ECONOMETRIC MODELS & ECONOMIC FORECASTS

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&
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SECOND EDITION

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PREFACE

Comments and suggestions from a large number of users of the first edition have led us to make a number of substantive changes as well as smaller revisions in this second edition. We have incorporated several changes which we feel have pedagogical value, as well as a number of new topics which currently are receiving relatively wide attention. Nonetheless, the book has the same general outline as the first edition.

In terms of content, Part One includes two new chapters. Chapter 2 contains an expanded and more carefully developed review of important statistical concepts, while Chapter 5 contains a number of topics relating to the multiple regression model that were not treated in detail in the first edition. These include the use of t tests, F tests, and dummy variables. In general, we have tried to make the first five chapters more accessible to those with a weak mathematical background by including more algebraic derivations in footnotes, appendixes, and exercises. Also, Chapter 10 now contains a much more extensive discussion of the estimation of models with qualitative dependent variables.

Part Two of the book is unchanged in overall structure, but it does contain a newly estimated and improved macroeconomic model as well as an expansion of the material on corporate planning models (in Chapter 14). Finally, Part Three has been expanded to include an additional chapter in which simple non-stochastic forecasting models are covered. Topics covered in that chapter include techniques for the smoothing and extrapolation of time series, as well as seasonal adjustment methods.

Just as important as these substantive changes is the fact that many examples have been reworked, and the data for a number of them have been included either in the text or in our instructor's manual. The manual also contains answers to all the rather extensive end-of-chapter questions. All the empirical questions relate to data sets given in the text and the manual so that instructors can make direct use of the assignments in their classes.

In preparing the second edition, we have benefited substantially from the comments and criticisms of our colleagues and our students, as well as suggestions given to us from a wide variety of individuals. We should thank Stephen Dietrich and Annette Hall, who helped plan and edit the first edition. Without their extremely valuable support, we would not have had the courage to tackle a second one. Likewise, Bonnie Lieberman and Susan Norton have been of great assistance with the second edition. We can't possibly thank everyone who provided assistance with this revision, but we will give special thanks to Joseph Langsam, who played a crucial role in the development of the instructor's manual; John Neese, who helped develop the new version of the macroeconometric model; and William Keech, David Kendrick, Ed Kuh, Deborah Swift, Carl Van Duyne, and a number of anonymous reviewers who provided numerous helpful comments and suggestions. Also, we would like to mention some of the people who have found minor errors or argued persuasively for one or more changes in the text. They include H. Akhavipour, Peter An, John G. Bell, Abdul Rauf Butt, George Downs, Alan Fox, Jeffrey Frankel, Rob Gerin, Sue Goldstone, Shuh-Tzy Hsu, Mark Kamlet, Robert Kleinbaum, Jan Kmenta, Nancy E. Meiners, Jonathan Shane, Chandler Stolp, Donald Wise, and Kenneth White. Finally, our thanks to Karen Shamban and Judith Jackson for their patience and diligence in typing the final manuscript of this new edition.

Robert S. Pindyck
Daniel L. Rubinfeld

INTRODUCTION

This book is an introduction to the science and art of building and using models. The science of model building consists of a set of tools, most of them quantitative, which are used to construct and then test mathematical representations of portions of the real world. The development and use of these tools are subsumed under the subject heading of econometrics. Econometrics is a well-defined field and therefore relatively easy to describe. The science of model building is a primary concern of this book. The art of model building is, unfortunately, much harder to describe in words, since it consists mostly of intuitive judgments that occur during the modeling process. Unfortunately, since there are no clear-cut rules for making these model-building judgments, the art of model building is more difficult to master. Nonetheless, one of the purposes of this book is to convey the nature of that art to the reader to the extent possible. This will be done in part by examples and by discussions of technique but also by encouraging readers to do what is ultimately necessary to master the art, namely, to build models of their own.

The book focuses upon models of processes that occur in business, economics, and the social sciences in general. These might include models of aggregate economic activity; the sales of an individual firm, or a political process (e.g., estimating the number of votes that a particular candidate can be expected to receive in an election). Discussions of the purposes of building these models are directed toward forecasting and policy analysis, but the reader should bear in mind the general nature of the content.

As one might expect, there are many types of models that can and often have been used for policy analysis and forecasting. This book does not attempt to cover the entire spectrum of model types and modeling methodologies; instead, it concentrates on models that can be expressed in equation form, relating variables quantitatively. Data are then used to estimate the parameters of the equation or equations, and theoretical relationships are tested statistically.

