

PATRICIA E. GAYNOR ▲ RICKEY C. KIRKPATRICK

Ex Ante

INTRODUCTION TO

TIME-SERIES
MODELING
AND
FORECASTING
IN
BUSINESS
AND
ECONOMICS

INTRODUCTION TO TIME-SERIES MODELING AND FORECASTING IN BUSINESS AND ECONOMICS

Patricia E. Gaynor
Rickey C. Kirkpatrick

Appalachian State University

McGraw-Hill, Inc.

New York St. Louis San Francisco Auckland Bogotá Caracas
Lisbon London Madrid Mexico City Milan Montreal New Delhi
San Juan Singapore Sydney Tokyo Toronto

This book was set in Times Roman by Science Typographers, Inc.
The editors were Lynn Richardson and Dan Alpert;
the production supervisor was Annette Mayeski.
The cover was designed by John Hite.
Project supervision was done by Science Typographers, Inc.
R. R. Donnelley & Sons Company was printer and binder.

**INTRODUCTION TO TIME-SERIES MODELING AND
FORECASTING IN BUSINESS AND ECONOMICS**

Copyright © 1994 by McGraw-Hill, Inc. All rights reserved.
Printed in the United States of America. Except as permitted under the
United States Copyright Act of 1976, no part of this publication may be
reproduced or distributed in any form or by any means, or stored in a data
base or retrieval system, without prior written permission of the
publisher.



This book is printed on recycled, acid-free paper containing a minimum of
50% total recycled fiber with 10% postconsumer de-inked fiber.

1 2 3 4 5 6 7 8 9 0 D O H D O H 9 0 9 8 7 6 5 4 3

ISBN 0-07-034913-4

Library of Congress Catalog Card Number: 93-86478

**INTRODUCTION TO TIME-SERIES MODELING AND
FORECASTING IN BUSINESS AND ECONOMICS**

ABOUT THE AUTHORS

Patricia E. Gaynor is a Professor of Statistics in the Economics Department at Appalachian State University. She received her MA and Ph.D. from the University of Miami, where she was elected to Pi Mu Epsilon (National Honorary Mathematics Fraternity) and Phi Kappa Phi (Scholastic Honor Society). In addition to teaching, Professor Gaynor served, for seven years, as Assistant Director of the Computer Center and Manager of Academic and Institutional Research. In 1979–1981 she served as a Statistician/Computer Specialist for a HUD Section 8 Evaluation Research Project. She has authored and co-authored many publications in journals and proceedings. Professor Gaynor is a member of the American Statistical Association and CSWEP (Committee on the Status of Women in the Economic Profession).

Rickey C. Kirkpatrick is a graduate of Tulane University with a Ph.D. degree in economics. Currently, he is Associate Professor of Economics and Director of Special International Programs for the Broyhill Institute for Business Development in the John A. Walker College of Business at Appalachian State University. In his position as Director of the Institute, he has implemented business training programs throughout Russia and has served as a consultant to a newly established business school in Poland. He is the recipient of a National Urban League Summer Fellowship and a National Science Foundation Grant in regional science and has published in the *Review of Economics and Statistics*, *the Journal of Regional Science*, and *Public Finance Quarterly*.

PREFACE

Introduction to Time-Series Modeling and Forecasting in Business and Economics is designed to give a thorough, applied, and simple to comprehend presentation of most of the procedures useful in modeling and forecasting time series data. It is written so that a reader with only a background in basic statistics and high school algebra will have no difficulty in understanding the material. We have attempted in each chapter to present easy to read discussions of the methods with numerous graphs and worked out examples. Each modeling technique is illustrated in an example that applies the procedure to a data set. In each case, an appropriate model is employed to find the “best fit” to the data and then is used to forecast future (short term) values of the time series. We have also incorporated an ongoing case study, demonstrating the procedures discussed in each chapter. In the presentation of the case study, we also include an explanation of why or why not a certain technique can or cannot be used. Certain key words along with their definitions are highlighted in the body of the text.

