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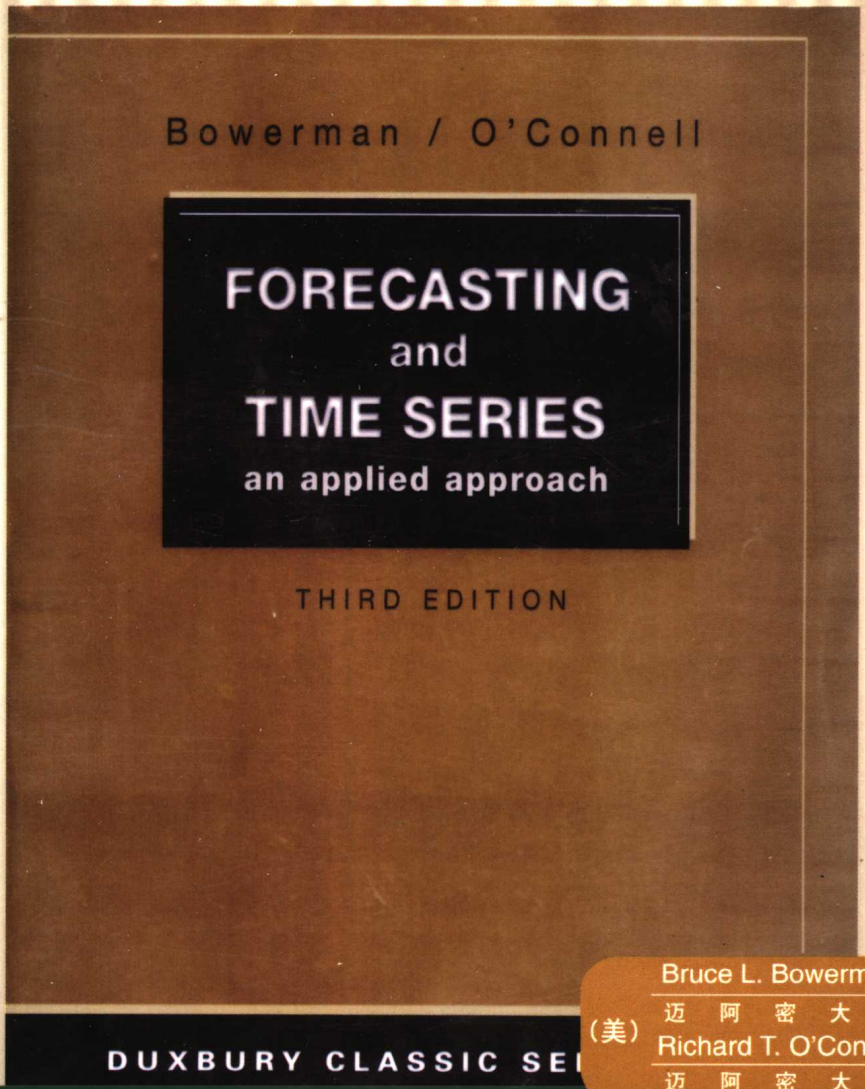
（英文版·第3版）



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Forecasting and Time Series

An Applied Approach

(Third Edition)

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PREFACE

Forecasting and Time Series: An Applied Approach, third edition, is designed as a textbook for applied courses in forecasting and time series analysis and as a reference book for practitioners who must make real world forecasts. It is appropriate for advanced (junior- and senior-level) undergraduates and graduate students in business, engineering, and the sciences (including mathematics, statistics, operations research, and computer science). The required mathematical and statistical background for this book is college algebra and basic statistics.

This third edition attempts to combine and somewhat expand the best aspects of the first two editions. The first edition began with a short discussion of regression analysis, proceeded to a complete discussion of exponential smoothing and time series decomposition techniques, and concluded with a moderately complete presentation of the Box–Jenkins methodology. The second edition began with a more complete treatment of the Box–Jenkins methodology. This methodology was then used to integrate and unify most of the remaining forecasting techniques presented. We have found that some instructors who liked the first edition did not like the organization and Box–Jenkins emphasis of the second. On the other hand, many instructors preferred these aspects of the second

edition. The third edition is organized into five parts in a way that should satisfy both those who prefer the first edition and those who prefer the second. Some instructors may wish to teach a course that covers all five sections. However, most courses will not cover the entire text. For instance, some instructors will wish to build their course around the regression/exponential smoothing/decomposition material. Others will wish to build their course around the Box–Jenkins methodology. We now describe the five parts and then explain how they can be structured into different courses.

