

# A Guide to Modern Econometrics

Fourth Edition

Marno Verbeek



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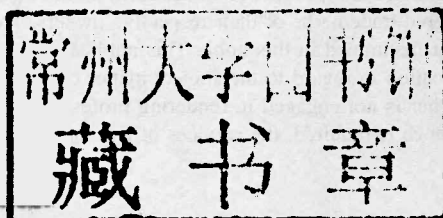
# A Guide to Modern Econometrics

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4th edition

**Marno Verbeek**

*Rotterdam School of Management, Erasmus University, Rotterdam*



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# **A Guide to Modern Econometrics**

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4th edition



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# Preface

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Emperor Joseph II: *"Your work is ingenious. It's quality work. And there are simply too many notes, that's all. Just cut a few and it will be perfect."*

Wolfgang Amadeus Mozart: *"Which few did you have in mind, Majesty?"*

from the movie *Amadeus*, 1984 (directed by Milos Forman)

The field of econometrics has developed rapidly in the last three decades, while the use of up-to-date econometric techniques has become more and more standard practice in empirical work in many fields of economics. Typical topics include unit root tests, cointegration, estimation by the generalized method of moments, heteroskedasticity and autocorrelation consistent standard errors, modelling conditional heteroskedasticity, models based on panel data, models with limited dependent variables, endogenous regressors and sample selection. At the same time econometrics software has become more and more user friendly and up-to-date. As a consequence, users are able to implement fairly advanced techniques even without a basic understanding of the underlying theory and without realizing potential drawbacks or dangers. In contrast, many introductory econometrics textbooks pay a disproportionate amount of attention to the standard linear regression model under the strongest set of assumptions. Needless to say that these assumptions are hardly satisfied in practice (but not really needed either). On the other hand, the more advanced econometrics textbooks are often too technical or too detailed for the average economist to grasp the essential ideas and to extract the information that is needed. This book tries to fill this gap.

The goal of this book is to familiarize the reader with a wide range of topics in modern econometrics, focusing on what is important for doing and understanding empirical work. This means that the text is a guide to (rather than an overview of) alternative techniques. Consequently, it does not concentrate on the formulae behind each technique (although the necessary ones are given) nor on formal proofs, but on the intuition behind the approaches and their practical relevance. The book covers a wide range of topics that is usually not found in textbooks at this level. In particular, attention is paid to cointegration, the generalized method of moments, models with

limited dependent variables and panel data models. As a result, the book discusses developments in time series analysis, cross-sectional methods as well as panel data modelling. Throughout, a few dozen full-scale empirical examples and illustrations are provided, taken from fields like labour economics, finance, international economics, consumer behaviour, environmental economics and macro-economics. In addition, a number of exercises are of an empirical nature and require the use of actual data.

In this fourth edition, I have tried to further fine-tune and update the text, adding additional discussion and material. To prevent the manuscript from growing too long, I have substantially increased the number of references to other sources, for additional detail, discussion, derivations or recent developments. The overall structure and organization of the material have not changed, so that users of the first three editions will feel familiar. A number of empirical illustrations have been replaced or updated. Chapter 2 contains a new section on missing data, outliers and influential observations, with an intuitive discussion of the potential problems and solutions. Chapter 3 has additional material on forecast evaluation, in the context of the empirical illustration on forecasting stock returns. Chapter 4 has been shortened by eliminating some outdated material. The literature on the estimation of treatment effects has evolved over the past decade and this is reflected in an expanded and updated section in Chapter 7. The two time series chapters, Chapters 8 and 9, have a number of updated illustrations. Chapter 10 is also expanded with additional material on the Fama–MacBeth approach, the problem of having too many instruments when estimating dynamic panel data models, and on panel data unit root tests and cointegration. Several chapters contain new exercises and each chapter is now concluded with a short wrap-up section. Overall, there is more focus on small sample properties of estimators and tests, with additional references to, for example, Monte Carlo studies that look into this. As before, all data sets are available through the book's website.