As mentioned above, the book is written for a student with a limited knowledge of mathematics and statistics. Thus, it would serve well as an undergraduate textbook for any applied course in time-series modeling and forecasting. In particular, any of the disciplines found in business or the social sciences (such as economics, political science, decision science, management science) would find this text useful in their curriculum. It should also prove to be a valuable reference book for those practitioners who must model and forecast time series data in the “real world.” The review of basic statistics we have included in two of the appendices will be helpful for those students/practitioners that want to refresh their memories in some of the elementary statistical procedures needed for the understanding of the present material.

At the end of each chapter, we incorporate a detailed explanation of four commonly used computer programs for modeling time-series data. These are Lotus 1-2-3, MicroTSP, Minitab, and Soritec Sampler. We include all four, not because we expect the reader to use all four, but because the probability of at least one being at his/her institution is quite high. In addition, since not all programs will accomplish all things, we hope that we will be presenting some options. Since Lotus is almost universal and Sampler is free for the asking, no

student should be without computer program availability. Furthermore, the use of Lotus as a computer program for the first six chapters is a great pedagogical tool, and we highly recommend it! The accompanying table identifies the computer applications available to the student in each of the chapters.

This book is organized into five parts; each part contains several chapters. It is designed to be covered in a one semester course; however, chapters or even a complete part may be skipped without loss of continuity.

Part I introduces the concepts of time-series analysis and demonstrates some of the most basic procedures in modeling. Included in Chapter 1 is an examination of forecasting accuracy and how it can be measured. One unique feature of Part I is Chapter 2, which explains the many techniques for describing and transforming data. Students will find this chapter a good reference source for topics and classes other than time-series analysis.

The remainder of the text, Parts II through V, leads the students into modeling and forecasting data from its simplest form (trend, irregular) to its most complex form (trend, seasonal, irregular) using Box-Jenkins and/or econometric models.

Part II contains two chapters on modeling and forecasting data containing trend and irregular components. Chapter 3 discusses the use of simple and multiple regression analysis for the modeling of linear and curvilinear trend. Using time as a predictor variable, the form, assumptions, and tests for regression are discussed. Updating regression-based trend models by using an exponential smoothing approach (simple, double, or triple) is covered in Chapter 4. In both chapters, the formulas for the construction of confidence intervals and point forecasts are presented.

Part III describes the use of decomposition techniques and Winters' exponential smoothing to model and forecast time-series described by trend, seasonal, and irregular components. In this part, we present both the additive and multiple models for fitting seasonal data. Detailed discussions as to the differences in the model, the procedures for obtaining the estimates of the components, and the point and interval forecasts are included both for the decomposition method (Chapter 5) and Winters' exponential smoothing (Chapter 6).

Part IV presents a detailed, nontheoretical discussion of the Box-Jenkins methodology for modeling nonseasonal (Chapter 7) and seasonal (Chapter 8) time-series data. The four-step procedure is explained using graphs and correlograms. The techniques (and rules of thumb) for using the behavior of the correlograms to identify a tentative model are also discussed. The diagnostic tests that are presented include the modified Box-Pierce statistic, the t -ratios for the individual parameters, the conditions of stationarity and invertibility, and the correlation matrix of the parameters. Examples that convert a forecast model back to the original data are examined.

Part V examines the use of econometric models to forecast time-series data. The assumptions, testing, and forecasting methods of a multiple regression model are discussed in Chapter 9. The techniques and tests for choosing the

best model are also presented. Many important time-series techniques, often only presented in econometric books, are presented through the use of practical examples. Chapter 10 brings together the entire process of modeling and forecasting by illustrating the technique of combining forecasting methodologies, averaging forecasts, and summarizing the different forecasting techniques presented in the book.

