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高等院校双语教材 · 经济系列

# ECONOMETRIC ANALYSIS

(Sixth Edition)

# 计量经济分析

(第六版)

威廉·H·格林 (William H. Greene) 著

张成思 改编

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## 出 版 说 明

中国的入世，使其真正融入到经济全球化的浪潮中。中国政府“引进来，走出去”战略，使得中国经济的发展需要大量的“国际化”人才储备。这就对我国一般本科院校多年来所采取的单一语言（母语）教学提出严峻挑战，财经院校涉外经济类专业实行双语教学改革迫在眉睫。

顺应这一潮流，中国人民大学出版社携手众多国际知名的大出版公司，如麦格劳-希尔、培生教育出版公司等，面向大学本科层次，遴选了一批国外最优秀的经济类原版教材，包括宏观经济学、微观经济学、计量经济学、金融学等经济类专业基础课。

我们在引进出版过程中，注重把好质量关，每一本书都经过该学科领域的专家审核选题和内容，争取做到把国外真正高水平的适合国内实际的优秀教材引进来。本套教材主要有以下特点：

第一，体系设计完整。本套教材精选了一批国外著名出版公司的优秀教材，基本上涵盖了经济学专业的核心课程。

第二，保持英文原版教材的特色。本套教材根据国内教学需要，对原书进行了一定的改编，主要删减了一些不适合和不符合我国国情的内容，但体系结构和内容方面都保持原版教材的特色。

第三，内容紧扣学科前沿。本套教材在原著选择上紧扣国外教学的前沿，基本上都选择国外最流行教材的最新版本，有利于老师和学生掌握国外教学研究的最新发展趋势。

第四，篇幅合理，价格适中。为适应国内双语教学内容和课时上的实际需要，本套教材在进行了删减改编后，篇幅更为合理。同时，考虑到学生实际的购买能力，我们采取低定价策略，这样，读者既能领略原版图书的风貌，又避免了高额的购买费用。

第五，提供强大的教学支持。依托国外大出版公司的力量，本套教材为教师提供了配套的教辅资料，如教师手册、PPT课堂演示文稿、试题库等，并配套有内容丰富的网络资源，从而使教学更为便利。

本套教材既适合高等院校经济类专业的本科教学使用，也适合从事经济类工作和研究的人员阅读和培训使用。我们在选书、改编过程中虽然全面听取了专家的意见，做到尽可能满足读者的需求，但由于各教材的作者所处的政治、经济和文化背景不同，书中内容仍可能有不妥之处，我们真诚希望广大读者提出宝贵意见和建议，以便我们在以后的版本中不断改进和完善。

## 改 编 者 前 言

《计量经济分析》(Econometric Analysis)是计量经济学领域经典的教材之一。这本教材自1990年问世以来,在全球众多高校的中高级计量经济学课程中得到广泛使用,成为计量经济学领域的研究人员不可多得的案头参考资料。

近年来,随着计量经济学学科的飞速发展,许多最新的前沿研究成果不断地充实到教材当中。这样,与其他主流的经济类教材一样,《计量经济分析》从1990年第一版开始至2008年,已经更新到第六版。

通读第六版原文,不难发现其内容详尽,资料充实,案例丰富,为读者提供了非常全面的参考素材。而这本经典教材在内容上的不断扩充,也确实彰显了学科的发展速度。但是,在选用教材的过程中,广大教师可能还需要考虑教学学时、教学内容的覆盖面以及教学难度等问题。尤其是在学时安排比较紧凑的情况下,不可能将全书所有内容都进行讲解。同时,学生可能也需要有选择地阅读基本且重要的内容。有鉴于此,《计量经济分析》(第六版)的精编版在完整版的基础上进行了删节,删减的依据是主要保留计量经济学比较基本与核心的重点内容(如最小二乘、广义回归以及重要的模型诊断检验内容等),适当保留部分重要的前沿内容(如面板数据回归的相关内容等)。这样,如果没有足够的时间阅读《计量经济分析》的全书完整版,就可以选择精编版,从而也能体会到这本著作的精髓。这在一定程度上避免了由于教材篇幅过长而可能给读者带来“只见树木不见森林”的问题。

当然,在条件和时间允许的情况下,格林的这本经典计量经济学教材的完整版<sup>①</sup>,还是非常值得一读的。对于学生、教师和研究人员来说,选择完整版作为案头必备的参考资料,而选择精编版作为教学和研读的工具,可能会收到更好的效果。