This still leaves a rather wide range of models from which to choose. On one end of this range, one might determine the effect of alternative monetary policies on the behavior of the United States economy by constructing a large, multi-equation econometric model of the economy and then simulating it using different monetary policies. The resulting model would be rather complicated and would *presume to explain a complex structure in the real world.* On the other end of the range, one might wish to forecast the sales volume of a firm and, believing that those sales follow a strong cyclical pattern, use a time-series model to extrapolate the past behavior of sales.

It is this range of models that is the subject matter of this book. The objective of this book is to give the reader some understanding of the science and art of determining what type of model to build, building the model which is most appropriate, testing the model statistically, and then finally applying the model to practical problems in forecasting and analysis.

1 WHY MODELS?

Many of us often either use or produce forecasts of one sort or another. Few of us recognize, however, that some kind of logical structure, or model, is implicit in every forecast or analysis of a social or a physical system. Consider, for example, a stockbroker who tells you that the Dow Jones Industrial Average will rise next year. The stockbroker might have made this forecast because the Dow Jones average has been rising during the past few years and the broker feels that whatever it was that made it rise in the past will continue to make it rise in the future. On the other hand, the feeling that the Dow Jones Industrial Average will rise next year may result from a belief that this variable is linked to a set of economic and political variables through a complex set of relationships. The broker might believe, for example, that the Dow Jones average is related in a certain way to the gross national product and to interest rates, so that given certain other beliefs about the most probable future behavior of these latter variables, a rise in the Dow Jones average would appear likely.

If we have to find a word to describe the method by which our stockbroker made this forecast, we would probably say that it was intuitive, although the chain of reasoning differed substantially in the two cases cited above. The stockbroker certainly would not say that the forecast was made by building a model of the Dow Jones average; indeed, no equations were written down, nor was any computer used. Nonetheless, in each case, some *implicit* form of model building was involved. A stockbroker who based the optimistic forecast for the Dow Jones average on past increases has in effect constructed a *time-series model* which extrapolates past trends into the future. If, instead, the forecast was based on a knowledge of economics, a model would still be implicitly involved; it would be composed of the relationships that were loosely conceived in the stockbroker's mind as a result of past experience.

Thus, even the intuitive forecaster constructs some type of model even without being aware of doing so. Of course, it is reasonable to ask why one might want to work with an *explicit* model to produce forecasts. Would it be worth the trouble, for example, for our stockbroker to read this book in order to construct an explicit model, estimate it on the computer, and test it statistically? Our response is that there are several advantages to working with models explicitly. Model building forces the individual to think clearly about, and account for, all the important interrelationships involved in a problem. The reliance on intuition can be dangerous at times because of the possibility that important relationships will be ignored or improperly used. In addition, it is important that individual relationships be tested or validated in some way or another. Unfortunately, this is not usually done when intuitive forecasts are made. In the process of building a model, however, a person must test or validate not only the model as a whole but also the individual relationships that make up the model.

When making a forecast, it is also important to provide a statistical measure of confidence to the user of the forecast, i.e., some measure of how accurate one might expect the forecast to be. The use of purely intuitive methods usually precludes any quantitative measure of confidence in the resulting forecast. The statistical analysis of the individual relationships that make up a model, and of the model as a whole, makes it possible to attach a measure of confidence to the model's forecasts.

Once a model has been constructed and fitted to data, a sensitivity analysis can be used to study many of its properties. In particular, the effects of small changes in individual variables in the model can be evaluated. For example, in the case of a model that describes and predicts interest rates, one could measure the effect on a particular interest rate of a change in the rate of inflation. This type of quantitative sensitivity study, which is important both in understanding and in using the model, can be made only if the model is an explicit one.

2 TYPES OF MODELS

In this book we examine three general classes of models that can be constructed for purposes of forecasting or policy analysis. Each involves a different degree of model complexity and structural explanation, and each presumes a different level of comprehension about the real world processes one is trying to model.

Time-series models In this class of models we presume to know nothing about the real world causal relationships that affect the variable we are trying to forecast. Instead we examine the past behavior of a time series in order to infer something about its future behavior. The time-series method used to produce a forecast might involve the use of a simple deterministic model such as a linear extrapolation or the use of a complex stochastic model for adaptive forecasting.

