

# CONTENTS

CHAPTER 1 INTRODUCTION .....	1
1.1 Examples of Time Series .....	1
1.2 A Model-Building Strategy .....	8
1.3 Time Series Plots in History .....	8
1.4 An Overview of the Book .....	9
Exercises .....	10
CHAPTER 2 FUNDAMENTAL CONCEPTS .....	11
2.1 Time Series and Stochastic Processes .....	11
2.2 Means, Variances, and Covariances .....	11
2.3 Stationarity .....	16
2.4 Summary .....	19
Exercises .....	19
Appendix A: Expectation, Variance, Covariance, and Correlation ..	24
CHAPTER 3 TRENDS .....	27
3.1 Deterministic Versus Stochastic Trends .....	27
3.2 Estimation of a Constant Mean .....	28
3.3 Regression Methods .....	30
3.4 Reliability and Efficiency of Regression Estimates .....	36
3.5 Interpreting Regression Output .....	40
3.6 Residual Analysis .....	42
3.7 Summary .....	50
Exercises .....	50
CHAPTER 4 MODELS FOR STATIONARY TIME SERIES .....	55
4.1 General Linear Processes .....	55
4.2 Moving Average Processes .....	57
4.3 Autoregressive Processes .....	66
4.4 The Mixed Autoregressive Moving Average Model .....	77
4.5 Invertibility .....	79
4.6 Summary .....	80
Exercises .....	81
Appendix B: The Stationarity Region for an AR(2) Process .....	84
Appendix C: The Autocorrelation Function for ARMA( $p,q$ ) .....	85

<b>CHAPTER 5 MODELS FOR NONSTATIONARY TIME SERIES</b>	<b>87</b>
5.1 Stationarity Through Differencing	88
5.2 ARIMA Models	92
5.3 Constant Terms in ARIMA Models	97
5.4 Other Transformations	98
5.5 Summary	102
Exercises	103
Appendix D: The Backshift Operator	106
<b>CHAPTER 6 MODEL SPECIFICATION</b>	<b>109</b>
6.1 Properties of the Sample Autocorrelation Function	109
6.2 The Partial and Extended Autocorrelation Functions	112
6.3 Specification of Some Simulated Time Series	117
6.4 Nonstationarity	125
6.5 Other Specification Methods	130
6.6 Specification of Some Actual Time Series	133
6.7 Summary	141
Exercises	141
<b>CHAPTER 7 PARAMETER ESTIMATION</b>	<b>149</b>
7.1 The Method of Moments	149
7.2 Least Squares Estimation	154
7.3 Maximum Likelihood and Unconditional Least Squares	158
7.4 Properties of the Estimates	160
7.5 Illustrations of Parameter Estimation	163
7.6 Bootstrapping ARIMA Models	167
7.7 Summary	170
Exercises	170
<b>CHAPTER 8 MODEL DIAGNOSTICS</b>	<b>175</b>
8.1 Residual Analysis	175
8.2 Overfitting and Parameter Redundancy	185
8.3 Summary	188
Exercises	188

- CHAPTER 9 FORECASTING..... 191
  - 9.1 Minimum Mean Square Error Forecasting ..... 191
  - 9.2 Deterministic Trends..... 191
  - 9.3 ARIMA Forecasting ..... 193
  - 9.4 Prediction Limits..... 203
  - 9.5 Forecasting Illustrations ..... 204
  - 9.6 Updating ARIMA Forecasts ..... 207
  - 9.7 Forecast Weights and Exponentially Weighted Moving Averages ..... 207
  - 9.8 Forecasting Transformed Series..... 209
  - 9.9 Summary of Forecasting with Certain ARIMA Models ... 211
  - 9.10 Summary ..... 213
  - Exercises ..... 213
  - Appendix E: Conditional Expectation..... 218
  - Appendix F: Minimum Mean Square Error Prediction ..... 218
  - Appendix G: The Truncated Linear Process ..... 221
  - Appendix H: State Space Models ..... 222
  
- CHAPTER 10 SEASONAL MODELS..... 227
  - 10.1 Seasonal ARIMA Models ..... 228
  - 10.2 Multiplicative Seasonal ARMA Models..... 230
  - 10.3 Nonstationary Seasonal ARIMA Models ..... 233
  - 10.4 Model Specification, Fitting, and Checking..... 234
  - 10.5 Forecasting Seasonal Models ..... 241
  - 10.6 Summary ..... 246
  - Exercises ..... 246
  