Part I consists of an introduction to forecasting (Chapter 1) and a review of basic statistical concepts (Chapter 2). Part II discusses forecasting by using regression analysis. This part begins with Chapter 3, which presents simple linear regression. Chapter 4 discusses multiple regression, including an introduction to model building and residual analysis. Chapter 5 presents various advanced topics in regression. These topics are not needed for studying any other chapter in the book, but would be covered by an instructor interested in a more complete discussion of using regression analysis in forecasting. Part III discusses forecasting by using time series regression, decomposition methods, and exponential smoothing. The prerequisite for reading this part is a basic knowledge of simple and multiple regression analysis, as provided by Chapters 3 and 4 of Part II.

We suspect that some forecasting courses will have a regression prerequisite, and that instructors teaching such courses will begin with Part III. Therefore, we have written this material to stand on its own as much as possible. Part III begins with Chapter 6, which covers time series regression. This includes modeling trends and seasonal effects by using polynomial functions of time, dummy variables, and trigonometric functions. Also covered is an introduction to modeling autocorrelated error terms. Chapter 7 discusses time series decomposition methods. Part III concludes with Chapter 8, which presents exponential smoothing. Included are discussions of simple and double exponential smoothing, Winters' Method, and damped trend methods.

Parts IV and V discuss forecasting by using the Box–Jenkins methodology. These parts are written from first principles and can be read without reading Part II or Part III. Therefore, an instructor may begin a course with Part IV, which presents basic techniques of the Box–Jenkins methodology. Chapters 9 and 10 begin this part and discuss nonseasonal Box–Jenkins modeling. Chapter 11 concludes this part and presents an introduction to Box–Jenkins seasonal modeling. It is important to note that, in order to simplify notation, we have delayed use of the backshift operator until Part V. Therefore, the reader can obtain from Part IV a complete knowledge of nonseasonal Box–Jenkins modeling and an introduction to seasonal Box–Jenkins modeling without using this operator. Part V begins with Chapter 12, which presents a more advanced treatment of seasonal Box–Jenkins modeling. Chapter 13 covers the use of the Box–Jenkins methodology in time series regression and exponential smoothing. This chapter refers the reader to the necessary prerequisite parts of Chapters 6 and 8 as needed. Part V concludes with Chapter 14, which discusses transfer functions and intervention models.

Below we list some possible courses that can be based on this book. All courses are assumed to include the introduction to forecasting provided in Chapter 1 and any needed basic statistical review from Chapter 2.

1. A course on forecasting by using regression analysis, time series regression, decomposition methods, and exponential smoothing would consist of Parts II

and III. A more intensive course would also include the basic techniques of the Box–Jenkins methodology, as given by Part IV.

2. A course on forecasting by using time series regression, decomposition methods, exponential smoothing, and the basic techniques of the Box–Jenkins methodology would consist of Parts III and IV. A more intensive course would also include the advanced techniques of the Box–Jenkins methodology, as given by Part V.
3. A course on forecasting by using the Box–Jenkins methodology would consist of Parts IV and V, with relevant portions of Chapters 6 and 8 included as indicated by the discussions of Chapter 13.
4. A course on forecasting by using regression analysis and the Box–Jenkins methodology would consist of Part II, Chapter 6 of Part III, and Part IV. A more intensive course would also include portions or all of Part V.

We have placed a premium in this book on illustrating forecasting by using many real world data sets in the examples and exercises. In addition, we utilize Minitab and SAS outputs to present forecasting results and show in optional sections how to use these packages. A data disk that contains many of the time series in this book is also available.

We wish to thank Kathleen Billus, Marcia Cole, Curt Hinrichs, Susan London, Michael Payne, and the other fine people at Duxbury Press for their help in this writing endeavor, as well as Rachel Youngman of Hockett Editorial Service. We would also like to thank the reviewers of this book. We would especially like to thank S. Chakraborti, University of Alabama; Terry Dielman, Texas Christian University; Benito Flores, Texas A & M University; Michael L. Hand, Willamette University; Robert McAuliffe, Babson College; Helmut Schneider, Louisiana State University; Stanley R. Schultz, Cleveland State University; and Mack C. Shelley, II, Iowa State University for their many useful comments and suggestions. Finally, we thank our wives and children for their love and encouragement.

