA	149
		4.6.2	The Implementation of PCA	150
5	INTE	REST F	RATE DERIVATIVES: FORWARDS AND SWAPS	153
	5.1	Forwar	rd Rates and Forward Discount Factors	154
		5.1.1	Forward Rates by No Arbitrage	157
		5.1.2	The Forward Curve	158
		5.1.3	Extracting the Spot Rate Curve from Forward Rates	161
	5.2	Forwa	rd Rate Agreements	162
		5.2.1	The Value of a Forward Rate Agreement	164
	5.3	Forwa	rd Contracts	167
		5.3.1	A No Arbitrage Argument	169
		5.3.2	Forward Contracts on Treasury Bonds	170
		5.3.3	The Value of a Forward Contract	171
	5.4	Interes	t Rate Swaps	171
		5.4.1	The Value of a Swap	175
		5.4.2	The Swap Rate	175
		5.4.3	The Swap Curve	176
		5.4.4	The LIBOR Yield Curve and the Swap Spread	178
		5.4.5	The Forward Swap Contract and the Forward Swap Rate	179
		5.4.6	Payment Frequency and Day Count Conventions	181
	5.5	Interes	t Rate Risk Management using Derivative Securities	182
	5.6	Summ	ary	184
	5.7	Exerci	ses	184
	5.8	Case S	tudy: PiVe Capital Swap Spread Trades	189
		5.8.1	Setting Up the Trade	191

		5.8.2	The Quarterly Cash Flow	192
		5.8.3	Unwinding the Position?	193
		5.8.4	Conclusion	196
6	INTE	REST F	ATE DERIVATIVES: FUTURES AND OPTIONS	199
	6.1	Interes	t Rate Futures	199
		6.1.1	Standardization	200
		6.1.2	Margins and Mark-to-Market	202
		6.1.3	The Convergence Property of Futures Prices	203
		6.1.4	Futures versus Forwards	205
		6.1.5	Hedging with Futures or Forwards?	208
	6.2	Option	IS	209
		6.2.1	Options as Insurance Contracts	213
		6.2.2	Option Strategies	220
		6.2.3	Put-Call Parity	223
		6.2.4	Hedging with Futures or with Options?	223
	6.3	Summ	ary	225
	6.4	Exerci	ses	226
	6.5	Appen	dix: Liquidity and the LIBOR Curve	233
7	INC	ATION	MONETARY POLICY, AND THE FEDERAL FUNDS	
1	RAT		MONETANT POLICI, AND THE FEDERAL FONDS	239
	7.1	The Fe	ederal Reserve	239
		7.1.1	Monetary Policy, Economic Growth, and Inflation	241
		7.1.2	The Tools of Monetary Policy	242
		7.1.3	The Federal Funds Rate	243
	7.2	Predict	ting the Future Fed Funds Rate	244
		7.2.1	Fed Funds Rate, Inflation and Employment Growth	244
		7.2.2	Long-Term Fed Funds Rate Forecasts	247
		7.2.3	Fed Funds Rate Predictions Using Fed Funds Futures	250
	7.3	Unders	standing the Term Structure of Interest Rates	254
		7.3.1	Why Does the Term Structure Slope up in Average?	255
		7.3.2	The Expectation Hypothesis	257
		7.3.3	Predicting Excess Returns	259
		7.3.4	Conclusion	261
	7.4	Coping	g with Inflation Risk: Treasury Inflation-Protected Securities	261
		7.4.1	TIPS Mechanics	264
		7.4.2	Real Bonds and the Real Term Structure of Interest Rates	264
		7.4.3	Real Bonds and TIPS	267
		7.4.4	Fitting the Real Yield Curve	267
		7.4.5	The Relation between Nominal and Real Rates	268