This textbook and the instructor's data disk are abundant with time-series data. In most cases, data are obtained from published secondary sources, which would be readily available to students in their university library. However, a particularly valuable secondary source is the Federal Reserve Economic Data (FRED) electronic bulletin board maintained by the Federal Reserve Bank of St. Louis. Reference to data obtained from this bulletin board is listed in source lines simply as the Federal Reserve Bank, St. Louis.

Many people have contributed to this book. We would especially like to thank officials of Food Lion, Inc., for providing data, students in the John A. Walker College of Business at Appalachian State University for their inspiration, Robert J. Richardson for his indexing services, and Deborah Culler for her clerical assistance in preparation of the final manuscript.

Finally, we wish to thank the following reviewers for their many helpful comments and suggestions on the manuscript: Benito E. Flores, Texas A & M University; Paul S. Foote, California State University–Fullerton; Hans Levenbach, Delphus; Ved P. Sharma, Mankato State University; and Ebenge E. Usip, Youngstown State University.

Patricia E. Gaynor
Rickey C. Kirkpatrick

INTRODUCTION

Relevant Computer Applications by Chapter

	Lotus 1-2-3	MicroTSP	Minitab	Soritec
Chapter 1	×	×		×
Chapter 2	×	×	× *	× *
Chapter 3	×	×	×	×
Chapter 4	× *	×		× *
Chapter 5	×	×		×
Chapter 6	× *	×		×
Chapter 7	×	×	×	
Chapter 8	×	×	×	
Chapter 9	× *	×	×	×
Chapter 10	×	×		×

× = Complete coverage.

× * = Limited coverage.

COMPUTER SOFTWARE USED IN THIS TEXTBOOK

All output from the computer software programs presented in the appendixes of this text was generated using the latest versions of the following:

Lotus[®] 1-2-3[®] is a registered trademark of Lotus Development Corporation. It is available in a student edition.

MicroTSP[™] is a registered trademark of

Quantitative Micro Software
4521 Campus Drive, Suite 336
Irvine, CA 92715
(714) 856-3368
FAX (714) 856-2044

It is available in a student edition.

MINITAB[®] Statistical Software (referred to in the text simply as Minitab) is a registered trademark of

Minitab Inc.
3081 Enterprise Dr.
State College, PA 16801
(814) 238-3280
FAX (814) 238-4383

It is available in a student edition.

SORITEC SAMPLER[™] is a registered trademark of

The Sorites Group, Inc.
P. O. Box 2939
Springfield, VA 22152
(703) 569-1400
FAX (703) 569-1429

It is available from the above address and can be freely reproduced for non-commercial purposes.

The authors gratefully acknowledge their cooperation.

**INTRODUCTION TO TIME-SERIES MODELING AND
FORECASTING IN BUSINESS AND ECONOMICS**

CONTENTS

Preface	xv
Introduction	xix
Computer Software Used In This Textbook	xxi
1 Introduction to Time-Series Analysis and Forecasting	1
1.1 Introduction	1
1.2 Types of Forecasting Methods	2
1.2.1 Qualitative Methods	2
1.2.2 Quantitative Methods	5
1.3 The Methodology of Time-Series Data and Forecasts	7
1.4 Measuring the Accuracy of Forecasting Models	12
1.4.1 The Definition of Forecast Error	12
1.4.2 Applications of Statistical Methods to Measure Forecast Accuracy	13
1.4.3 Graphical Methods of Forecast Accuracy	16
1.5 The Task Order in Forecasting	18
1.6 Specifying Simple Forecast Methods	19
1.6.1 The Naive Forecast	19
1.6.2 The Simple Moving Average Forecast	20
1.6.3 Trend Forecasts	20
1.6.4 Bivariate Causal Model Forecast	20
1.6.5 Illustrating the Task Order	21
1.6.6 Graphical Evaluation of the Forecast Models	26
1.7 Choosing a Forecasting Model	29
Exercises	29
Case Study: Food Lion, Inc.	33
Case Study Questions	33
Appendix 1A Elementary Statistical Review	34
Appendix 1B Introduction to Spreadsheet Analysis Using Lotus 1-2-3	51
Appendix 1C Introduction to Microcomputer Applications: MicroTSP, Minitab, and Soritec Sampler	65
2 Building Tools for Time-Series Analysis: Describing and Transforming Data	76
2.1 Introduction to Time-Series Data	76
2.2 Collecting Time-Series Data	78
2.2.1 Sources of Data	79
2.2.2 Comparability of Data over Time	79

