Analysis of Panel Data, Fourth Edition

Now in its fourth edition, this comprehensive introduction to fundamental panel data methodologies provides insights on what is most essential in panel literature. A capstone to the 40-year career of a pioneer of panel data analysis, this new edition's primary contribution will be the coverage of advancements in panel data analysis, a statistical method widely used to analyze two- or higher-dimensional panel data. The topics discussed in early editions have been reorganized and streamlined to comprehensively introduce panel econometric methodologies useful for identifying causal relationships among variables, supported by interdisciplinary examples and case studies. This book, to be featured in Cambridge's Econometric Society Monographs series, has been the leader in the field since the first edition. It is essential reading for researchers, practitioners, and graduate students interested in the analysis of microeconomic behavior.

Cheng Hsiao is Professor of Economics at the University of Southern California.

Econometric Society Monographs Series

Editors:

Andrea Prat, Columbia University
Stéphane Bonhomme, University of Chicago

The Econometric Society is an international society for the advancement of economic theory in relation to statistics and mathematics. The Econometric Society Monograph series is designed to promote the publication of original research contributions of high quality in mathematical economics and theoretical and applied econometrics.

Books in the Series

C. Hsiao, *Analysis of Panel Data: 4th edn, 2022*
D. M. Kreps, *The Black–Scholes–Merton Model as an Idealization of Discrete-Time Economies, 2019*
W. Thomson, *How to Divide When There Isn't Enough: From Aristotle, the Talmud, and Maimonides to the Axiomatics of Resource Allocation, 2019*
O. Compte & A. Postlewaite, *Ignorance and Uncertainty, 2018*
I. Molchanov & F. Molinari, *Random Sets in Econometrics, 2018*
B. Honoré, A. Pakes, M. Piazzesi, & L. Samuelson (eds.), *Advances in Economics and Econometrics: Eleventh World Congress, Vols. I & II, 2017*
S. Maurer, *On the Shoulders of Giants: Colleagues Remember Suzanne Scotchmer's Contributions to Economics, 2017*
C. P. Chambers & F. Echenique, *Revealed Preference Theory, 2016*
J.-F. Mertens, S. Sorins, & S. Samir, *Repeated Games, 2015*
C. Hsiao, *Analysis of Panel Data: 3rd edn, 2014*
C. Cameron & P. Trivedi, *Regression Analysis of Count Data, 2nd edn, 2013*
A. Harvey, *Dynamic Models for Volatility and Heavy Tails, with Applications to Financial and Economic Time Series, 2013*
D. Acemoglu, M. Areilano, & E. Dekel (eds.), *Advances in Economics and Econometrics: Theory and Applications, Tenth World Congress, Vols. I, II, & III, 2013*
M. Fleurbaey & F. Maniquet, *A Theory of Fairness and Social Justice, 2011*
R. Vohra, *Mechanism Design: A Linear Programming Approach, 2011*
K. Samphantharak & R. Townsend, *Households as Corporate Firms: An Analysis of Household Finance Using Integrated Household Surveys and Corporate Financial Accounting, 2009*
I. Gilboa, *Theory of Decision under Uncertainty, 2009*
F. Vega-Redondo, *Complex Networks, 2007*
R. Blundell, W. Newey, & T. Persson, (eds.), *Advances in Economics and Econometrics: Theory and Applications, Ninth World Congress, Vols. I, II, & III, 2006*
J. Roemer, *Democracy, Education, and Equality, 2006*
C. Blackorby, W. Bossert, & D. Donaldson, *Population Issues in Social Choice Theory, Welfare Economics and Ethics, 2005*
R. Koenker, *Quantile Regression, 2005*
C. Hsiao, *Analysis of Panel Data, 2nd ed., 2003*
M. Dewatripont, L. P. Hausen, & S. J. Turnovsky (eds.), *Advances in Economics and Econometrics: Theory and Applications, Eighth World Congress, Vols. I, II, & III, 2003*
E. Ghysels, N. Swanson, & M. Watson (eds.), *Essays in Econometrics: Collected Papers of Clive W. J. Granger, Vols. I &II, 2001*
S. Strøm (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium, 1999*
A. C. Cameron & P. K. Trivedi, *Regression Analysis of Count-Data, 1998*
D. Jacobs, E. Kalai, & M. Kamien (eds.), *Frontiers of Research in Economic Theory: The Nancy L. Schwartz Memorial Lectures, 1998*
D. M. Kreps & K. F. Wallis (eds.), *Advances in Economics and Econometrics: Theory and Applications, Seventh World Congress, Vols. I, II, & III, 1997*

Continued on page following the index

Analysis of Panel Data

Fourth Edition

Cheng Hsiao
University of Southern California

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India

103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781316512104
DOI: 10.1017/9781009057745

First edition published 1986
Second edition 2003
Third edition 2014
Fourth edition 2022

A catalogue record for this publication is available from the British Library.

