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Proceedings of the International Conference on Research in Management
Vol. 1, Issue. 1, 2024, pp. 7-17
DOI: https://doi.org/10.33422/icrmanagement.v1i1.527

ISSN: 3030-1114 online

Diamond Scientific Publishing

Application of the environmentally extended input-output method in the identification of key sectors: A PRISMA-guided systematic review

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Abstract

The overarching goal of this systematic literature review is to identify, present, and in detail analyze relevant published studies in Scopus-indexed publications regarding identifying key economic sectors with the application of the environmentally extended input-output methodology (EEIO). For this reason, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic literature reviews have been adopted. The Scopus scientific database was surveyed with the keywords "Environmentally extended input-output", "key sectors", "transmission sectors" and "key industries", which led to a total of 50 published papers in English. After implementing all of the steps of the PRISMA guidelines, which included both electronic and manual searches, 8 relevant papers remained for qualitative analysis. Most of these papers were conducted for the period between 2000 and 2017. The key findings are elaborated in a narrative synthesis and reveal that most authors indicate the electricity, transport, and construction sectors as the sectors with the highest pollutant emissions; the household sector is also singled out as a sector that has a large impact on carbon emissions. The underlying purpose of this paper is to raise awareness and knowledge among scholars and local and national policymakers regarding the key sectors and empirical ways for their identification with the application of the EEIO method. Lastly, the scientific and practical implications of the study are provided, and plans and guidelines for future work are presented.

Keywords: environmentally extended input-output method, key sectors, systematic literature review

1. Introduction

Environmentally extended input-output analysis (thereafter EEIO) is a powerful analytical tool for assessing the impact of certain economic activities on environmental degradation, depletion of natural resources, and emission of pollutants. The development and application of EEIO tables with ecological and social indicators is of great benefit to every country or region, especially in the processes of increasing globalization. EEIO enables key sectors of the national economy identification that have above-average effects on the environment, which are the result of continuously growing production to satisfy the needs of the population. EEIO enables the assessment of the sustainability of the development of various economic sectors, in a way that encourages the development of those sectors that do not impair ecological sustainability and maximize economic effects. EEIO provides a quantitative framework for the effective identification of sustainable management of the national economy through an analysis of key sectors in terms of direct and indirect environmental impacts.

The objective of this paper is to identify, present, and analyze relevant papers from the Scopus scientific database in which key sectors that maximize economic effects and minimize effects on the environment, i.e. on the resources use and the pollutants emissions with the application of the EEIO methodology are detected.

Therefore, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines for systematic literature review were followed to survey and present relevant published studies employing the EEIO methodology in the identification and revelation of key sectors and industries. The main scientific and practical contribution of this paper mirrors both the presentation of the different ways of applying the EEIO methodology and the summary of their findings regarding the key sectors.

The structure of the paper takes the form of five parts. Section 2 gives a theoretical background of both the EEIO and key economic sectors. Section 3 unveils the research design and methodology. The research results are presented in Section 4, and a discussion and conclusion are provided in the fifth section.

2. Theoretical overview

2.1 Environmentally extended input-output method (EEIO)

In parallel with the growth of production to meet the growing global demand, economic systems face certain natural limitations and become confronted with climate change, increasing natural resource depletion, fossil fuels use, loss of biological diversity, and worsening socioeconomic inequality. Therefore, it is necessary to tailor the strategy of sustainable development that considers the establishment of a balance between economic, social, and environmental circumstances. EEIO analysis is increasingly important because of the ever-increasing vital role of the assessment of the impact of individual economic activities on the environment. EEIO analysis is based on the EEIO tables that, in addition to the values of economic transactions between productive sectors, including output for private and government consumption, exports, and capital formation, are expanded with environmental and social indicators (Joint Research Centre, 2006). EEIO tables are a powerful tool in supporting economic and environmental policies for the adoption or revision of existing strategies and reflections on measures that simultaneously act on the objectives of economic and sustainability policies. Such IO tables are used to produce data on the role of

certain economic activities in the use of natural resources and the emission of pollutants (European Commission, 2021).

