

HANDBOOK OF ECONOMETRICS

VOLUME II

Edited by

ZVI GRILICHES

and

MICHAEL D. INTRILIGATOR

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Harvard University

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University of California, Los Angeles

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PREFACE TO THE HANDBOOK

Purpose

The *Handbook of Econometrics* aims to serve as a source, reference, and teaching supplement for the field of econometrics, the branch of economics concerned with the empirical estimation of economic relationships. Econometrics is conceived broadly to include not only econometric models and estimation theory but also econometric data analysis, econometric applications in various substantive fields, and the uses of estimated econometric models. Our purpose has been to provide reasonably comprehensive and up-to-date surveys of recent developments and the state of various aspects of econometrics as of the early 1980s, written at a level intended for professional use by economists, econometricians, and statisticians and for use in advanced graduate econometrics courses.

Econometrics is the application of mathematics and statistical methods to the analysis of economic data. Mathematical models help us to structure our perceptions about the forces generating the data we want to analyze, while statistical methods help us to summarize the data, estimate the parameters of our models, and interpret the strength of the evidence for the various hypotheses that we wish to examine. The evidence provided by the data affects our ideas about the appropriateness of the original model and may result in significant revisions of such models. There is, thus, a continuous interplay in econometrics between mathematical-theoretical modeling of economic behavior, data collection, data summarizing, model fitting, and model evaluation. Theory suggests data to be sought and examined; data availability suggests new theoretical questions and stimulates the development of new statistical methods. The examination of theories in light of data leads to their revision. The examination of data in the light of theory leads often to new interpretations and sometimes to questions about its quality or relevance and to attempts to collect new and different data.

In this volume we review only a subset of what might be called "econometrics". The mathematical-theoretical tools required for model building are discussed primarily in the *Handbook of Mathematical Economics*. Issues of sampling theory, survey design, data collection and editing, and computer programming, all important aspects of the daily life of a practicing econometrician, had, by and large, to be left out of the scope of this *Handbook*. We concentrate, instead, on statistical problems and economic interpretation issues associated with the modeling and estimation of economic behavioral relationships from already assembled and often badly collected data. If economists had access to good experimental data, or were able to design and to perform the relevant economic experiments,

the topics to be covered in such a *Handbook* would be quite different. The fact that the generation and collection of economic data is mostly outside the hands of the econometrician is the cause of many of the inferential problems which are discussed in this *Handbook*.

Organization

The organization of the *Handbook* follows in relatively systematic fashion the way an econometric study would proceed, starting from basic mathematical and statistical methods and econometric models, proceeding to estimation and computation, through testing, and ultimately to applications and uses. The *Handbook* also includes a fairly detailed development of time series topics and many other special topics. In particular:

Part 1 summarizes some basic tools used repeatedly in econometrics, including linear algebra, matrix methods, and statistical theory.

Part 2 deals with econometric models, their relationship to economic models, their identification, and the question of model choice and specification analysis.

Part 3 takes up more advanced topics in estimation and computation theory such as non-linear regression methods, biased estimation, and computational algorithms in econometrics. This part also includes a series of chapters on simultaneous equations models, their specification and estimation, distribution theory for such models, and their Bayesian analysis.

Part 4 considers testing of econometric estimators, including Wald, likelihood ratio, and Lagrange multiplier tests; multiple hypothesis testing; distribution theory for econometric estimators and associated test statistics; and Monte Carlo experimentation in econometrics.

Part 5 treats various topics in time series analysis, including time series and spectral methods in econometrics, dynamic specification, inference and causality in economic time series models, continuous time stochastic models, random and changing coefficient models, and the analysis of panel data.

Parts 6 and 7 present discussions of various special topics in econometrics, including latent variable, limited dependent variable, and discrete choice models; functional forms in econometric model building; economic data issues including longitudinal data issues; and disequilibrium, self selection, and switching models.

Finally, *Part 8* covers selected applications and uses of econometrics. Because of the extremely wide range of applications of econometrics, we could select only a few of the more prominent applications. (Other applications will be treated in later volumes in the "Handbooks in Economics" Series.) Applications discussed here include demand analysis, production and cost analysis, and labor economics. This part includes also chapters on evaluating the predictive accuracy of models, econometric approaches to stabilization policy, the formulation and estimation of

models with actors having rational expectations, and the use of econometric models for economic policy formation.