One example of the use of time-series analysis would be the simple extrapolation of a past trend in predicting population growth. Another example would be the development of a complex linear stochastic model for passenger loads on an airline. Models such as this have been developed and used to forecast the demand for airline capacity, seasonal telephone demand, the movement of short-term interest rates, as well as other economic variables. Time-series models are particularly useful when little is known about the underlying process that one is trying to forecast. The limited structure in time-series models makes them most reliable only in the short run, but they are nonetheless rather useful.

Single-equation regression models In this class of models the variable under study is explained by a single function (linear or nonlinear) of explanatory variables. The equation will often be time-dependent (i.e., the time index will appear explicitly in the model), so that one can predict the response over time of the variable under study to changes in one or more of the explanatory variables.

An example of a single-equation regression model might be an equation that relates a particular interest rate, such as the 3-month Treasury bill rate, to a set of explanatory variables such as the money supply, the rate of inflation, and the rate of change in the gross national product. Regression models are often used to forecast not only the movement in short- and long-term interest rates but also many other economic and business variables.

Multi-equation simulation models In this class of models the variable to be studied may be a function of several explanatory variables, which now are related to each other as well as to the variable under study through a set of equations. The construction of a simulation model begins with the specification of a set of individual relationships, each of which is fitted to available data. Simulation is the process of solving these equations simultaneously over some range in time.

An example of a multi-equation simulation model would be a complete model of the United States textile industry that contains equations explaining variables such as textile demand, textile production output, employment of production workers in the textile industry, investment in the industry, and textile prices. These variables would be related to each other and to other variables (such as total national income, the Consumer Price Index, interest rates, etc.), through a set of linear or nonlinear equations. Given assumptions about the future behavior of national income, interest rates, etc., one could simulate this model into the future and obtain a forecast for each of the model's variables. A model such as this can be used to analyze the impact on the industry of changes in external economic variables.

Multi-equation simulation models presume to explain a great deal about the structure of the actual process being studied. Not only are individual relationships specified, but the model accounts for the interaction of all these interrelationships at the same time. Thus, a five-equation simulation model actually contains more information than the sum of five individual regression equations.

The model not only explains the five individual relationships but also describes the dynamic structure implied by the simultaneous operation of these relationships.

The choice of the type of model to develop is a difficult one, involving trade-offs between time, energy, costs, and desired forecast precision. The construction of a multi-equation simulation model might require large expenditures of time and money, not only in terms of actual work but also in terms of computer time. The gains that result from this effort might include the better understanding of the relationships and structure involved as well as the ability to make a better forecast. However, in some cases these gains may be small enough so to be outweighed by the heavy costs involved. Because the multi-equation model necessitates a good deal of knowledge about the process being studied, the construction of such models may be extremely difficult.

The decision to build a time-series model usually occurs when little or nothing is known about the determinants of the variable being studied, when a large number of data points are available (thus making some kind of inference feasible), and when the model is to be used largely for short-term forecasting. Given some information about the processes involved, however, it may not be obvious whether a time-series model or a single-equation regression model is preferable as a means of forecasting. It may be reasonable for a forecaster to construct both types of models and compare their relative performances.

In the course of this book, we plan not only to describe how each type of model is constructed and used, but also to give some insight into the relative costs and benefits involved. Unfortunately, this can be a rather hard problem, as the choice of model type is often not clear. In any case, it seems natural to include a discussion of all three types of models (single-equation regression, multi-equation simulation, and time series) in the confines of a single book.

3 WHAT THE BOOK CONTAINS

The book is divided into three parts, each concentrating on a different class of models. The most fundamental class of models, discussed in the first part of the book, is the single-equation regression model. The econometric methods developed and used to construct single-equation regression models will, with modification, find application in the construction of multi-equation simulation models as well as time-series models. Thus, Part One of this book presents an introduction to the development and estimation of single-equation econometric models.

Chapters 1 and 2 begin with an introduction to the basic concepts of regression analysis, and a review of elementary statistics. The regression model then is developed in detail, beginning with a two-variable model in Chapter 3 and proceeding to the multiple regression model in Chapters 4 and 5. These chapters also develop statistical tests and procedures that can be used to evaluate the properties of a regression model.

