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清华经济学系列英文版教材

计量经济学导论

现代观点

第 2 版

(美) Jeffrey M. Wooldridge 著

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A Modern Approach
Second Edition



清华大学出版社

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Jeffrey M. Wooldridge

Introductory Econometrics: A Modern Approach, 2e

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出 版 说 明

为了适应经济全球化的发展趋势，满足国内广大读者了解、学习和借鉴国外先进的管理经验和掌握经济理论的前沿动态，清华大学出版社与国外著名出版公司合作影印出版一系列英文版经济管理方面的图书。我们所选择的图书，基本上已是再版多次、在国外深受欢迎、并被广泛采用的优秀教材，绝大部分是该领域中较具权威性的经典之作。在选书的过程中，我们得到了很多专家、学者的支持、帮助和鼓励，在此表示谢意！清华经济学系列英文版教材由清华大学经济管理学院和北京大学经济学院朱宝宪、杨炘、李明志、钟笑寒、姚志勇、刘群艺等老师审阅，在此一并致谢！

由于原作者所处国家的政治、经济和文化背景等与我国不同，对书中所持观点，敬请广大读者在阅读过程中注意加以分析和鉴别。

我们期望这套影印书的出版对我国经济科学的发展能有所帮助，对我国经济管理专业的教学能有所促进。

欢迎广大读者给我们提出宝贵的意见和建议；同时也欢迎有关的专业人士向我们推荐您所接触到的国外优秀图书。

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世纪之交, 中国与世界的发展呈现最显著的两大趋势——以网络为代表的信息技术的突飞猛进, 以及经济全球化的激烈挑战。无论是无远弗界的因特网, 还是日益密切的政治、经济、文化等方面的国际合作, 都标示着 21 世纪的中国是一个更加开放的中国, 也面临着一个更加开放的世界。

教育, 特别是管理教育总是扮演着学习与合作的先行者的角色。改革开放以来, 尤其是 20 世纪 90 年代之后, 为了探寻中国国情与国际上一切优秀的管理教育思想、方法和手段的完美结合, 为了更好地培养高层次的“面向国际市场竞争、具备国际经营头脑”的管理者, 我国的教育机构与美国、欧洲、澳洲以及亚洲一些国家和地区的大量的著名管理学院和顶尖跨国企业建立了长期密切的合作关系。以清华大学经济管理学院为例, 2000 年, 学院顾问委员会成立, 并于 10 月举行了第一次会议, 2001 年 4 月又举行了第二次会议。这个顾问委员会包括了世界上最大的一些跨国公司和中国几家顶尖企业的最高领导人, 其阵容之大、层次之高, 超过了世界上任何一所商学院。在这样高层次、多样化、重实效的管理教育国际合作中, 教师和学生与国外的交流机会大幅度增加, 越来越深刻地融入到全球性的教育、文化和思想观念的时代变革中, 我们的管理教育工作者和经济管理学习者, 更加真切地体验到这个世界正发生着深刻的变化, 也更主动地探寻和把握着世界经济发展和跨国企业运作的脉搏。

我国管理教育的发展, 闭关锁国、闭门造车是绝对不行的, 必须同国际接轨, 按照国际一流的水准来要求自己。正如朱镕基总理在清华大学经济管理学院成立十周年时所发的贺信中指出的那样: “建设有中国特色的社会主义, 需要一大批掌握市场经济的一般规律, 熟悉其运行规则, 而又了解中国企业实情的经济管理人才。清华大学经济管理学院就要敢于借鉴、引进世界上一切优秀的经济管理学院的教学内容、方法和手段, 结合中国的国情, 办成世界第一流的经管学院。”作为达到世界一流的一个重要基础, 朱镕基总理多次建议清华的 MBA 教育要加强英语教学。我体会, 这不仅因为英语是当今世界交往中重要的语言工具, 是连接中国与世界的重要桥梁和媒介, 而且更是中国经济管理人才参与国际竞争, 加强国际合作, 实现中国企业的国际战略的基石。推动和实行英文教学并不是目的, 真正的目的在于培养学生——这些未来的企业家——能够具备同国际竞争对手、合作伙伴沟通和对抗的能力。按照这一要求, 清华大学经济管理学院正在不断推动英语教学的步伐, 使得英语不仅是一门需要学习的核心

