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Analysis of Panel Data, Third Edition

This book provides a comprehensive, coherent, and intuitive review of panel data methodologies that are useful for empirical analysis. Substantially revised from the second edition, it includes two new chapters on modeling cross-sectionally dependent data and dynamic systems of equations. Some of the more complicated concepts have been further streamlined. Other new material includes correlated random coefficient models, pseudo-panels, duration and count data models, quantile analysis, and alternative approaches for controlling the impact of unobserved heterogeneity in nonlinear panel data models.

Cheng Hsiao is Professor of Economics at the University of Southern California and adjunct professor at Xiamen University. He received his PhD in Economics from Stanford University. He has worked mainly in integrating economic theory with econometric analysis. Professor Hsiao has made extensive contributions in methodology and empirical analysis in the areas of panel data, time series, cross-sectional data, structural modeling, and measurement errors, among other fields. He is the author of the first two editions of *Analysis of Panel Data* and was a co-editor of the *Journal of Econometrics* from 1991 to 2013.

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Analysis of Panel Data

Third Edition

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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*

Cambridge University Press

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Preface to the Third Edition

Panel data econometrics is one of the most exciting fields in econometrics today. The possibility of modeling more realistic behavioral hypotheses and challenging methodological issues, together with the increasing availability of panel data have led to the phenomenal proliferation of studies on panel data. This edition is a substantial revision of the second edition. Two new chapters on modeling cross-sectionally dependent data and the dynamic system of equations have been added. Some of the more complicated concepts have been further streamlined and new material on correlated random-coefficients models, pseudo-panels, duration and count data models, quantile analysis, alternative approaches for controlling the impact of unobserved heterogeneity in nonlinear panel data models, inference with data having both large cross section and long time series, etc. have been incorporated into existing chapters. It is hoped that the present version can provide a reasonably comprehensive, coherent, and intuitive review of panel methodologies that are useful for empirical analysis. However, no single monograph can do justice to the huge amount of literature in this field. I apologize for any omissions of the important contributions in panel data analysis.

I would like to thank the former and current Cambridge University Press publisher, Scott Parris and Karen Maloney, for their encouragement and support for this project. I am grateful to *Econometrica*, International Monetary Fund, *Financial Times*, *Journal of the American Statistical Association*, *Journal of Applied Econometrics*, *Journal of Econometrics*, *Regional Science and Urban Economics*, *Review of Economic Studies*, the University of Chicago Press, and Elsevier for permission to reproduce some of the materials published here. Thanks to Kristin Purdy and Kate Gavino for assistance in obtaining the copyright permissions and K. Bharadwaj, S. Shankar, J. Penney, and T. Kornak for their excellent work on copyediting and typesetting. During the process of preparing this monograph I have benefited from the excellent working conditions provided by the University of Southern California, Xiamen University, the City University of Hong Kong, and Hong Kong University of Science and Technology and the partial research support of the China Natural Science Foundation grant #71131008. I am grateful to Sena Schlessinger for her excellent

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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-sectional 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 as neither an encyclopedia nor 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

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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).

I would like to thank the editor, Scott Parris, for his encouragement and assistance in preparing the revision, and Andrew Chesher and two anonymous readers for helpful comments on an early draft. I am also very grateful to E. Kyriazidou for her careful and detailed comments on Chapters 7 and 8, S. Chen and J. Powell for their helpful comments and suggestions on Chapter 8, H. R. Moon for the section on large panels, Sena Schlessinger for her expert typing of the manuscript except for Chapter 7, Yan Shen for carefully proofreading the manuscript and for expertly typing Chapter 7, and Siyan Wang for drawing the figures for Chapter 8. Of course, all remaining errors are mine. The kind permissions to reproduce parts of articles by James Heckman, C. Manski, Daniel McFadden, Ariel Pakes, *Econometrica*, *Journal of the American Statistical Association*, *Journal of Econometrics*, *Regional Science and Urban Economics*, *Review of Economic Studies*, the University of Chicago Press, and Elsevier Science are also gratefully acknowledged.

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.