This text originates from lecture notes used for courses in Applied Econometrics in the M.Sc. programmes in Economics at K. U. Leuven and Tilburg University. It is written for an intended audience of economists and economics students that would like to become familiar with up-to-date econometric approaches and techniques, important for doing, understanding and evaluating empirical work. It is very well suited for courses in applied econometrics at the masters or graduate level. At some schools this book will be suited for one or more courses at the undergraduate level, provided students have a sufficient background in statistics. Some of the later chapters can be used in more advanced courses covering particular topics, for example, panel data, limited dependent variable models or time series analysis. In addition, this book can serve as a guide for managers, research economists and practitioners who want to update their insufficient or outdated knowledge of econometrics. Throughout, the use of matrix algebra is limited.

I am very much indebted to Arie Kapteyn, Bertrand Melenberg, Theo Nijman and Arthur van Soest, who all have contributed to my understanding of econometrics and have shaped my way of thinking about many issues. The fact that some of their ideas have materialized in this text is a tribute to their efforts. I also owe many thanks to several generations of students who helped me to shape this text into its current form. I am very grateful to a large number of people who read through parts of the manuscript and provided me with comments and suggestions on the basis of the first three editions. In particular, I wish to thank Niklas Ahlgren, Sascha Becker, Peter Boswijk, Bart

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# Contents

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<b>Preface</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 About Econometrics	1
1.2 The Structure of this Book	3
1.3 Illustrations and Exercises	4
<b>2 An Introduction to Linear Regression</b>	<b>6</b>
2.1 Ordinary Least Squares as an Algebraic Tool	7
2.1.1 Ordinary Least Squares	7
2.1.2 Simple Linear Regression	9
2.1.3 Example: Individual Wages	10
2.1.4 Matrix Notation	11
2.2 The Linear Regression Model	12
2.3 Small Sample Properties of the OLS Estimator	15
2.3.1 The Gauss–Markov Assumptions	15
2.3.2 Properties of the OLS Estimator	16
2.3.3 Example: Individual Wages (Continued)	20
2.4 Goodness-of-fit	20
2.5 Hypothesis Testing	22
2.5.1 A Simple $t$ -Test	23
2.5.2 Example: Individual Wages (Continued)	25
2.5.3 Testing One Linear Restriction	25
2.5.4 A Joint Test of Significance of Regression Coefficients	26
2.5.5 Example: Individual Wages (Continued)	28
2.5.6 The General Case	29
2.5.7 Size, Power and $p$ -Values	31



2.6	Asymptotic Properties of the OLS Estimator	32
2.6.1	Consistency	32
2.6.2	Asymptotic Normality	34
2.6.3	Small Samples and Asymptotic Theory	36
2.7	Illustration: The Capital Asset Pricing Model	38
2.7.1	The CAPM as a Regression Model	39
2.7.2	Estimating and Testing the CAPM	40
2.7.3	The World's Largest Hedge Fund	42
2.8	Multicollinearity	43
2.8.1	Example: Individual Wages (Continued)	46
2.9	Missing Data, Outliers and Influential Observations	47
2.9.1	Outliers and Influential Observations	47
2.9.2	Robust Estimation Methods	49
2.9.3	Missing Observations	50
2.10	Prediction	52
	Wrap-up	53
	Exercises	54
<b>3</b>	<b>Interpreting and Comparing Regression Models</b>	<b>58</b>
3.1	Interpreting the Linear Model	58
3.2	Selecting the Set of Regressors	62
3.2.1	Misspecifying the Set of Regressors	62
3.2.2	Selecting Regressors	63
3.2.3	Comparing Non-nested Models	67
3.3	Misspecifying the Functional Form	70
3.3.1	Nonlinear Models	70
3.3.2	Testing the Functional Form	71
3.3.3	Testing for a Structural Break	71
3.4	Illustration: Explaining House Prices	72
3.5	Illustration: Predicting Stock Index Returns	76
3.5.1	Model Selection	76
3.5.2	Forecast Evaluation	79
3.6	Illustration: Explaining Individual Wages	81
3.6.1	Linear Models	81
3.6.2	Loglinear Models	84
3.6.3	The Effects of Gender	87
3.6.4	Some Words of Warning	89
	Wrap-up	90
	Exercises	90
<b>4</b>	<b>Heteroskedasticity and Autocorrelation</b>	<b>94</b>
4.1	Consequences for the OLS Estimator	94
4.2	Deriving an Alternative Estimator	96
4.3	Heteroskedasticity	97
4.3.1	Introduction	97
4.3.2	Estimator Properties and Hypothesis Testing	100
4.3.3	When the Variances are Unknown	101