According to Kitzes (2013), EEIO analysis enables the calculation of "upstream environmental impacts associated with a downstream consumption activity" and the calculation of the "amount of embodied environmental impact in goods traded between nations" and therefore enables "a new generation of analyses that take a consumption-focused, rather than a production-focused, perspective on the causes of global environmental degradation and resource use". The first extensions of standard IO tables with ecological indicators were presented in the work of Ayres and Kneese (1969) and Leontief (1970), who included pollution in the IO model.

Recent and relevant environmental extensions include those focused on water pollution (Lu et al., 2023; Chapagain et al., 2022), carbon emissions (Demeter et al., 2022; Zha et al., 2022), greenhouse gas emissions (Yang et al., 2022), waste (He et al., 2019) and food waste (Albizzati et al., 2022; Meshulam, 2023).

2.2 Key sectors

Even though the concept of key sectors has been introduced in the scholarly literature around the 1940s, in the first edition of The Conditions of Economic Progress by Colin Clark (Wolfe, 1955), the central issue and question of the identification of key sectors in the economy remains vital even today, after 80 years.

The postulates of the existence of "sectors" were set by Clark (1940), who defined them as "groups of industries with significantly different characteristics". Hewings (1982) defined them as the sectors "which are assumed to exercise a greater than average impact upon the economy". Their identification is vital in the processes of fund allocation, employment support programs, granting tax exemptions, and the implementation of other policy activities to reinforce the whole economic system and to ensure that it will stay resilient in the long term. However, this is a very difficult task, since it involves deciding whether the sector with the highest productivity and output, or the one with the highest employment is a key sector. Obviously, "different sectors are "key" under different assumptions, and for different purposes" (DePaolis et al., 2022). Acknowledging the differences between major economic sectors, such as agriculture, commerce, or manufacturing has been traditionally conducted in economic reasoning throughout history (Kenessey, 1987).

The importance of key sectors and research on them is highlighted in the emerging studies revolving around their identification. This is reflected in the notion that key sectors are very important for decision-makers and policymakers and for achieving sustainable development for each country (Brika et al., 2021). Moreover, some economists go one step further and claim that the “large distortions in a few key sectors explain the bulk of the gap in aggregate productivity between rich and poor countries” (Leal, 2015). Therefore, it is no wonder that this is a burning issue among policymakers in both developed and developing countries.

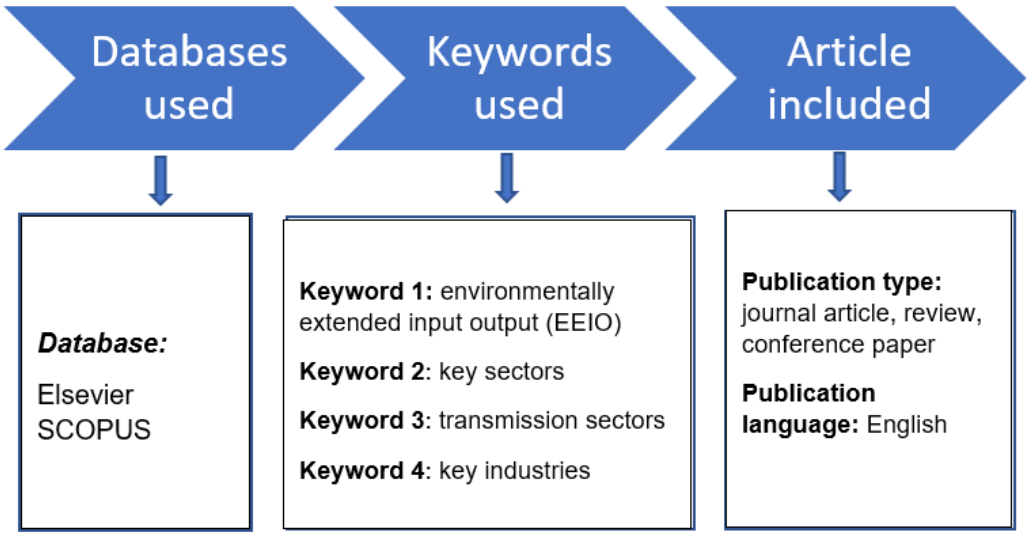
The attempts at key sector identifications in an economy with IO methods have experienced a history of considerable debate (Hewings et al., 1989). Hewings (1982) noted that there are many different methods and combinations of methods used in key sector identification, but he recommended the IO method as "the most appropriate one". Nowadays, some critics claim that IO methods have been replaced with more complex and advanced economic modeling approaches, such as general equilibrium, but still, they emphasize the "straightforward process" of IO methods in the description and decomposing of local economies (DePaolis et al., 2022). This was the main rationale for this study, to encompass the current trends of key sectors identification with the EEIO methodology.

