

# Estimation and inference in cross-sectionally dependent panel data models

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# Valorization

Knowledge valorization of a scientific work is particularly concerned with the societal relevance of that work, thus with its contribution to real life phenomena, in particular on social and economic issues. In this addendum, I outline the knowledge valorization of the results obtained in this thesis. I do so, by first focusing on the importance of research in econometric theory, then, by providing an overview of the societal relevance of the results reported in this dissertation, the target groups that can benefit from these results and the activities that these results can be translated into. Further, I discuss the innovative characteristics of the current research and its implementability.

This thesis is concerned with developing methodologies for the estimation and inference of cross-sectionally dependent panel data models. Although, the research reported in thesis is theoretical and methodological and the results can be considered as contributions to the field of econometric theory, its knowledge valorization is far from being inconsiderable. The results provided by econometric theory are used by researchers in fields of applied sciences, who aim at improving societal and economical conditions by giving answers to socially and economically relevant questions. Whenever a set of data is at a researcher's disposal, the usage of econometric and statistical techniques is in order. From this point of view, progress in econometric theory, which provides advanced tools to empirical researchers, directly effects the world of applied research.

Technological advancements associated with obtaining and recording data in societal and economic fields have made huge data sets available to researchers in relevant fields. Apart from that, new communication technologies, developing financial markets, agreements between financial entities, increasing world popula-

tion, cultural accumulation within societies have lead to an increase in the number and complexity of economically and socially relevant questions that can be investigated by social scientists. Accumulation of data and increase in the number and complexity of questions, have together increased the demand for technical tools that can be used to answer those questions by using available data more effectively. For instance, questions regarding causal relationships between certain variables, effects of certain variables on others or dynamic relations between economic indicators may be answered by using available data related to the questions and proper econometric tools. The knowledge valorization of research on econometric theory should be viewed by reckoning with these arguments.

Panel data analysis is used to investigate the behaviour of a set of entities that is periodically observed over time. It has many applications in social sciences, particularly in the fields of behavioural sciences like psychology or sociology, where one studies the characteristics of groups of people over time, or in economics, where one investigates the behaviour of economic and financial indicators of multiple entities; for instance, people, firms, regions, countries, products and markets over time. Although, panel data analysis is used in many other fields such as health sciences, educational research, etc., in this knowledge valorization addendum I focus on its applications in the fields of economics and sociology.

The discussion until this point illustrates the social and economic relevance and importance of the research in econometric theory and panel data econometrics in general whereas the research reported in this dissertation investigates a special topic in panel data analysis. In particular, in this thesis, we study stationary and non-stationary panel data models with cross-sectional dependence. In order to narrow the discussion down to the specific topic of the research reported in this dissertation, consider a data set that enlists the gross domestic products (GDP) of countries in the Middle East, for twenty years, say 1994-2014. This is an example of a panel data set. Empirical research has shown that the GDP data series are usually non-stationary. We say that a data series is non-stationary if the underlying distribution changes over time. Presence of non-stationarity necessitates the utilization of methodologies that are specifically developed for that phenomena. Estimation and inference of cross-sectionally dependent non-stationary panels are considered in Chapter 3 of this thesis. To illustrate the concept of cross-sectional dependence suppose that the determination of the GDPs of each country at each time period depends on several factors. Those factors can be grouped in two main categories, country specific factors such as inflation, interest rates, private con-

sumption, imports and exports etc., and factors that are common to all countries such as oil prices, interest rates in the U.S., etc. In such a setup, if data sets meet certain criteria, econometric modelling techniques and econometric analysis can be used to analyse the determination of the GDP, the effects of changes in the factors on changes in GDP and the causal relations between the variables considered. For the results of econometric analysis to be reliable, it is important that the data sets and the models that are being considered to meet certain assumptions of the econometric techniques that are being used. Classical methods of panel data analysis assume that the innovation processes that generate the data are cross-sectionally independent. In the current example, let me name the part of the GDP that remains after accounting for the effects of the individual specific factors and observed common factors as the error term. Cross-sectional independence requires that the error terms of each country to be independent of other countries. However, most of the panel data sets do not satisfy this assumption. For instance, some of the common factors, such as global shocks, might not be observed, hence cannot be included in the models when investigating the determination of the gross domestic product. Unobserved common factors that are left in the error terms of each country, induce a dependence between the error terms. In the literature this phenomena is called the cross-sectional dependence and it necessitates using special techniques to obtain reliable results from econometric analysis of panel data.