A brief history of econometrics

A brief review of the history of econometrics will put this *Handbook* in perspective. The historical evolution of econometrics was driven both by the increased availability of data and by the desire of generations of scientists to analyze such data in a rigorous and coherent fashion. There are many historical precursors to that which became "econometrics" in this century. Attempts to interpret economic data "scientifically" go back at least as far as Sir William Petty's "political arithmetic" in the seventeenth century and Engel's studies of household expenditures in the nineteenth. The results of the latter became known as Engel's Law, stating that the proportion of total expenditures devoted to food falls as income rises. This "Law" has been tested extensively for many countries over various time periods, as discussed in Houthakker's (1957) centenary article.

The development of statistical theory has played a critical role in the history of econometrics since econometric techniques are, to a large extent, based on multivariable statistics. Modern statistical theory starts with the work of Legendre and Gauss on least squares, motivated by the attempt to remove errors of observation in astronomy and geodesy. The next great impulse from biology, in particular from evolutionary theory with, among others, Galton's work on regression (a term he invented). Later developments in mathematical statistics included Yule's work on multiple regression, Karl Pearson's formulation of the notions of probable error and of testing hypotheses, the more rigorous small-sample theory of Student and R. A. Fisher, R. A. Fisher's work on the foundations of statistical inference, and the Neyman-Pearson theory of hypothesis testing. All of these developments in mathematical statistics had a significant influence on the development of econometrics.

In the first half of the twentieth century the increased availability of price and quantity data and the interest in price indexes aided by the development of family expenditure surveys generated interest both in theoretical modeling of demand structures and their empirical estimation. Particularly noteworthy were the demand studies of Moore (1914, 1917), Marschak (1931), and Schultz (1928, 1938) and studies of family expenditure by Allen and Bowley (1935). This period also witnessed the initial formulation of the identification problem in econometrics in E. Working (1927); studies of production functions by Cobb and Douglas (1928) [see also Douglas (1948)], and Marschak and Andrews (1944); studies of price determination in agricultural markets by H. Working (1922), Wright (1925), Hanau (1928), Bean (1928), and Waugh (1929), among others; and the statistical modeling of business cycles by Slutsky (1927) and Frisch (1933). Macroeconomet-

ric modeling also began in the 1930s by Tinbergen (1935, 1939) and was given additional impetus by the development of National Income Accounts in the United States and other countries and by Keynes' theoretical work.

The growth of data availability and the development of economic and statistical theory generated a demand for more extensive, more rigorous and higher quality data analysis efforts, stimulating significant research into the methodology of economic data analysis. Of great importance in this respect was the founding of the Econometric Society in 1930 and the publication, starting in 1933, of its journal *Econometrica*. Ragnar Frisch played a key role as the first editor of this Journal.

There was a great flourishing of econometric theory and applications in the period after World War II, particularly due to the work of the Cowles Commission at the University of Chicago. The development of the simultaneous equations model in Haavelmo (1943, 1944, 1947), Koopmans (1950), Hood and Koopmans (1953), Theil (1954) and Basmann (1957) provided econometricians with tools designed specifically for them, rather than for biologists and psychologists. The estimation of simultaneous equations and macroeconomic models in Klein (1950) and Klein and Goldberger (1955) started economic forecasting on a new path. This period also witnessed the important demand studies by Stone (1954a, 1954b) for the United Kingdom and Wold and Jureen (1953) for Sweden and the influential studies by Friedman (1957) of the consumption function and by Theil (1958) of economic forecasts and policy. [For collections of historically important papers in econometrics see Zellner (1968), Hooper and Nerlove (1970), and Dowling and Glahe (1970).]

The more recent period of the 1960s and 1970s has witnessed many important developments in econometric theory and applications. Econometric theory has been refined and extended in many ways. Of particular note is the Bayesian approach to econometrics and the study of special features of econometric models, such as limited dependent variables, latent variables, and non-linear models. Great progress was also made in the statistical analysis of time series. In addition, the development of electronic computers, the great increase in computing power, and the development of sophisticated econometric software packages made it possible to pursue much more ambitious data analysis strategies. These developments expanded the range of applications of econometric methods greatly beyond the earlier applications to household expenditure, demand functions, production and cost functions, and macroeconomic models. Econometrics is now used in virtually every field of economics, including public finance, monetary economics, labor economics, international economics, economic history, health economics, studies of fertility, and studies of criminal behavior, just to mention a few. In all of these fields the greater use of econometric techniques, based in part on increased data availability and more powerful estimation techniques, has led to greater precision in the specification, estimation, and testing of economic data-based models.

Most of the important developments in econometric methods during the 1960s and 1970s are discussed in this *Handbook*. The significant topics under development in this period and the chapters treating them include:

(1) *Bayesian econometrics*, using Bayesian methods in the specification and estimation of econometric models. These topics are discussed in Chapter 2 by Zellner and Chapter 9 by Drèze and Richard.

