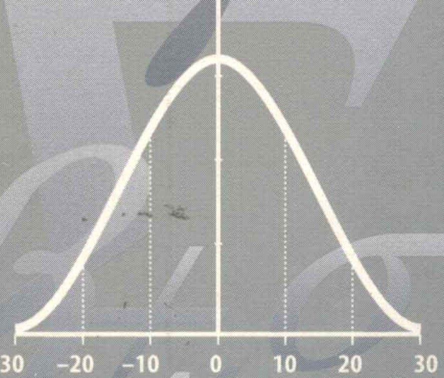
BADI H. BALTAGI

Econometrics

2nd Revised Edition



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Badi H. Baltagi

Econometrics

Second, Revised Edition

With 33 Figures
and 19 Tables

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Preface

This book is intended for a first year graduate course in econometrics. However, the first six chapters have no matrix algebra and can be used in an advanced undergraduate class. This can be supplemented by some of the material in later chapters that do not require matrix algebra, like the first part of Chapter 11 on simultaneous equations and Chapter 14 on time-series analysis.

This book teaches some of the basic econometric methods and the underlying assumptions behind them. Estimation, hypotheses testing and prediction are three recurrent themes in this book. Some uses of econometric methods include (i) empirical testing of economic theory, whether it is the permanent income consumption theory or purchasing power parity, (ii) forecasting, whether it is GNP or unemployment in the U.S. economy or future sales in the computer industry. (iii) Estimation of price elasticities of demand, or returns to scale in production. More importantly, econometric methods can be used to simulate the effect of policy changes like a tax increase on gasoline consumption, or a ban on advertising on cigarette consumption.

It is left to the reader to choose among the available econometric software to use, like TSP, SHAZAM, PcGive, Microfit, HUMMER, LIMDEP, SAS, STATA, GAUSS and EViews. The empirical illustrations in the book utilize a variety of these software packages. Of course, these packages have different advantages and disadvantages. However, for the basic coverage in this book, these differences may be minor and more a matter of what software the reader is familiar or comfortable with. In most cases, I encourage my students to use more than one of these packages and to verify these results using simple programming languages. Several of these packages are reviewed in the *Journal of Applied Econometrics* and *The American Statistician.*

This book is not meant to be encyclopedic. I did not attempt the coverage of Bayesian econometrics simply because it is not my comparative advantage. The reader should consult the classic on the subject by Zellner (1971) and the more recent treatment by Poirier (1995). Nonparametrics and semiparametrics, and the Generalized Methods of Moments are popular methods in today's econometrics, yet they are not covered in this book to keep the technical difficulty at a low level. These are a must for a follow-up course in econometrics. Also, for a more rigorous treatment of asymptotic theory, see White (1984). Despite these limitations, the topics covered in this book are basic and necessary in the training of every economist. In fact, it is but a 'stepping stone', a 'sample of the good stuff' the reader will find in this young, energetic and ever evolving field.

I hope you will share my enthusiasm and optimism in the importance of the tools you will learn when you are through reading this book. Hopefully, it will encourage you to consult the suggested readings on this subject that are referenced at the end of each chapter. In his inaugural lecture at the University of Birmingham, entitled "Econometrics: A View from the Toolroom," Peter C.B. Phillips (1977) concluded:

> *the toolroom may lack the glamour of economics as a practical art in government or business, but it is every bit as important. For the tools (econometricians) fashion provide the key to improvements in our quantitative information concerning matters of economic policy.*"

As a student of econometrics, I have benefited from reading Johnston (1984), Kmenta (1986), Theil (1971), Klein (1974), Maddala (1977), and Judge, et.al. (1985), to mention a few. As a teacher of undergraduate econometrics, I have learned from Kelejian and Oates (1989), Wallace and Silver (1988), Maddala (1992) and Kennedy (1992). As a teacher of graduate econometrics courses, Greene (1993), Judge, et.al. (1985), Fomby, Hill and Johnson (1984) and Davidson and MacKinnon (1993) have been my regular companions. The influence of these books will be evident in the pages that follow. At the end of each chapter I direct the reader to some of the classic references as well as further suggested readings.