世纪之交,中国与世界的发展呈现最显著的两大趋势——以网络为代表的信息技术的突飞猛进,以及经济全球化的激烈挑战。无论是无远弗界的因特网,还是日益密切的政治、经济、文化等方面的国际合作,都标示着21世纪的中国是一个更加开放的中国,也面临着一个更加开放的世界。

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Preface

My motivation for writing the first edition of *Introductory Econometrics: A Modern Approach* was that I saw a fairly wide gap between how econometrics is taught to undergraduates and how empirical researchers think about and apply econometric methods. Just as important, I was convinced that teaching introductory econometrics from the perspective of professional users of econometrics would actually simplify the presentation, in addition to making the subject much more interesting.

Based on the numerous positive reactions to the first edition, it appears my philosophy about teaching introductory econometrics is shared by many others. It is gratifying that instructors with a variety of backgrounds and interests—including applied microeconomics, applied macroeconomics, policy analysis, political science, and theoretical econometrics—teaching students with very different levels of preparation, have embraced the modern approach to econometrics espoused in this text. Consequently, the structure of the second edition is very much like the first. The emphasis is still on applying econometrics to real-world problems. Each econometric method is motivated by a particular issue facing researchers analyzing nonexperimental data. The emphasis in the main text is on understanding and interpreting the assumptions in light of actual empirical applications: the mathematics required is no more than college algebra and basic probability and statistics.

ORGANIZED FOR TODAY'S ECONOMETRICIAN

The second edition preserves the organization of the first edition. The most noticeable feature that distinguishes this text from others is the separation of topics by the kind of data being analyzed. This is a clear departure from the traditional approach, which presents a linear model, lists all assumptions that may be needed at some future point in the analysis, and then proves or asserts results without clearly connecting them to the assumptions. My approach is to first treat, in Part One, multiple regression analysis with cross-sectional data, under the assumption of random sampling. This setting is completely natural to students because they are familiar with it from their introductory statistics courses. Importantly, it allows us to distinguish between assumptions made about the underlying population regression model—assumptions that can be given economic or general behavioral content—from assumptions about how the data were sampled.

课程，而且渗透到各门专业课程的学习当中。

课堂讲授之外，课前课后的大量英文原版著作、案例的阅读对于提高学生的英文水平也是非常关键的。这不仅是积累相当的专业词汇的重要手段，而且是对学习者思维方式的有效训练。

我们知道，就阅读而言，学习和借鉴国外先进的管理经验和掌握经济理论动态，或是阅读翻译作品，或是阅读原著。前者属于间接阅读，后者属于直接阅读。直接阅读取决于读者的外文阅读能力，有较高外语水平的读者当然喜欢直接阅读原著，这样不仅可以避免因译者的疏忽或水平所限而造成的纰漏，同时也可以尽享原作者思想的真实表达。而对于那些有一定外语基础，但又不能完全独立阅读国外原著的读者来说，外文的阅读能力是需要加强培养和训练的，尤其是专业外语的阅读能力更是如此。如果一个人永远不接触专业外版图书，他在获得国外学术信息方面就永远会比别人差半年甚至一年的时间，他就会在无形中减弱自己的竞争能力。因此，我们认为，有一定外语基础的读者，都应该尝试一下阅读外文原版，只要努力并坚持，就一定能过了这道关，到那时就能体验到直接阅读的妙处了。

在掌握大量术语的同时，我们更看重读者在阅读英文原版著作时对于西方管理者或研究者的思维方式的学习和体会。我认为，原汁原味的世界级大师富有特色的表达方式背后，反映了思维习惯，反映了思想精髓，反映了文化特征，也反映了战略偏好。知己知彼，对于跨文化的管理思想、方法的学习，一定要熟悉这些思想、方法所孕育、成长的文化土壤，这样，有朝一日才能真正“具备国际战略头脑”。

