

**HANDBOOKS IN ECONOMICS 2**

# **HANDBOOK OF ECONOMETRICS**

**VOLUME 6A**

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**NORTH-HOLLAND**



# HANDBOOK OF ECONOMETRICS

## VOLUME 6A

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON  
NEW YORK • OXFORD • PARIS • SAN DIEGO  
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO  
North-Holland is an imprint of Elsevier

North-Holland is an imprint of Elsevier  
Radarweg 29, PO Box 211, 1000 AE Amsterdam, The Netherlands  
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

First edition 2007

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**Library of Congress Cataloging-in-Publication Data**

A catalog record for this book is available from the Library of Congress

**British Library Cataloguing in Publication Data**

A catalogue record for this book is available from the British Library

ISBN: 978-0-444-50631-3 (Volume 6A)

ISBN: 978-0-444-53200-8 (Volume 6B)

ISSN: 0169-7218 (Handbooks in Economics series)

ISSN: 1573-4412 (Handbook of Econometrics series)

For information on all North-Holland publications  
visit our website at [books.elsevier.com](http://books.elsevier.com)

Printed and bound in the UK

07 08 09 10 11 10 9 8 7 6 5 4 3 2 1

## INTRODUCTION TO THE SERIES

The aim of the *Handbooks in Economics* series is to produce Handbooks for various branches of economics, each of which is a definitive source, reference, and teaching supplement for use by professional researchers and advanced graduate students. Each Handbook provides self-contained surveys of the current state of a branch of economics in the form of chapters prepared by leading specialists on various aspects of this branch of economics. These surveys summarize not only received results but also newer developments, from recent journal articles and discussion papers. Some original material is also included, but the main goal is to provide comprehensive and accessible surveys. The Handbooks are intended to provide not only useful reference volumes for professional collections but also possible supplementary readings for advanced courses for graduate students in economics.

KENNETH J. ARROW and MICHAEL D. INTRILIGATOR



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## PREFACE TO THE HANDBOOK

As conceived by the founders of the Econometric Society, econometrics is a field that uses economic theory and statistical methods to address empirical problems in economics. It is a tool for empirical discovery and policy analysis. The chapters in this volume embody this vision and either implement it directly or provide the tools for doing so. This vision is not shared by those who view econometrics as a branch of statistics rather than as a distinct field of knowledge that designs methods of inference from data based on models of human choice behavior and social interactions. All of the essays in this volume offer guidance to the practitioner on how to apply the methods they discuss to interpret economic data. The authors of the chapters are all leading scholars in the fields they survey and extend.

Auction theory and empirical finance are two of the most exciting areas of empirical economics where theory and data combine to produce important practical knowledge. These fields are well represented in this Handbook by Susan Athey and Philip Haile (auctions) and Lars Hansen, John Heaton, Nikolai Roussanov and Junghoon Lee (finance). Both papers present state of the art knowledge of their respective fields and discuss economic models for the pricing of goods and risk. These papers feature agent response to uncertainty as an integral part of the analysis. Work on the pricing of labor services lies at the core of empirical labor economics. Thomas MaCurdy surveys empirical methods for estimating wage equations from panel data in a way that is accessible to practitioners.

The econometrics of industrial organization (IO) is another vibrant area of applied econometrics. Scholars in the field of IO have embraced econometrics. The resulting symbiosis between theory and practice is a paragon for econometric research. Modern developments in game theory have been incorporated in econometric models that enrich both theory and empirical analysis. These developments are well-represented in this volume by the essays of Daniel Akerberg, Lanier Benkard, Steven Berry, and Ariel Pakes and of Peter Reiss and Frank Wolak. Stephen Bond and John van Reenen summarize the related literature on modeling the dynamics of investment and employment, which is an integral part of macroeconomics and modern IO.

The essay by Erwin Diewert and Alice Nakamura surveys methods for measuring national productivity. They exposit a literature that provides the tools for comparing the economic performance of policies and of nations. The authors survey the methods that underlie this important field of economics. Edward Leamer's essay stresses the interplay between data and theory in the analysis of international trade patterns. In an increasingly global market, the measurement of trade flows and the study of the impact of trade on economic welfare is important for understanding recent economic trends.

