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Essays in honor of Professor Badi H Baltagi

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It is our pleasure and great honor to serve as Guest Editors of the present special issue published in *Empirical Economics*, aiming to celebrate Professor Badi Baltagi's myriad contributions to the field of econometrics, as well as his long service to this journal.

The influential work carried out by Badi during the past four decades or so is recognized in this issue by nineteen peer-reviewed, state-of-the-art articles, written by some of the leading researchers in econometrics. The diversity of the topics covered constitutes a testament to the wide-ranging scope of Badi's research interests and contributions.

Born in Beirut, Lebanon, Badi received his PhD in economics from the University of Pennsylvania in 1979, having previously studied at the American University of Beirut and the Carnegie-Mellon University. Currently, Badi is Distinguished Professor of Economics at the Maxwell School of Citizenship & Public Affairs, as well as a Senior Research Associate in the Center for Policy Research, both at Syracuse University. Prior to joining Syracuse in 2005, he was George Summey, Jr. Professor of Liberal Arts, at Texas A&M University from 1988 to 2005.

Badi's pioneering research has focused both on developing the theoretical underpinnings of several econometric models that are routinely used by practitioners nowadays, as well as on the sound application of modern econometric methods to analyze real-world data. As part of his fifteen-year-long role as replication editor for the *Journal of Applied Econometrics* (2003–2018), Badi also

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established and enforced frameworks that have led to more ethical and rigorous econometric practice.

Badi has authored or co-authored over 200 publications in leading economics journals across a wide range of topics, such as model specification and testing, multi-dimensional panels, common factor structures, nonparametric estimation, models for spatial data analysis, systems of simultaneous equations, Bayesian estimation of binary choice and random coefficient models; with applications to health economics, energy demand, gravity models of trade, housing markets, productivity and technological change, and many others.

Badi is perhaps most well known for the way he has shaped and continues to shape the field of panel data analysis. His book entitled *Econometric Analysis of Panel Data (Wiley)*, which was first published in 1995, laid the foundations of the subject matter and quickly became a must-read essential reference for all econometricians and applied economists working with panel data. As one of the pioneers in the field, he has also edited several comprehensive volumes on panel data econometrics, including *the Oxford Handbook of Panel Data* (2015a, Oxford University Press), *Panel Data Econometrics: Critical Concepts in Economics, Four Volumes,* (2015b, Routledge, Taylor & Francis Group), *Spatial Econometrics: Methods and Applications* (2009, Physica-Verlag), *Recent Developments in the Econometrics of Panel Data, Volumes I and II (*2002*, Edward Elgar), Nonstationary Panels, Panel Cointegration and Dynamic Panels (*2000*, Elsevier),* and *A Companion to Theoretical Econometrics* (2001, Blackwell).

In addition to honoring Badi's contributions to scholarly economics research, this special issue also serves as a tribute to his long editorial service in *Empirical Economics*, which he served as Editor from 1999 to 2018. Empirical Economics was established in 1976 with the objective of publishing high-quality papers using cutting-edge econometric/statistical methods to integrate economic theory with real-world data. Badi's academic endeavors throughout his career are evidence that this objective has been largely fulfilled.

Currently, Badi is editor of *Economics Letters*, associate editor of *Econometric Reviews*, and the series editor for *Contributions to Economic Analysis (Emerald Publishing)* and *Advanced Studies in Theoretical and Applied Econometrics* (Springer). In the past, he served as associate editor of the *Journal of Econometrics* for twenty years (1999–2018).

Badi has received numerous awards throughout his career. He is a fellow of the *Journal of Econometrics* and *Econometric Reviews*, and a recipient of the *Multa Scripsit and Plura Scripsit Awards* from *Econometric Theory*. He is also recipient of the Distinguished Authors Award from the *Journal of Applied Econometrics*. He is a founding fellow and member of the Board of Directors of the *Spatial Econometrics Association*, and a founding member of the *International Association for Applied Econometrics*.

All these engagements are highly reflective of Badi's boundless creative energy, relentless work ethic, commitment to the profession and selflessness as an exemplary and inspiring colleague. In addition to all of these qualities, Badi has also had the extreme good fortune to have by his side his wife Phyllis, who has

been a constant source of encouragement and support, his proof-reader, sounding board and—above all—his muse.

We believe we can speak on behalf of the community of econometric scholars when we express our gratitude for all the inspiring work Badi has contributed to the field. We look forward to many more years of his leadership and mentorship.