4.3.4	Heteroskedasticity-consistent Standard Errors for OLS	102
4.3.5	Multiplicative Heteroskedasticity	103
4.3.6	Weighted Least Squares with Arbitrary Weights	104
4.4	Testing for Heteroskedasticity	105
4.4.1	Testing for Multiplicative Heteroskedasticity	105
4.4.2	The Breusch–Pagan Test	106
4.4.3	The White Test	106
4.4.4	Which Test?	107
4.5	Illustration: Explaining Labour Demand	107
4.6	Autocorrelation	112
4.6.1	First-order Autocorrelation	113
4.6.2	Unknown $\rho$	115
4.7	Testing for First-order Autocorrelation	116
4.7.1	Asymptotic Tests	116
4.7.2	The Durbin–Watson Test	117
4.8	Illustration: The Demand for Ice Cream	119
4.9	Alternative Autocorrelation Patterns	122
4.9.1	Higher-order Autocorrelation	122
4.9.2	Moving Average Errors	122
4.10	What to do When you Find Autocorrelation?	123
4.10.1	Misspecification	124
4.10.2	Heteroskedasticity-and-autocorrelation-consistent Standard Errors for OLS	125
4.11	Illustration: Risk Premia in Foreign Exchange Markets	127
4.11.1	Notation	127
4.11.2	Tests for Risk Premia in the 1 Month Market	128
4.11.3	Tests for Risk Premia Using Overlapping Samples	132
	Wrap-up	134
	Exercises	134
<b>5</b>	<b>Endogenous Regressors, Instrumental Variables and GMM</b>	<b>137</b>
5.1	A Review of the Properties of the OLS Estimator	138
5.2	Cases Where the OLS Estimator Cannot be Saved	141
5.2.1	Autocorrelation with a Lagged Dependent Variable	141
5.2.2	Measurement Error in an Explanatory Variable	142
5.2.3	Endogeneity and Omitted Variable Bias	144
5.2.4	Simultaneity and Reverse Causality	146
5.3	The Instrumental Variables Estimator	148
5.3.1	Estimation with a Single Endogenous Regressor and a Single Instrument	148
5.3.2	Back to the Keynesian model	152
5.3.3	Back to the Measurement Error Problem	153
5.3.4	Multiple Endogenous Regressors	153

5.4	Illustration: Estimating the Returns to Schooling	154
5.5	The Generalized Instrumental Variables Estimator	158
5.5.1	Multiple Endogenous Regressors with an Arbitrary Number of Instruments	159
5.5.2	Two-stage Least Squares and the Keynesian Model Again	162
5.5.3	Specification Tests	163
5.5.4	Weak Instruments	164
5.6	The Generalized Method of Moments	166
5.6.1	Example	166
5.6.2	The Generalized Method of Moments	167
5.6.3	Some Simple Examples	170
5.6.4	Weak Identification	171
5.7	Illustration: Estimating Intertemporal Asset Pricing Models	171
	Wrap-up	175
	Exercises	176
<b>6</b>	<b>Maximum Likelihood Estimation and Specification Tests</b>	<b>179</b>
6.1	An Introduction to Maximum Likelihood	180
6.1.1	Some Examples	180
6.1.2	General Properties	183
6.1.3	An Example (Continued)	186
6.1.4	The Normal Linear Regression Model	187
6.2	Specification Tests	189
6.2.1	Three Test Principles	189
6.2.2	Lagrange Multiplier Tests	191
6.2.3	An Example (Continued)	194
6.3	Tests in the Normal Linear Regression Model	195
6.3.1	Testing for Omitted Variables	196
6.3.2	Testing for Heteroskedasticity	197
6.3.3	Testing for Autocorrelation	198
6.4	Quasi-maximum Likelihood and Moment Conditions Tests	199
6.4.1	Quasi-maximum Likelihood	199
6.4.2	Conditional Moment Tests	201
6.4.3	Testing for Normality	202
	Wrap-up	203
	Exercises	203
<b>7</b>	<b>Models with Limited Dependent Variables</b>	<b>206</b>
7.1	Binary Choice Models	207
7.1.1	Using Linear Regression?	207
7.1.2	Introducing Binary Choice Models	207
7.1.3	An Underlying Latent Model	210
7.1.4	Estimation	211

