
Contents

Preface	vii
1 The Nature of Financial Data	1
1.1 Financial Time Series	5
1.1.1 Autocorrelations	7
1.1.2 Stationarity	7
1.1.3 Time Scales and Data Aggregation	8
1.2 Financial Assets and Markets	12
1.2.1 Markets and Regulatory Agencies	16
1.2.2 Interest	20
1.2.3 Returns on Assets	29
1.2.4 Stock Prices; Fair Market Value	32
1.2.5 Splits, Dividends, and Return of Capital	45
1.2.6 Indexes and “the Market”	48
1.2.7 Derivative Assets	63
1.2.8 Short Positions	65
1.2.9 Portfolios of Assets: Diversification and Hedging	66
1.3 Frequency Distributions of Returns	76
1.3.1 Location and Scale	79
1.3.2 Skewness	81
1.3.3 Kurtosis	81
1.3.4 Multivariate Data	82
1.3.5 The Normal Distribution	87
1.3.6 Q-Q Plots	91
1.3.7 Outliers	93
1.3.8 Other Statistical Measures	94
1.4 Volatility	98
1.4.1 The Time Series of Returns	99
1.4.2 Measuring Volatility: Historical and Implied	102
1.4.3 Volatility Indexes: The VIX	108
1.4.4 The Curve of Implied Volatility	112
1.4.5 Risk Assessment and Management	113
1.5 Market Dynamics	120
1.6 Stylized Facts about Financial Data	129
Notes and Further Reading	130
Exercises and Questions for Review	132

Appendix A1: Accessing and Analyzing Financial Data in R	139
A1.1 R Basics	140
A1.2 Data Repositories and Inputting Data into R	158
A1.3 Time Series and Financial Data in R	172
A1.4 Data Cleansing	183
Notes, Comments, and Further Reading on R	187
Exercises in R	191
2 Exploratory Financial Data Analysis	205
2.1 Data Reduction	207
2.1.1 Simple Summary Statistics	207
2.1.2 Centering and Standardizing Data	208
2.1.3 Simple Summary Statistics for Multivariate Data	208
2.1.4 Transformations	209
2.1.5 Identifying Outlying Observations	210
2.2 The Empirical Cumulative Distribution Function	211
2.3 Nonparametric Probability Density Estimation	217
2.3.1 Binned Data	217
2.3.2 Kernel Density Estimator	219
2.3.3 Multivariate Kernel Density Estimator	220
2.4 Graphical Methods in Exploratory Analysis	221
2.4.1 Time Series Plots	222
2.4.2 Histograms	222
2.4.3 Boxplots	224
2.4.4 Density Plots	226
2.4.5 Bivariate Data	227
2.4.6 Q-Q Plots	229
2.4.7 Graphics in R	234
Notes and Further Reading	238
Exercises	239
3 Probability Distributions in Models of Observable Events	245
3.1 Random Variables and Probability Distributions	247
3.1.1 Discrete Random Variables	248
3.1.2 Continuous Random Variables	252
3.1.3 Linear Combinations of Random Variables; Expectations and Quantiles	256
3.1.4 Survival and Hazard Functions	257
3.1.5 Multivariate Distributions	258
3.1.6 Measures of Association in Multivariate Distributions	261
3.1.7 Copulas	264
3.1.8 Transformations of Multivariate Random Variables . .	267
3.1.9 Distributions of Order Statistics	269
3.1.10 Asymptotic Distributions; The Central Limit Theorem	270
3.1.11 The Tails of Probability Distributions	273