3. Research approach

This study implements the systematic literature review as a methodology, which is referred to as "an essential tool for summarizing evidence accurately and reliably" (Liberati et al., 2009). The PRISMA guidelines were followed as a means to give a summary of the relevant published papers in this research area, with the implementation of the EEIO methodology. They were first published in 2009 and were introduced "in an attempt to increase the clarity, transparency, quality, and value of these reports" (Liberati et al., 2009; Sohrabi et al., 2021).

The first stage of the research included a selection of the surveyed scientific database (in this case, the Scopus database). In the second stage of the study, the keywords selection was conducted, with the following selection of keywords: "Environmentally extended input-output", "key sectors", "transmission sectors" and "key industries". The third stage of the research represents the inclusion phase of papers written in English, which were published as journal articles, reviews, and conference papers. All of these stages are shown in Figure 1.

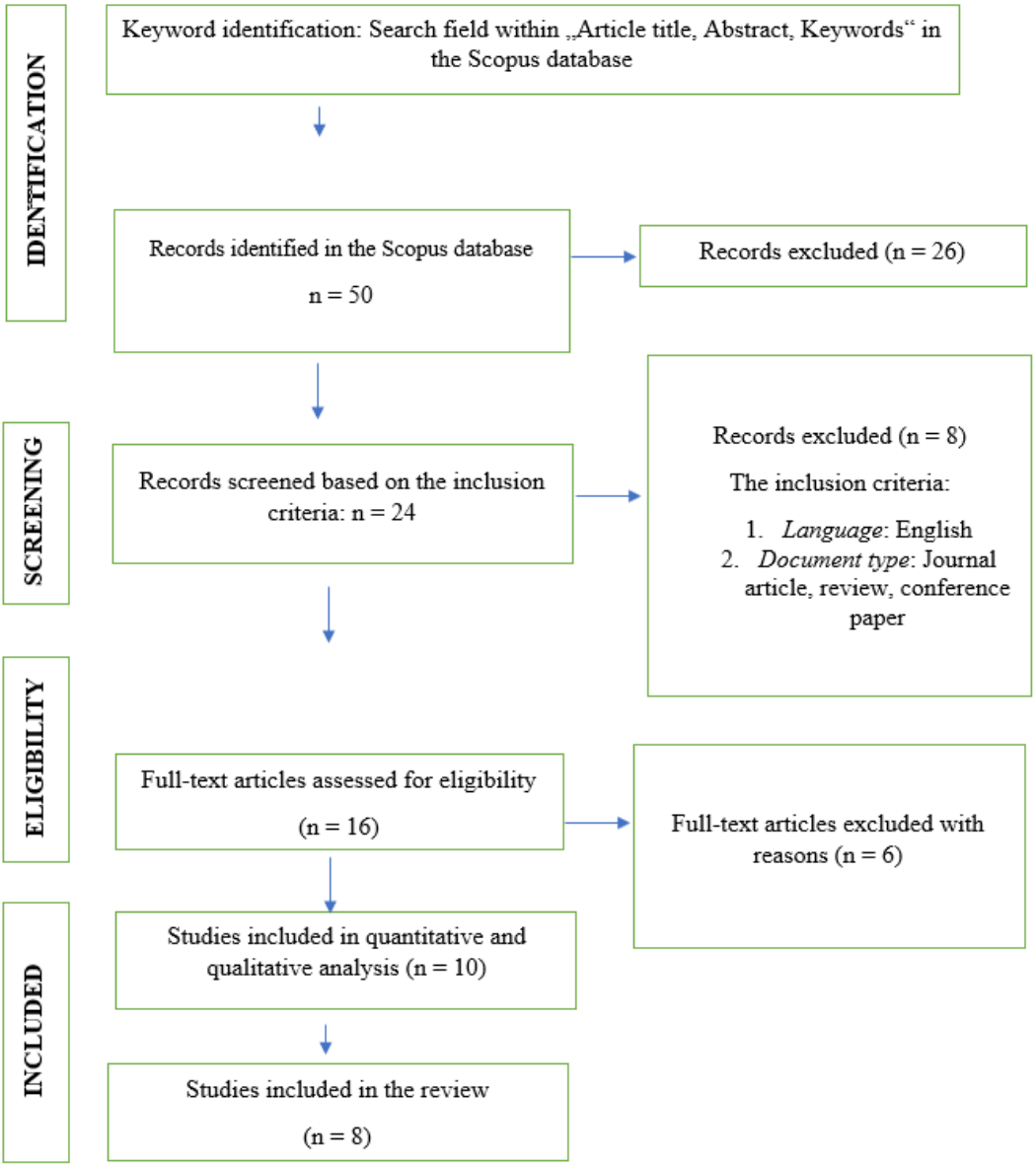
Figure 1. Stages of the review study



SOURCE: Authors.

The PRISMA-guided research design consists of "a four-phase flow diagram" (Selçuk, 2019) and is presented in Figure 2. The PRISMA guidelines include four phases as follows (the identification, screening, eligibility, and the inclusion phase). In the first phase of identification, the research began with the survey of one of the globally most renowned scientific databases (the Elsevier Scopus database). For this reason, the database was surveyed with the keywords "Environmentally extended input-output", "key sectors", "transmission sectors" and "key industries", which initially resulted in 50 results. In the second phase of the PRISMA-guided systematic review, the first electronic screening of the papers was initiated, identifying papers written in English and publications such as journal articles, reviews, and conference papers. In this phase, eight papers were excluded from further analysis. In the third phase of eligibility, full-texts were manually screened, as an attempt to include only relevant papers that employed the EEIO methodology in the key sectors identification. In the last, fourth phase of the study, only 8 papers were left for in-depth qualitative presentation and analysis. A tabular overview of the analyzed papers, their analyzed country or region, their time frame, and their findings, is laid out in Section 4.