	7.5	Summa	ary	271
	7.6	Exercis	ses	272
	7.7	Case S	tudy: Monetary Policy during the Subprime Crisis of 2007 -	
		2008		275
		7.7.1	Problems on the Horizon	276
		7.7.2	August 17, 2007: Fed Lowers the Discount Rate	280
		7.7.3	September - December 2007: The Fed Decreases Rates and	
			Starts TAF	280
		7.7.4	January 2008: The Fed Cuts the Fed Funds Target and	
			Discount Rates	281
		7.7.5	March 2008: Bearn Stearns Collapses and the Fed Bolsters	
			Liquidity Support to Primary Dealers	281
		7.7.6	September - October 2008: Fannie Mae, Freddie Mac,	
			Lehman Brothers, and AIG Collapse	282
	7.8	Appen	dix: Derivation of Expected Return Relation	282
8	BAS	ICS OF	RESIDENTIAL MORTGAGE BACKED SECURITIES	285
	8.1	Securit	tization	285
		8.1.1	The Main Players in the RMBS Market	287
		8.1.2	Private Labels and the 2007 - 2009 Credit Crisis	288
		8.1.3	Default Risk and Prepayment in Agency RMBSs	289
	8.2	Mortga	ages and the Prepayment Option	290
		8.2.1	The Risk in the Prepayment Option	293
		8.2.2	Mortgage Prepayment	294
	8.3	Mortga	age Backed Securities	295
		8.3.1	Measures of Prepayment Speed	296
		8.3.2	Pass-Through Securities	297
		8.3.3	The Effective Duration of Pass-Through Securities	300
		8.3.4	The Negative Effective Convexity of Pass-Through	
			Securities	302
		8.3.5	The TBA Market	305
	8.4	Collate	eralized Mortgage Obligations	306
		8.4.1	CMO Sequential Structure	309
		8.4.2	CMO Planned Amortization Class (PAC)	310
		8.4.3	Interest Only and Principal Only Strips.	314
	8.5	Summ	ary	317
	8.6	Exerci	ses	318
	8.7	Case S	tudy: PiVe Investment Group and the Hedging of Pass-Through	
		Securit	ties	324
		8.7.1	Three Measures of Duration and Convexity	325
		8.7.2	PSA-Adjusted Effective Duration and Convexity	325

		8.7.3 Empirical Estimate of Duration and Convexity	326
		8.7.4 The Hedge Ratio	328
	8.8	Appendix: Effective Convexity	330
		PART II TERM STRUCTURE MODELS: TREES	
9	ONE	STEP BINOMIAL TREES	335
	9.1	A one-step interest rate binomial tree	335
		9.1.1 Continuous Compounding	338
		9.1.2 The Binomial Tree for a Two-Period Zero Coupon Bond	338
	9.2	No Arbitrage on a Binomial Tree	338
		9.2.1 The Replicating Portfolio Via No Arbitrage	340
		9.2.2 Where Is the Probability <i>p</i> ?	343
	9.3	Derivative Pricing as Present Discounted Values of Future Cash Flows	344
		9.3.1 Risk Premia in Interest Rate Securities	344
		9.3.2 The Market Price of Interest Rate Risk	345
		9.3.3 An Interest Rate Security Pricing Formula	346
		9.3.4 What If We Do Not Know <i>p</i> ?	347
	9.4	Risk Neutral Pricing	348
		9.4.1 Risk Neutral Probability	349
		9.4.2 The Price of Interest Rate Securities	349
		9.4.3 Risk Neutral Pricing and Dynamic Replication	350
		9.4.4 Risk Neutral Expectation of Future Interest Rates	351
	9.5	Summary	352
	9.6	Exercises	353
10	MUL	TI-STEP BINOMIAL TREES	357
	10.1	A Two-Step Binomial Tree	357
	10.2	Risk Neutral Pricing	358
		10.2.1 Risk Neutral Pricing by Backward Induction	359
		10.2.2 Dynamic Replication	361
	10.3	Matching the Term Structure	365
	10.4	Multi-step Trees	365
		10.4.1 Building a Binomial Tree from Expected Future Rates	367
		10.4.2 Risk Neutral Pricing	369
	10.5	Pricing and Risk Assessment: The Spot Rate Duration	372
	10.6	Summary	376
	10.7	Exercises	376
11	RISK	NEUTRAL TREES AND DERIVATIVE PRICING	381
	11.1	Risk Neutral Trees	381
		11.1.1 The Ho-Lee Model	381
		11.1.2 The Simple Black, Derman, and Toy (BDT) Model	383

