Preface

Tracing key sectors and important input-output coefficients: Methods and applications

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Constraints on development of input-output field

It has been more than 30 years since the International Input-Output Association (IIOA) was founded and the first issue of field journal – *Economic Systems Research* was released. By that time, the field of input-output (IO) analysis had experienced some development; several of its important ideas have since undergone a deep examination. However, due to the short time series of the available input-output tables, this type of scientific progress has mostly taken place in the theoretical dimension and was aimed at an analysis of the algebraic properties of traditional static demand- or supply-driven models. Most of the famous algebraic results published in the field of IO analysis in the 1980s and 90s were aimed at making large-scaled matrix operations (e.g. finding an inverse of a large Leontief matrix) less time-consuming, which was an important task given the computational properties of computers at that time.

Unfortunately, the field of IO analysis has gone through hard times and lost a lot of its appeal in the economics profession over the past 25 years. Among the main obstacles that slowed down the further development of the IO field, one can list two issues: the lack of reliable statistical data on the capital matrices that are crucial components of dynamic IO models, and the insufficient amount of reliable time series data on multi-country input-output tables. As a consequence, the empirical applications of IO models became rather numerous, although they were typically concentrated around the use of purely static IO models that were usually constructed for single economies.

Gaining new impetus – role of WIOD

In recent years, the IO field has experienced a revival. The recently updated World Input-Output Database (WIOD November 2016 Release) is a long-awaited source of statistical data that contains the time series of global inter-country

input-output tables assembled from national account data, supply-use tables, and data on the international trade of goods and services (Dietzenbacher et al., 2013b; Timmer et al., 2015; Timmer et al., 2016). Since its first release in 2013, the database has often been used in studies aimed at examining the effects of the increased integration of markets through international trade, changes in productivity and income inequality, the fragmentation of production processes, the requirements of skills, labor, and resources, and environmental pollution (Daaniyall et al., 2017).

In general, there are two main channels through which the WIOD data supports empirical analyses. First, the WIOD database has been used in a number of high-impact scientific research projects – mainly on global value chains (GVCs), but also on the effect of the fragmentation of global production on labor markets and incomes as well as on accounting for emissions[1]. The second group of studies contains purely policy-oriented papers in which the WIOD data was used to support the recommendations and reports of various international agendas and organizations (see di Mauro et al., 2013; Saito et al., 2013; Timmer et al., 2013b; Amador and di Mauro, 2015; UNIDO, 2016, among others).

Identifying key sectors and tracing important coefficients in IO model

Alongside the analyses of global value chains and carbon footprints, two particular applications of IO models seem to have gained a considerable attention among economists in the empirical studies. These are key sector analysis and the issue of tracing important coefficients in an IO model. For many years, identifying the so-called 'key sectors' in an economy has been one of the most important research topics in input-output analysis. In any economy, the identification and classification of its most influential branches can provide the basis for the taxonomy of an economy and can contribute to a better understanding of its growth and developmental problems[2]. So, it is not surprising that there is a long tradition of studies in the input-output field that are dedicated to the determination of key sectors. Among others, the pioneering works of Rasmussen (1956), Chenery and Watanabe (1958), and Hirschman (1958) provided a framework for using linkages to compare productive structures and identify key sectors in an economy. Since the 1950s, this framework has been extensively used, studied, and modified in both theoretical and empirical contributions[3].

The second important research topic in input-output analysis is the identification of the so-called 'important coefficients' (ICs) that underlay the most crucial

[1] The WIOD 2013 Release provides free access to a set of detailed environmental accounts including country-sector-specific data on industry energy use, CO_2 emissions, and other types of emissions into the atmosphere. The environmental satellites are defined such as to cover the broadest range of environmental topics (Genty et al., 2012).

[2] See Chenery and Watanabe (1958), Hewings and Romanos (1981), Hewings (1982), Defourny and Thorbecke (1984), Białas and Gurgul (1998), Ćmiel and Gurgul, (2002), Gurgul and Majdosz (2006), Temurshoev and Oosterhaven (2014), Gurgul and Wójtowicz (2015), among others.

[3] See Miller and Lahr (2001) and Temurshoev and Oosterhaven (2014) for comparisons of many widely used key sector linkages.

transactions. Since the development of Sherman and Morrison's fundamental formula for estimating the effects on the inverse matrix of a change in an element of the original matrix (Sherman and Morrison, 1950), several studies have aimed to extend and modify this initial proposition. The motivation for this stream of research is straightforward since the ability to identify ICs opens up two general categories of applications within the input-output framework. Firstly, it enables the compilers of income accounts to be better able to direct statistical resources toward particular portions of tables so as to create more-accurate input-output accounts. Secondly, it enables researchers to conduct a broadly defined structural change analysis that, in particular, may be aimed at examining economic integration in a country or region (Tarancón et al., 2008).

Although the literature on tracing ICs in IO tables is rather extensive (especially when one takes purely empirical applications of well-known quantitative procedures into account), two papers seem to stand out from the crowd. The first one is the seminal study by Sonis and Hewings (1992) who outlined a general theory of coefficient change in input-output and social accounting models. The major contribution of the authors was the concept of a 'field of influence' as the basis for interpreting the effects of coefficient change. In general, Sonis and Hewings (1992) provided useful theoretical formulas for detecting inverse-important coefficients; i.e., input-output coefficients in the case of which a small change in their levels leads to a large relative change in the elements of the Leontief inverse.