The estimation techniques used in simple regression analysis require that certain assumptions be made about both the data and the model. At times, these assumptions break down. Chapters 6 and 7 begin a discussion of what can be done in some of these cases. Chapter 6 deals with heteroscedasticity and serial correlation and includes statistical tests for these problems as well as estimation methods that correct for them. Chapter 7 deals with the problem of correlation between explanatory variables and the implicit error term in the regression model. It concentrates on the development of the instrumental variable and two-stage least-squares estimation techniques.

Chapter 8 discusses the use of a single-equation regression model for forecasting purposes. The chapter discusses not only the methods by which a forecast is produced, but also measures that describe the reliability of a forecast, such as confidence intervals and the error of forecast.

The last two chapters of Part One of the book consider extensions of the regression model. These chapters are somewhat more advanced in nature, and could be skipped by the beginning student. Chapter 9 deals with the problems of missing observations, the estimation of nonlinear models, distributed lag models, and models which pool cross-section and time-series data. Chapter 10 deals with models in which the variable to be explained is qualitative in nature. These include linear probability models, probit models, and logit models.

The foundation of econometrics of Part One is essential for the development of multi-equation simulation models in Part Two of the book. Part Two begins with a chapter on estimation techniques particular to simultaneous equation models. This includes problems of model identification, as well as techniques such as three-stage least squares. Chapters 12 and 13 discuss the methodology of constructing and using multi-equation simulation models. Chapter 12 is an introduction to simulation models, and includes a discussion of the simulation process, methods of evaluating simulation models, alternative methods of estimating simulation models, and general approaches to model construction. Chapter 13 is more technical in nature and discusses methods of analyzing the dynamic behavior of simulation models, including questions of model stability, dynamic multipliers, and methods of tuning and adjusting simulation models. Chapter 13 concludes with a discussion of sensitivity analysis and stochastic simulation.

Part Two closes with a chapter that presents three detailed examples of the construction and use of simulation models. In the first example, a small but complete model of the United States economy is constructed and used for simple policy analysis. The second example develops an industry market model and shows how it can be used to forecast production and prices. The last example shows how simulation techniques can be useful for financial planning in a corporation.

Instructors interested in using some of the econometric models described in Part Two should know about MODSIM, a computer program for simulating macroeconometric models, written by Carl Van Duyne of Williams College and distributed by CONDUIT at the University of Iowa. The program was designed for use in undergraduate and graduate economics courses, and it can perform all the computations normally employed to simulate and systematically evaluate econometric models, including dynamic and static simulation, ex ante forecasting, and the calculation of dynamic multipliers and summary measures of prediction error. The program contains three models of the United States economy: the small macroeconometric model, described in Chapter 14; the complete April 1979 version of the St. Louis model, parts of which are analyzed in Chapter 13; and the simple four-equation macro model in Chapter 12, reestimated using recently revised data. The complete MODSIM package, which includes a magnetic tape of the computer program, User's Manuals, and an Instructor's Guide, is available from CONDUIT, P.O. Box 388, Iowa City, Iowa 52244.

Part Three of this book is devoted to time-series models, which can be viewed as a special class of single-equation regression models. Thus, the econometric tools developed in Part One of the book will find extensive application in Part Three. Part Three begins with Chapters 15 and 16, which discuss basic smoothing and extrapolation techniques, and which introduce the basic properties of random time series, as well as the notion of a time-series model. Chapter 16 also discusses the properties of stationary and nonstationary time series, and the calculation and use of the autocorrelation function.

Chapters 17, 18, and 19 develop the methods by which time-series models are specified, estimated, and used for forecasting. Chapter 17 covers linear time-series models in detail, including moving average models, autoregressive models, mixed models, and finally models of nonstationary time series. Chapter 18 develops regression methods that can be used to estimate a time-series model, as well as methods of diagnostic checking that can be used to ascertain how well the estimated model "fits" the data. Chapter 19 deals with the computation of the minimum mean-square-error forecast, forecast error, and forecast confidence intervals.

The last chapter of Part Three is devoted entirely to examples of the construction and use of time-series models. After we review the modeling process, we construct models of several economic variables and use them to produce short-term forecasts. Finally we demonstrate through examples how models can be constructed that combine time-series with regression analysis.

4 USE OF MATHEMATICAL TOOLS

This book is written on a rather elementary level, and can be understood with only a limited knowledge of calculus and no knowledge of matrix algebra. Mathematical derivations and proofs are generally reserved for appendixes or suppressed entirely. In Part One of the book, the development of the regression model in matrix form is included in the appendixes. Thus most if not all of the book should be accessible to advanced undergraduate students as well as graduate students.