		11.1.3	Comparison of the Two Models	385
		11.1.4 l	Risk Neutral Trees and Future Interest Rates	386
	11.2	Using Ris	sk Neutral Trees	387
		11.2.1	Intermediate Cash Flows	387
		11.2.2	Caps and Floors	387
		11.2.3	Swaps	392
		11.2.4	Swaptions	395
	11.3	Implied V	lolatilities and the Black, Derman, and Toy Model	397
		11.3.1	Flat and Forward Implied Volatility	398
		11.3.2 I	Forward Volatility and the Black, Derman, and Toy Model	402
	11.4	Risk Neu	tral Trees for Futures Prices	404
		11.4.1	Eurodollar Futures	406
		11.4.2	T-Note and T-Bond Futures	408
	11.5	Implied T	rees: Final Remarks	413
	11.6	Summary	7	413
	11.7	Exercises		416
12	AME	RICAN OF	PTIONS	423
	12.1	Callable I	Bonds	424
		12.1.1	An Application to U.S. Treasury Bonds	427
		12.1.2	The Negative Convexity in Callable Bonds	428
		12.1.3	The Option Adjusted Spread	431
		12.1.4 I	Dynamic Replication of Callable Bonds	431
	12.2	American	1 Swaptions	435
	12.3	Mortgage	es and Residential Mortgage Backed Securities	438
		12.3.1	Mortgages and the Prepayment Option	440
		12.3.2	The Pricing of Residential Mortgage Backed Securities	444
		12.3.3	The Spot Rate Duration of MBS	447
	12.4	Summary	,	450
	12.5	Exercises		451
13	MON		O SIMULATIONS ON TREES	459
	13.1	Monte Ca	arlo Simulations on a One-step Binomial Tree	459
	13.2	Monte Ca	arlo Simulations on a Two-step Binomial Tree	461
		13.2.1	Example: Non-Recombining Trees in Asian Interest Rate	
			Options	463
			Monte Carlo Simulations for Asian Interest Rate Options	465
	13.3		arlo Simulations on Multi-step Binomial Trees	466
			Does This Procedure Work?	468
			Illustrative Example: Long-Term Interest Rate Options	469
		13.3.3	How Many Simulations are Enough?	472

	13.4	Pricing Path Dependent Options	473
		13.4.1 Illustrative Example: Long-Term Asian Options	473
		13.4.2 Illustrative Example: Index Amortizing Swaps	473
	13.5	Spot Rate Duration by Monte Carlo Simulations	481
	13.6	Pricing Residential Mortgage Backed Securities	482
		13.6.1 Simulating the Prepayment Decision	483
		13.6.2 Additional Factors Affecting the Prepayment Decision	u 484
		13.6.3 Residential Mortgage Backed Securities	487
		13.6.4 Prepayment Models	490
	13.7	Summary	490
	13.8	Exercises	492
	PA	ART III TERM STRUCTURE MODELS: CONTINUOUS T	ME
14	INTE	REST RATE MODELS IN CONTINUOUS TIME	499
	14.1	Brownian Motions	502
		14.1.1 Properties of the Brownian Motion	504
		14.1.2 Notation	505
	14.2	Differential Equations	506
	14.3	Continuous Time Stochastic Processes	510
	14.4	Ito's Lemma	515
	14.5	Illustrative Examples	521
	14.6	Summary	525
	14.7	Exercises	526
	14.8	Appendix: Rules of Stochastic Calculus	529
15	NO A	ARBITRAGE AND THE PRICING OF INTEREST RATE	
	SEC	URITIES	531
	15.1	Bond Pricing with Deterministic Interest Rate	532
	15.2	Interest Rate Security Pricing in the Vasicek Model	535
		15.2.1 The Long / Short Portfolio	535
		15.2.2 The Fundamental Pricing Equation	537
		15.2.3 The Vasicek Bond Pricing Formula	538
		15.2.4 Parameter Estimation	541
	15.3	Derivative Security Pricing	545
		15.3.1 Zero Coupon Bond Options	545
		15.3.2 Options on Coupon Bonds	547
		15.3.3 The Three Steps to Derivative Pricing	548
	15.4	No Arbitrage Pricing in a General Interest Rate Model	549
		15.4.1 The Cox, Ingersoll, and Ross Model	550
		15.4.2 Bond Prices under the Cox, Ingersoll, and	
		Ross Model	551