Two alternative approaches for measuring a sector's importance to an economy were proposed in the second influential paper; i.e., the study by Tarancón et al. (2008). The first alternative approach of Tarancón et al. (2008) was an innovative application of the measure of elasticity based on Sherman and Morrison's formula from 1950. The second approach used linear programming. Tarancón et al. (2008) mainly focused on the 'tolerable limits' approach since they emphasized that the approach has been extensively written about in the context of the important IO coefficients.

Aims and scopes of book

This book summarizes the main findings of the research in the field of IO models that I conducted between 2015 and 2019 in the Department of Applications of Mathematics in Economics at AGH University of Science and Technology in Krakow. The results presented in this monograph extend, modify, and update some preliminary findings in the field, most of which were published in cooperation with Prof. Henryk Gurgul (my colleague and mentor) in several journals recognized in the IO field, including *Economic Systems Research*, *Structural Change and Economic Dynamics*, *Central European Journal of Operations Research*, *Communist and Post-Communist Studies*, and *Metroeconomica*. The value added of this book is three-fold[4]. Firstly, I will try to extend the range of applications of the seminal propositions of Sonis and Hewings (1992) and Tarancón et al. (2008) on tracing

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ICs in IO models. The new approach will allow me to deal with two shortcomings found in the previous methods. First of all, neither the proposition of Sonis and Hewings (1992) nor the method of Tarancón et al. (2008) provided any tools or methods to formally deal with the issue of the redistribution of value added in a global IO model. Despite the undisputable usefulness of the theoretical formulas proposed in Sonis and Hewings (1992) and Tarancón et al. (2008), these tools do not allow the researcher to freely choose a family of subareas of a given IO matrix to be analyzed and compared. Instead, one may simply focus on measuring the importance of single elements, single rows, or columns of elements in a given input matrix. Moreover, applying the formulas of Sonis and Hewings (1992) and Tarancón et al. (2008) to different sets of elements of a given IO matrix does not necessarily prompt one to draw any conclusions on the union of these sets (e.g., finding the two most important individual coefficients does not simply translate into finding the most important pair of coefficients, etc.). In my opinion, it would be more desirable to have access to a flexible approach in the practicable applications that enables one to assess the overall importance of (any) set of coefficients, not necessarily a single coefficient nor a single column/row of coefficients[5]. I also adapt the IC-oriented approach in the context of measuring the eco-efficiency in generalized IO models and tracing the so-called 'eco-efficiency-important coefficients' (EEIC, in short). For this purpose, I propose a new approach that may be used as a supplementary method to traditional data envelopment analysis (DEA). Unlike DEA, this approach takes the detailed data on intersectoral flows in supply- and demand-driven generalized input-output (gIO) models into account. I focus on cases of traditional and size-adjusted measures of interindustry linkages in gIO models; in each case, I suggest respective indices of eco-efficiency and prove their usefulness in policymaking.

Secondly, I do not restrict myself to only applying static IO models (in contrast to most of the previous IO research) – I also aim at focusing on the dynamic framework. Alongside the analysis of historical data (a static approach), I analyze the forecasts and simulations that arise from dynamic IO models. For this purpose, I will release some of the limitations of previous studies and propose a new optimization-based approach to approximating of the elements of capital matrices on the basis of recent historical WIOD data instead of setting the crucial parameters of the dynamic input-output model on an arbitrary basis. Using recent IO data, I will first formally prove that the new theoretical approach allows one to obtain a significantly better fit to the historical data in the short-run as compared to arbitrarily adjusted dynamic IO models. This result also has some implications for long-run analyses, as it suggests that using the new approach for typical empirical applications of dynamic IO models seems relatively much more reasonable with respect to the modeling the future behaviors of economies.

Finally, I will illustrate the application of the discussed methods of key sector analysis and identification of ICs and EEICs in IO models constructed on a basis of time series of IO data on the Polish economy in the empirical part of the monograph.

[5] As emphasized by Lahr (2001) and Tarancón et al. (2008), such a generalization is important in several major IO applications, especially identifying key sectors as well as identifying sectors as targets of further enhancement with primary data (this would expedite the work of national statistical bureaus).

In addition to the well-known procedures that have already been used in the empirical studies, I will also illustrate the two new approaches (i.e., the new proposition of approximating capital matrices in dynamic IO modeling and the new optimization-based procedure of tracing ICs and EEICs). In order to illustrate the possible applications of the new approach of tracing EEICs, I will conduct an empirical analysis aimed at identifying the eco-efficient sectors based on the 1995 and 2009 national input-output tables and environmental accounts for Poland provided by the World Input-Output Database.

To summarize – most of the empirical results presented in this monograph will fill the gaps in the economic literature regarding Poland. However, selected methodological aspects (e.g., the new algorithm of approximating capital matrices in a dynamic IO model, the construction and first illustrative application of a new version of an endogenous dynamic IO model with layers of techniques, and the new method of tracing ICs and EEICs in an IO model) seem to be of international significance.