张成思

2009年7月于北京

<sup>①</sup> 本书完整版的中文翻译版已由中国人民大学出版社购买版权并将出版。

## PREFACE



### THE SIXTH EDITION OF ECONOMETRIC ANALYSIS

*Econometric Analysis* is intended for a one-year graduate course in econometrics for social scientists. The prerequisites for the course would include calculus, mathematical statistics, and an introduction to econometrics at the level of, say, Gujarati's (2002) *Basic Econometrics*, Stock and Watson's (2006) *Introduction to Econometrics*, or Wooldridge's *Introductory Econometrics: A Modern Approach* (2006). We assume, for example, that the reader has already learned about the basics of econometric methodology; the distinctions between time-series, cross section, and panel data sets; and the fundamental role of economic and statistical assumption in econometric model building. Rather than being an introduction to econometrics, this work is a bridge between an introduction to the field and the professional literature for graduate students in the social sciences.

The arrangement of this book is as follows: Our formal presentation of econometrics begins in Part I with development of its fundamental pillar, the *classical linear multiple regression model*, in Chapters 1 through 4. Estimation and inference with the linear least squares estimator is analyzed here. In Part II, Chapters 5 through 7 relax the crucial assumptions of the classical model to introduce the *generalized regression model* and *nonlinear regressions*. This provides the frameworks for the most familiar extensions of the linear model: heteroscedasticity, systems of regression equations, and fixed and random effects models for panel data sets. Part III, Chapters 8 and 9, presents the method of *instrumental variables* and its application to the estimation of simultaneous equations models. The linear model, even in its generalized form, is usually not the sole technique used in most of the current literature. In view of this, the (ever-expanding) second half of the book is devoted to topics that will extend the linear regression model in many directions. In Part IV, Chapters 10 to 11 present different estimation methodologies. The leading application of semiparametric estimation in the current literature is the *generalized method of moments (GMM) estimator* presented in Chapter 10. This is a technique that provides the platform for much of modern econometrics. *Maximum likelihood estimation* is developed in Chapter 11. Monte Carlo and simulation-based methods have become a major component of current research. Part V, Chapters 12 to 13, and Part VI, all Chapters 14 to 15, present two (not *the* two) major subdivisions of econometric methods, macroeconometrics, which is usually associated with analysis of timeseries data, and microeconometrics, which is typically based on cross-section and panel data. In Chapters 12–13, we consider models of serial correlation, lagged variables, and nonstationary data—the usual substance of macroeconomic analysis. Chapters 14 to 15 are concerned with models of discrete choice, censoring, truncation, sample

selection, treatment effects, and the analysis of events (how many and when they occur).

This book has two objectives. The first is to introduce students to *applied econometrics*, including basic techniques in linear regression analysis and some of the rich variety of models that are used when the linear model proves inadequate or inappropriate. The second is to present students with sufficient *theoretical background* so that they will recognize new variants of the models learned about here as merely natural extensions that fit within a common body of principles. Thus, I have spent what might seem to be a large amount of effort explaining the mechanics of GMM estimation, nonlinear least squares, and maximum likelihood estimation, for example, of GARCH models. To meet the second objective, this book also contains a fair amount of theoretical material, such as that on maximum likelihood estimation and on asymptotic results for regression models. Modern software has made complicated modeling very easy to do, and an understanding of the underlying theory is important.

Among the changes in the order of the topics is a fairly noticeable reorientation of the maximum likelihood estimator (MLE). The development of maximum likelihood has, like its use in the literature, become somewhat more sharply focused. Where there exist robust alternatives to the MLE, such as moment-based estimators for the random effects linear model, researchers have tended to gravitate to them. By dint of its stronger distributional assumption, the MLE in that and like models is a less attractive choice. Nonetheless, the MLE is still the estimator of choice in most settings, and it is used where there is no preferable alternative. Antwiler's (2001) estimator for nested random effects is an intriguing application. In like fashion, our treatment of maximum likelihood estimation is more compartmentalized in this edition; we have moved several of the discussions of specific MLEs—for example, the multiplicative heteroscedasticity model, the random effects model, the seemingly unrelated regressions model, and a few others—to a single presentation of the ML estimator in Chapter 16, where they are developed as applications. Later in the book, in the section on microeconometrics, the MLE reemerges as the leading estimator.

