
Contents

Preface to the Fourth Edition	v
Preface to the Third Edition	vii
1 Characteristics of Time Series	1
1.1 The Nature of Time Series Data	2
1.2 Time Series Statistical Models	8
1.3 Measures of Dependence	15
1.4 Stationary Time Series	19
1.5 Estimation of Correlation	26
1.6 Vector-Valued and Multidimensional Series	33
Problems	38
2 Time Series Regression and Exploratory Data Analysis	45
2.1 Classical Regression in the Time Series Context	45
2.2 Exploratory Data Analysis	54
2.3 Smoothing in the Time Series Context	65
Problems	70
3 ARIMA Models	75
3.1 Autoregressive Moving Average Models	75
3.2 Difference Equations	88
3.3 Autocorrelation and Partial Autocorrelation	94
3.4 Forecasting	100
3.5 Estimation	113
3.6 Integrated Models for Nonstationary Data	131
3.7 Building ARIMA Models	135
3.8 Regression with Autocorrelated Errors	142
3.9 Multiplicative Seasonal ARIMA Models	145
Problems	154

4	Spectral Analysis and Filtering	165
4.1	Cyclical Behavior and Periodicity	166
4.2	The Spectral Density	172
4.3	Periodogram and Discrete Fourier Transform	179
4.4	Nonparametric Spectral Estimation	189
4.5	Parametric Spectral Estimation	203
4.6	Multiple Series and Cross-Spectra	206
4.7	Linear Filters	211
4.8	Lagged Regression Models	217
4.9	Signal Extraction and Optimum Filtering	222
4.10	Spectral Analysis of Multidimensional Series	226
	Problems	229
5	Additional Time Domain Topics	241
5.1	Long Memory ARMA and Fractional Differencing	241
5.2	Unit Root Testing	250
5.3	GARCH Models	253
5.4	Threshold Models	262
5.5	Lagged Regression and Transfer Function Modeling	266
5.6	Multivariate ARMAX Models	272
	Problems	285
6	State Space Models	289
6.1	Linear Gaussian Model	290
6.2	Filtering, Smoothing, and Forecasting	294
6.3	Maximum Likelihood Estimation	304
6.4	Missing Data Modifications	313
6.5	Structural Models: Signal Extraction and Forecasting	318
6.6	State-Space Models with Correlated Errors	321
6.6.1	ARMAX Models	323
6.6.2	Multivariate Regression with Autocorrelated Errors	324
6.7	Bootstrapping State Space Models	328
6.8	Smoothing Splines and the Kalman Smoother	333
6.9	Hidden Markov Models and Switching Autoregression	336
6.10	Dynamic Linear Models with Switching	348
6.11	Stochastic Volatility	360
6.12	Bayesian Analysis of State Space Models	367
	Problems	378
7	Statistical Methods in the Frequency Domain	385
7.1	Introduction	385
7.2	Spectral Matrices and Likelihood Functions	388
7.3	Regression for Jointly Stationary Series	390
7.4	Regression with Deterministic Inputs	399
7.5	Random Coefficient Regression	407

7.6	Analysis of Designed Experiments	409
7.7	Discriminant and Cluster Analysis	423
7.8	Principal Components and Factor Analysis	439
7.9	The Spectral Envelope	455
	Problems	466
Appendix A Large Sample Theory		473
A.1	Convergence Modes	473
A.2	Central Limit Theorems	480
A.3	The Mean and Autocorrelation Functions	484
Appendix B Time Domain Theory		493
B.1	Hilbert Spaces and the Projection Theorem	493
B.2	Causal Conditions for ARMA Models	497
B.3	Large Sample Distribution of the AR Conditional Least Squares Estimators	499
B.4	The Wold Decomposition	502
Appendix C Spectral Domain Theory		505
C.1	Spectral Representation Theorems	505
C.2	Large Sample Distribution of the Smoothed Periodogram	509
C.3	The Complex Multivariate Normal Distribution	519
C.4	Integration	524
	C.4.1 Riemann–Stieltjes Integration	524
	C.4.2 Stochastic Integration	526
C.5	Spectral Analysis as Principal Component Analysis	528
C.6	Parametric Spectral Estimation	531
Appendix R R Supplement		533
R.1	First Things First	533
R.2	astsa	533
R.3	Getting Started	534
R.4	Time Series Primer	538
	R.4.1 Graphics	541
References		545
Index		557