7.1.5	Goodness-of-fit	212
7.1.6	Illustration: The Impact of Unemployment Benefits on Reciprocity	215
7.1.7	Specification Tests in Binary Choice Models	217
7.1.8	Relaxing Some Assumptions in Binary Choice Models	219
7.2	Multiresponse Models	220
7.2.1	Ordered Response Models	221
7.2.2	About Normalization	222
7.2.3	Illustration: Explaining Firms' Credit Ratings	223
7.2.4	Illustration: Willingness to Pay for Natural Areas	225
7.2.5	Multinomial Models	228
7.3	Models for Count Data	231
7.3.1	The Poisson and Negative Binomial Models	231
7.3.2	Illustration: Patents and R&D Expenditures	235
7.4	Tobit Models	238
7.4.1	The Standard Tobit Model	238
7.4.2	Estimation	241
7.4.3	Illustration: Expenditures on Alcohol and Tobacco (Part 1)	242
7.4.4	Specification Tests in the Tobit Model	245
7.5	Extensions of Tobit Models	247
7.5.1	The Tobit II Model	248
7.5.2	Estimation	250
7.5.3	Further Extensions	253
7.5.4	Illustration: Expenditures on Alcohol and Tobacco (Part 2)	253
7.6	Sample Selection Bias	257
7.6.1	The Nature of the Selection Problem	257
7.6.2	Semi-parametric Estimation of the Sample-Selection Model	260
7.7	Estimating Treatment Effects	260
7.7.1	Regression-based Estimators	262
7.7.2	Alternative Approaches	266
7.8	Duration Models	268
7.8.1	Hazard Rates and Survival Functions	268
7.8.2	Samples and Model Estimation	270
7.8.3	Illustration: Duration of Bank Relationships	273
	Wrap-up	274
	Exercises	274
<b>8</b>	<b>Univariate Time Series Models</b>	<b>278</b>
8.1	Introduction	279
8.1.1	Some Examples	279
8.1.2	Stationarity and the Autocorrelation Function	281
8.2	General ARMA Processes	284



8.2.1	Formulating ARMA Processes	284
8.2.2	Invertibility of Lag Polynomials	287
8.2.3	Common Roots	288
8.3	Stationarity and Unit Roots	289
8.4	Testing for Unit Roots	291
8.4.1	Testing for Unit Roots in a First-order Autoregressive Model	291
8.4.2	Testing for Unit Roots in Higher-order Autoregressive Models	294
8.4.3	Extensions	296
8.4.4	Illustration: Stock Prices and Earnings	297
8.5	Illustration: Long-run Purchasing Power Parity (Part 1)	300
8.6	Estimation of ARMA Models	304
8.6.1	Least Squares	304
8.6.2	Maximum Likelihood	305
8.7	Choosing a Model	306
8.7.1	The Autocorrelation Function	306
8.7.2	The Partial Autocorrelation Function	308
8.7.3	Diagnostic Checking	309
8.7.4	Criteria for Model Selection	310
8.8	Illustration: The Persistence of Inflation	311
8.9	Predicting with ARMA Models	314
8.9.1	The Optimal Predictor	315
8.9.2	Prediction Accuracy	317
8.9.3	Evaluating predictions	319
8.10	Illustration: The Expectations Theory of the Term Structure	320
8.11	Autoregressive Conditional Heteroskedasticity	325
8.11.1	ARCH and GARCH Models	325
8.11.2	Estimation and Prediction	329
8.11.3	Illustration: Volatility in Daily Exchange Rates	331
8.12	What about Multivariate Models?	333
	Wrap-up	333
	Exercises	334
<b>9</b>	<b>Multivariate Time Series Models</b>	<b>338</b>
9.1	Dynamic Models with Stationary Variables	339
9.2	Models with Nonstationary Variables	342
9.2.1	Spurious Regressions	342
9.2.2	Cointegration	343
9.2.3	Cointegration and Error-correction Mechanisms	346
9.3	Illustration: Long-run Purchasing Power Parity (Part 2)	348
9.4	Vector Autoregressive Models	350
9.5	Cointegration: the Multivariate Case	354
9.5.1	Cointegration in a VAR	354
9.5.2	Example: Cointegration in a Bivariate VAR	356
9.5.3	Testing for Cointegration	358