以往，普通读者购买和阅读英文原版还有一个书价的障碍。一本外版书少则几十美元，多则上百美元，一般读者只能望书兴叹。随着全球经济合作步伐的加快，目前在出版行业有了一种新的合作出版的方式，即外文影印版，其价格几乎与国内同类图书持平。这样一来，读者可以不必再为书价发愁。清华大学出版社这些年在这方面一直以独特的优势领先于同行。早在1997年，清华大学出版社敢为人先，在国内最早推出一批优秀商学英文版教材，规模宏大，在企业界和管理教育界引起不小的轰动，更使国内莘莘学子受益良多。

为了配合清华大学经济管理学院推动英文授课的急需，也为了向全国更多的MBA试点院校和更多的经济管理学院的教师和学生提供学习上的支持，清华大学出版社再次隆重推出与世界著名出版集团合作的英文原版影印商学教科书，也使广大工商界人士、经济管理类学生享用到最新最好质优价廉的国际教材。

祝愿我国的管理教育事业在社会各界的大力支持和关心下不断发展、日进日新；祝愿我国的经济建设在不断涌现的大批高层次的面向国际市场竞争、具备国际经营头脑的管理者的勉力经营下早日中兴。

赵纯钧 教授

清华大学经济管理学院院长
全国工商管理硕士教育指导委员会副主任

variable problem by instrumental variables methods. I appear to have made sound choices, as I can recall very few suggestions for adding or deleting material, especially in the basic regression chapters in Parts One and Two. A topic that I did expand on is least absolute deviations estimation (LAD) in Chapter 9. LAD is becoming more and more popular in empirical work, especially when the conditional distribution of the dependent variable is asymmetric or has fat tails. Students reading empirical research in labor economics, public economics, and other fields are more and more likely to run across models estimated by LAD.

In rewriting segments of the text, I have tried to further improve on the systematic approach of the first edition. By systematic, I mean that each topic is presented by building on the previous material in a logical fashion, and assumptions are introduced only as they are needed to obtain a conclusion. For example, applied researchers, as well as theorists, know that not all of the Gauss-Markov assumptions are needed to show that the ordinary least squares (OLS) estimators are unbiased. Yet, almost all econometrics texts introduce the full set of assumptions (many of which are redundant or, in some cases, even logically conflicting) before proving unbiasedness of OLS. Similarly, the normality assumption is included among the assumptions that are needed for the Gauss-Markov Theorem, when it is fairly well known that normality plays no role in showing that the OLS estimators are the best linear unbiased estimators.

My systematic approach carries over to studying large sample properties, where assumptions for consistency are introduced only as needed. This makes it relatively easy to cover more advanced topics, such as using pooled cross sections, exploiting panel data structures, and applying instrumental variables methods. I have worked to provide a unified view of econometrics, by which I mean that all estimators and test statistics are obtained using just a few, intuitively reasonable principles of estimation and testing (which, of course, also have rigorous justification). For example, regression-based tests for heteroskedasticity and serial correlation are easy for students to grasp because they already have a solid understanding of regression. This is in contrast to treatments that give a set of disjointed recipes for outdated econometric procedures.

Throughout the text, I emphasize *ceteris paribus* relationships, which is why, after one chapter on the simple regression model, I move to multiple regression analysis. This motivates students to think about serious applications early. I also give much more prominence to policy analysis with all kinds of data structures. Practical topics, such as using proxy variables to obtain *ceteris paribus* effects and obtaining standard errors for partial effects in models with interaction terms, are covered in a simple fashion.

NEW TO THIS EDITION

In Chapter 3, I have added a complete discussion of omitted variable bias in the multiple regression model; it turns out not to be especially difficult to characterize the bias in the general case. The appendix to Chapter 3 contains a derivation of the bias that requires only basic algebra and statistics.

Chapter 6 contains a more detailed discussion of models with interaction terms. I find that students can have difficulty interpreting the parameters of such models, so I have tried to provide better explanations. Chapters 7 and 13 go into more detail about

Discussions about the consequences of nonrandom sampling can be treated in an intuitive fashion after the students have a good grasp of the multiple regression model as applied to random samples.