Figure 2. The PRISMA-guided research design and the selection process of the articles for the literature review



SOURCE: Authors.

4. Research results

As discussed above, this paper's main objective was to identify the most relevant published studies from the Scopus scientific database as a means to systemize the thus far published application of the EEIO analysis in key sectors and industries. In this section, a tabular presentation of the surveyed relevant papers is presented in Table 1, and a more detailed analysis in a narrative manner of each of the relevant 8 articles and their findings is made thereafter.

Table 1. Applications of EEIO methodology in the key sectors identification

Author/s and year of publication	Title of the paper	Analysed country/region	Time frame
Koskela et al. (2013)	Identifying Key Sectors and Measures for a Transition towards a Low Resource Economy	Finland	2008
Ou et al. (2017)	Demand-driven air pollutant emissions for a fast-developing region in China	Guangdong, a region in China	2007 and 2012
Nguyen et al. (2018)	Structural analysis of the interrelationship between economic activities and water pollution in Vietnam in the period of 2000–2011	Vietnam	2000 and 2011
Long et al. (2021)	Fuel-specific carbon footprint embodied in Japanese household lifestyles	Japan	2015
Pirmana et al. (2021)	Environmental Cost in Indonesia Spillover Effect Between Consumption and Production	Indonesia	2010
Shmelev and Brook (2021)	Macro Sustainability across Countries: Key Sector Environmentally Extended Input-Output Analysis	Austria, China, France, Germany, Sweden and the USA	2007
Cornaro and Rizzini (2022)	Environmentally extended input-output analysis in complex networks: a multilayer approach	189 countries	2016
Nie et al. (2022)	Modeling Structural Effect and Linkage on Carbon Emissions in China: An Environmentally Extended Semi-Closed Ghosh Input-Output Model	China	2007 to 2017