2.3	Specific Components in Time-Series Models	79
2.4	Graphical Presentation of Time-Series Data	83
2.4.1	Single-Scale Plot of a Time Series	84
2.4.2	Dual-Scale Plot of a Time-Series	84
2.4.3	Scatter Diagram	85
2.4.4	High/Low/Close Plot	85
2.4.5	Bar Graphs	86
2.4.6	Pie Charts	87
2.5	Index Numbers	89
2.5.1	The Simple Unweighted Index	92
2.5.2	Simple Unweighted Aggregative Index	93
2.5.3	Weighted Aggregative Index: The Laspeyres Index	94
2.5.4	Weighted Aggregative Index: The Paasche Index	96
2.5.5	Changing the Base Period	98
2.6	Smoothing Time-Series Data: The Simple Moving Average and the Centered Moving Average	99
2.6.1	The Simple Moving Average	99
2.6.2	The Centered Moving Average	100
2.7	Conversion of Quarterly and Monthly Data to Annual Rates	104
2.8	Data Frequency Conversion	105
2.8.1	Data Conversion from Higher to Lower Frequencies	106
2.8.2	Data Conversion from Lower to Higher Frequencies	109
2.9	Data Transformations: Differences and Percent Change	115
2.9.1	Differences	115
2.9.2	The Use of Natural Logarithms in Time-Series Analysis	120
2.9.3	Percent Growth Rates	121
2.10	Calculating Compound Annual Growth Rates as Descriptive Statistics	125
2.10.1	The Geometric Mean Method	126
2.10.2	The Method of Ordinary Least Squares	127
2.10.3	Compound Annual Growth Rates (Annualized Growth Rates) for Monthly and/or Quarterly Data	127
2.10.4	The Semilogarithmic Graph	128
2.11	Other Data Transformations	129
2.11.1	Adjusting a Series for Price Changes: Real Terms	130
2.11.2	Adjusting a Series for Population Changes: Per Capita Terms	130
2.12	Missing Data	132
	Exercises	133
	Case Study: Food Lion, Inc.	136
	Case Study Questions	139
	Appendix 2A Sources of Data	140
	Appendix 2B Basic Graphical and Technical Tools in Lotus 1-2-3	143
	Appendix 2C Microcomputer Graph and Transformation Basics	158
3	Modeling Trend Using Regression Analysis	179
3.1	Introduction	179
3.2	Building a Linear Model	182