I had several purposes in undertaking this revision. As in the past, readers continue to send me interesting ideas for topics in my “next edition.” It is impossible to use them all, of course. Because the five received volumes of the *Handbook of Econometrics*, two volumes of the *Handbook of Applied Econometrics*, and the *Palgrave Handbook of Econometrics* already run to well over 6,000 pages, it is also unnecessary. Nonetheless, there are new and interesting developments in the field, particularly in the areas of microeconometrics (panel data and models for discrete choice) and, of course, in time series, which continues its rapid development, that students will enjoy learning about. Second, I have taken the opportunity to continue fine-tuning the text as the experience and shared wisdom of my readers accumulates. For this revision (as in the previous one), that adjustment has entailed a substantial rearrangement of the material. With this edition, I have taken the advice of some of my readers and reordered the material somewhat to make it easier to construct a course outline (“the Greene course,” I have been told) with the text. Although *Econometric Analysis* has (to my great delight) become a common reference for professional analysts, at its heart, it is a textbook. It is my hope that this revision will enhance that aspect of the work. Of course, the literature in econometrics has continued to evolve, and my third objective is to grow with it. This purpose is inherently difficult to accomplish in a textbook. Most of the literature is written by professionals for other professionals, and this textbook is written for students

who are in the early stages of their training. But I do hope to provide a bridge to that literature, both theoretical and applied.

This book is a broad survey of the field of econometrics. This field grows continually, and such an effort becomes increasingly difficult. (A partial list of journals devoted at least in part, if not completely, to econometrics now includes *The Journal of Applied Econometrics*, *Journal of Econometrics*, *The Econometric Journal*, *Econometric Theory*, *Econometric Reviews*, *Journal of Business and Economic Statistics*, *Empirical Economics*, *Foundations and Trends in Econometrics*, and *Econometrica*.) Still, my view has always been that the serious student of the field must start somewhere, and one *can* successfully seek that objective in a single textbook. This text attempts to survey, at an entry level, enough of the fields in econometrics that a student can comfortably move from here to practice or more advanced study in one or more specialized areas. At the same time, I have tried to present the material in sufficient generality so that the reader is also able to appreciate the important common foundation of all these fields and to use the tools that they all employ.

There are also quite a few recently published texts in econometrics. Several have gathered in compact, elegant treatises the increasingly advanced and advancing background theory of econometrics. Others, such as this book, focus more attention on applications of econometrics. One feature that distinguishes this work from its predecessors is its greater emphasis on nonlinear models. Computer software now in wide use has made estimation of nonlinear models as routine as estimation of linear ones, and the recent literature reflects that progression. My purpose is to provide a textbook treatment that is in line with current practice. The book includes four chapters on estimation methods used in current research and seven chapters on applications in macro and microeconomics. The nonlinear models used in these fields are now the staples of the applied econometrics literature. This book also contains a fair amount of material that will extend beyond many first courses in econometrics. Once again, I have included this in the hope of providing a bridge to the professional literature in these areas.

I have had one overriding purpose that has motivated all six editions of this work. For the vast majority of readers of books such as this, whose ambition is to use, not develop econometrics, I believe that it is simply not sufficient to recite the theory of estimation, hypothesis testing, and econometric analysis. Understanding the often subtle background theory is extremely important. But, at the end of the day, my purpose in writing this work, and in my continuing efforts to update it, is to show readers how to *do* econometric analysis. I unabashedly accept the unflattering assessment of a correspondent who once likened this book to a “user’s guide to econometrics.”

## SOFTWARE AND DATA

There are many computer programs that are widely used for the computations described in this book. All were written by econometricians or statisticians, and in general, all are regularly updated to incorporate new developments in applied econometrics. A sampling of the most widely used packages and Internet home pages where you can find information about them are:

<i>EViews</i>	<a href="http://www.eviews.com">www.eviews.com</a>	(QMS, Irvine, CA)
<i>Gauss</i>	<a href="http://www.aptech.com">www.aptech.com</a>	(Aptech Systems, Kent, WA)



<i>LIMDEP</i>	<a href="http://www.limdep.com">www.limdep.com</a>	(Econometric Software, Plainview, NY)
<i>MATLAB</i>	<a href="http://www.mathworks.com">www.mathworks.com</a>	(Mathworks, Natick, MA)
<i>NLOGIT</i>	<a href="http://www.nlogit.com">www.nlogit.com</a>	(Econometric Software, Plainview, NY)
<i>RATS</i>	<a href="http://www.estima.com">www.estima.com</a>	(Estima, Evanston, IL)
<i>SAS</i>	<a href="http://www.sas.com">www.sas.com</a>	(SAS, Cary, NC)
<i>Shazam</i>	<a href="http://www.shazam.econ.ubc.ca">www.shazam.econ.ubc.ca</a>	(Shazam, UBC, Vancouver, BC)
<i>Stata</i>	<a href="http://www.stata.com">www.stata.com</a>	(Stata, College Station, TX)
<i>TSP</i>	<a href="http://www.tspintl.com">www.tspintl.com</a>	(TSP International, Stanford, CA)

Programs vary in size, complexity, cost, the amount of programming required of the user, and so on. Journals such as *The American Statistician*, *The Journal of Applied Econometrics*, and *The Journal of Economic Surveys* regularly publish reviews of individual packages and comparative surveys of packages, usually with reference to particular functionality such as panel data analysis or forecasting.