SOURCE: Authors.

Koskela et al. (2013) used EEIO analysis and total flow analysis to examine productive sectors that have the highest flow of materials. The analysis was carried out for Finland in 2008. The goal of this analysis is the transition to a low-resource economy. The key sectors with the highest use of resources have been identified. According to the authors, those sectors are: "residential construction, followed by sand and clay quarrying, civil engineering, manufacture of non-ferrous metals, and pulp and paper". Changes in terms of improvement in any of the above sectors would greatly reduce the overall consumption of resources in the entire economy.

Ou et al. (2017) used an EEIO analysis for Guangdong, a region in China, to examine air pollutant emissions. This region is developing rapidly and consequently faces challenges in how to reduce air pollution and sustain economic development. Production-based emission

inventories for seven pollutants for the years 2007 and 2012 were developed. The drivers of air pollutant emissions "from the production perspective were electric power, transport, nonmetallic mineral products, and some equipment machinery and light industries" (Ou et al., 2017). From the consumption point of view, the largest contributions are from sectors construction, transportation, and other services".

The mutual influence of productive sectors and their impact on water pollution, driven by fast economic growth and ineffective waste management in Vietnam for the period 2000 and 2011, were analyzed by Nguyen et al. (2018). Based on the EEIO analysis authors concluded that sector "agriculture, fishery and forestry and sector food, beverage and tobacco are considered key sectors that had the highest propensity to cause water pollution across the economy". Sector "construction and sector manufacturing of fabricated metal products, machinery, and equipment were detected as sectors with high pollution amount by high inputs from other sectors", while "sector basic metal industries was considered as a sector whose pollution is virtually sold to other sectors without it finally returning to this sector".

The impact of household carbon emissions by region concerning the entire Japanese economy was analyzed by Long et al. (2021). Based on the EEIO table, the regional household consumption inventory, and data from 2015, direct and indirect household carbon emissions were analyzed. The authors concluded that the household sector accounts for approximately 80% of direct and indirect emissions in Japan. In terms of regions, there are significant differences in carbon emissions. Authors suggest tailored strategies for Japan's decarburization at the subnational level considering the impact of households and the type of fuel used.

The environmental costs of pollutant emissions and use of forest resources for the year 2010 in Indonesia are analyzed by Pirmana et al. (2021). This environmental cost is largely caused by "domestic products, with household consumption being the largest contributor". The manufacture of basic iron and steel, the electricity sector, the sea and coastal water transport sector, manufacture of rubber and plastic products are sectors that are the most responsible for total environmental costs of emissions. Key sectors from the point of economic and environmental performance and sustainability view are "textile manufacturing; publishing, printing, and reproduction of recorded media; chemicals n.e.c.; manufacture of other non-metallic mineral products; construction; and other land transport".

Shmelev and Brook (2021) applied EEIO and the multi-criteria decision aid method ELECTRE III to identify the most sustainable sectors in the six analyzed countries, i.e. Austria, China, France, Germany, Sweden, and the USA, based on the EXIOPOL data from 2007. Environmental and social indicators used in this research were CO2 emissions and employment. Education, health and social work, and hotels and restaurants are sectors that have been identified as very sustainable in almost all of the analyzed countries. The sectors identified as the least sustainable sectors are the production of electricity from gas, coal, oil, and other petroleum products; extraction of metals and other ores; Production of cement, lime, and gypsum; and Air Transport. Based on the obtained results, the authors conclude that there is no effective universal sustainable development policy strategy that would apply to all countries. The results of this analysis can be helpful for individual countries to strive for sustainable development so that common international goals such as the Paris Climate Agreement from 2015, which all analyzed countries have ratified, can be achieved in the best possible way.

