

Contents

Preface	xiii
Acknowledgments	xv
Abbreviations	xvii
Notation	xix
1 Financial markets, prices and risk	1
1.1 Prices, returns and stock indices	2
1.1.1 Stock indices	2
1.1.2 Prices and returns	2
1.2 S&P 500 returns	5
1.2.1 S&P 500 statistics	6
1.2.2 S&P 500 statistics in R and Matlab	7
1.3 The stylized facts of financial returns	9
1.4 Volatility	9
1.4.1 Volatility clusters	11
1.4.2 Volatility clusters and the ACF	12
1.5 Nonnormality and fat tails	14
1.6 Identification of fat tails	16
1.6.1 Statistical tests for fat tails	16
1.6.2 Graphical methods for fat tail analysis	17
1.6.3 Implications of fat tails in finance	20
1.7 Nonlinear dependence	21
1.7.1 Sample evidence of nonlinear dependence	22
1.7.2 Exceedance correlations	23
1.8 Copulas	25
1.8.1 The Gaussian copula	25
1.8.2 The theory of copulas	25
1.8.3 An application of copulas	27
1.8.4 Some challenges in using copulas	28
1.9 Summary	29

2	Univariate volatility modeling	31
2.1	Modeling volatility	31
2.2	Simple volatility models	32
2.2.1	Moving average models	32
2.2.2	EWMA model	33
2.3	GARCH and conditional volatility	35
2.3.1	ARCH	36
2.3.2	GARCH	38
2.3.3	The “memory” of a GARCH model	39
2.3.4	Normal GARCH	40
2.3.5	Student- t GARCH	40
2.3.6	(G)ARCH in mean	41
2.4	Maximum likelihood estimation of volatility models	41
2.4.1	The ARCH(1) likelihood function	42
2.4.2	The GARCH(1,1) likelihood function	42
2.4.3	On the importance of σ_1	43
2.4.4	Issues in estimation	43
2.5	Diagnosing volatility models	44
2.5.1	Likelihood ratio tests and parameter significance	44
2.5.2	Analysis of model residuals	45
2.5.3	Statistical goodness-of-fit measures	45
2.6	Application of ARCH and GARCH	46
2.6.1	Estimation results	46
2.6.2	Likelihood ratio tests	47
2.6.3	Residual analysis	47
2.6.4	Graphical analysis	48
2.6.5	Implementation	48
2.7	Other GARCH-type models	51
2.7.1	Leverage effects and asymmetry	51
2.7.2	Power models	52
2.7.3	APARCH	52
2.7.4	Application of APARCH models	52
2.7.5	Estimation of APARCH	53
2.8	Alternative volatility models	54
2.8.1	Implied volatility	54
2.8.2	Realized volatility	55
2.8.3	Stochastic volatility	55
2.9	Summary	56
3	Multivariate volatility models	57
3.1	Multivariate volatility forecasting	57
3.1.1	Application	58
3.2	EWMA	59
3.3	Orthogonal GARCH	62
3.3.1	Orthogonalizing covariance	62
3.3.2	Implementation	62
3.3.3	Large-scale implementations	63

3.4	CCC and DCC models	63
3.4.1	Constant conditional correlations (CCC)	64
3.4.2	Dynamic conditional correlations (DCC)	64
3.4.3	Implementation	65
3.5	Estimation comparison	65
3.6	Multivariate extensions of GARCH	67
3.6.1	Numerical problems	69
3.6.2	The BEKK model	69
3.7	Summary	70
4	Risk measures	73
4.1	Defining and measuring risk	73
4.2	Volatility	75
4.3	Value-at-risk	76
4.3.1	Is VaR a negative or positive number?	77
4.3.2	The three steps in VaR calculations	78
4.3.3	Interpreting and analyzing VaR	78
4.3.4	VaR and normality	79
4.3.5	Sign of VaR	79
4.4	Issues in applying VaR	80
4.4.1	VaR is only a quantile	80
4.4.2	Coherence	81
4.4.3	Does VaR really violate subadditivity?	83
4.4.4	Manipulating VaR	84
4.5	Expected shortfall	85
4.6	Holding periods, scaling and the square root of time	89
4.6.1	Length of holding periods	89
4.6.2	Square-root-of-time scaling	90
4.7	Summary	90
5	Implementing risk forecasts	93
5.1	Application	93
5.2	Historical simulation	95
5.2.1	Expected shortfall estimation	97
5.2.2	Importance of window size	97
5.3	Risk measures and parametric methods	98
5.3.1	Deriving VaR	99
5.3.2	VaR when returns are normally distributed	101
5.3.3	VaR under the Student- <i>t</i> distribution	102
5.3.4	Expected shortfall under normality	103
5.4	What about expected returns?	104
5.5	VaR with time-dependent volatility	106
5.5.1	Moving average	106
5.5.2	EWMA	107
5.5.3	GARCH normal	108
5.5.4	Other GARCH models	109
5.6	Summary	109