	15.5	Summary	552
	15.6	Exercises	554
	15.7	Appendix: Derivations	559
		15.7.1 Derivation of the Pricing Formula in Equation 15.4	559
		15.7.2 The Derivation of the Vasicek Pricing Formula	560
		15.7.3 The CIR Model	561
16	DYN	AMIC HEDGING AND RELATIVE VALUE TRADES	563
	16.1	The Replicating Portfolio	563
	16.2	Rebalancing	565
	16.3	Application 1: Relative Value Trades on the Yield Curve	570
		16.3.1 Relative Pricing Errors Discovery	570
		16.3.2 Setting Up the Arbitrage Trade	570
	16.4	Application 2: Hedging Derivative Exposure	572
		16.4.1 Hedging and Dynamic Replication	572
		16.4.2 Trading on Mispricing and Relative Value Trades	575
	16.5	The Theta - Gamma Relation	575
	16.6	Summary	576
	16.7	Exercises	578
	16.8	Case Study: Relative Value Trades on the Yield Curve	579
		16.8.1 Finding the Relative Value Trade	581
		16.8.2 Setting Up the Trade	584
		16.8.3 Does It Work? Simulations	585
		16.8.4 Does It Work? Data	586
		16.8.5 Conclusion	588
	16.9	Appendix: Derivation of Delta for Call Options	590
17	RISK	NEUTRAL PRICING AND MONTE CARLO SIMULATIONS	593
	17.1	Risk Neutral Pricing	593
	17.2	Feynman-Kac Theorem	594
	17.3	Application of Risk Neutral Pricing: Monte Carlo Simulations	598
		17.3.1 Simulating a Diffusion Process	599
		17.3.2 Simulating the Payoff	599
		17.3.3 Standard Errors	602
	17.4	Example: Pricing a Range Floater	603
	17.5	Hedging with Monte Carlo Simulations	606
	17.6	Convexity by Monte Carlo Simulations	
	17.7	Summary	611
	17.8	Exercises	613
	17.9	Case Study: Procter & Gamble / Bankers Trust Leveraged	
		Swap	619

		17.9.1	Parameter Estimates	621
		17.9.2	Pricing by Monte Carlo Simulations	622
18	THE	RISK AN	ND RETURN OF INTEREST RATE SECURITIES	627
	18.1	Expecte	ed Return and the Market Price Risk	627
		18.1.1	The Market Price of Risk in a General Interest	
			Rate Model	631
	18.2	Risk Ar	nalysis: Risk Natural Monte Carlo Simulations	631
		18.2.1	Delta Approximation Errors	633
	18.3	A Macr	roeconomic Model of the Term Structure	635
		18.3.1	Market Participants	636
		18.3.2	Equilibrium Nominal Bond Prices	639
			Conclusion	642
	18.4		nalysis: The Risk in the P&G Leveraged Swap	644
	18.5	Summa	5	648
	18.6	Exercis		648
	18.7	Append	lix: Proof of Pricing Formula in Macroeconomic Model	649
19	NO A	RBITRA	GE MODELS AND STANDARD DERIVATIVES	651
	19.1	No Arb	itrage Models	651
	19.2	The Ho	-Lee Model Revisited	653
		19.2.1	Consistent Derivative Pricing	656
		19.2.2	The Term Structure of Volatility in the Ho-Lee Model	658
	19.3	The Hu	ll-White Model	659
		19.3.1	The Option Price	660
	19.4	Standar	d Derivatives under the "Normal" Model	663
		19.4.1	Options on Coupon Bonds	663
		19.4.2	Caps and Floors	665
		19.4.3	Caps and Floors Implied Volatility	669
		19.4.4	European Swaptions	673
		19.4.5	Swaptions' Implied Volatility	675
	19.5	The "Lo	ognormal" Model	675
		19.5.1	The Black, Derman, and Toy Model	675
		19.5.2	The Black and Karasinski Model	677
	19.6	General	lized Affine Term Structure Models	677
	19.7	Summa	ry	678
	19.8	Exercise	es	679
	19.9	Append	lix: Proofs	681
		19.9.1	Proof of the Ho-Lee Pricing Formula	681
		19.9.2	Proof of the Expression in Equation 19.13	682
		19.9.3	Proof of the Hull-White Pricing Formula	682