3.3	Assumptions Underlying Regression Analysis	185
3.3.1	The Conditions for Modeling Trend Using sRegression Analysis	185
3.3.2	The Normality of the Error	186
3.3.3	Test for Autocorrelation	187
3.4	Evaluating the Accuracy of the Linear Model	191
3.4.1	Testing the Slope Coefficient	191
3.4.2	The Coefficient of Determination	192
3.4.3	Theil's U Inequality Coefficient: A Different Computational Formula	196
3.4.4	Other Statistical Measures of Forecast Error	197
3.5	Forecasting Linear Trend	197
3.6	Building a Model: The Case of a Decreasing Linear Trend Model	200
3.7	Building a Curvilinear Model	202
3.7.1	Transformation of the Data and Use of Bivariate Regression	204
3.7.2	Bivariate Regression Models of Curvilinear Trend	204
3.7.3	Using Multiple Regression to Model Curvilinear Trend	211
3.7.4	The Conditions for Multivariate Regression	214
3.8	Evaluating the Accuracy of the Curvilinear Model	214
3.8.1	The Coefficient of Determination	214
3.8.2	The Slopes	215
3.9	Forecasting Curvilinear Trend	216
3.10	Outliers	220
	Exercises	222
	Case Study: Food Lion, Inc.	226
	Case Study Questions	233
	Appendix 3A Multiple Linear Regression	233
	Appendix 3B Regression Analysis Using Lotus 1-2-3	244
	Appendix 3C Computer Applications in Trend Regression Analysis	263
4	Exponential Smoothing: Updating Regression-Based Trend Models	289
4.1	Introduction	289
4.2	The Methodology of Exponential Smoothing	290
4.3	Forecasting Time Series with No Trend	291
4.3.1	The Single Exponential Smoothing Approach	291
4.3.2	Determination of an Appropriate Weighting Factor	294
4.3.3	Building a Prediction Interval	296
4.4	Forecasting Time Series with a Linear Trend	298
4.4.1	The Double Exponential Smoothing Approach	299
4.4.2	Determining an Appropriate Weighting Factor	302
4.4.3	Building a Prediction Interval	303
4.5	Time Series with a Curvilinear Trend	304
4.5.1	The Triple Exponential Smoothing Approach	304
4.5.2	Determining an Appropriate Weighting Factor	307
4.5.3	Building a Prediction Interval	309

4.6	Damped Exponential Smoothing	310
4.7	Forecast Errors and Adaptive Control Processes	311
4.7.1	Computing a Tracking Signal	311
4.7.2	Controlling the Weighting Factor—The Chow Method	312
4.8	Advantages and Disadvantages of Exponential Smoothing	312
	Exercises	313
	Case Study: Food Lion, Inc.	315
	Case Study Questions	315
Appendix 4A	Exponential Smoothing Using Lotus 1-2-3	316
Appendix 4B	Exponential Smoothing in MicroTSP and Soritec Sampler	334
5	The Decomposition Method	339
5.1	Introduction	339
5.1.1	Additive and Multiplicative Models	340
5.1.2	The Seasonal and Cyclical Components	341
5.2	Additive Decomposition	341
5.2.1	Steps in the Decomposition Method	342
5.2.2	Evaluating the Model	345
5.2.3	Forecasts and Confidence Intervals	346
5.3	Multiplicative Decomposition	347
5.3.1	Steps in the Decomposition Method	348
5.3.2	Evaluating the Model	351
5.3.3	Forecasts and Confidence Intervals	351
5.4	Test for Seasonality	353
5.5	Dealing with the Cyclical Component	355
5.6	Advantages and Disadvantages of the Decomposition Method	356
5.7	The Census Bureau's Method of Decomposition	356
	Exercises	357
	Case Study: Food Lion, Inc.	358
	Case Study Questions	358
Appendix 5A	The Multiplicative Decomposition Method in Spreadsheets	359
Appendix 5B	The Decomposition Method in MicroTSP and Soritec Sampler	366
6	Updating Seasonal Models with Winters' Exponential Smoothing	372
6.1	Introduction	372
6.2	The Additive Winters' Method	373
6.2.1	Updating the Decomposition Results	373
6.2.2	Updating the Multiple Regression Results	379
6.3	Obtaining the Optimal Weights	384
6.4	Forecasts and Confidence Intervals	385
6.5	The Multiplicative Winters' Method	386
6.5.1	Updating the Decomposition Results	387
6.6	Obtaining the Optimal Weights	392