Bruce L. Bowerman
Richard T. O'Connell

To our wives and children:
Drena and Jean
Michael, Christopher, Bradley, Asa, and Nicole

To Susan London:
our dedicated and talented production editor

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PART I

INTRODUCTION

CHAPTER 1

AN INTRODUCTION TO FORECASTING

1.1 INTRODUCTION

This chapter introduces the topic of *forecasting*. We begin in Section 1.2 by discussing *time series data*, the type of data that we will use in this book to make forecasts. Then, in Section 1.3, we explain the general natures of different kinds of forecasting methods. Both *qualitative* and *quantitative* methods are considered. Section 1.4 discusses the fact that forecasts of future time series values are not likely to be perfectly accurate and explains how to measure *forecast errors*. In Section 1.5 we present some important factors that must be considered when choosing a forecasting method. Section 1.6 presents an overview of the quantitative forecasting techniques discussed in this book. We conclude this chapter with Section 1.7, which briefly introduces the *computer packages* that we will use to implement the forecasting techniques presented here.

1.2

FORECASTING AND TIME SERIES

This book is about forecasting and some of the statistical techniques that can be used to produce forecasts. We begin with the following definition.

> Predictions of future events and conditions are called *forecasts*, and the act of making such predictions is called *forecasting*.

Forecasting is very important in many types of organizations since predictions of future events must be incorporated into the decision-making process. The government of a country must be able to forecast such things as air quality, water quality, unemployment rate, inflation rate, and welfare payments in order to formulate its policies. A university must be able to forecast student enrollment in order to make decisions concerning faculty resources and housing availability. The university might also wish to forecast daily mean temperature so that it can plan its fuel purchases for the coming months. A local school board must be able to forecast the number of children of elementary school age who will be living in the school district years in the future in order to decide whether a new school should be built. Any organization must be able to make forecasts in order to make intelligent decisions.

Business firms, in particular, require forecasts of many events and conditions in all phases of their operations. The following lists some examples of situations in which business forecasts are needed.

In marketing departments, reliable forecasts of demand must be available so that sales strategies can be planned. For example, total demand for products must be forecasted in order to plan total promotional effort. Besides this, demand in various market regions and among various consumer groups must be predicted in order to plan effective advertising strategies.

In finance, interest rates must be predicted so that new capital acquisitions can be planned and financed. Financial planners must also forecast receipts and expenditures in order to predict cash flows and maintain company liquidity.

In personnel management, forecasts of the number of workers required in different job categories are required in order to plan job recruiting and training programs. In addition, personnel managers need predictions of the supply of labor in various areas and of the amount of absenteeism and the rate of labor turnover to be expected.

In production scheduling, predictions of demand for each product line are needed. Such predictions are made for specific time periods, for example, for specific weeks and months. These forecasts allow the firm to plan production schedules and inventory maintenance. Forecasts of demand for individual products can be translated into forecasts of raw material requirements so that

purchases can be planned. The planning of resource purchases also requires predictions about resource availabilities and prices.

Process control requires forecasts of the future behavior of the process. For example, an industrial process may begin to produce increasing numbers of defective items as the process operates over time. If the behavior of this process can be predicted accurately, it will be possible to determine when it should be shut down and overhauled so that the number of defective items produced can be minimized.

Strategic management requires forecasts of general economic conditions, price and cost changes, technological change, market growth, and the like in order to plan the long-term future of the company. For example, such forecasts might be used to determine whether investment in new plant and equipment will be needed in the future.

In forecasting events that will occur in the future, a forecaster must rely on information concerning events that have occurred in the past. That is, in order to prepare a forecast, the forecaster must analyze past data and must base the forecast on the results of this analysis. Forecasters use past data in the following way. First, *the forecaster analyzes the data in order to identify a pattern* that can be used to describe it. Then *this pattern is extrapolated, or extended, into the future in order to prepare a forecast.* This basic strategy is employed in most forecasting techniques and *rests on the assumption that the pattern that has been identified will continue in the future.* A forecasting technique cannot be expected to give good predictions unless this assumption is valid. If the data pattern that has been identified does not persist in the future, this indicates that the forecasting technique being used is likely to produce inaccurate predictions. A forecaster should not be surprised by such a situation, but must try to anticipate when such a change in pattern will take place so that appropriate changes in the forecasting system can be made before the predictions become too inaccurate.

In this book we use time series data to prepare forecasts.

A *time series* is a chronological sequence of observations on a particular variable.

As an example, the data in Table 1.1 are a time series that gives the quarterly total value of time deposits held by the Baarth National Bank during 1990 and 1991. Notice that the value of time deposits was observed at equally spaced time points (quarterly). Equally spaced time points are used in most time series studies. Business time series often consist of yearly, quarterly, or monthly observations, but any other period may be used. There are many, many examples of time series data, some of which are listed below.

Unit sales of a product over time

Total dollar sales for a company over time

Number of unemployed over time

Unemployment rate over time

Production of a product over time

Air or water quality over time