Springer Texts in Business and Economics

For further volumes:
http://www.springer.com/series/10099

Badi H. Baltagi

Econometrics

Fifth Edition

Springer

Prof. Badi H. Baltagi
Syracuse University
Center for Policy Research
Department of Economics
Eggers Hall 426
13244-1020 Syracuse
New York
USA
bbaltagi@maxwell.syr.edu

ISBN 978-3-642-20058-8 e-ISBN 978-3-642-20059-5
DOI 10.1007/978-3-642-20059-5
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011926694

© Springer-Verlag Berlin Heidelberg 1997, 1999, 2002, 2008, 2011
This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.
The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Cover design: eStudio Calamar

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To My Wife Phyllis

Preface

This book is intended for a first year graduate course in econometrics. I tried to strike 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 my area of expertise in econometrics and the intent here is to make this material more accessible to the general readership of econometrics.

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/statistical software to use, like EViews, SAS, Stata, TSP, SHAZAM, Microfit, PcGive, LIMDEP, and RATS, to mention a few. The empirical illustrations in the book utilize a variety of these software packages but mostly with Stata and EViews. 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 like GAUSS, OX, R and MATLAB.

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 Koop (2003) for a more recent treatment of the subject. Nonparametrics and semiparametrics 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, see Li and Racine (2007). 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), Kennedy (1992), Wooldridge (2003) and Stock and Watson (2003). 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. Courses requiring matrix algebra as a pre-requisite to econometrics can start with Chapter 7. Chapter 2 has a quick refresher on some of the required background needed from statistics for the proper understanding of the material in this book.

For an advanced undergraduate/masters class not requiring matrix algebra, one can structure a course based on Chapter 1; Section 2.6 on descriptive statistics; Chapters 3–6; Section 11.1 on simultaneous equations; and Chapter 14 on time-series analysis.

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). 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 and students 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 Business and Economic Statistics are two such journals. In fact, the Journal of Applied Econometrics has a replication section for which I am serving as an editor. In my econometrics course, I require my students to replicate an empirical paper. Many students find this experience rewarding in terms of giving them hands on application of econometric methods that prepare them for doing their own empirical work.

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, Aris Spanos, Farshid Vahid, Heather Anderson, Arnold Zellner and Bryan Brown. Also, I would like to thank my students Wei-Wen Xiong, Ming-Jang Weng, Kiseok Nam, Dong Li, Gustavo Sanchez, Long Liu and Liu Tian who read parts of this book and solved several of the exercises. Martina Bihn at Springer for her continuous support and professional editorial help. I have also benefited from my visits to the University of Arizona, University of California San-Diego, Monash University, the University of Zurich, the Institute of Advanced Studies in Vienna, and the University of Dortmund, Germany. A special thanks to my wife Phyllis whose help and support were essential to completing this book.

References

Berndt, E.R. (1991), *The Practice of Econometrics: Classic and Contemporary* (Addison-Wesley: Reading, MA).

Davidson, R. and J.G. MacKinnon (1993), *Estimation and Inference In Econometrics* (Oxford University Press: Oxford, MA).

Fomby, T.B., R.C. Hill and S.R. Johnson (1984), *Advanced Econometric Methods* (Springer-Verlag: New York).

Greene, W.H. (1993), *Econometric Analysis* (Macmillan: New York).

Johnston, J. (1984), *Econometric Methods*, 3rd. Ed., (McGraw-Hill: New York).

Judge, G.G., W.E. Griffiths, R.C. Hill, H. Lütkepohl and T.C. Lee (1985), *The Theory and Practice of Econometrics* 2nd Ed., (John Wiley: New York).

Kelejian, H. and W. Oates (1989), *Introduction to Econometrics: Principles and Applications* 2nd Ed., (Harper and Row: New York).

Kennedy, P. (1992), *A Guide to Econometrics* (The MIT Press: Cambridge, MA).

Klein, L.R. (1974), *A Textbook of Econometrics* (Prentice-Hall: New Jersey).

Kmenta, J. (1986), *Elements of Econometrics* 2nd Ed., (Macmillan: New York).

Koop, G. (2003), *Bayesian Econometrics* (Wiley: New York).

Li, Q. and J.S. Racine (2007), *Nonparametric Econometrics,* (Princeton University Press: New Jersey).

Maddala, G.S. (1977), *Econometrics* (McGraw-Hill: New York).