1 Contributions

The first paper in this issue, "*General diagnostic tests for cross-sectional dependence in panels*" by Hashem Pesaran, has already become a seminal contribution and is extremely well cited in the literature. The idea of the paper is as simple as it is intuitive, which is arguably one of the reasons it has become so popular. Specifically, the objective of the proposed CD test is to test whether the errors of a panel regression model are correlated across individual units. The test statistic involves using the sample average of all pairwise correlation coefficients of the least squares residuals. The paper has led to renewed interest in specification testing in panel data in general, and in testing for cross-sectional dependence specifically. As a result, there is nowadays a separate econometric literature devoted to the topic of testing for cross-sectional dependence, one in which Badi Baltagi is also a leading figure. Moreover, the CD test has been analyzed, improved and extended in several directions, and it is available in all standard econometric software programs. It is the workhorse of relevant empirical literature with countless applications.

Model specification and testing is an integral part of the process of building an econometric model. Zhenlin Yang's paper entitled "*Joint tests for dynamic and spatial effects in short panels with fixed effects and heteroskedasticity*" contributes to the large and ever-growing literature on specification testing in spatial panel data analysis, a field that constitutes one of Badi's main areas of research as well. The paper extends existing work by Baltagi and Yang (2013a, b) and proposes an adjusted quasi score-based test for testing the existence of dynamic and/or spatial effects in fixed effects panel data models with possible heteroskedasticity. The test is easy to implement, it is robust to general forms of cross-sectional heteroskedasticity, and it performs well in Monte Carlo experiments. Spatial dynamic panel data models can be very general and hence difficult to implement. This prompts the question: Do we really need such generality, or does a simpler model suffice to capture the main features of the data? The proposed test carries out specification tests to identify a suitable model based on the data.

The issue of dynamic specification and causal inference is also the subject of analysis in the paper "*A homogeneous approach to testing for Granger non-causality in heterogeneous panels*" by Artūras Juodis, Yiannis Karavias and Vasilis Sarafidis. These authors propose a novel approach for testing for Granger non-causality in a dynamic panel data model with fixed effects. In comparison with existing literature, this method makes use of the fact that under the null hypothesis of no Granger causality, the Granger-causation parameters are all equal to zero, which means they are homogeneous. Thus, estimation can be carried out using pooled least squares, which is expected to be relatively more efficient compared to estimators that do not impose

homogeneity. In order to account for the well-known "Nickell bias," the approach employs the split panel jackknife method. Subsequently, a Wald test statistic is constructed, based on the bias-corrected estimator. The small sample properties of the new test are investigated in a simulation study, and the empirical usefulness is illustrated using an application on the profitability of US banks.

The construction of counterfactuals in treatment effects models for panel data is a challenging task, as the outcomes of receiving and not receiving the treatment are not observed simultaneously. An important issue is whether the parameters of the predictive regression used to construct the counterfactuals have constant or time-varying parameters. Shui Ki Wan, Cheng Hsiao and Qiankun Zhou shed light on this issue with their paper entitled "*Can a time-varying structure provide a more robust panel construction of counterfactuals-Straitjacket or Straitjackets?*" The authors consider several tests for the adequacy of the assumption that the parameters are constant over time, based on data from either the pre-treatment or the post-treatment periods. Results from a Monte Carlo study and two empirical illustrations show that if the objective is minimization of the mean square prediction error, then a "straitjacket" approach based on selecting the most suitable model from the pre-treatment period is the best option.

Understanding the consequences of model misspecification in linear regression with measurement error remains a topic of vital interest and importance (Baltagi 2013; Hu and Wansbeek 2017). Unlike in fields such as physics and the medical sciences, in economics a major complicating factor is that the absolute magnitude of the variance of the measurement error is rarely known. Yet, in practice researchers may have some idea about its magnitude relative to the observed variance, known as *reliability*. The paper entitled "*How measurement error affects inference in linear regression*" by Erik Meijer, Edward Oczkowski and Tom Wansbeek digs further into this problem and considers inference under three increasingly realistic kinds of prior knowledge: known absolute variances, known reliabilities and estimated reliabilities (or estimated measurement error variances). For each case, the authors derive a consistent estimator of the regression coefficient and its asymptotic variance, both without and with assuming normality of the measurement error variance. As an illustration, the authors estimate a hedonic regression model for the price of Australian wines.