6.7	Forecasts and Confidence Intervals	393
6.8	A Modified Winters' Method	394
6.9	Advantages and Disadvantages of the Winters' Methodology	394
	Exercises	395
	Case Study: Food Lion, Inc.	396
	Case Study Questions	396
Appendix 6A	Spreadsheet Applications in Holt-Winters Smoothing	396
Appendix B	Microcomputer Applications of Holt-Winters Smoothing	402
7	Box-Jenkins Methodology—Nonseasonal Models	405
7.1	Introduction	405
7.2	The Basic Steps in the Box-Jenkins Procedure	406
7.3	The Identification Procedure	407
	7.3.1 Stationary and Nonstationary Time Series	407
	7.3.2 Determining a Tentative ARIMA Model	410
7.4	Estimating the Model Parameters	424
7.5	Diagnostic Checking	426
	7.5.1 Analyzing the Residuals	427
	7.5.2 Testing the Parameters	429
	7.5.3 Parameter Redundancy	431
	7.5.4 Choosing the Best Model	431
7.6	Forecasting	433
	7.6.1 Obtaining Point Forecasts	433
	7.6.2 Obtaining a Prediction Interval	434
7.7	Problems in Implementing Box-Jenkins	435
	Exercises	436
	Case Study: Food Lion, Inc.	440
	Case Study Questions	445
Appendix 7A	Microcomputer Applications of Box-Jenkins	445
8	Box-Jenkins Methodology—Seasonal Models	469
8.1	Introduction	469
8.2	Identification	469
	8.2.1 Stationary and Nonstationary Time Series	470
	8.2.2 Autocorrelation and Partial Correlation Functions	472
	8.2.3 Box-Jenkins Models	475
8.3	Estimating Model Parameters	480
8.4	Diagnostic Checking	481
8.5	Forecasting	482
8.6	The General Model	484
	Exercises	485
	Case Study: Food Lion, Inc.	493
	Case Study Questions	495
Appendix 8A	Microcomputer Applications in Seasonal Box-Jenkins Models	

9	Multiple Regression in Time-Series Analysis: The Causal Model	515
9.1	Introduction	515
9.2	The Multiple Regression Model	516
9.3	Steps in Econometric Analysis	517
9.3.1	Specification of the Theoretical Model	517
9.3.2	Specification of the Functional Form of the Model	519
9.3.3	Data Collection, Tabulation, and Correlation	521
9.3.4	Model Estimation, Evaluation, and Interpretation	522
9.3.5	Evaluation of Model Forecasts over Historical and <i>Ex Post</i> Periods	525
9.4	Application: Building a Model for Monthly Church Collections	525
9.4.1	Specification of the Model	525
9.4.2	Collection and Tabulation of the Data	526
9.4.3	Model Estimation, Evaluation, and Interpretation	530
9.4.4	Evaluation of Model Forecasts over Historical and <i>Ex Post</i> Periods	532
9.5	Application: Building a Model for U.S. Retail Sales	533
9.5.1	Specification of the Retail Sales Model	534
9.5.2	Data Collection, Tabulation, Transformation, and Correlation	535
9.5.3	Model Estimation, Interpretation, and Tests of Hypotheses	537
9.5.4	Model Evaluation	538
9.5.5	Evaluation of Model Forecasts over Historical and <i>Ex Post</i> Periods	539
9.6	The Log-Linear Specification: An Alternative Model of Forecasting Retail Sales	540
9.6.1	Specification of the Model	541
9.6.2	Tabulation and Transformation of the Data for the Retail Sales Model	541
9.6.3	Model Estimation, Interpretation, and Tests of Hypotheses	542
9.6.4	Model Evaluation	542
9.6.5	Evaluation of Model Forecasts over Historical and <i>Ex Post</i> Periods	542
9.7	Models with First-Order Autocorrelation: The Cochrane-Orcutt Procedure	543
9.7.1	Specification of the Model	544
9.7.2	Tabulation and Transformation of the Data for the Demand for Electricity	544
9.7.3	Model Estimation, Interpretation, and Tests of Hypotheses	544
9.7.4	Evaluation of Model Forecasts over Historical and <i>Ex Post</i> Periods	545
9.8	Lagged Dependent Variable	547
9.8.1	Specification of the Model	548
9.8.2	Tabulation and Transformation of the Data for the Savings Model	548