Maddala, G.S. (1992), *Introduction to Econometrics* (Macmillan: New York).

Phillips, P.C.B. (1977), "Econometrics: A View From the Toolroom," Inaugural Lecture, University of Birmingham, Birmingham, England.

Stock, J.H. and M.W. Watson (2003), *Introduction to Econometrics* (Addison-Wesley: New York).

Theil, H. (1971), *Principles of Econometrics* (John Wiley: New York).

Wallace, T.D. and L. Silver (1988), *Econometrics: An Introduction* (Addison-Wesley: New York).

White, H. (1984), *Asymptotic Theory for Econometrics* (Academic Press: Florida).

Wooldridge, J.M. (2003), *Introductory Econometrics* (South-Western: Ohio).

Data

The data sets used in this text can be downloaded from the Springer website in Germany. The address is: *http://www.springer.com/978-3-642-20058-8.* Please select the link "Samples & Supplements" from the right-hand column.

Table of Contents

Preface **VII**

Part I **1**

1 What Is Econometrics? **3**
1.1 Introduction . . . 3
1.2 A Brief History . . . 5
1.3 Critiques of Econometrics . . . 7
1.4 Looking Ahead . . . 8
Notes . . . 10
References . . . 10

2 Basic Statistical Concepts **13**
2.1 Introduction . . . 13
2.2 Methods of Estimation . . . 13
2.3 Properties of Estimators . . . 16
2.4 Hypothesis Testing . . . 21
2.5 Confidence Intervals . . . 30
2.6 Descriptive Statistics . . . 31
Notes . . . 36
Problems . . . 36
References . . . 42
Appendix . . . 42

3 Simple Linear Regression **49**
3.1 Introduction . . . 49
3.2 Least Squares Estimation and the Classical Assumptions . . . 50
3.3 Statistical Properties of Least Squares . . . 55
3.4 Estimation of σ^2 . . . 56
3.5 Maximum Likelihood Estimation . . . 57
3.6 A Measure of Fit . . . 58
3.7 Prediction . . . 60
3.8 Residual Analysis . . . 60
3.9 Numerical Example . . . 63
3.10 Empirical Example . . . 64
Problems . . . 67
References . . . 71
Appendix . . . 72

4 Multiple Regression Analysis **73**
4.1 Introduction . . . 73

4.2 Least Squares Estimation . . . 73
4.3 Residual Interpretation of Multiple Regression Estimates . . . 75
4.4 Overspecification and Underspecification of the Regression Equation . . . 76
4.5 R-Squared Versus R-Bar-Squared . . . 78
4.6 Testing Linear Restrictions . . . 78
4.7 Dummy Variables . . . 81
Note . . . 85
Problems . . . 85
References . . . 91
Appendix . . . 92

5 Violations of the Classical Assumptions 95
5.1 Introduction . . . 95
5.2 The Zero Mean Assumption . . . 95
5.3 Stochastic Explanatory Variables . . . 96
5.4 Normality of the Disturbances . . . 98
5.5 Heteroskedasticity . . . 98
5.6 Autocorrelation . . . 110
Notes . . . 120
Problems . . . 120
References . . . 126

6 Distributed Lags and Dynamic Models 131
6.1 Introduction . . . 131
6.2 Infinite Distributed Lag . . . 137
6.2.1 Adaptive Expectations Model (AEM) . . . 138
6.2.2 Partial Adjustment Model (PAM) . . . 138
6.3 Estimation and Testing of Dynamic Models with Serial Correlation . . . 139
6.3.1 A Lagged Dependent Variable Model with AR(1) Disturbances . . . 140
6.3.2 A Lagged Dependent Variable Model with MA(1) Disturbances . . . 142
6.4 Autoregressive Distributed Lag . . . 143
Note . . . 144
Problems . . . 144
References . . . 146

Part II 149

7 The General Linear Model: The Basics 151
7.1 Introduction . . . 151
7.2 Least Squares Estimation . . . 151
7.3 Partitioned Regression and the Frisch-Waugh-Lovell Theorem . . . 154
7.4 Maximum Likelihood Estimation . . . 156
7.5 Prediction . . . 159
7.6 Confidence Intervals and Test of Hypotheses . . . 160
7.7 Joint Confidence Intervals and Test of Hypotheses . . . 160