The social and economic relevance of this research can be explained better by considering some examples of applied research that attempt to answer socially and economically relevant questions by using cross-sectionally dependent panel data. Herzer and Nunnenkamp (2012) investigate the short-run and long-run affects of foreign aid on income inequality by considering 21 recipient countries over the period 1970-1995. They consider the potential cross-sectional dependence by recognizing that aid flows to each country might be affected by global shocks such as business cycles, global natural disasters, regional wars and income inequality in each country might be affected by technological progress. Long-run and short-run affects of foreign aid on income inequality can be investigated by using panel cointegration techniques. However, cross-sectional dependence has to be accounted for properly, in order to obtain reliable estimates. In Chapter 3 of this dissertation we provide techniques to be used in situations similar to this example. Other examples of applications of the techniques investigated in this dissertation can be listed as follows. Burger and Teal (2014) measure the effect of schooling on individual

earning in African countries where cross-sectional dependence in data is present because of global productivity shocks. Eberhardt and Teal (2008) investigate the cointegrating relationship between output and a set of inputs. Cesa-Bianchi (2013) investigates the effects of housing demand shocks on real economic activity. Questions such as above demand empirical researchers to use techniques that are specifically developed for cross-sectionally dependent data. In particular, developing models and estimating those models can only be done in a reliable way by using techniques that take into account the potential cross-sectional dependence. This fact reveals the social and economical relevance of the research reported in this thesis.

The results of this thesis can be useful to researchers that are doing empirical research in almost any field, for instance finance, marketing, demography and climatology. In all these fields panel data analysis is a common practice and the likelihood of coming across with non-stationary and cross-sectionally dependent data is considerably high. For example, in climatology, the temperature measured in several locations over time may be non-stationary due to the increase of CO<sub>2</sub> emissions, where the level of CO<sub>2</sub> emission has the effect of changing the underlying distribution of temperature over time. Outcomes of this thesis can be interesting for government officials, policy makers in investigating, forecasting the effects of their policies. They can be used by the researchers in central banks to forecast and estimate the effects of certain decisions regarding interest rates, exchange rates, money supply and other financial products central banks control. They may be and are used by applied macroeconomists for instance at the European Central Bank or other central banks, in testing validity of macroeconomic theories. For example, to see if the Fisher Effect is a real phenomena, one can use the results of Chapter 3 to estimate the cointegrating relation between real interest rates, nominal interest rates and inflation. Firms might also benefit from the results of this dissertation, if, for example they are interested in the factors that are affecting their sales in different countries over time. Social organisations constitute another indirect target group of this research, in the sense that these results can be used by them in understanding the effects of certain variables on others and how do the effects change among social groups. In this case, using a more accurate technique is crucial in choosing the right action.

Apart from their applicability in applied social sciences, the results of this thesis provide a range of options for future research in econometric theory, that

is to say the researchers in econometric theory are the natural audience of this research.

The above discussion provides an overview of the target groups of the research presented in this thesis. Now I shall discuss the products that the research in this thesis can be translated into. Each chapter can be seen as an introduction of a toolbox that an empirical researcher can use. These constitute the set of immediate products of the research in this thesis. Nevertheless, the consequences of employment of the outcomes of this thesis by potential audiences mentioned above should be counted as well. For instance, social organisations that are aiming at improving societal conditions can take actions based on their research that is conducted by using the toolboxes developed in this thesis. Other potential final products of this research can be listed as, inter alia, firms' pricing, marketing and segmentation decisions, central bankers' decisions regarding the interest rates, money supply, improvements in macroeconomic theory.

The literature on cross-sectionally dependent panel data analysis has become voluminous in the last decades as applied research has repeatedly proven that cross-sectional dependence is present in most of the panel data sets. The contribution of this thesis to the literature of cross-sectionally dependent panel data models is discussed in Chapter 1 in detail. The research reported in this thesis extends the existing results and allows the empirical researchers to answer more sophisticated questions that can be answered by analysis of panel data sets. For instance, investigating the short-run and long-run effects of certain variables on some others simultaneously, in a cross-sectionally dependent panel can be done by using the results of this thesis. The method developed in Chapter 2 allows the empirical researchers to work under less restrictive assumptions. The result of Chapter 4 provides a method to test for one of the crucial assumptions of the method developed in Chapter 3. The results of this thesis can be called innovative in the sense that they provide a wider range of opportunities for empirical researchers in modelling and estimation of cross-sectionally dependent panel data.

The implementation of the results of this thesis can be considered as a continuous process. The toolboxes developed in this thesis can be used by empirical researchers whenever they have a panel data in which they suspect presence of cross-sectional dependence. Besides that, the results can be used as a stepping stone for further theoretical research. For further extensions of the results I refer the reader to the conclusion part of this thesis.