With a few exceptions, the computations described in this book can be carried out with any of these packages. I hesitate to link the text to any of them in particular—LIMDEP/NLOGIT was used for the computations in the chapters to follow. I will leave it to the authors of the software to show their users how to do econometrics with their programs. Many authors have produced RATS, LIMDEP, EVIEWS, SAS, and Stata code for some of the applications as well—including, in a few cases, in the documentations for their computer programs.

Most of the data sets used in most of the examples are also on the Web site for the text. Throughout the text, these data sets are referred to “Table A.n.m,” for example Table A4.1. The “A” refers to Appendix at the back of the text, which contains descriptions of the data sets. The actual data are posted in generic ASCII format on the Web site with the other supplementary materials for the text. I should also note, there are now thousands of interesting Web sites containing software, data sets, papers, and commentary on econometrics. It would be hopeless to attempt any kind of a survey here. One that is particularly agreeably structured and well targeted for readers of this book is the data archive for the *Journal of Applied Econometrics*. This journal publishes many papers that are precisely at the right level for readers of this text. They have archived all the nonconfidential data sets used in their publications since 1994. This useful site can be found at [www.qed.econ.queensu.ca/jae/](http://www.qed.econ.queensu.ca/jae/). Several of the examples in the text use the *JAE* data sets. Where we have done so, we direct the reader to the *JAE*’s Web site, rather than our own, for replication. (Other journals have begun to ask their authors to provide code and data to encourage replication, an effort grossly underpursued in economics. The *JAE* is far ahead of their contemporaries in this effort.) Another vast, easy to navigate site for aggregate data on the U.S. economy is [www.economagic.com](http://www.economagic.com).

William H. Greene

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## INTRODUCTION



## 1.1 ECONOMETRICS

In the first issue of *Econometrica*, the Econometric Society stated that

its main object shall be to promote studies that aim at a unification of the theoretical-quantitative and the empirical-quantitative approach to economic problems and that are penetrated by constructive and rigorous thinking similar to that which has come to dominate the natural sciences.

But there are several aspects of the quantitative approach to economics, and no single one of these aspects taken by itself, should be confounded with econometrics. Thus, econometrics is by no means the same as economic statistics. Nor is it identical with what we call general economic theory, although a considerable portion of this theory has a definitely quantitative character. Nor should econometrics be taken as synonymous [*sic*] with the application of mathematics to economics. Experience has shown that each of these three viewpoints, that of statistics, economic theory, and mathematics, is a necessary, but not by itself a sufficient, condition for a real understanding of the quantitative relations in modern economic life. It is the *unification* of all three that is powerful. And it is this unification that constitutes econometrics.

Frisch (1933) and his society responded to an unprecedented accumulation of statistical information. They saw a need to establish a body of principles that could organize what would otherwise become a bewildering mass of data. Neither the pillars nor the objectives of econometrics have changed in the years since this editorial appeared. Econometrics is the field of economics that concerns itself with the application of mathematical statistics and the tools of statistical inference to the empirical measurement of relationships postulated by economic theory.

The crucial role that econometrics plays in economics has grown over time. For example, the Nobel Prize in Economic Sciences has recognized this contribution with numerous awards to econometricians, including the first which went to (the same) Ragnar Frisch in 1969, Lawrence Klein in 1980, Trygve Haavelmo in 1989, James Heckman and Daniel McFadden in 2000, and Robert Engle and Clive Granger in 2003. The 2000 prize was noteworthy in that it celebrated the work of two scientists whose research was devoted to the marriage of behavioral theory and econometric modeling.

**Example 1.1 Behavioral Models and the Nobel Laureates**

The pioneering work by both James Heckman and Dan McFadden rests firmly on a theoretical foundation of utility maximization.

For Heckman's, we begin with the standard theory of household utility maximization over consumption and leisure. The textbook model of utility maximization produces a demand