(2) *Time series methods*, including specialized techniques and problems arising in the analysis of economic time series, such as spectral methods, dynamic specification, and causality. These techniques and problems are discussed in Part 5 on "Time Series Topics," including Chapter 17 by Granger and Watson; Chapter 18 by Hendry, Pagan and Sargan; Chapter 19 by Geweke; Chapter 20 by Bergstrom; and Chapter 21 by Chow. Related issues are discussed in Chapter 33 by Fair.

(3) *Discrete choice models*, in which there is a discrete choice of alternatives available, e.g. buy/don't buy decisions, yes/no responses, or alternative possibilities for urban transportation. Such models are discussed specifically in Chapter 27 by Dhrymes and Chapter 24 by McFadden and are also treated in Chapter 22 by Chamberlain, Chapter 28 by Maddala, and Chapter 29 by Heckman and Singer.

(4) *Latent variables models*, in which certain unmeasurable variables systematically influence measured phenomena, such as ability influencing earnings. This topic is treated in Chapter 23 by Aigner, Hsiao, Kapteyn, and Wansbeek and reappears in various guises in Chapter 22 by Chamberlain and Chapter 32 by Heckman and MaCurdy, among others.

(5) *Specification analysis*, involving problems of model choice and their specification and identification. These issues are treated in Chapter 3 by Intriligator, Chapter 4 by Hsiao, Chapter 5 by Leamer, Chapter 26 by Lau, and Chapter 28 by Maddala. This topic, of course, pervades many other chapters in this *Handbook* and overlaps with chapters which deal with testing and distribution theory.

(6) *Non-linear models and methods*, in which models that are intrinsically nonlinear are specified and estimated. Such models are discussed in Chapter 6 by Amemiya and Chapter 12 by Quandt and surface also in many of the other chapters of this *Handbook*.

(7) *Data analysis issues*, involving various problems with data and how they can be treated. These issues are treated in Chapter 10 by Judge and Bock, in Chapter 11 by Krasker, Kuh, and Welsch, Chapter 22 by Chamberlain, Chapter 25 by Griliches, and Chapter 29 by Heckman and Singer, among others.

(8) *Testing and small sample theory*, including various test procedures and Monte Carlo experimentation. These topics are treated in Part 4 on "Testing," including Chapter 13 by Engle, Chapter 14 by Savin, Chapter 15 by Rothenberg, and Chapter 16 by Hendry. Related issues are discussed in Chapter 8 by Phillips.

(9) *Rational expectations* models which treat economic agents as forming expectations in an optimal fashion, given the information available to them,

impose cross-equation constraints on parameters and lead to new problems of identification and estimation. This topic is discussed in Chapter 34 by Taylor.

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CONTENTS OF VOLUME II

Introduction to the Series

v

Preface to the Handbook

xi

Part 4 – TESTING

Chapter 13

Wald, Likelihood Ratio, and Lagrange Multiplier Tests in Econometrics

ROBERT F. ENGLE

775

1. Introduction	776
2. Definitions and intuitions	776
3. A general formulation of Wald, Likelihood Ratio, and Lagrange Multiplier tests	780
4. Two simple examples	785
5. The linear hypothesis in generalized least squares models	788
5.1. The problem	788
5.2. The test statistics	790
5.3. The inequality	792
5.4. A numerical example	793
5.5. Instrumental variables	794
6. Asymptotic equivalence and optimality of the test statistics	796
7. The Lagrange Multiplier test as a diagnostic	801
8. Lagrange Multiplier tests for non-spherical disturbances	802
8.1. Testing for heteroscedasticity	803
8.2. Serial correlation	805
9. Testing the specification of the mean in several complex models	808
9.1. Testing for non-linearities	809
9.2. Testing for common factor dynamics	811
9.3. Testing for exogeneity	812
9.4. Discrete choice and truncated distributions	817
10. Alternative testing procedures	819
11. Non-standard situations	822
12. Conclusion	824
References	825

Chapter 14

Multiple Hypothesis Testing

N. E. SAVIN

	827
1. Introduction	828
2. t and F tests	830
2.1. The model	830
2.2. Tests	831
2.3. Critical values—finite induced test	833
2.4. Acceptance regions	835
3. Induced tests and simultaneous confidence intervals	843
3.1. Separate hypotheses	843
3.2. Finite induced test— ψ of primary interest	844
3.3. Infinite induced test—Scheffé test	848
3.4. Finite induced test— ψ of secondary interest	855
3.5. Simultaneous confidence intervals	857
4. The power of the Bonferroni and Scheffé tests	860
4.1. Background	860
4.2. Power contours	861
4.3. Average powers	862
4.4. The problem of multicollinearity	867
5. Large sample induced tests	871
6. Empirical examples	874
6.1. Textile example	874
6.2. Klein's Model I example	876
References	877