9.5.4	Illustration: Long-run Purchasing Power Parity (Part 3)	360
9.6	Illustration: Money Demand and Inflation	362
	Wrap-up	368
	Exercises	369
<b>10</b>	<b>Models Based on Panel Data</b>	<b>372</b>
10.1	Introduction to Panel Data Modelling	373
10.1.1	Efficiency of Parameter Estimators	374
10.1.2	Identification of Parameters	375
10.2	The Static Linear Model	376
10.2.1	The Fixed Effects Model	377
10.2.2	The First-difference Estimator	379
10.2.3	The Random Effects Model	381
10.2.4	Fixed Effects or Random Effects?	384
10.2.5	Goodness-of-fit	386
10.2.6	Alternative Instrumental Variables Estimators	387
10.2.7	Robust Inference	389
10.2.8	Testing for Heteroskedasticity and Autocorrelation	391
10.2.9	The Fama–MacBeth Approach	392
10.3	Illustration: Explaining Individual Wages	394
10.4	Dynamic Linear Models	396
10.4.1	An Autoregressive Panel Data Model	396
10.4.2	Dynamic Models with Exogenous Variables	401
10.4.3	Too Many Instruments	403
10.5	Illustration: Explaining Capital Structure	405
10.6	Panel Time Series	410
10.6.1	Heterogeneity	411
10.6.2	First Generation Panel Unit Root Tests	412
10.6.3	Second Generation Panel Unit Root Tests	415
10.6.4	Panel Cointegration Tests	416
10.7	Models with Limited Dependent Variables	417
10.7.1	Binary Choice Models	418
10.7.2	The Fixed Effects Logit Model	419
10.7.3	The Random Effects Probit Model	420
10.7.4	Tobit Models	422
10.7.5	Dynamics and the Problem of Initial Conditions	423
10.7.6	Semi-parametric Alternatives	424
10.8	Incomplete Panels and Selection Bias	425
10.8.1	Estimation with Randomly Missing Data	426
10.8.2	Selection Bias and Some Simple Tests	427
10.8.3	Estimation with Nonrandomly Missing Data	429
10.9	Pseudo Panels and Repeated Cross-sections	430
10.9.1	The Fixed Effects Model	431
10.9.2	An Instrumental Variables Interpretation	433

10.9.3	Dynamic Models	434
	Wrap-up	435
	Exercises	436
<b>A</b>	<b>Vectors and Matrices</b>	<b>441</b>
A.1	Terminology	441
A.2	Matrix Manipulations	442
A.3	Properties of Matrices and Vectors	443
A.4	Inverse Matrices	444
A.5	Idempotent Matrices	445
A.6	Eigenvalues and Eigenvectors	445
A.7	Differentiation	446
A.8	Some Least Squares Manipulations	447
<b>B</b>	<b>Statistical and Distribution Theory</b>	<b>449</b>
B.1	Discrete Random Variables	449
B.2	Continuous Random Variables	450
B.3	Expectations and Moments	451
B.4	Multivariate Distributions	452
B.5	Conditional Distributions	453
B.6	The Normal Distribution	454
B.7	Related Distributions	457
	<b>Bibliography</b>	<b>459</b>
	<b>Index</b>	<b>477</b>

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# 1 Introduction

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## 1.1 About Econometrics

Economists are frequently interested in relationships between different quantities, for example between individual wages and the level of schooling. The most important job of econometrics is to quantify these relationships on the basis of available data and using statistical techniques, and to interpret, use or exploit the resulting outcomes appropriately. Consequently, econometrics is the interaction of economic theory, observed data and statistical methods. It is the interaction of these three that makes econometrics interesting, challenging and, perhaps, difficult. In the words of a seminar speaker, several years ago: ‘Econometrics is much easier without data’.