This book strikes a balance between a rigorous approach that proves theorems and a completely empirical approach where no theorems are proved. Some of the strengths of this book lie in presenting some difficult material in a simple, yet rigorous manner. For example, Chapter 12 on pooling time-series of cross-section data is drawn from the author's area of expertise in econometrics and the intent here is to make this material more accessible to the general readership of econometrics.

The exercises contain theoretical problems that should supplement the understanding of the material in each chapter. Some of these exercises are drawn from the Problems and Solutions series of *Econometric Theory* (reprinted with permission of Cambridge University Press). Students should be encouraged to solve additional problems from more current issues of *Econometric Theory* and submit their solutions for possible publication in that journal. In addition, the book has a set of empirical illustrations demonstrating some of the basic results learned in each chapter. Data sets from published articles are provided for the empirical exercises. These exercises are solved using several econometric software packages and are available in the Solution Manual. This book is by no means an applied econometrics text, and the reader should consult Berndt's (1991) textbook for an excellent treatment of this subject. Instructors are encouraged to get other data sets from the internet or journals that provide backup data sets to published articles. The *Journal of Applied Econometrics* and the *Journal of Money, Credit and Banking* are two such journals. In addition, Lott and Ray (1992) provide some data sets for classroom use.

I would like to thank my teachers Lawrence R. Klein, Roberto S. Mariano and Robert Shiller who introduced me to this field; James M. Griffin who provided some data sets, empirical exercises and helpful comments, and many colleagues who had direct and indirect influence on the contents of this book including G.S. Maddala, Jan Kmenta, Peter Schmidt, Cheng Hsiao,Tom Wansbeek, Walter Krämer, Maxwell King, Peter C. B. Phillips, Alberto Holly, Essie Maasoumi, Farshid Vahid, Heather Anderson, Arnold Zellner and Bryan Brown. Also, I would like to thank my students Wei-Wen Xiong, Ming-Jang Weng and Kiseok Nam who read parts of this book and solved several of the exercises; Teri Bush who typed numerous drafts and revisions of this book, and Werner Müller for his prompt and professional editorial help. I have also benefited from my visits to the University of Arizona, Monash University, Australia and the University of Dortmund, Germany. This book is dedicated to my wife Phyllis whose help and support were essential to completing this book.

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Data

There are fourteen data sets used in this text. These can be downloaded from the Springer web site in Germany. The address is: *www.springer.de/economics/samsup/baltagi.* There is also a readme file that describes the contents of each data sets and its source.

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CHAPTER 1
What is Econometrics?

1.1 Introduction

What is econometrics? A few definitions are given below:

> *The method of econometric research aims, essentially, at a conjunction of economic theory and actual measurements, using the theory and technique of statistical inference as a bridge pier.*
>
> Trygve Haavelmo (1944)

> *Econometrics may be defined as the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference.*
>
> Samuelson, Koopmans and Stone (1954)

> *Econometrics is concerned with the systematic study of economic phenomena using observed data.*
>
> Aris Spanos (1986)

For other definitions of econometrics, see Tintner (1953).

An econometrician has to be a competent mathematician and statistician who is an economist by training. Fundamental knowledge of mathematics, statistics and economic theory are a necessary prerequisite for this field. As Ragnar Frisch (1933) explains in the first issue of *Econometrica*, it is the unification of statistics, economic theory and mathematics that constitutes econometrics. Each view point, by itself is necessary but not sufficient for a real understanding of quantitative relations in modern economic life.

Ragnar Frisch is credited with coining the term 'econometrics' and he is one of the founders of the *Econometrics Society*, see Christ (1983). Econometrics aims at giving empirical content to economic relationships. The three key ingredients are economic theory, economic data, and statistical methods. Neither 'theory without measurement', nor 'measurement without theory' are sufficient for explaining economic phenomena. It is as Frisch emphasized their union that is the key for success in the future development of econometrics.

