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计量经济学导论

现代观点

Introductory Econometrics

A Modern Approach Third Edition

(美) Jeffrey M. Wooldridge 著

第3版

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Jeffrey M. Wooldridge

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密歇根州立大学经济学教授，他拥有加州大学伯克利分校学士学位、加州大学圣迭戈分校经济学博士学位。伍德里奇博士曾在国际知名期刊发表学术论文三十余篇，参与过多本图书的写作。他所获的奖项有：Alfred P.斯隆(Sloan)研究员基金、《应用计量经济学》期刊的R.斯通(Stone)爵士奖等，并三次获MIT研究生班优秀教师奖。他还是《计量经济学》期刊(*Journal of Econometrics*)的资深会员、*Journal of Business and Economic Statistics*的编委，并供职于*Journal of Econometrics*和*Review of Economics and Statistics*的编辑委员会。

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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，基本上是已再版多次、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！

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。

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总 序

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。正如朱镕基同志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，朱镕基同志多次建议清华的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。

赵纯均

清华大学经济管理学院

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. I became 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 positive reactions to the first two editions, it appears that my hunch was correct. A growing number of instructors, with a variety of backgrounds and interests, and teaching students with different levels of preparation, have embraced the modern approach to econometrics espoused in this text. Consequently, the structure of the third edition is much like the second, although I describe some notable changes below. 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 focus 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 Econometrics Instructor

The third edition preserves the overall organization of the second edition. The most noticeable feature that distinguishes this text from most 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 natural to students because they are familiar with random sampling from a population 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 behavioral content—from assumptions about how the data were sampled. 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 estimated using 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 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. For example, I explain why the usual R-squared is still valid as a goodness-of-fit measure in the presence of heteroskedasticity (Chapter 8) or serially correlated errors (Chapter 12); I demonstrate that tests for functional form should not be viewed as general tests of omitted variables (Chapter 9); and I 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 (Chapter 6).

Because the assumptions for cross-sectional analysis are relatively straightforward yet 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 earlier editions, 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 variable problem by instrumental variables methods. I appear to have made sound choices, as I have received only a few suggestions for adding or deleting material. Like the second edition, the third edition contains an introductory treatment of 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 linear models estimated by LAD.

In rewriting segments of the text, I have tried to further improve on the systematic approach of the second 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, professional users of econometrics understand that not all of the Gauss-Markov assumptions are needed to show that the ordinary least squares (OLS) estimators are unbiased. Yet, the vast majority of 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 often included among the assumptions that are needed for the Gauss-Markov Theorem, even though 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

I have made changes in the third edition that are meant to make the text more user-friendly. First, in the earlier editions, some empirical examples could not be replicated (because I did not make the data available) or confirmed by reading a journal article. In the third edition, all empirical results either can be replicated using the included data sets or can be found in a published article. Because replication is more helpful to students, I have changed a few examples so that the numbers can be obtained using a new data set. A notable example is Example 7.7, which studies the effect of "beauty" on wages.

Based on several requests, I have added summaries of assumptions at the end of the relevant chapters (Chapters 3, 4, 10, and 11). Consequently, students now have a quick reference for the assumptions, as well as brief descriptions of how each is used.

An important difference from earlier editions, especially for instructors who have written lecture notes from the first or second edition, is that I have slightly reordered the assumptions for simple and multiple regression (as well as for panel data analysis and instrumental variables estimation in the more advanced part). In particular, I have reversed Assumptions SLR.3 and SLR.4 in Chapter 2 and, likewise, Assumptions MLR.3 and MLR.4 in Chapter 3, as noted below. (Similar changes are made in Chapters 5, 10, and 11.) Pedagogically, the new ordering is more natural, and I give credit to Angelo Melino

at the University of Toronto for convincing me to make this change. Especially when reviewing assumptions of multiple regression (which I do often throughout my own course), the new ordering is appealing. In this edition, all assumptions about how the conditional distribution of the unobserved error depends on the observed explanatory variables are grouped together, as MLR.4, MLR.5, and MLR.6. The result is a natural progression in briefly summarizing the importance of each assumption:

MLR.1: Introduce the population model and interpret the parameters (which we hope to estimate).

