

## Analysis of Panel Data

Panel data models have become increasingly popular among applied researchers due to their heightened capacity for capturing the complexity of human behavior as compared to cross-sectional or time-series data models. As a consequence, more and richer panel data sets also have become increasingly available. This second edition is a substantial revision of the highly successful first edition of 1986. Recent advances in panel data research are presented in a rigorous and accessible manner and are carefully integrated with the older material. The thorough discussion of theory and the judicious use of empirical examples will make this book useful to graduate students and advanced researchers in economics, business, sociology, political science, etc. Other specific revisions include the introduction of Bayes method and the notion of strict exogeneity with estimators presented in a generalized method of moments framework to link the identification of various models, intuitive explanations of semiparametric methods of estimating discrete choice models and methods of pairwise trimming for the estimation of panel sample selection models, etc.

Cheng Hsiao is Professor of Economics at the University of Southern California. His first edition of *Analysis of Panel Data* (Econometric Society Monograph 11, Cambridge University Press, 1986) has been the standard introduction for students to the subject in the economics literature. Professor Hsiao is also a coauthor of *Econometric Models, Techniques, and Applications*, Second Edition (Prentice Hall, 1996, with M. Intriligator and R. Bodkin), coeditor of *Analysis of Panels and Limited Dependent Variable Models* (Cambridge University Press, 1999, with K. Lahiri, L.F. Lee, and M.H. Pesaran), and coeditor of *Nonlinear Statistical Inference* (Cambridge University Press, 2001, with K. Morimune and J.L. Powell). He is a Fellow of the Econometric Society and coeditor and Fellow of the *Journal of Econometrics*.

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Second Edition

CHENG HSIAO

*University of Southern California*



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*To my wife, Amy Mei-Yun  
and my children,  
Irene Chiayun  
Allen Chenwen  
Michael Chenyee  
Wendy Chiawen*

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## Preface to the Second Edition

Since the publication of the first edition of this monograph in 1986, there has been a phenomenal growth of articles dealing with panel data. According to the *Social Science Citation Index*, there were 29 articles related to panel data in 1989. But in 1997 there were 518; in 1998, 553; and in 1999, 650. The increasing attention is partly due to the greater availability of panel data sets, which can better answer questions of substantial interest than a single set of cross-section or time series data can, and partly due to the rapid growth in computational power of the individual researcher. It is furthermore motivated by the internal methodological logic of the subject (e.g., Trognon (2000)).

The current version is a substantial revision of the first edition. The major additions are essentially on nonlinear panel data models of discrete choice (Chapter 7) and sample selection (Chapter 8); a new Chapter 10 on miscellaneous topics such as simulation techniques, large  $N$  and  $T$  theory, unit root and cointegration tests, multiple level structure, and cross-sectional dependence; and new sections on estimation of dynamic models (4.5–4.7), Bayesian treatment of models with fixed and random coefficients (6.6–6.8), and repeated cross-sectional data (or pseudopanel), etc. In addition, many of the discussions in old chapters have been updated. For instance, the notion of strict exogeneity is introduced, and estimators are also presented in a generalized method of moments framework to help link the assumptions that are required for the identification of various models. The discussion of fixed and random effects is updated in regard to restrictions on the assumption about unobserved specific effects, etc.

The goal of this revision remains the same as that of the first edition. It aims to bring up to date a comprehensive analytical framework for the analysis of a greater variety of data. The emphasis is on formulating appropriate statistical inference for issues shaped by important policy concerns. The revised edition of this monograph is intended neither as an encyclopedia nor as a history of panel data econometrics. I apologize for the omissions of many important contributions. A recount of the history of panel data econometrics can be found in Nerlove (2000). Some additional issues and references can also be found in a survey by Arellano and Honoré (2001) and in four recent

edited volumes – Matyás and Sevester (1996); Hsiao, Lahiri, Lee, and Pesaran (1999); Hsiao, Morimune, and Powell (2001); and Krishnakumar and Ronchetti (2000). Software is reviewed by Blanchard (1996).

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## Preface to the First Edition

Recently, empirical research in economics has been enriched by the availability of a wealth of new sources of data: cross sections of individuals observed over time. These allow us to construct and test more realistic behavioral models that could not be identified using only a cross section or a single time series data set. Nevertheless, the availability of new data sources raises new issues. New methods are constantly being introduced, and points of view are changing. An author preparing an introductory monograph has to select the topics to be included. My selection involves controlling for unobserved individual and/or time characteristics to avoid specification bias and to improve the efficiency of the estimates. The more basic and more commonly used methods are treated here, although to some extent the coverage is a matter of taste. Some examples of applications of the methods are also given, and the uses, computational approaches, and interpretations are discussed.

I am very much indebted to C. Manski and to a reader for Cambridge University Press, as well as to G. Chamberlain and J. Ham, for helpful comments and suggestions. I am also grateful to Mario Tello Pacheco, who read through the manuscript and made numerous suggestions concerning matters of exposition and corrections of errors of every magnitude. My appreciation also goes to V. Bencivenga, A.C. Cameron, T. Crawley, A. Deaton, E. Kuh, B. Ma, D. McFadden, D. Mountain, G. Solon, G. Taylor, and K.Y. Tsui, for helpful comments, and Sophia Knapik and Jennifer Johnson, who patiently typed and retyped innumerable drafts and revisions. Of course, in material like this it is easy to generate errors, and the reader should put the blame on the author for any remaining errors.

Various parts of this monograph were written while I was associated with Bell Laboratories, Murray Hill, Princeton University, Stanford University, the University of Southern California, and the University of Toronto. I am grateful to these institutions for providing me with secretarial and research facilities and, most of all, stimulating colleagues. Financial support from the National Science Foundation, U.S.A., and from the Social Sciences and Humanities Research Council of Canada is gratefully acknowledged.