Cornaro and Rizzini (2022) develop the global embodied energy flow multilayer network, based on the EEIO analysis. The approach was applied to 189 countries and covered 26 sectors in the year 2016. The authors detected sectors that contribute the most to global

economic development and environmental degradation: "electricity, petroleum, chemical and non-metallic mineral products, transport, and metal products". Sectors that require large amounts of energy flow are "construction, education, health and other services, electrical and machinery".

Based on the environmentally extended semi-closed Ghosh IO model, structural decomposition analysis, and the hypothetical extraction method, Nie et al. (2022) analyzed the drivers and links of carbon emissions in the productive sectors and households in the Chinese economy for the period 2007 to 2017. The above model reflects the mutual effects of the industrial sector and the household sector on carbon emissions. It also analyses the effects of primary inputs on carbon emissions. According to the results, sectors "electricity, gas, and water supply sector was the key sector with the highest carbon emission intensity enabled by primary inputs". The mining sector was also detected as a sector with high enabled carbon emission intensity, followed by the household sector.

5. Discussion and conclusion

In this paper, the PRISMA guidelines were implemented to research the Scopus scientific database and review papers with an emphasis on the EEIO method. The main objective was to examine the role of individual economic activities on the resources use and the pollutants emissions. Relevant papers identification in the Scopus scientific database was carried out based on the keywords "Environmentally extended input-output", "key sectors", "transmission sectors" and "key industries". Based on the implemented process, a total of 8 relevant papers were qualitatively analyzed. The results of this approach can be systematized as follows. Most of the reviewed papers cover Asian countries (Ou et al., 2017); Nguyen et al., 2018; Long et al., 2021; Pirmana et al., 2021) and Nie et al., 2022), while two papers have a multinational approach (Shmelev & Brook, 2021 and Cornaro & Rizzini, 2022). Shmelev and Brook (2021) combined EEIO methodology with the multi-criteria decision aid method ELECTRE III, and Cornaro and Rizzini (2022) embodied energy flow multilayer network. Most of these studies were conducted for the period between 2000 and 2017. Most authors pointed out the electricity, transport, and construction sectors as the sectors with the highest pollutant emissions (Ou et al., 2017; Pirmana et al., 2021; Shmelev & Brook, 2021; Cornaro & Rizzini, 2022). In addition to the productive sectors, the household sector is also singled out as a sector that has a large impact on carbon emissions (Long et al., 2021; Pirmana et al., 2021; Nie, Gao, and He, 2022). Only in the paper of Shmelev and Brook (2021), apart from the least sustainable, the most sustainable sectors were singled out. These are the sectors education, health and social work, and hotels and restaurants.

The main contribution of this paper is mirrored in the new insights and information it provides for local and national policymakers, economic geographers, planners, and other stakeholders who realize there are clusters (groupings) in the economy that play a vital role in the performance and development of the local economy. The scientific contributions are reflected in the promotion of the EEIO methodology among the academic community. Namely, this is essential, due to the notion that EEIO, even though so beneficial for key sector identification, is rarely implemented in empirical studies on this subject, which is one of the key findings of this study (with a review of only 8 relevant published papers). Therefore, academic members must make efforts to implement and promote this methodology in the academic community.

This work is, however, not without limitations. First and foremost, there is a large possibility that not all relevant published studies implementing EEIO in the identification of key sectors in the economy have been identified and presented since the authors have focused

solely on the Scopus scientific database. One way of avoiding this limitation is to provide a more extensive systematic literature review surveying all the relevant global scientific databases, which is a plan for the future work of the authors. Furthermore, in future work, the authors plan to implement the EEIO methodology empirically to identify the key sectors in the Republic of Croatia and the European Union.

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