Chapter 15

Approximating the Distributions of Econometric Estimators
and Test Statistics

THOMAS J. ROTHENBERG

	881
1. Introduction	882
2. Alternative approximation methods	884
2.1. Preliminaries	884
2.2. Curve-fitting	886
2.3. Transformations	887
2.4. Asymptotic expansions	889
2.5. Ad hoc methods	891
3. Edgeworth approximations	892
3.1. Sums of independent random variables	893
3.2. A general expansion	896
3.3. Non-normal expansions	900
4. Second-order comparisons of estimators	902
4.1. General approach	903

4.2. Optimality criteria	904
4.3. Second-order efficient estimators	905
4.4. Deficiency	907
4.5. Generalizations	908
5. Second-order comparisons of tests	909
5.1. General approach	909
5.2. Some results when $q = 1$	912
5.3. Results for the multiparameter case	915
5.4. Confidence intervals	917
6. Some examples	918
6.1. Simultaneous equations	918
6.2. Autoregressive models	925
6.3. Generalized least squares	929
6.4. Departures from normality	930
7. Conclusions	931
References	932

Chapter 16

Monte Carlo Experimentation in Econometrics

DAVID F. HENDRY

1. Monte Carlo experimentation	937
1.1. Introduction	939
1.2. Simulation experiments	942
1.3. Experimentation versus analysis	943
2. The econometric model	945
2.1. The data generation process	945
2.2. Known distributional and invariance results	946
3. The Monte Carlo model	947
3.1. Random numbers	947
3.2. Efficient simulation: Reliability and validity	949
3.3. Embedding the econometric model in the Monte Carlo model	950
4. Reducing imprecision: Variance reduction	951
4.1. Common random numbers	951
4.2. Antithetic random numbers	952
4.3. Control variates	952
5. Reducing specificity: Response surfaces	955
5.1. Response surface formulations	955
5.2. Heteroscedasticity transformations	959
5.3. Investigating validity	962
6. An application to a simple model	963
6.1. Formulation of the experiments	963
6.2. Estimating $E(\hat{\alpha} \alpha, T)$	965
6.3. Estimating $\psi_{T2}(\hat{\alpha})$	968

6.4. Estimating $V_T(\hat{\alpha})$	969
6.5. Estimating $E(\hat{\sigma}_\varepsilon^2 \alpha, T)$	970
6.6. Estimating $P(Z \alpha, T, \delta)$	971
7. Some loose ends	972
7.1. Non-existent moments	972
7.2. Evaluating integrals	973
References	974

Part 5 – TIME SERIES TOPICS

Chapter 17

Time Series and Spectral Methods in Econometrics

C. W. J. GRANGER and MARK W. WATSON	979
1. Introduction	980
2. Methodology of time-series analysis	980
3. Theory of forecasting	993
4. Multiple time series and econometric models	1002
5. Differencing and integrated models	1006
6. Seasonal adjustment	1009
7. Applications	1016
8. Conclusion	1019
References	1019

Chapter 18

Dynamic Specification

DAVID F. HENDRY, ADRIAN R. PAGAN and J. DENIS SARGAN	1023
1. Introduction	1025
2. Data generation processes	1028
2.1. Conditional models	1028
2.2. Estimation, inference and diagnostic testing	1031
2.3. Interpreting conditional models	1034
2.4. The status of an equation	1035
2.5. Quasi-theoretical bases for dynamic models	1037
2.6. A typology of single dynamic equations	1040
3. Finite distributed lags	1049
3.1. A statement of the problem	1049
3.2. Exact restrictions on lag weights	1050
3.3. Choosing lag length and lag shape	1054
3.4. Weaker restrictions on lag weights	1060
3.5. Alternative estimators	1062
3.6. Reformulations to facilitate model selection	1065

4. Infinite distributed lags	1066
4.1. Rational distributed lags	1066
4.2. General error correction mechanisms	1069
4.3. Derived statistics	1072
5. Stochastic specification	1073
6. Dynamic specification in multi-equation models	1080
6.1. Identification with autoregressive errors	1080
6.2. Reduced form, final form and dynamic multipliers	1084
6.3. Unconstrained autoregressive modelling	1087
6.4. Alternative forms of disequilibrium model	1089
References	1092