Traditionally econometrics has focused upon aggregate economic relationships. Macro-economic models consisting of several up to many hundreds of equations were specified, estimated and used for policy evaluation and forecasting. The recent theoretical developments in this area, most importantly the concept of cointegration, have generated increased attention to the modelling of macro-economic relationships and their dynamics, although typically focusing on particular aspects of the economy. Since the 1970s econometric methods have increasingly been employed in micro-economic models describing individual, household or firm behaviour, stimulated by the development of appropriate econometric models and estimators that take into account problems like discrete dependent variables and sample selection, by the availability of large survey data sets and by the increasing computational possibilities. More recently, the empirical analysis of financial markets has required and stimulated many theoretical developments in econometrics. Currently econometrics plays a major role in empirical work in all fields of economics, almost without exception, and in most cases it is no longer sufficient to be able to run a few regressions and interpret the results. As a result, introductory econometrics textbooks usually provide insufficient coverage for applied researchers. On the other hand, the more advanced econometrics textbooks are often too technical or too detailed for the average economist to grasp the essential ideas and to extract the information that is needed. Thus there is a need for an accessible textbook that discusses the recent and relatively more advanced developments.



The relationships that economists are interested in are formally specified in mathematical terms, which lead to econometric or statistical models. In such models there is room for deviations from the strict theoretical relationships owing to, for example, measurement errors, unpredictable behaviour, optimization errors or unexpected events. Broadly, econometric models can be classified in a number of categories.

A first class of models describes relationships between present and past. For example, how does the short-term interest rate depend on its own history? This type of model, typically referred to as a time series model, usually lacks any economic theory and is mainly built to get forecasts for future values and the corresponding uncertainty or volatility.

A second type of model considers relationships between economic quantities over a certain time period. These relationships give us information on how (aggregate) economic quantities fluctuate over time in relation to other quantities. For example, what happens to the long-term interest rate if the monetary authority adjusts the short-term one? These models often give insight into the economic processes that are operating.

Thirdly, there are models that describe relationships between different variables measured at a given point in time for different units (for example households or firms). Most of the time, this type of relationship is meant to explain why these units are different or behave differently. For example, one can analyse to what extent differences in household savings can be attributed to differences in household income. Under particular conditions, these cross-sectional relationships can be used to analyse 'what if' questions. For example, how much more would a given household, or the average household, save if income were to increase by 1%?

Finally, one can consider relationships between different variables measured for different units over a longer time span (at least two periods). These relationships simultaneously describe differences between different individuals (why does person 1 save much more than person 2?), and differences in behaviour of a given individual over time (why does person 1 save more in 1992 than in 1990?). This type of model usually requires panel data, repeated observations over the same units. They are ideally suited for analysing policy changes on an individual level, provided that it can be assumed that the structure of the model is constant into the (near) future.

The job of econometrics is to specify and quantify these relationships. That is, econometricians formulate a statistical model, usually based on economic theory, confront it with the data and try to come up with a specification that meets the required goals. The unknown elements in the specification, the parameters, are *estimated* from a sample of available data. Another job of the econometrician is to judge whether the resulting model is 'appropriate'. That is, to check whether the assumptions made to motivate the estimators (and their properties) are correct, and to check whether the model can be used for its intended purpose. For example, can it be used for prediction or analysing policy changes? Often, economic theory implies that certain restrictions apply to the model that is estimated. For example, the efficient market hypothesis implies that stock market returns are not predictable from their own past. An important goal of econometrics is to formulate such hypotheses in terms of the parameters in the model and to test their validity.

The number of econometric techniques that can be used is numerous and their validity often depends crucially upon the validity of the underlying assumptions. This book attempts to guide the reader through this forest of estimation and testing procedures,