MLR.2: Introduce random sampling, which also serves to describe the data that we need to estimate the population parameters.

MLR.3: Add the assumption that allows us to compute the estimates from our data sample; this is the so-called "no perfect collinearity" assumption.

MLR.4: Assume that the mean of the unobservable does not depend on the values of the explanatory variables; this is the "zero conditional mean" assumption, and it is the key assumption that delivers unbiasedness of OLS.

After introducing Assumptions MLR.1 to MLR.3, one can discuss the algebraic properties of ordinary least squares—that is, the properties of OLS for a particular set of data. By adding Assumption MLR.4, we can turn to unbiasedness. As in earlier editions, Assumption MLR.5 (homoskedasticity) is added for the Gauss-Markov theorem, and MLR.6 (normality) is added to round out the classical linear model assumptions (for exact statistical inference).

Other specific changes include those in chapter 6, where I expand on how it is possible to get "good" parameter estimates even with poor fit. I appeal to an example with experimental data, where we know we can get unbiased, and even fairly precise, estimators of slope coefficients—even though the R-squared is very small. Also in this chapter I have expanded the discussion of how it is possible to include too many control variables in a multiple regression.

In Chapter 8, I have added a discussion that should help students weigh the pros and cons of using weighted least squares, as opposed to just using heteroskedasticity-robust statistics after ordinary least squares estimation. The bottom line is that, for efficiency reasons, it can be better to use weighted least squares even if we misspecify the variance function. Robust inference is available for weighted least squares just as it is for ordinary least squares.

In Chapter 9, I have added an alternative view of regression analysis where, rather than discussing properties of the error term, the focus is on estimating the conditional expectation of the response variable given the observed explanatory variables (which may only be rough proxies for the explanatory variables we would like to have). This material is optional but complementary to the usual approach.

Even though Chapter 17 received the most reworking for the second edition, I (and others) still found several deficiencies. In the third edition, I have included more on goodness-of-fit with binary responses. More importantly, I have added material on an alternative, often more appealing, way to report partial effects in probit, logit, and Tobit models.

For those who use matrix algebra in their teaching, I revised the notation in Appendix E to be consistent with the text. Now, it is easier to jump between, say, Chapter 3 and the matrix formulations in Appendix E.

I have added some more data sets. Of particular note are the "beauty" data set mentioned earlier (BEAUTY.RAW), more recent data on elementary school performance and school spending (MEAP01.RAW), and an experimental data set on job training (JTRAIN3.RAW). In addition to using these new data sets for end-of-chapter computer exercises, I have found ways to have students further explore some of the old data sets. Some of the new data sets are not used in the text, but can be used for problem sets, exams, and term projects. At the request of a reviewer, I now include several problems and computer exercises at the end of Chapter 1. (Incidentally, the computer exercises are now numbered separately from the problems.)

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 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, 14, 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 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, I have tried to do so 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 pioneering feature of this introductory econometrics 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 third edition.

Student Supplements

The *Student Solutions Manual* contains suggestions on how to read each chapter as well as answers to selected problems and computer exercises. The *Student Solutions Manual* is available online at http://aise.swlearning.com.

Data Sets—Available in Five Formats

Almost 100 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 in which computer work plays an integral role. The data sets can be found at http://aise.swlearning.com. For instructors adopting the text, an extensive data description manual is available online. 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.

Web Site

The text Web site at http://aise.swlearning.com contains access to the *Student Solutions Manual,* Data Sets, and Economic Applications (EconNews Online, EconDebates Online, EconData Online, and EconLinks Online).

Instructor Supplements

The *Instructor's Manual with Solutions* 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. This supplement is available online only to instructors at http://aise.swlearning.com.

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. However, because Student EViews restricts the size of a data set that can be analyzed, some of the full data sets used in the text and in the problems cannot be used in Student EViews. Instead—with the exception of a few of the data sets used only in Part Three of the text—I have provided smaller versions of the EViews data sets that can be used in Student EViews. These are described in the instructor's manual. For more information on this special EViews offer, contact your South-Western/Thomson Learning representative, or call the Academic Resource Center at 1-800-423-0563.

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 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.