



SAS® for Forecasting Time Series, Third Edition. Full book available for purchase [here](#).

Contents

About This Book	ix
About The Authors	xi
Acknowledgments	xiii
Chapter 1: Overview of Time Series	1
1.1 Introduction.....	1
1.2 Analysis Methods and SAS/ETS Software.....	2
1.2.1 Options.....	2
1.2.2 How SAS/ETS Procedures Interrelate	3
1.3 Simple Models: Regression.....	5
1.3.1 Linear Regression	5
1.3.2 Highly Regular Seasonality	11
1.3.3 Regression with Transformed Data	17
Chapter 2: Simple Models: Autoregression.....	23
2.1 Introduction.....	23
2.1.1 Terminology and Notation.....	23
2.1.2 Statistical Background	23
2.2 Forecasting	24
2.2.1 PROC ARIMA for Forecasting.....	25
2.2.2 Backshift Notation B for Time Series	32
2.2.3 Yule-Walker Equations for Covariances.....	33
2.3 Fitting an AR Model in PROC REG.....	37
Chapter 3: The General ARIMA Model	41
3.1 Introduction.....	41
3.1.1 Statistical Background	41
3.1.2 Terminology and Notation.....	41
3.2 Prediction	42
3.2.1 One-Step-Ahead Predictions.....	42
3.2.2 Future Predictions	43
3.3 Model Identification.....	46
3.3.1 Stationarity and Invertibility	46
3.3.2 Time Series Identification	47
3.3.3 Chi-Square Check of Residuals	56
3.3.4 Summary of Model Identification	56
3.4 Examples and Instructions	56
3.4.1 IDENTIFY Statement for Series 1-8.....	57
3.4.2 Example: Iron and Steel Export Analysis.....	65

3.4.3 Estimation Methods Used in PROC ARIMA.....	70
3.4.4 ESTIMATE Statement for Series 8-A	72
3.4.5 Nonstationary Series.....	77
3.4.6 Effect of Differencing on Forecasts.....	78
3.4.7 Examples: Forecasting IBM Series and Silver Series	80
3.4.8 Models for Nonstationary Data	84
3.4.9 Differencing to Remove a Linear Trend	91
3.4.10 Other Identification Techniques.....	95
3.5 Summary of Steps for Analyzing Nonseasonal Univariate Series	104
Chapter 4: The ARIMA Model: Introductory Applications	107
4.1 Seasonal Time Series	107
4.1.1 Introduction to Seasonal Modeling	107
4.1.2 Model Identification.....	108
4.2 Models with Explanatory Variables	119
4.2.1 Case 1: Regression with Time Series Errors	120
4.2.2 Case 1A: Intervention.....	120
4.2.3 Case 2: Simple Transfer Functions.....	121
4.2.4 Case 3: General Transfer Functions	121
4.2.5 Case 3A: Leading Indicators	121
4.2.6 Case 3B: Intervention.....	121
4.3 Methodology and Example	122
4.3.1 Case 1: Regression with Time Series Errors	122
4.3.2 Case 2: Simple Transfer Functions.....	131
4.3.3 Case 3: General Transfer Functions	133
4.3.4 Case 3B: Intervention.....	155
4.4 Further Example	161
4.4.1 North Carolina Retail Sales	161
4.4.2 Construction Series Revisited.....	168
4.4.3 Milk Scare (Intervention).....	172
4.4.4 Terrorist Attack.....	175
Chapter 5: The ARIMA Model: Special Applications.....	177
5.1 Regression with Time Series Errors and Unequal Variances.....	177
5.1.1 Autoregressive Errors	177
5.1.2 Example: Energy Demand at a University.....	178
5.1.3 Unequal Variances.....	182
5.1.4 ARCH, GARCH, and IGARCH for Unequal Variances	184
5.2 Cointegration.....	189
5.2.1 Cointegration and Eigenvalues	191
5.2.2 Impulse Response Function.....	192
5.2.3 Roots in Higher-Order Models	192
5.2.4 Cointegration and Unit Roots.....	194
5.2.5 An Illustrative Example	196
5.2.6 Estimation of the Cointegrating Vector.....	199
5.2.7 Intercepts and More Lags	201
5.2.8 PROC VARMAX.....	202