Lawrence R. Klein, the 1980 recipient of the Nobel Prize in economics "for the creation of econometric models and their application to the analysis of economic fluctuations and economic policies,"[1] has always emphasized

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[1]See the interview of Professor L.R. Klein by Mariano (1987). *Econometric Theory* publishes interviews with some of the giants in the field. These interviews offer a wonderful glimpse at the life and work of these giants.

the integration of economic theory, statistical methods and practical economics. The exciting thing about econometrics is its concern for verifying or refuting economic laws, such as purchasing power parity, the life cycle hypothesis, the quantity theory of money, etc. These economic laws or hypotheses are testable with economic data. In fact, David F. Hendry (1980) emphasized this function of econometrics:

> *The three golden rules of econometrics are test, test and test; that all three rules are broken regularly in empirical applications is fortunately easily remedied. Rigorously tested models, which adequately described the available data, encompassed previous findings and were derived from well based theories would enhance any claim to be scientific.*

Econometrics also provides quantitative estimates of price and income elasticities of demand, estimates of returns to scale in production, technical efficiency, the velocity of money, etc. It also provides predictions about future interest rates, unemployment, or GNP growth. Lawrence Klein (1971) emphasized this last function of econometrics:

> *Econometrics had its origin in the recognition of empirical regularities and the systematic attempt to generalize these regularities into "laws" of economics. In a broad sense, the use of such "laws" is to make predictions -- about what might have or what will come to pass. Econometrics should give a base for economic prediction beyond experience if it is to be useful. In this broad sense it may be called the science of economic prediction.*

Econometrics, while based on scientific principles, still retains a certain element of art. According to Malinvaud (1966), the art in econometrics is trying to find the right set of assumptions which are sufficiently specific, yet realistic to enable us to take the best possible advantage of the available data. Data in economics are not generated under ideal experimental conditions as in a physics laboratory. This data cannot be replicated and is most likely measured with error. In some cases, the available data are proxies for variables that are either not observed or cannot be measured. Many published empirical studies find that economic data may not have enough variation to discriminate between two competing economic theories. To some, the "art" element in econometrics has left a number of distinguished economists doubtful of the power of econometrics to yield sharp predictions. In his presidential address to the American Economic Association, Wassily Leontief (1971, pp. 2-3) characterized econometrics work as:

> *an attempt to compensate for the glaring weakness of the data base available to us by the widest possible use of more and more sophisticated techniques. Alongside the mounting pile of elaborate theoretical models we see a fast growing stock of equally intricate statistical tools. These are intended to stretch to the limit the meager supply of facts.*

Griliches (1986; p. 1466) argues that:

Econometricians have an ambivalent attitude towards economic data. At one level, the 'data' are the world that we want to explain, the basic facts that economists purport to elucidate. At the other level, they are the source of all our trouble. Their imperfection makes our job difficult and often impossible...We tend to forget that these imperfections are what gives us our legitimacy in the first place...Given that it is the 'badness' of the data that provides us with our living, perhaps it is not all that surprising that we have shown little interest in improving it, in getting involved in the grubby task of designing and collecting original data sets of our own. Most of our work is on 'found' data, data that have been collected by somebody else, often for quite different purposes .

1.2 A Brief History

For a brief review of the origins of econometrics before World War II and its development in the 1940-1970 period, see Klein (1971). Klein gives an interesting account of the pioneering works of Moore (1914) on economic cycles, Working (1927) on demand curves, Cobb and Douglas (1928) on the theory of production, Schultz (1938) on the theory and measurement of demand, and Tinbergen (1939) on business cycles. As Klein (1971, p. 415) adds:

The works of these men mark the beginnings of formal econometrics. Their analysis was systematic, based on the joint foundations of statistical and economic theory, and they were aiming at meaningful substantive goals - to measure demand elasticity, marginal productivity and the degree of macroeconomic stability.

The story of the early progress in estimating economic relationships in the U.S. is given in Christ (1985). The modern era of econometrics, as we know it today, started in the 1940's. Klein (1971) attributes the formulation of the econometrics problem in terms of the theory of statistical inference to Haavelmo (1943, 1944) and Mann and Wald (1943). This work was extended later by T.C. Koopmans, J. Marschak, L. Hurwicz, T.W. Anderson and others at the Cowles Commission in the late 1940's and early 1950's, see Koopmans (1950). Klein (1971, p. 416) adds:

At this time econometrics and mathematical economics had to fight for academic recognition. In retrospect, it is evident that they were growing disciplines and becoming increasingly attractive to the new generation of economic students after World War II, but only a few of the largest and most advanced universities offered formal work in these subjects. The mathematization of economics was strongly resisted.