An important feature of a modern approach is that the explanatory variables—along with the dependent variable—are treated as outcomes of random variables. For the social sciences, allowing random explanatory variables is much more realistic than the traditional assumption of nonrandom explanatory variables. As a nontrivial benefit, the population model/random sampling approach that I take greatly reduces the number of assumptions that students must absorb and understand. Ironically, the classical approach to regression analysis, which treats the explanatory variables as fixed in repeated samples and is pervasive in introductory texts, literally applies to data collected in an experimental setting. In addition, the contortions required to state and explain assumptions can be confusing to students.

My focus on the population model emphasizes that the fundamental assumptions underlying regression analysis, such as the zero mean assumption on the unobservables, are properly stated conditional on the explanatory variables. This leads to a clear understanding of the kinds of problems, such as heteroskedasticity (nonconstant variance), that can invalidate standard inference procedures. Plus, I am able to dispel several misconceptions that arise in econometrics texts at all levels. As just a few examples, I am able to explain why the usual R -squared is still valid as a goodness-of-fit measure in the presence of heteroskedasticity (and, later on, in the presence of serially correlated errors in time series equations); I am able to discuss, at a very intuitive level, why tests for functional form should not be viewed as general tests of omitted, unobserved variables; and I can easily explain why one should always include in a regression model extra control variables that are uncorrelated with the explanatory variable of interest (such as a policy variable).

Because the assumptions for cross-sectional analysis are relatively straightforward and realistic, students can get involved early with serious cross-sectional applications without having to worry about the thorny issues of trends, seasonality, serial correlation, high persistence, and spurious regression that are ubiquitous in time series regression models. Initially, I figured that my treatment of regression with cross-sectional data followed by regression with time series data would find favor with instructors whose own research interests are in applied microeconomics, and that appears to be the case. It has been gratifying that adopters of the text with an applied time series bent have been equally enthusiastic about the structure of the text. By postponing the econometric analysis of time series data, I am able to put proper focus on the potential pitfalls in analyzing time series data that do not arise with cross-sectional data. In effect, time series econometrics finally gets the serious treatment it deserves in an introductory text.

As in the first edition, I have consciously chosen topics that are important for reading journal articles and for conducting basic empirical research. Within each topic, I have deliberately omitted many tests and estimation procedures that, while traditionally included in textbooks, have not withstood the empirical test of time. Likewise, I have emphasized more recent topics that have clearly demonstrated their usefulness, such as obtaining test statistics that are robust to heteroskedasticity (or serial correlation) of unknown form, using multiple years of data for policy analysis, or solving the omitted

The structure of the text makes it ideal for a course with a cross-sectional/policy analysis focus: the time series chapters can be skipped in lieu of topics from Chapters 9, 13, 14, or 15. Chapter 13 is “advanced” only in the sense that it treats two new data structures: independently pooled cross sections and two-period panel data analysis. Such data structures are especially useful for policy analysis, and the chapter provides several examples. Students with a good grasp of Chapters 1 through 8 will have little difficulty with Chapter 13. Chapter 14 covers more advanced panel data methods and would probably be covered only in a second course. A good way to end a course on cross-sectional methods is to cover the rudiments of instrumental variables estimation in Chapter 15.

I have used selected material in Part Three, including Chapters 13, 15, and 17, in a senior seminar geared at producing a serious research paper. Along with the basic one-semester course, students who have been exposed to basic panel data analysis, instrumental variables estimation, and limited dependent variable models are in a position to read large chunks of the applied social sciences literature. Chapter 17 provides an introduction to the most common limited dependent variable models.

The text is also well suited for an introductory master’s level course, where the emphasis is on applications rather than derivations using matrix algebra. Still, for instructors wanting to present the material in matrix form, Appendices D and E are self-contained treatments of the matrix algebra and the multiple regression model in matrix form. For the second edition, Appendix E has been expanded somewhat so that asymptotic analysis can be covered in more depth for advanced students.

At Michigan State, Ph.D. students in many fields that require data analysis—including accounting, agricultural economics, development economics, finance, international economics, labor economics, macroeconomics, political science, and public finance—have found the text to be a useful bridge between the empirical work that they read and the more theoretical econometrics they learn at the Ph.D. level.