5.2.9 Interpretation of the Estimates.....	205
5.2.10 Diagnostics and Forecasts	206
Chapter 6: Exponential Smoothing	209
6.1 Single Exponential Smoothing	209
6.1.1 The Smoothing Idea.....	209
6.1.2 Forecasting with Single Exponential Smoothing.....	210
6.1.3 Alternative Representations	210
6.1.4 Atlantic Ocean Tides: An Example	211
6.1.5 Improving the Tide Forecasts.....	213
6.2 Exponential Smoothing for Trending Data	216
6.2.1 Linear and Double Exponential Smoothing.....	216
6.2.2 Properties of the Forecasts	217
6.2.3 A Generated Multi-Series Example	217
6.2.4 Real Data Examples.....	219
6.2.5 Boundary Values in Linear Exponential Smoothing	222
6.2.6 Damped Trend Exponential Smoothing.....	228
6.2.7 Diagnostic Plots	229
6.2.8 Sums of Forecasts	231
6.3 Smoothing Seasonal Data	232
6.3.1 Seasonal Exponential Smoothing	232
6.3.2 Winters Method.....	234
6.4.1 Validation	236
6.4.2 Choosing a Model Visually.....	237
6.4.3 Choosing a Model Numerically.....	239
6.5 Advantages of Exponential Smoothing	240
6.6 How the Smoothing Equations Lead to ARIMA in the Linear Case	240
Chapter 7: Unobserved Components and State Space Models	243
7.1 Nonseasonal Unobserved Components Models.....	243
7.1.1 The Nature of Unobserved Components Models	243
7.1.2 A Look at the PROC UCM Output	246
7.1.3 A Note on Unit Roots in Practice	247
7.1.4 The Basic Structural Model Related to ARIMA Structures.....	247
7.1.5 A Follow-Up on the Example	249
7.2 Diffuse Likelihood and Kalman Filter: Overview and a Simple Case	250
7.2.1 Diffuse Likelihood in a Simple Model.....	251
7.2.2 Definition of a Diffuse Likelihood	251
7.2.3 A Numerical Example	252
7.3 Seasonality in Unobserved Components Models	254
7.3.1 Description of Seasonal Recursions.....	254
7.3.2 Tourism Example with Regular Seasonality.....	254
7.3.3 Decomposition	257
7.3.4 Another Seasonal Model: Sine and Cosine Terms	258
7.3.5 Example with Trigonometric Components.....	259
7.3.6 The Seasonal Component Made Local and Damped.....	261

7.4 A Brief Introduction to the SSM Procedure.....	265
7.4.1 Brief Overview.....	265
7.4.2 Simple Examples	265
7.4.3 Extensions of the AR(1) Model.....	266
7.4.4 Accommodation for Curvature	267
7.4.5 Models with Several Lags.....	270
7.4.6 Bivariate Examples.....	273
7.4.7 The Start-up Problem Revisited.....	274
7.4.8 Example and More Details on the State Space Approach	276
Chapter 8: Adjustment for Seasonality with PROC X13	285
8.1 Introduction	285
8.2 The X-11 Method.....	287
8.2.1 Moving Averages	287
8.2.2 Outline of the X-11 Method	290
8.2.3 Basic Seasonal Adjustment Using the X-11 Method	291
8.2.4 Tests for Seasonality.....	292
8.3 regARIMA Models and TRAMO	295
8.3.1 regARIMA Models.....	295
8.3.2 Automatic Selection of ARIMA Orders.....	296
8.4 Data Examples	296
8.4.1 Airline Passengers Revisited.....	296
8.4.3 Employment in the United States	299
Chapter 9: SAS Forecast Studio	305
9.1 Introduction	305
9.2 Creating a Project.....	305
9.3 Overview of Available Modes.....	310
9.4 Project Settings.....	312
9.4.1 Model Generation	312
9.4.2 Goodness of Fit and Honest Assessment.....	313
9.4.2 Transformation and Outlier Detection	314
9.5 Creating Custom Events	318
9.6 Hierarchical Time Series and Reconciliation	320
Chapter 10: Spectral Analysis	333
10.1 Introduction	333
10.2 Example: Plant Enzyme Activity	334
10.3 PROC SPECTRA.....	335
10.4 Tests for White Noise	337
10.5 Harmonic Frequencies	338
10.6 Extremely Fast Fluctuations and Aliasing	342
10.7 The Spectral Density.....	342
10.8 Some Mathematical Detail (Optional Reading).....	345
10.9 Estimation of the Spectrum: The Smoothed Periodogram	345

10.10 Cross-Spectral Analysis	346
10.10.1 Interpretation of Cross-Spectral Quantities.....	346
10.10.2 Interpretation of Cross-Amplitude and Phase Spectra	348
10.10.3 PROC SPECTRA Statements	349
10.10.4 Cross-Spectral Analysis of the Neuse River Data	352
10.10.5 Details on Gain, Phase, and Pure Delay	354
References	359
Index	363