6	Analytical value-at-risk for options and bonds	111
6.1	Bonds	112
6.1.1	Duration-normal VaR	112
6.1.2	Accuracy of duration-normal VaR	114
6.1.3	Convexity and VaR	114
6.2	Options	115
6.2.1	Implementation	117
6.2.2	Delta-normal VaR	119
6.2.3	Delta and gamma	120
6.3	Summary	120
7	Simulation methods for VaR for options and bonds	121
7.1	Pseudo random number generators	122
7.1.1	Linear congruential generators	122
7.1.2	Nonuniform RNGs and transformation methods	123
7.2	Simulation pricing	124
7.2.1	Bonds	125
7.2.2	Options	129
7.3	Simulation of VaR for one asset	132
7.3.1	Monte Carlo VaR with one basic asset	133
7.3.2	VaR of an option on a basic asset	134
7.3.3	Options and a stock	136
7.4	Simulation of portfolio VaR	137
7.4.1	Simulation of portfolio VaR for basic assets	137
7.4.2	Portfolio VaR for options	139
7.4.3	Richer versions	139
7.5	Issues in simulation estimation	140
7.5.1	The quality of the RNG	140
7.5.2	Number of simulations	140
7.6	Summary	142
8	Backtesting and stress testing	143
8.1	Backtesting	143
8.1.1	Market risk regulations	146
8.1.2	Estimation window length	146
8.1.3	Testing window length	147
8.1.4	Violation ratios	147
8.2	Backtesting the S&P 500	147
8.2.1	Analysis	150
8.3	Significance of backtests	153
8.3.1	Bernoulli coverage test	154
8.3.2	Testing the independence of violations	155
8.3.3	Testing VaR for the S&P 500	157
8.3.4	Joint test	159
8.3.5	Loss-function-based backtests	159
8.4	Expected shortfall backtesting	160
8.5	Problems with backtesting	162

8.6	Stress testing	163
8.6.1	Scenario analysis	163
8.6.2	Issues in scenario analysis	165
8.6.3	Scenario analysis and risk models	165
8.7	Summary	166
9	Extreme value theory	167
9.1	Extreme value theory	168
9.1.1	Types of tails	168
9.1.2	Generalized extreme value distribution	169
9.2	Asset returns and fat tails	170
9.3	Applying EVT	172
9.3.1	Generalized Pareto distribution	172
9.3.2	Hill method	173
9.3.3	Finding the threshold	174
9.3.4	Application to the S&P 500 index	175
9.4	Aggregation and convolution	176
9.5	Time dependence	179
9.5.1	Extremal index	179
9.5.2	Dependence in ARCH	180
9.5.3	When does dependence matter?	180
9.6	Summary	181
10	Endogenous risk	183
10.1	The Millennium Bridge	184
10.2	Implications for financial risk management	184
10.2.1	The 2007–2010 crisis	185
10.3	Endogenous market prices	188
10.4	Dual role of prices	190
10.4.1	Dynamic trading strategies	191
10.4.2	Delta hedging	192
10.4.3	Simulation of feedback	194
10.4.4	Endogenous risk and the 1987 crash	195
10.5	Summary	195
APPENDICES		
A	Financial time series	197
A.1	Random variables and probability density functions	197
A.1.1	Distributions and densities	197
A.1.2	Quantiles	198
A.1.3	The normal distribution	198
A.1.4	Joint distributions	200
A.1.5	Multivariate normal distribution	200
A.1.6	Conditional distribution	200

A.1.7	Independence	201
A.2	Expectations and variance	201
A.2.1	Properties of expectation and variance	202
A.2.2	Covariance and independence	203
A.3	Higher order moments	203
A.3.1	Skewness and kurtosis	204
A.4	Examples of distributions	206
A.4.1	Chi-squared (χ^2)	206
A.4.2	Student- t	206
A.4.3	Bernoulli and binomial distributions	208
A.5	Basic time series concepts	208
A.5.1	Autocovariances and autocorrelations	209
A.5.2	Stationarity	209
A.5.3	White noise	210
A.6	Simple time series models	210
A.6.1	The moving average model	210
A.6.2	The autoregressive model	211
A.6.3	ARMA model	212
A.6.4	Random walk	212
A.7	Statistical hypothesis testing	212
A.7.1	Central limit theorem	213
A.7.2	p -values	213
A.7.3	Type 1 and type 2 errors and the power of the test	214
A.7.4	Testing for normality	214
A.7.5	Graphical methods: QQ plots	215
A.7.6	Testing for autocorrelation	215
A.7.7	Engle LM test for volatility clusters	216
B	An introduction to R	217
B.1	Inputting data	217
B.2	Simple operations	219
B.2.1	Matrix computation	220
B.3	Distributions	222
B.3.1	Normality tests	223
B.4	Time series	224
B.5	Writing functions in R	225
B.5.1	Loops and repeats	226
B.6	Maximum likelihood estimation	228
B.7	Graphics	229
C	An introduction to Matlab	231
C.1	Inputting data	231
C.2	Simple operations	233
C.2.1	Matrix algebra	234
C.3	Distributions	235
C.3.1	Normality tests	237
C.4	Time series	237

C.5	Basic programming and M-files	238
C.5.1	Loops	239
C.6	Maximum likelihood	242
C.7	Graphics	243
D	Maximum likelihood	245
D.1	Likelihood functions	245
D.1.1	Normal likelihood functions	246
D.2	Optimizers	247
D.3	Issues in ML estimation	248
D.4	Information matrix	249
D.5	Properties of maximum likelihood estimators	250
D.6	Optimal testing procedures	250
D.6.1	Likelihood ratio test	251
D.6.2	Lagrange multiplier test	252
D.6.3	Wald test	253
Bibliography		255
Index		259

<http://www.pbookshop.com>

<http://www.pbookshop.com>