		19.9.4	Proof of the Expression in Equation 19.28	683
		19.9.5	Proof of the Expressions in Equations 19.41 and 19.42	683
20	THE N		MODEL FOR STANDARD DERIVATIVES	<b>68</b> 5
	20.1	The Bla	ck Formula for Caps and Floors Pricing	686
		20.1.1	Flat and Forward Volatilities	688
		20.1.2	Extracting Forward Volatilities from Flat Volatilities	<b>69</b> 0
		20.1.3	The Behavior of the Implied Forward Volatility	695
		20.1.4	Forward Volatilities and the Black, Derman, and Toy	
			Model	699
	20.2	The Bla	ck Formula for Swaption Pricing	699
	20.3	Summar	ry	702
	20.4	Exercise	28	704
21	FORV		ISK NEUTRAL PRICING AND THE LIBOR MARKET	
	MODE	EL		707
	21.1	One Dif	ficulty with Risk Neutral Pricing	707
	21.2	Change	of Numeraire and the Forward Risk Neutral Dynamics	708
		21.2.1	Two Important Results	710
		21.2.2	Generalizations	711
	21.3	The Opt	tion Pricing Formula in "Normal" Models	712
	21.4	The LIE	SOR Market Model	714
		21.4.1	The Black Formula for Caps and Floors	715
		21.4.2	Valuing Fixed Income Securities that Depend on a Single	-
			LIBOR Rate	716
		21.4.3	The LIBOR Market Model for More Complex Securities	718
		21.4.4	Extracting the Volatility of Forward Rates from Caplets'	720
		01.4.5	Forward Volatilities	720
	21.5	21.4.5	Pricing Fixed Income Securities by Monte Carlo Simulations	723
	21.5	21.5.1	Risk Neutral Pricing and the Black Formula for Swaptions	727
	21.6		Remarks: Forward Risk Neutral Pricing and No Arbitrage	729
	21.6		ath, Jarrow, and Morton Framework	729
	21.7	21.6.1	Futures and Forwards	731
	21.7		ral Lag and Convexity Adjustment	733
		21.7.1	Unnatural Lag and Convexity	735
	21.0	21.7.2	A Convexity Adjustment	736
	21.8	Summa	•	737
	21.9	Exercise		738
	21.10		ix: Derivations	740
		21.10.1	Derivation of the Partial Differential Equation in the Forward	-
			Risk Neutral Dynamics	740

		21.10.2	21.10.2 Derivation of the Call Option Pricing Formula (Equations	
			21.11)	741
		21.10.3	Derivation of the Formula in Equations 21.27 and 21.31	742
		21.10.4	Derivation of the Formula in Equation 21.21	743
		21.10.5	Derivation of the Formula in Equation 21.37	743
22	MULTIFACTOR MODELS			745
	22.1	Multifactor Ito's Lemma with Independent Factors		745
	22.2	No Arbitrage with Independent Factors		747
		22.2.1	A Two-Factor Vasicek Model	748
		22.2.2	A Dynamic Model for the Short and Long Yield	750
		22.2.3	Long-Term Spot Rate Volatility	754
		22.2.4	Options on Zero Coupon Bonds	755
	22.3	Correlated Factors		757
		22.3.1	The Two-Factor Vasicek Model with Correlated Factors	760
		22.3.2	Zero Coupon Bond Options	762
		22.3.3	The Two-Factor Hull–White Model	764
	22.4	The Fey	nman-Kac Theorem	768
		22.4.1	Application: Yield Curve Steepener	768
		22.4.2	Simulating Correlated Brownian Motions	770
	22.5	Forward	Risk Neutral Pricing	771
		22.5.1	Application: Options on Coupon Bonds	773
	22.6	The Multifactor LIBOR Market Model		775
		22.6.1	Level, Slope, and Curvature Factors for Forward Rates	777
	22.7	Affine and Quadratic Term Structure Models		781
		22.7.1	Affine Models	781
		22.7.2	Quadratic Models	783
	22.8	Summary		785
	22.9	Exercises		785
	22.10	Appendix		787
			The Coefficients of the Joint Process for Short- and	
			Long-Term Rates	787
		22.10.2	The Two-Factor Hull-White Model	787
References				789
Index				797