7.8 Restricted MLE and Restricted Least Squares . . . 161
7.9 Likelihood Ratio, Wald and Lagrange Multiplier Tests . . . 162
Notes . . . 167
Problems . . . 167
References . . . 172
Appendix . . . 173

8 Regression Diagnostics and Specification Tests 179
8.1 Influential Observations . . . 179
8.2 Recursive Residuals . . . 187
8.3 Specification Tests . . . 196
8.4 Nonlinear Least Squares and the Gauss-Newton Regression . . . 206
8.5 Testing Linear Versus Log-Linear Functional Form . . . 213
Notes . . . 215
Problems . . . 215
References . . . 219

9 Generalized Least Squares 223
9.1 Introduction . . . 223
9.2 Generalized Least Squares . . . 223
9.3 Special Forms of Ω . . . 225
9.4 Maximum Likelihood Estimation . . . 226
9.5 Test of Hypotheses . . . 226
9.6 Prediction . . . 227
9.7 Unknown Ω . . . 227
9.8 The W, LR and LM Statistics Revisited . . . 228
9.9 Spatial Error Correlation . . . 230
Note . . . 231
Problems . . . 232
References . . . 237

10 Seemingly Unrelated Regressions 241
10.1 Introduction . . . 241
10.2 Feasible GLS Estimation . . . 243
10.3 Testing Diagonality of the Variance-Covariance Matrix . . . 246
10.4 Seemingly Unrelated Regressions with Unequal Observations . . . 246
10.5 Empirical Examples . . . 248
Problems . . . 251
References . . . 254

11 Simultaneous Equations Model 257
11.1 Introduction . . . 257
11.1.1 Simultaneous Bias . . . 257
11.1.2 The Identification Problem . . . 260
11.2 Single Equation Estimation: Two-Stage Least Squares . . . 263
11.2.1 Spatial Lag Dependence . . . 271

11.3 System Estimation: Three-Stage Least Squares . . . 272
11.4 Test for Over-Identification Restrictions . . . 273
11.5 Hausman's Specification Test . . . 275
11.6 Empirical Examples . . . 278
Notes . . . 285
Problems . . . 286
References . . . 296
Appendix . . . 298

12 Pooling Time-Series of Cross-Section Data 305
12.1 Introduction . . . 305
12.2 The Error Components Model . . . 305
12.2.1 The Fixed Effects Model . . . 306
12.2.2 The Random Effects Model . . . 308
12.2.3 Maximum Likelihood Estimation . . . 312
12.3 Prediction . . . 313
12.4 Empirical Example . . . 313
12.5 Testing in a Pooled Model . . . 317
12.6 Dynamic Panel Data Models . . . 321
12.6.1 Empirical Illustration . . . 324
12.7 Program Evaluation and Difference-in-Differences Estimator . . . 326
12.7.1 The Difference-in-Differences Estimator . . . 327
Problems . . . 327
References . . . 330

13 Limited Dependent Variables 333
13.1 Introduction . . . 333
13.2 The Linear Probability Model . . . 333
13.3 Functional Form: Logit and Probit . . . 334
13.4 Grouped Data . . . 336
13.5 Individual Data: Probit and Logit . . . 341
13.6 The Binary Response Model Regression . . . 342
13.7 Asymptotic Variances for Predictions and Marginal Effects . . . 344
13.8 Goodness of Fit Measures . . . 344
13.9 Empirical Examples . . . 345
13.10 Multinomial Choice Models . . . 350
13.10.1 Ordered Response Models . . . 350
13.10.2 Unordered Response Models . . . 354
13.11 The Censored Regression Model . . . 356
13.12 The Truncated Regression Model . . . 359
13.13 Sample Selectivity . . . 360
Notes . . . 362
Problems . . . 362
References . . . 368
Appendix . . . 370

14 Time-Series Analysis **373**
14.1 Introduction . . . 373
14.2 Stationarity . . . 373
14.3 The Box and Jenkins Method . . . 375
14.4 Vector Autoregression . . . 378
14.5 Unit Roots . . . 379
14.6 Trend Stationary Versus Difference Stationary . . . 383
14.7 Cointegration . . . 384
14.8 Autoregressive Conditional Heteroskedasticity . . . 387
Note . . . 390
Problems . . . 390
References . . . 394

Appendix **397**

List of Figures **403**

List of Tables **405**

Index **407**