Modern economics has come to recognize heterogeneity and diversity among economic agents. It is now widely acknowledged that the representative agent paradigm is an inaccurate and misleading description of modern economies. The essay by Richard Blundell and Thomas Stoker summarizes and synthesizes a large body of work on the aggregation of measurements across agents to produce reliable aggregate statistics and the pitfalls in the use of aggregates.

Consumer theory, including the theory of labor supply, is at the heart of empirical economics. The essay by Richard Blundell, Thomas MaCurdy, and Costas Meghir surveys a vast literature with an ancient lineage that has been at the core of empirical economics for over 100 years. They develop empirical models of consumer demand and labor supply in an integrated framework.

The evaluation of economic and social programs is a central activity in economics. It is the topic of three essays in this Handbook. James Heckman and Edward Vytlačil contribute two chapters. The first chapter moves the literature on program evaluation outside of the framework of conventional statistics to consider economic policy questions of interest, to incorporate agent choice behavior and the consequences of uncertainty, and to relate the recent work on policy evaluation in statistics to older and deeper frameworks developed in econometrics. Issues of causality and the construction of counterfactuals are addressed within the choice-theoretic framework of economics.

Their second chapter uses the *marginal treatment effect* to unify a diverse and disjointed literature on treatment effects and estimators of treatment effects. The marginal treatment effect can be interpreted as a willingness to pay parameter. This chapter focuses on mean treatment effects in static environments without explicit analysis of uncertainty.

The essay by Jaap Abbring and James Heckman surveys new methods for identifying *distributions* of treatment effects under uncertainty. It surveys and develops methods for the analysis of dynamic treatment effects, linking the statistical literature on dynamic sequential randomization to the econometric literature on dynamic discrete choices. It also surveys recent approaches to the general equilibrium evaluation of social programs.

One of the most important contributions of econometric theory to empirical knowledge is the analysis of the identifiability of econometric models – determining under what conditions a unique model describes the data being used in an empirical analysis. Cowles Commission analysts formalized these ideas, focusing largely on linear systems [Tjalling Koopmans, Herman Rubin, and Roy Leipnik (1950)]. Later work by Franklin Fisher (1966) extended the Cowles analysis to nonlinear, but parametric systems. Rosa Matzkin's contribution to this Handbook synthesizes and substantially extends these analyses to consider a large body of work on the identification of non-parametric models. The methods she surveys and extends underlie a large literature in applied economics.

Hidehiko Ichimura and Petra Todd present a guide to the recent literature on non-parametric and semiparametric estimators in econometrics that has been developed in

the past 20 years. They conduct the reader through the labyrinth of modern nonparametric econometrics to offer both practical and theoretical guides to this literature.

Robert Moffitt and Geert Ridder address the important problem of how to combine diverse data sets to identify models and improve the precision of estimation of any model. This topic is of great importance because many data sets in many areas of economics contain valuable information on subsets of variables which, if they were combined in a single data set, would identify important empirical relationships. Moffitt and Ridder present the state of the art in combining data to address interesting economic questions.

Xiaohong Chen presents a detailed, informative survey of sieve estimation of semiparametric models. The sieve principle organizes many different approaches to nonparametric and semiparametric estimation within a common analytical framework. Her analysis clarifies an extensive and widely used literature. Marine Carrasco, Jean-Pierre Florens, and Eric Renault survey the literature on nonparametric and semiparametric econometrics that is based on inverse operators. Their analysis subsumes recent research on nonparametric instrumental variable methods as well as research on deconvolution of distributions. They present both theoretical and practical guides to this frontier area of econometrics.

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## Acknowledgements

We gratefully acknowledge support from the National Science Foundation, the University of Chicago, and University College London for conferences at which many of these papers were presented. We also thank the many referees and conference participants whose helpful comments have improved every chapter in this volume.

## References

- Fisher, F.M. (1966). *The Identification Problem in Econometrics*. McGraw-Hill, New York.
- Koopmans, T.C., Rubin, H., Leipnik, R.B. (1950). "Measuring the equation systems of dynamic economics". In: Koopmans, T.C. (Ed.), *Statistical Inference in Dynamic Economic Models*. In: Cowles Commission Monograph, Number 10. John Wiley & Sons, New York, pp. 53–237. Chapter 2.

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