DESIGN FEATURES

Instructors and students seem to appreciate the in-text questions, with answers supplied in Appendix F. These questions are intended to provide students with immediate feedback. Each chapter contains many numbered examples. Several of these are case studies drawn from recently published papers, but where I have used my judgment to simplify the analysis, hopefully without sacrificing the main point.

The end-of-chapter problems and computer exercises are heavily oriented toward empirical work, rather than complicated derivations. The students are asked to carefully reason based on what they have learned. The computer exercises often expand on the in-text examples. Several exercises use data sets from published works or similar data sets that are motivated by published research in economics and other fields.

A unique feature of this text is the extensive glossary. The short definitions and descriptions will be a helpful refresher for students studying for exams or reading empirical research that uses econometric methods. I have added and updated several entries for the second edition.

computing Chow tests for regression models across groups of different cross-sectional units as well as across different time periods. In Chapters 8 and 12, I provide an explicit, simple argument about why the usual R -squared is still valid as a goodness-of-fit measure when the model suffers from either heteroskedasticity or serial correlation. Chapter 9 now includes a simple discussion of basic stratified sampling, a topic that has come up in a second-semester course that I teach.

Chapter 17 has been given the most extensive reworking. This chapter contains difficult material, and it was too terse in the first edition. I have expanded the discussion of how to interpret nonlinear limited dependent variable models, including how they can be compared with standard linear model estimates. New graphs are used to illustrate the comparisons.

The text comes with about 90 data sets, several of which are new to the second edition. Among the new data sets are those that allow one to compare estimates of the returns to attending two-year and four-year colleges; to test whether 401(k) pension savings simply crowd out other forms of saving or represent new saving; to test whether fast-food restaurants practice price discrimination against minorities; to test whether marriage affects the productivity or earnings of professional basketball players; to study the effect of more choice on pension investments; to estimate the effects of school spending on student performance; to test whether seat belt and speed limit laws affect accident and fatality rates; and to estimate demand functions for ecologically-friendly apples and fish. Accordingly, the end-of-chapter computer exercises have been greatly expanded to exploit the new data sets. Some of the data sets are not used in the text. Instead, they can be used in problem sets, to generate exam problems, or to assign a common topic for a term paper.

TARGETED AT UNDERGRADUATES, ADAPTABLE FOR MASTER'S STUDENTS

The text is designed for undergraduate economics majors who have taken college algebra and one semester of introductory probability and statistics. (Appendices A, B, and C contain the requisite background material.) A one-semester or one-quarter econometrics course would not be expected to cover all, or even any, of the more advanced material in Part Three. A typical introductory course would include Chapters 1 through 8, which cover the basics of simple and multiple regression for cross-sectional data. Provided the emphasis is on intuition and interpreting the empirical examples, the material from the first eight chapters should be accessible to undergraduates in most economics departments. Most instructors will also want to cover at least parts of the chapters on regression analysis with time series data, Chapters 10, 11, and 12, with varying degrees of depth. In the one-semester course that I teach at Michigan State, I cover Chapter 10 fairly carefully, give an overview of the material in Chapter 11, and cover the material on serial correlation in Chapter 12. I find that this basic one-semester course puts students on solid footing to write empirical papers, such as a term paper or a senior seminar paper. Chapter 9 contains more specialized topics that arise in analyzing cross-sectional data, including data problems such as outliers and nonrandom sampling; for a one-semester course, it can be skipped without loss of continuity.

the importance of simultaneous equations. Some think this material is fundamental; others think it is rarely applicable. My own view is that simultaneous equations models are overused (see Chapter 16 for a discussion). If one reads applications carefully, omitted variables and measurement error are much more likely to be the reason one adopts instrumental variables estimation, and this is why I use omitted variables to motivate instrumental variables estimation in Chapter 15. Still, simultaneous equations models are indispensable for estimating demand and supply functions, and they apply in some other important cases as well.

Chapter 17 is the only chapter that considers models inherently nonlinear in their parameters, and this puts an extra burden on the student. The first material one would cover in this chapter is on probit and logit models for binary response. My presentation of Tobit models and censored regression still appears to be novel: I explicitly recognize that the Tobit model is applied to corner solution outcomes on random samples, while censored regression is applied when the data collection process censors the dependent variable.