Empirical researchers often use economic theory to inform the specification of their econometric models. In addition to offering some guidance on the choice of functional forms, covariates and distributions of stochastic components, economic theories sometimes also suggest shape restrictions on functional relationships. This is where the contribution entitled "*Bayesian estimation of bidding process and bidder's preference under shape restrictions*" by Dong Li, Luya Wang and Ximing Wu sits. The authors apply a novel Bayesian nonparametric estimator to the modelling of auctions subject to shape restrictions. These restrictions are implied either by the rule of auctions (in bidding processes of ascending auctions) or by economic theories (in the case of sealed-bid auctions). The paper demonstrates that the Bayesian estimator with a Gaussian process prior can be well parameterized by a spectral representation, which facilitates posterior analysis and MCMC sampling. The shape restrictions are accommodated by assuming that the derivatives of the functions of

interest are squared Gaussian processes. Two interesting applications are provided. In the first one, the authors estimate the bidding process from time series of bids based on online ascending auctions, wherein the bids increase over time. In the second application, they investigate sealed-bid auctions and estimate the relationship between bidders' value and their bids. In both applications, the estimation uncertainty is reduced by incorporating the shape restrictions.

An important advantage of panel data analysis is the ability to estimate dynamic relationships from micro-data without suffering aggregation bias, and often using a relatively small number of time series observations (T). In this case, it is well known that the fixed effects estimator is not $\sqrt{N}$-consistent; instead, it is subject to bias of order $1/T$. Comprehensive treatments on this topic have been provided by Baltagi and Kao (2000) and Bun and Sarafidis (2015), among others. In Choi and Sanghyun Jung revisit this problem and develop "*Cross-sectional quasi maximum likelihood and bias-corrected pooled least squares estimators for short dynamic panels.*" The proposed method, suitable for the panel autoregressive model of order 1, is based on a cross-sectional regression that makes use of the first time series observation as the regressor and the last one as the dependent variable. The resulting estimators are consistent for T fixed under fairly general conditions that do not impose any restrictions on the parameter space of the autoregressive coefficient. Therefore, identification of the autoregressive coefficient becomes possible even in the explosive case. By contrast, existing approaches mostly require the parameter space to be either $(-1,1)$ or $(-1,1]$. An additional advantage is that the method permits estimation of the effect of time-invariant regressors because it does not rely on differencing or within-group demeaning. Finally, the proposed estimators are also suitable to the panel autoregressive model with endogenous regressors, provided that exogenous instruments are available.

In "*A bias-corrected fixed effects estimator in the dynamic panel data model,*" Chihwa Kao, Long Liu and Rui Sun consider a similar dynamic panel data model with fixed effects, but in this case under large N, T asymptotics. While the bias of the fixed effects estimator can be removed using analytical correction, the appropriate correction to use depends on whether the autoregressive parameter is in the stationary or unit root regions. Hence, estimation typically requires some pre-knowledge of the size of the parameter to be estimated, and such information is not always available. The present paper puts forward a new bias-corrected fixed effects estimator, which is asymptotically bias free under both stationary and unit root cases. Thus, the proposed estimator does not require the—otherwise so common—assumption of stationary initial conditions. The idea of building a bridge estimator to simultaneously accommodate stationary and non-stationary settings was first developed by Perron and Yabu (2009) and subsequently extended by Baltagi et al. (2014a, b, 2020), in the context of testing for structural breaks in time series and panel data settings, respectively.

While most research on panel data focuses on mean regression, in practice the conditional mean is not always the most effective central tendency measure to characterize the relationship between economic variables, especially so when the data are skewed or have outliers (see, e.g., Baltagi and Egger 2016, for a forceful example in the context of gravity models). Quantile and modal panel regressions

complement mean regression and can provide robust fit and better prediction performance in such settings. Georges Bresson, Guy Lacroix and Mohammad Arshad Rahman study "*Bayesian panel quantile regression for binary outcomes with correlated random effects: an application on crime recidivism in Canada*." The problem of how to estimate a quantile panel regression with a binary dependent variable and correlated unobserved heterogeneity is a challenging one. Their proposed solution is based on Bayesian techniques. In particular, because the joint posterior density does not have a tractable form, the estimation is carried out using Markov Chain Monte Carlo simulations. The resulting estimator is studied extensively using Monte Carlo experiments and appears to perform very well. The empirical usefulness of the approach is illustrated in a study of crime recidivism in Canada.

Rather than focusing on the conditional median, Aman Ullah, Tao Wang and Weixin Yao consider "*Modal Regression for Fixed Effects Panel Data.*" They put forward two different approaches, which are valid in the case where the number of time series observations, T, is large. The first one involves linear dummy variables modal regression, in which the conditional mode is assumed to be a linear function of covariates and individual-specific dummy variables. This approach is general and suitable for datasets where the number of individual units, N, is not too large. The latter approach involves a two-stage procedure: In the first stage, the individual-specific effect is estimated by mean regression; in the second stage, the modal regression is adjusted to account for the individual fixed effect, obtained at first stage. The two-stage method, which hinges on the assumption that the individual-specific effect from mean regression remains a source of unobserved heterogeneity in the modal regression, has the advantage that the number of estimable parameters is greatly reduced, and thus, it can be used more effectively when N is large. The asymptotic properties of the modal estimators are studied under large N, T asymptotics, based on mild regularity conditions.

