

CONTENTS

Preface

xi

1	<i>TIME SERIES DATA: EXAMPLES AND BASIC CONCEPTS</i>	1
1.1	Introduction	1
1.2	Examples of Time Series Data	1
1.3	Understanding Autocorrelation	10
1.4	The Wold Decomposition	12
1.5	The Impulse Response Function	14
1.6	Superposition Principle	15
1.7	Parsimonious Models	18
	Exercises	19
2	<i>VISUALIZING TIME SERIES DATA STRUCTURES: GRAPHICAL TOOLS</i>	21
2.1	Introduction	21
2.2	Graphical Analysis of Time Series	22
2.3	Graph Terminology	23
2.4	Graphical Perception	24
2.5	Principles of Graph Construction	28
2.6	Aspect Ratio	30
2.7	Time Series Plots	34
2.8	Bad Graphics	38
	Exercises	46
3	<i>STATIONARY MODELS</i>	47
3.1	Basics of Stationary Time Series Models	47
3.2	Autoregressive Moving Average (ARMA) Models	54
3.3	Stationarity and Invertibility of ARMA Models	62
3.4	Checking for Stationarity using Variogram	66
3.5	Transformation of Data	69
	Exercises	73
4	<i>NONSTATIONARY MODELS</i>	79
4.1	Introduction	79
4.2	Detecting Nonstationarity	79
4.3	Autoregressive Integrated Moving Average (ARIMA) Models	83
4.4	Forecasting using ARIMA Models	91
4.5	Example 2: Concentration Measurements from a Chemical Process	93

4.6	The EWMA Forecast Exercises	103 104
5	SEASONAL MODELS	111
5.1	Seasonal Data	111
5.2	Seasonal ARIMA Models	116
5.3	Forecasting using Seasonal ARIMA Models	124
5.4	Example 2: Company X's Sales Data Exercises	126 152
6	TIME SERIES MODEL SELECTION	155
6.1	Introduction	155
6.2	Finding the "BEST" Model	155
6.3	Example: Internet Users Data	156
6.4	Model Selection Criteria	163
6.5	Impulse Response Function to Study the Differences in Models	166
6.6	Comparing Impulse Response Functions for Competing Models	169
6.7	ARIMA Models as Rational Approximations	170
6.8	AR Versus Arma Controversy	171
6.9	Final Thoughts on Model Selection	173
	Appendix 6.1: How to Compute Impulse Response Functions with a Spreadsheet Exercises	173 174
7	ADDITIONAL ISSUES IN ARIMA MODELS	177
7.1	Introduction	177
7.2	Linear Difference Equations	177
7.3	Eventual Forecast Function	183
7.4	Deterministic Trend Models	187
7.5	Yet Another Argument for Differencing	189
7.6	Constant Term in ARIMA Models	190
7.7	Cancellation of Terms in ARIMA Models	191
7.8	Stochastic Trend: Unit Root Nonstationary Processes	194
7.9	Overdifferencing and Underdifferencing	195
7.10	Missing Values in Time Series Data Exercises	197 201
8	TRANSFER FUNCTION MODELS	203
8.1	Introduction	203
8.2	Studying Input-Output Relationships	203
8.3	Example 1: The Box-Jenkins' Gas Furnace	204
8.4	Spurious Cross Correlations	207
8.5	Prewhitening	207
8.6	Identification of the Transfer Function	213
8.7	Modeling the Noise	215
8.8	The General Methodology for Transfer Function Models	222

8.9	Forecasting Using Transfer Function-Noise Models	224
8.10	Intervention Analysis Exercises	238 261

9 ADDITIONAL TOPICS 263

9.1	Spurious Relationships	263
9.2	Autocorrelation in Regression	271
9.3	Process Regime Changes	278
9.4	Analysis of Multiple Time Series	285
9.5	Structural Analysis of Multiple Time Series Exercises	296 310

Appendix A DATASETS USED IN THE EXAMPLES 311

Table A.1	Temperature Readings from a Ceramic Furnace	312
Table A.2	Chemical Process Temperature Readings	313
Table A.3	Chemical Process Concentration Readings	314
Table A.4	International Airline Passengers	315
Table A.5	Company X's Sales Data	316
Table A.6	Internet Users Data	317
Table A.7	Historical Sea Level (mm) Data in Copenhagen, Denmark	317
Table A.8	Gas Furnace Data	318
Table A.9	Sales with Leading Indicator	319
Table A.10	Crest/Colgate Market Share	320
Table A.11	Simulated Process Data	322
Table A.12	Coen <i>et al.</i> (1969) Data	323
Table A.13	Temperature Data from a Ceramic Furnace	324
Table A.14	Temperature Readings from an Industrial Process	325
Table A.15	US Hog Series	326

Appendix B DATASETS USED IN THE EXERCISES 327

Table B.1	Beverage Amount (ml)	328
Table B.2	Pressure of the Steam Fed to a Distillation Column (bar)	329
Table B.3	Number of Paper Checks Processed in a Local Bank	330
Table B.4	Monthly Sea Levels in Los Angeles, California (mm)	331
Table B.5	Temperature Readings from a Chemical Process (°C)	334
Table B.6	Daily Average Exchange Rates between US Dollar and Euro	335
Table B.7	Monthly US Unemployment Rates	336
Table B.8	Monthly Residential Electricity Sales (MWh) and Average Residential Electricity Retail Price (c/kWh) in the United States	337
Table B.9	Monthly Outstanding Consumer Credits Provided by Commercial Banks in the United States (million USD)	340
Table B.10	100 Observations Simulated from an ARMA (1, 1) Process	342
Table B.11	Quarterly Rental Vacancy Rates in the United States	343
Table B.12	Wölfer Sunspot Numbers	344
Table B.13	Viscosity Readings from a Chemical Process	345
Table B.14	UK Midyear Population	346
Table B.15	Unemployment and GDP data for the United Kingdom	347

X CONTENTS

Table B.16	Monthly Crude Oil Production of OPEC Nations	348
Table B.17	Quarterly Dollar Sales of Marshall Field & Company (\$1000)	360
<i>Bibliography</i>		361
<i>Index</i>		365