Chapter 18 covers some recent important topics from time series econometrics, including testing for unit roots and cointegration. I cover this material only in a second-semester course at either the undergraduate or master's level. A fairly detailed introduction to forecasting is also included in Chapter 18.

Chapter 19, which would be added to the syllabus for a course that requires a term paper, is much more extensive than similar chapters in other texts. It summarizes some of the methods appropriate for various kinds of problems and data structures, points out potential pitfalls, explains in some detail how to write a term paper in empirical economics, and includes suggestions for possible projects.

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STUDENT SUPPLEMENTS

The *Student Study Guide With Solutions* (ISBN 0-324-14994-8) contains suggestions on how to read each chapter as well as answers to selected problems and computer exercises.

INSTRUCTOR SUPPLEMENTS

The *Instructor's Manual With Solutions* (ISBN 0-324-14997-2) contains answers to all exercises, as well as teaching tips on how to present the material in each chapter. The instructor's manual also contains sources for each of the data files, with many suggestions for how to use them on problem sets, exams, and term papers.

Upon the instructor's request, EViews Student Version can be bundled with the text for an additional \$18.00 per book. With EViews, students can do homework anywhere they have access to a PC, so they won't have to depend on using a campus computer lab. For more information on this special offer, contact your South-Western/Thomson Learning representative, or call the Academic Resource Center at 1-800-423-0563.

DATA SETS—NOW AVAILABLE IN FIVE FORMATS

Over 80 data sets are available in ASCII, EViews, Excel, Stata, and Minitab. Most of the data sets come from actual research so some are very large. Except for partially listing data sets to illustrate the various data structures, the data sets are not reported in the text. This book is geared toward a course where computer work plays an important role. The data sets can be found at <http://wooldridge.swcollege.com>. For instructors adopting the text, an extensive data description manual is available on-line. This manual contains a list of data sources along with suggestions for ways to use the data sets that are not described in the text. A Web Access Card has been packaged with every new book, which will allow access to all of these data sets and the data description manual.

SUGGESTIONS FOR DESIGNING YOUR COURSE

I have already commented on the contents of most of the chapters as well as possible outlines for courses. Here, I will provide some more specific comments about material within chapters that might be covered or skipped.

Chapter 9 has some interesting examples (such as a wage regression that includes IQ score as an explanatory variable). The rubric of proxy variables does not have to be formally introduced to present these kinds of examples, and I typically do so when finishing up cross-sectional analysis. In Chapter 12, for a one-semester course, I skip the material on serial-correlation robust inference for ordinary least squares as well as dynamic models of heteroskedasticity.

Even in a second course, I tend to spend only a little time on Chapter 16, which covers simultaneous equations analysis. If there is one issue that people differ about, it is

I took many of their comments on the first edition to heart, even though I might not have changed the material to one particular reviewer's liking. In some cases, reviewer and user opinions conflicted, in which case I decided to leave the organization as is. In other cases, I will continue to mull over specific suggestions made by one or more reviewers. Naturally, I am open to suggestions about possible future improvements.

Several students and teaching assistants have caught mistakes in the first edition or suggested the rewording of some paragraphs. They are too numerous to list here. I would like to acknowledge the efforts of Chirok Han, who carefully proofread the first edition, and Ali Berker, who acted as verifier for the second edition.

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The second edition is still dedicated to my wife, Leslie, and to our children, Edmund and Gwenyth. Leslie has provided valuable feedback on the text, and she has caught her share of typos. Plus, she continues to be very supportive, even though she was rightly skeptical when, after the first edition came out, I announced how glad I was that the "project" was over.

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Dr. Wooldridge has been editor of the *Journal of Business and Economic Statistics*, econometrics co-editor of *Economics Letters*, and has served on the editorial boards of the *Journal of Econometrics* and the *Review of Economics and Statistics*. He has also acted as an occasional econometrics consultant for Arthur Andersen, Chicago, and Charles River Associates, Boston.