- CHAPTER 11 TIME SERIES REGRESSION MODELS ..... 249
  - 11.1 Intervention Analysis ..... 249
  - 11.2 Outliers..... 257
  - 11.3 Spurious Correlation..... 260
  - 11.4 Prewhitening and Stochastic Regression..... 265
  - 11.5 Summary ..... 273
  - Exercises ..... 274

<b>CHAPTER 12 TIME SERIES MODELS OF HETEROSCEDASTICITY</b> . . . . .	<b>277</b>
12.1 Some Common Features of Financial Time Series . . . . .	278
12.2 The ARCH(1) Model . . . . .	285
12.3 GARCH Models . . . . .	289
12.4 Maximum Likelihood Estimation . . . . .	298
12.5 Model Diagnostics . . . . .	301
12.6 Conditions for the Nonnegativity of the Conditional Variances . . . . .	307
12.7 Some Extensions of the GARCH Model . . . . .	310
12.8 Another Example: The Daily USD/HKD Exchange Rates . . . . .	311
12.9 Summary . . . . .	315
Exercises . . . . .	316
Appendix I: Formulas for the Generalized Portmanteau Tests . . . . .	318
<b>CHAPTER 13 INTRODUCTION TO SPECTRAL ANALYSIS</b> . . . . .	<b>319</b>
13.1 Introduction . . . . .	319
13.2 The Periodogram . . . . .	322
13.3 The Spectral Representation and Spectral Distribution . . . . .	327
13.4 The Spectral Density . . . . .	330
13.5 Spectral Densities for ARMA Processes . . . . .	332
13.6 Sampling Properties of the Sample Spectral Density . . . . .	340
13.7 Summary . . . . .	346
Exercises . . . . .	346
Appendix J: Orthogonality of Cosine and Sine Sequences . . . . .	349
<b>CHAPTER 14 ESTIMATING THE SPECTRUM</b> . . . . .	<b>351</b>
14.1 Smoothing the Spectral Density . . . . .	351
14.2 Bias and Variance . . . . .	354
14.3 Bandwidth . . . . .	355
14.4 Confidence Intervals for the Spectrum . . . . .	356
14.5 Leakage and Tapering . . . . .	358
14.6 Autoregressive Spectrum Estimation . . . . .	363
14.7 Examples with Simulated Data . . . . .	364
14.8 Examples with Actual Data . . . . .	370
14.9 Other Methods of Spectral Estimation . . . . .	376
14.10 Summary . . . . .	378
Exercises . . . . .	378
Appendix K: Tapering and the Dirichlet Kernel . . . . .	381

<b>CHAPTER 15 THRESHOLD MODELS</b> .....	<b>383</b>
15.1 Graphically Exploring Nonlinearity .....	384
15.2 Tests for Nonlinearity .....	390
15.3 Polynomial Models Are Generally Explosive .....	393
15.4 First-Order Threshold Autoregressive Models .....	395
15.5 Threshold Models .....	399
15.6 Testing for Threshold Nonlinearity .....	400
15.7 Estimation of a TAR Model .....	402
15.8 Model Diagnostics .....	411
15.9 Prediction .....	415
15.10 Summary .....	420
Exercises .....	420
Appendix L: The Generalized Portmanteau Test for TAR .....	421
<b>APPENDIX: AN INTRODUCTION TO R</b> .....	<b>423</b>
Introduction .....	423
Chapter 1 R Commands .....	429
Chapter 2 R Commands .....	433
Chapter 3 R Commands .....	433
Chapter 4 R Commands .....	438
Chapter 5 R Commands .....	439
Chapter 6 R Commands .....	441
Chapter 7 R Commands .....	442
Chapter 8 R Commands .....	446
Chapter 9 R Commands .....	447
Chapter 10 R Commands .....	450
Chapter 11 R Commands .....	451
Chapter 12 R Commands .....	457
Chapter 13 R Commands .....	460
Chapter 14 R Commands .....	461
Chapter 15 R Commands .....	462
New or Enhanced Functions in the TSA Library .....	468
<b>DATASET INFORMATION</b> .....	<b>471</b>
<b>BIBLIOGRAPHY</b> .....	<b>477</b>
<b>INDEX</b> .....	<b>487</b>