Panel data often have complicated structures of heteroskedasticity and correlations over both cross section and time. A popular method of estimation and inference in the context of linear prediction models is to use standard least squares with robust standard errors. The resulting inference is asymptotically valid in the presence of non-spherical errors. Jushan Bai, Sung Hoon Choi and Yuan Liao take a novel approach on this topic and propose "*Feasible generalized least squares for panel data with cross-sectional and serial correlations.*" Since the dimension of the error covariance matrix grows with the size of the panel data set, their approach is based on the use of banding and thresholding. The asymptotic theory is also nonstandard, although the properties of the proposed estimator are just as expected; the estimator is shown to be consistent, asymptotically normal and asymptotically more efficient than ordinary least squares. The small sample performance of the new estimator is evaluated using both simulated and real data.

An alternative, prominent framework for modelling complicated structures of cross-sectional correlations in panel data is the common factor approach. This assumes the presence of an unobserved common component in the error term, which is a linear combination of a fixed number of factors. Common factor structures are also appealing because they offer wider scope for controlling for unobserved heterogeneity and omitted variables; see Bai et al. (2016), Karabiyik et al. (2019)

and Sarafidis and Wansbeek (2012, 2020) for recent insightful overviews on this topic. Joerg Breitung and Philipp Hansen contribute to this literature by developing "*Alternative estimation approaches for the factor augmented panel data model with small T.*" In particular, they study and provide useful insights for three of the most well-known estimation approaches designed for factor augmented models, namely the principal components, common correlated effects (CCE) and generalized method of moments approaches. Their analysis addresses several important issues, first of all, the possibility of using an inappropriate normalization of the factor space (the so-called normalization failure). To this end, the authors propose a variant of the CCE estimator that avoids the normalization failure by adapting a weighting scheme inspired by the analysis of Mundlak (1978). Next, the paper investigates the impact of estimating versus fixing the number of factors in advance. Finally, it is shown that certain Monte Carlo designs could favor some estimators relative to others, which might help to explain some conflicting findings within the existing literature.

The rapid emergence of big datasets has fueled a burgeoning literature on the econometric analysis of panel data with multiple dimensions or hierarchical observations. The main objective of such analysis is to capture more complex sources of unobserved heterogeneity, compared to the traditional two-way error components model; see, e.g., Balazsi et al. (2017a, b). In the field of stochastic frontier analysis, Christine Amsler, Yi-Yi Chen, Peter Schmidt and Hung Jen Wang propose "*A hierarchical panel data stochastic frontier model for the estimation of stochastic metafrontiers.*" Under this empirically relevant framework, firms are nested within groups and firm-specific inefficiency reflects the distance relative to its group-specific frontier. At the same time, there exists group-specific inefficiency that represents the shortfall of a given group relative to the overall maximal frontier, as a result of (say) using different (potentially out of date) technologies. This is the so-called metafrontier. The authors show how to estimate the model by maximum likelihood and how to extract predictions of the inefficiencies by using the correlation between firms in the same group.

The paper entitled "*Gravity models of interprovincial migration flows in Canada with hierarchical multifactor structure*" by Laura Serlenga and Yongcheol Shin contributes to both strands of the literature on multi-dimensional and hierarchical panels. Gravity models are popular in the theoretical analysis of bilateral trade of goods and international flows across countries. The corresponding empirical research has long emphasized the advantage of using multi-dimensional panels to explain international relations, as evident by the early seminal contributions of Mátyás (1997) and Baltagi et al. (2003). The present paper extends the extant literature by using a flexible three-dimensional panel data model that accounts for multilateral resistance to migration via an unobserved hierarchical factor error structure. The main novelty is the generality with which multilateral resistance to migration is allowed to affect migration flows between provinces. Specifically, in addition to unobserved country-level factors with province-pair-specific sensitivities, there may exist local origin (destination) factors that have heterogeneous effects on destinations (origins). The results suggest that the recent rise in provincial Canadian migration is more likely to be due to relative income inequality and network presence rather than conventional long-run determinants such as income and unemployment differentials.