This resistance is a thing of the past, with econometrics being an integral part of economics, taught and practiced worldwide. *Econometrica*, the official journal of the *Econometric Society* is one of the leading journals in economics, and today the *Econometric Society* boast a large membership worldwide.

Research at the Cowles Commission was responsible for providing formal solutions to the problems of identification and estimation of the simultaneous equations model, see Christ (1985).[2] Two important monographs summarizing much of the work of the Cowles Commission at Chicago, are Koopmans and Marschak (1950) and Koopmans and Hood (1953).[3] The creation of large data banks of economic statistics, advances in computing, and the general acceptance of Keynesian theory, were responsible for a great flurry of activity in econometrics. Macroeconometric modelling started to flourish beyond the pioneering macro models of Klein (1950) and Klein and Goldberger (1955).

For the story of the founding of *Econometrica* and the *Econometric Society*, see Christ (1983). Suggested readings on the history of econometrics are Pesaran (1987), Epstein (1987) and Morgan (1990).

1.3 Critiques of Econometrics

Econometrics has its critics. Interestingly, John Maynard Keynes (1940, p. 156) had the following to say about Jan Tinbergen's (1939) pioneering work:

> *No one could be more frank, more painstaking, more free of subjective bias or parti pris than Professor Tinbergen. There is no one, therefore, so far as human qualities go, whom it would be safer to trust with black magic. That there is anyone I would trust with it at the present stage or that this brand of statistical alchemy is ripe to become a branch of science, I am not yet persuaded. But Newton, Boyle and Locke all played with alchemy. So let him continue.* [4]

In 1969, Jan Tinbergen shared the first Nobel Prize in economics with Ragnar Frisch.

Recent well cited critiques of econometrics include the Lucas (1976) critique which is based on the Rational Expectations Hypothesis (REH). As Pesaran (1990, p. 17) puts it:

> *The message of the REH for econometrics was clear. By postulating that economic agents form their expectations endogenously on the basis of the true model of the economy and a correct understanding of the processes generating exogenous variables of the model, including government policy, the REH raised serious doubts about the invariance of the structural parameters of the mainstream macroeconometric models in face of changes in government policy.*

---

[2] Simultaneous equations model is an integral part of econometrics and is studied in Chapter 11.

[3] Tjalling Koopmans was the joint recipient of the Nobel Prize in Economics in 1975. In addition to his work on the identification and estimation of simultaneous equations models, he received the Nobel Prize for his work in optimization and economic theory.

[4] I encountered this attack by Keynes on Tinbergen in the inaugural lecture that Peter C.B. Phillips (1977) gave at the University of Birmingham entitled "Econometrics: A View From the Toolroom," and David F. Hendry's (1980) article entitled "Econometrics - Alchemy or Science?"

Responses to this critique include Pesaran (1987). Other lively debates among econometricians include Ed Leamer's (1983) article entitled "Let's Take the Con Out of Econometrics," and the response by McAleer, Pagan and Volker (1985). Rather than leave the reader with criticisms of econometrics especially before we embark on the journey to learn the tools of the trade, we conclude with the following quote from Pesaran (1990, pp. 25-26):

> *There is no doubt that econometrics is subject to important limitations, which stem largely from the incompleteness of the economic theory and the non-experimental nature of economic data. But these limitations should not distract us from recognizing the fundamental role that econometrics has come to play in the development of economics as a scientific discipline. It may not be possible conclusively to reject economic theories by means of econometric methods, but it does not mean that nothing useful can be learned from attempts at testing particular formulations of a given theory against (possible) rival alternatives. Similarly, the fact that econometric modelling is inevitably subject to the problem of specification searches does not mean that the whole activity is pointless. Econometric models are important tools for forecasting and policy analysis, and it is unlikely that they will be discarded in the future. The challenge is to recognize their limitations and to work towards turning them into more reliable and effective tools. There seem to be no viable alternatives.*

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