ISBN 978-1-316-51210-4 Hardback
ISBN 978-1-009-06075-2 Paperback

To my parents,

Tseng Hsiao and Y. N. Shu Hsiao

and my family,

Amy Meiyun, Irene C., Allen C., Michael C. and Wendy C. Hsiao

Contents

Figures

Tables

Preface to the Fourth Edition

This is a substantially revised and expanded version of *Analysis of Panel Data* that considers new advancements in panel data analysis and streamlines and reorganizes topics discussed in earlier editions. The aim of this monograph remains the same: to comprehensively introduce panel econometric methodologies that are useful for identifying causal relationships among variables of interest to empirical investigators. Some empirical examples are also provided to give readers a perspective of the development of the field in the last half-century.

We start with modeling unobserved heterogeneity in additive forms for linear static and dynamic models, static and dynamic systems in structural and reduced forms, qualitative choice, limited dependent models, and some nonlinear models such as duration, count data, and nonparametric models. We then move to more complicated approaches to modeling unobserved heterogeneity, such as factor approach, spatial approach, and varying parameter models. We conclude with a chapter on the challenges of big data analytics to panel data analysis. However, no single monograph can cover the enormous contributions to panel data analysis. I apologize for the omissions.

I would like to thank Fatima Perez for patiently typing numerous versions of the manuscript, Dongwook Kim for carefully checking for errors, and China National Science Foundation grants 71631004 and 72033008 for partial research support. Comments by Xiaoyi Han on recent advances in spatial models, Cynthia Yang on stochastic SIR models, and Yuwei Xie on the big data approach to predictions are also much appreciated. I would also like to thank Robert Dreesen for support of this project, Laura Simmons for coordinating the production process, Matthew Van Atta for excellent copy editing, and the typesetting team led by Matthew Rohit Jayakumarxavier for their outstanding work; the journals *Computational Statistics, Econometrica, Econometrics Review*, the *Journal of the American Statistical Association*, the *Journal of Applied Econometrics*, the *Journal of Business and Economic Statistics*, and the *Journal of Econometrics*; the University of Chicago Press; and J.J. Heckman, D. McFadden, C. Manski, M.H. Pesaran, and C. Yang for their permissions to reproduce some of the materials published here.

I have received immeasurable help and support throughout my academic career from my family, teachers, colleagues, and students. I am grateful to my parents, Teng Hsiao and Y.N. Shu Hsiao, for providing a loving and safe environment during the tumultuous years of growing up; Leong Tan and Margaret Tan for giving a warm family environment to me as a lonely foreign student; Frank and Cynthia Kozin for advancing my understanding of mathematics in my youth; Helen Tu for typing up hundreds of job application letters; and the rest of my family members for their understanding and emotional support. I would like to thank Takeshi Amemiya and T.W. Anderson for being my lifelong mentors in

econometrics, and Dennis J. Aigner for his continuous support. I have also benefitted enormously from interactions with colleagues, collaborators, and friends, Jane Ayers, Pietro Balestra, Michael Binder, Badi Baltagi, Richard Blundell, Georges Bressons, Zongwu Cai, Luke M.W. Chan, Songnian Chen, H.S. Ching, In Choi, Hsinhsin Chou, Gregory Chow, Kannika Damronplasit, Hiroshi Fujiki, Ronald Gallant, Li Gan, Jiti Gao, John Geweke, John C. Ham, Toshihiko Hayashi, Yongmiao Hong, Arie Kapteyn, Xiao Ke, Kenneth C.W. Keng, Jae-Young Kim, Roger Klein, Roger Koenker, Chungming Kuan, Naoto Kunitomo, Ekaterini Kyriazidou, Lawrence J. Lau, Lungfei Lee, Lingfeng Li, Qi Li, Tong Li, Chongming Lin, Echu Liu, Esfandier Maasoumi, Jacques Mairesse, Michael McAleer, Roger H. Moon, Kimio Morimuni, Dean Mountain, Fred Nold, Jeffrey Nugent, Mario Tello Pacheco, Euston Quah, Scott Parris, Isabelle Perrigne, M. Hashem Pesaran, Dale J. Poirer, Geert Ridder, Peter M. Robinson, Patrick Sevester, Yan Shen, Baohong Sun, Kamil Tahmiscioglu, Derek Terrell, Kai Y. Tsui, Quang Vuong, Shui Ki Wan, Cindy SH Wang, Liqun Wang, Tongsan Wang, Yuenkang Wang, Thomas J. Wansbeek, Thomas Wilson, Zhije Xiao, Fengbei Yau, Eden Yu, Shihti Yu, Arnold Zellner, Xueyen Zhao, and Qiankun Zhou. To all of them, I am eternally grateful.