As mentioned earlier, one main area of applied research for Badi is the analysis of productivity and efficiency measurement. For instance, recent co-authored contributions include those by Baltagi et al. (2015, 2016). Shasha Liu and Robin Sickles focus on productivity and efficiency of banking institutions. Their study on "*The Agency Problem Revisited: A Structural Analysis of Managerial Productivity and CEO Compensation in Large U.S. Commercial Banks*" contributes decisively to a better understanding of the links among banking concentration, managerial performance, CEO compensation and the size and scope of bank operations. The banking industry is quite unique because it had been subject to constant deregulatory forces over several decades and up until, at least, the emergence of the sub-prime mortgage crisis of 2007. These waves of deregulation led to a gradual increase in the operational complexity and size of banking institutions, and a corresponding decline in their numbers. The present paper creates a new panel of large US commercial banks and analyzes their performance, incentives and inefficiencies that may arise due to agency problems and market power. A structural model is developed to characterize managerial inefficiency by incorporating managerial decisions, firm effects and market competition. A focal point underlying the modelling approach is the existence of discrepancies between the goals of maximizing a manager's utility and achieving the firm/shareholders' goal (profit maximization), i.e., the so-called agency problem.

The US Social Security Administration's two disability programs, Disability Insurance and Supplemental Security Income, provide cash benefits to individuals with long-term disabilities. A major contributor to customer satisfaction is the time it takes to process disability claims at field offices. In their contribution "*Productive Efficiency in Processing Social Security Disability Claims: A Look Back at the 1989–95 Surge,*" Kajal Lahiri and Jianting Hu take up the challenge of examining the factors that determine average processing time in disability applications to the Supplemental Security Income program. Using a unique dataset for the period 1988 to 1995, they find that 80% of the variation is accounted for by the included field office characteristics. This implies that there are persistent differences in the average processing time between US states that can be attributed to organizational efficiency.

Housing markets are of key concern to regulators, as they are often a source of economic and financial instability. Deeper understanding of housing market dynamics over time and space is important to be able to better guide economic policy, and for regulators to understand when additional interventions are warranted (see, e.g., Baltagi et al. 2014a, b, among many others). Xintong Yang, Yu Zhang and Qi Li contribute to this literature and study "*The role of price spillovers: what is different in China.*" In specific, the authors examine how local housing booms transmit via spillovers to other local housing markets in China. A structural break test is used to determine when a focal housing market experiences a boom, and subsequently how this boom transmits to other nearby housing markets on the intensive and extensive margin. The conclusion is that there is a distinctive dynamic spillover from focal housing markets in China, where metropolitan housing markets tend to experience booms first, and that this then spills over to other nearby housing markets.

The use of network models in the study of interconnectivity of economic agents allows researchers to better understand and explain important aspects of behavior in economics and finance. In their paper entitled "*Dynamic network and own*

effects on abnormal returns: evidence from China's stock market," Peter Egger and Jiaqing Zhu propose a new framework for studying abnormal returns on individual stocks. Unlike previous studies, this framework allows for heterogeneous parameters, dynamics and network interdependencies between firms, where the network is assumed to emanate from firms' input–output linkages. The proposed approach is applied to a large sample of daily Chinese stock returns in order to estimate abnormal returns and then to explain such returns as a function of trade-war tariff announcements, lagged abnormal returns and network-weighted abnormal returns. The results suggest that explicit consideration of adjustment costs and, particularly, of network effects may be an important avenue of future work. Network effects lead to nonlinear interactions among stocks, and shocks can have interesting and non-trivial effects on stock markets, an issue which is of potentially great importance when considering the vulnerability or resilience of stock markets and their dependence on core players in the network.

The need for establishing advanced environmental policies is of paramount importance nowadays. This is due to rapid climate change developments that have already put immense pressure on natural resources and ecosystems across the globe. The OECD Green Growth Strategy, launched in May 2011, provides recommendations and measurement tools to support countries' efforts to achieve economic growth and development. Innovations in the renewable energy sector are a key ingredient of this strategy. Esfandiar Maasoumi, Almas Heshmati and Inhee Lee examine the impact of public policies on the generation of "*Green Innovations and Patenting Renewable Energy Technologies in OECD.*" The main focus of the analysis lies on public and private investments, investments in education and research and development (R&D), and those related to environmental regulations. A balanced panel of 27 OECD countries spanning the period 1990–2018 is employed. The main conclusion is that despite the similarity of the countries being studied in terms of their levels of development, green growth strategies and data reporting practices, the results seem sensitive to the way in which parameter heterogeneity is allowed. Moreover, quantile results point to different effects at different scales of patent activity. This outcome highlights a need for further disaggregated analyses in the future.

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