3.1.12	Sequences of Random Variables; Stochastic Processes	278
3.1.13	Diffusion of Stock Prices and Pricing of Options	279
3.2	Some Useful Probability Distributions	282
3.2.1	Discrete Distributions	283
3.2.2	Continuous Distributions	285
3.2.3	Multivariate Distributions	294
3.2.4	General Families of Distributions Useful in Modeling .	295
3.2.5	Constructing Multivariate Distributions	309
3.2.6	Modeling of Data-Generating Processes	311
3.2.7	R Functions for Probability Distributions	311
3.3	Simulating Observations of a Random Variable	314
3.3.1	Uniform Random Numbers	315
3.3.2	Generating Nonuniform Random Numbers	317
3.3.3	Simulating Data in R	321
	Notes and Further Reading	323
	Exercises	325
4	Statistical Models and Methods of Inference	335
4.1	Models	336
4.1.1	Fitting Statistical Models	340
4.1.2	Measuring and Partitioning Observed Variation	340
4.1.3	Linear Models	343
4.1.4	Nonlinear Variance-Stabilizing Transformations	344
4.1.5	Parametric and Nonparametric Models	345
4.1.6	Bayesian Models	346
4.1.7	Models for Time Series	346
4.2	Criteria and Methods for Statistical Modeling	347
4.2.1	Estimators and Their Properties	347
4.2.2	Methods of Statistical Modeling	349
4.3	Optimization in Statistical Modeling; Least Squares and Maximum Likelihood	358
4.3.1	The General Optimization Problem	358
4.3.2	Least Squares	363
4.3.3	Maximum Likelihood	371
4.3.4	R Functions for Optimization	375
4.4	Statistical Inference	376
4.4.1	Confidence Intervals	379
4.4.2	Testing Statistical Hypotheses	381
4.4.3	Prediction	385
4.4.4	Inference in Bayesian Models	386
4.4.5	Resampling Methods; The Bootstrap	393
4.4.6	Robust Statistical Methods	396
4.4.7	Estimation of the Tail Index	399
4.4.8	Estimation of VaR and Expected Shortfall	404
4.5	Models of Relationships among Variables	408

4.5.1	Principal Components	409
4.5.2	Regression Models	413
4.5.3	Linear Regression Models	418
4.5.4	Linear Regression Models: The Regressors	422
4.5.5	Linear Regression Models: Individual Observations and Residuals	428
4.5.6	Linear Regression Models: An Example	435
4.5.7	Nonlinear Models	449
4.5.8	Specifying Models in R	454
4.6	Assessing the Adequacy of Models	455
4.6.1	Goodness-of-Fit Tests; Tests for Normality	456
4.6.2	Cross-Validation	463
4.6.3	Model Selection and Model Complexity	467
	Notes and Further Reading	469
	Exercises	472
5	Discrete Time Series Models and Analysis	487
5.1	Basic Linear Operations	495
5.1.1	The Backshift Operator	495
5.1.2	The Difference Operator	497
5.1.3	The Integration Operator	500
5.1.4	Summation of an Infinite Geometric Series	500
5.1.5	Linear Difference Equations	501
5.1.6	Trends and Detrending	505
5.1.7	Cycles and Seasonal Adjustment	508
5.2	Analysis of Discrete Time Series Models	510
5.2.1	Stationarity	514
5.2.2	Sample Autocovariance and Autocorrelation Functions; Stationarity and Estimation	518
5.2.3	Statistical Inference in Stationary Time Series	523
5.3	Autoregressive and Moving Average Models	528
5.3.1	Moving Average Models; $MA(q)$	529
5.3.2	Autoregressive Models; $AR(p)$	534
5.3.3	The Partial Autocorrelation Function, PACF	547
5.3.4	ARMA and ARIMA Models	549
5.3.5	Simulation of ARMA and ARIMA Models	555
5.3.6	Statistical Inference in ARMA and ARIMA Models	556
5.3.7	Selection of Orders in ARIMA Models	560
5.3.8	Forecasting in ARIMA Models	561
5.3.9	Analysis of ARMA and ARIMA Models in R	561
5.3.10	Robustness of ARMA Procedures; Innovations with Heavy Tails	566
5.3.11	Financial Data	568
5.3.12	Linear Regression with ARMA Errors	571
5.4	Conditional Heteroscedasticity	575

<i>Contents</i>	xix
5.4.1 ARCH Models	576
5.4.2 GARCH Models and Extensions	580
5.5 Unit Roots and Cointegration	584
5.5.1 Spurious Correlations; The Distribution of the Correlation Coefficient	584
5.5.2 Unit Roots	592
5.5.3 Cointegrated Processes	599
Notes and Further Reading	603
Exercises	604
References	615
Index	623