*Chapter 19***Inference and Causality in Economic Time Series Models**

JOHN GEWEKE	1101
1. Introduction	1102
2. Causality	1103
3. Causal orderings and their implications	1108
3.1. A canonical form for wide sense stationary multiple time series	1109
3.2. The implications of unidirectional causality	1113
3.3. Extensions	1115
4. Causality and exogeneity	1117
5. Inference	1122
5.1. Alternative tests	1122
5.2. Comparison of tests	1127
6. Some practical problems for further research	1133
6.1. The parameterization problem and asymptotic distribution theory	1133
6.2. Non-autoregressive processes	1135
6.3. Deterministic processes	1138
6.4. Non-stationary processes	1139
6.5. Multivariate methods	1140
References	1142

*Chapter 20***Continuous Time Stochastic Models and Issues of Aggregation Over Time**

A. R. BERGSTROM	1145
1. Introduction	1146
2. Closed first-order systems of differential and integral equations	1150
2.1. Stochastic limit operations and stochastic differential equations	1150
2.2. Random measures and systems with white noise disturbances	1157
2.3. Estimation	1171
3. Higher order systems	1193
4. The treatment of exogenous variables and more general models	1202
5. Conclusion	1209
References	1210

Chapter 21

Random and Changing Coefficient Models

GREGORY C. CHOW	1213
1. Introduction	1214
2. Derivation of β_{it} s by recursive regression of β_t on y_1, \dots, y_s	1215
3. Derivations of β_{it} s by regression of y_1, \dots, y_s on x_1, \dots, x_s	1220
4. Maximum likelihood estimation of σ^2 , V and M	1222
5. System of linear regressions with changing coefficients	1225
6. System of linear simultaneous equations	1228
7. System of non-linear simultaneous equations	1233
8. Model with stationary coefficients	1234
9. Identifiability of parameters	1237
10. Testing constancy of regression coefficients	1239
11. Problems for research	1242
References	1243

Chapter 22

Panel Data

GARY CHAMBERLAIN	1247
1. Introduction and summary	1248
2. Specification and identification: Linear models	1254
2.1. A production function example	1254
2.2. Fixed effects and incidental parameters	1256
2.3. Random effects and specification analysis	1257
2.4. A consumer demand example	1259
2.5. Strict exogeneity conditional on a latent variable	1262
2.6. Lagged dependent variables	1264
2.7. Serial correlation or partial adjustment?	1267
2.8. Residual covariances: Heteroskedasticity and serial correlation	1268
2.9. Measurement error	1269
3. Specification and identification: Nonlinear models	1270
3.1. A random effects probit model	1270
3.2. A fixed effects logit model: Conditional likelihood	1274
3.3. Serial correlation and lagged dependent variables	1278
3.4. Duration models	1282
4. Inference	1285
4.1. The estimation of linear predictors	1286
4.2. Imposing restrictions: The minimum distance estimator	1288
4.3. Simultaneous equations: A generalization of three-stage least squares	1292
4.4. Asymptotic efficiency: A comparison with the quasi-maximum likelihood estimator	1294
4.5. Multivariate probit models	1296
5. Empirical applications	1299
5.1. Linear models: Union wage effects	1299
5.2. Nonlinear models: Labor force participation	1304

6. Conclusion	1311
Appendix	1311
References	1313

Part 6 – SPECIAL TOPICS IN ECONOMETRICS – I

Chapter 23

Latent Variable Models in Econometrics

DENNIS J. AIGNER, CHENG HSIAO, ARIE KAPTEYN and TOM WANSBEEK	1321
1. Introduction	1323
1.1. Background	1323
1.2. Our single-equation heritage	1324
1.3. Multiple equations	1326
1.4. Simultaneous equations	1327
1.5. The power of a dynamic specification	1328
1.6. Prologue	1329
2. Contrasts and similarities between structural and functional models	1329
2.1. ML estimation in structural and functional models	1330
2.2. Identification	1332
2.3. Efficiency	1335
2.4. The ultrastructural relations	1336
3. Single-equation models	1337
3.1. Non-normality and identification: An example	1337
3.2. Estimation in non-normal structural models	1338
3.3. A non-normal model with extraneous information	1340
3.4. Identifying restrictions in normal structural and functional models	1341
3.5. Non-linear models	1344
3.6. Should we include poor proxies?	1345
3.7. Prediction and aggregation	1346
3.8. Bounds on parameters in underidentified models	1347
3.9. Tests for measurement error	1349
3.10. Repeated observations	1350
3.11. Bayesian analysis	1352
4. Multiple equations	1353
4.1. Instrumental variables	1354
4.2. Factor analysis	1357
4.3. The MIMIC model and extensions	1359
5. Simultaneous equations	1362
5.1. The case of Ω known	1363
5.2. Identification and estimation	1363
5.3. The analysis of covariance structures	1369