It is desirable that the reader of this book have some background in statistics. Although Chapter 2 contains a brief review of probability and statistics, the student with *no* background in statistics may find parts of the book somewhat difficult. Typically, this book would be used in an applied econometrics or business-forecasting course which a student would take after completing an introductory course in statistics.

5 ALTERNATIVE USES OF THE BOOK

The book is intended to have a wide spectrum of uses. Curriculum uses include an undergraduate or introductory graduate course in econometrics and an undergraduate or graduate course in business forecasting. In addition, this book can be of considerable value as a reference book for people doing statistical analyses of economic and business data or as a text or reference book for the social scientist or business analyst interested in the application of dynamic simulation models to forecasting or policy analysis.

Coverage in an introductory econometrics or business forecasting course must, of course, depend to some extent on the background of the student and the goals of the instructor. Emphasis on the use of econometric techniques for purposes of forecasting with econometric models would provide for one focus, but several alternatives are available. We list several alternative uses of the book below, but stress that the great variety of the material leaves a good deal of discretion to the instructor planning a course outline.

1. Undergraduate Econometrics (one semester)
   a. Standard
   Part One: Chapters 1 to 7; portions of Chapters 8 to 10 optional
   b. Simulation emphasis
   Part One: Chapters 1 to 8
   Part Two: Chapters 12 to 14
   Both courses would omit all matrix appendixes.
2. First-year graduate econometrics
   a. One semester
   Part One: Chapters 1 to 8; Chapters 9 and 10 optional
   Part Two: Chapters 11 to 14
   Portions of the above and the appendixes may be optional.
   b. Two semesters
   Part One: Chapters 1 to 10
   Part Two: Chapters 11 to 14
   Part Three: Chapters 15 to 17; portions of Chapters 18 to 20 optional
   Emphasis on either simulation and/or time-series analysis would depend upon the interest of the instructor.

3. Business forecasting (graduate or advanced undergraduate)
   a. *One semester*
      Part One: Chapter 8 plus review of Chapters 1 to 7
      Part Two: Chapters 12 to 14
      Part Three: Chapters 15 to 20 (selected portions)
   b. *Two semesters*
      Part One: Chapters 1 to 8
      Part Two: Chapters 11 to 14
      Part Three: Chapters 15 to 20
4. Quantitative methods for policy analysis
   a. *Undergraduate, one semester*
      Part One: Chapters 1 to 8
      Part Two: Chapters 12 to 14
   b. *Graduate, one semester*
      Part One: Chapters 1 to 8
      Part Two: Chapters 11 to 14
   c. *Graduate, two semesters*
      Part One: Chapters 1 to 8; Chapters 9 and 10 optional
      Part Two: Chapters 11 to 14
      Part Three: Chapters 15 to 20

The book could also be used for courses in quantitative social science modeling (as taught in departments of sociology or political science). Such a course using this book as a text would probably cover most of Parts One and Two.

6 WHAT DISTINGUISHES THIS BOOK FROM OTHERS?

This book attempts to explain the development and use of quantitative models from a broad perspective. Most textbooks on econometrics develop the single-equation regression model as a self-contained and isolated entity. The reader of such a book often infers that statistical regression models are somehow distinct and independent from other aspects of modeling, such as the analysis of a model's dynamic structure or the use of time-series analysis to forecast one or more exogenous variables in the model. This is certainly not the case, as any practitioner of the art knows. In developing a multi-equation simulation model, for example, one must be knowledgeable not only about regression methods but also about how a model's dynamic behavior results from the interaction of its individual equations.

This book develops the techniques and methods for the construction of all three types of models. Thus, the reader becomes aware of the use of single-equation econometrics as a modeling form in itself, as a tool that can be used in the development of multi-equation simulation models, and as a statistical basis for the development of stochastic time-series models for forecasting. The reader also becomes aware that there is more than one type of model and (we hope) gains an understanding of what models are preferable for a particular purpose.

We believe that this wide breadth of coverage is desirable. The simulation and time-series techniques that make up Parts Two and Three of this book are usually presented only at an advanced level. We feel that a strength of this book is that the coverage is broad and includes these advanced techniques but is presented on a level that can be understood and appreciated by the beginning student.

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