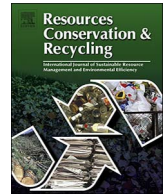




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## Review

## Trends and features of embodied flows associated with international trade based on bibliometric analysis

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## ABSTRACT

Trade plays an important role in redistributing resources and also brings significant environmental impacts to involved countries. This relatively complex research domain of international trade and environmental burden shifts is informed through study of embodied environmental flows of products. Research trends to identify features of international trade embodied flows between 1997 and 2016 are determined through a bibliometric study. Research contribution of countries, authors, institutions and journals are described. Co-citation and network analyses are completed. Results show that there has been significant research interest increase on this topic. Given the interdisciplinary and global nature of this topic, increases in countries, author, and institutional collaborations has occurred. USA, China, the Netherlands, the United Kingdom and Norway were the top 5 countries with high academic influence, and country as USA and institution as Chinese Academy of Sciences has the largest number of collaborations, respectively. Embodied flows such as carbon emission and water are popular ones associated with international trade in the given period, and the most popular methodological tool is Input/Output Analysis. In addition, hotspots which extracted from keywords are analyzed, additional avenues of research are also discussed in this study.

## 1. Introduction

Trade globalization has led to international economic integration that systemically links nations, and plays an important role in affecting sustainable economic development and ecological dynamics amongst nations (Jomo and Rudiger, 2009). Countries seek to determine if they are gaining or losing in international trade flows. The traditional economic discussion typically focuses levels of economic flows and imbalances. What has been given less focus in the literature and popular press are the impacts of trade on natural resources and the natural environment although these topics remain important and controversial (Jayadevappa and Chhatre, 2000; Moran et al., 2013).

Trade is sought out by nations to aid in their economic development. Countries seek out a share of the “trade pie”. International trade flows are associated with comparative advantages or nations and regions. Comparative advantages occur for many reasons, some of which are natural resources availability and capabilities, such as water, land and carbon efficiency resources. The beneficial aspects of international trade and natural resources may be exemplified by global water

resource balances. Countries and regions rich in water resources may be beneficial partners to those regions with water scarcity. For example, it has been found that international global water resources trade of agricultural products is 352 cubic gig meters per year (average over the period 1997–2001), greatly aiding water scarce areas (Chapagain et al., 2005). Another example is exports growth of carbon-intensive goods from Australia to China. This international trade relationship has helped in global carbon emissions reductions since Australian goods manufacturing carbon intensity is much less than China goods manufacturing carbon intensity (Tan et al., 2013).

International trade may result in resources and environmentally detrimental balances and trade shifts. This type of trade may allow one country to partially decouple its domestic economic and ecological systems while consuming goods from other national economic systems. Countries may seek to save their own environmental and resources capacity by shifting away from natural resources and pollutant-intensive activities in the manufacture of their goods (Machado et al., 2001). They can do this through importing high environmentally and resource burdensome products from other regions of the world. Under

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these circumstances, global issues such as “carbon leakage” and “ecologically unequal exchange” may occur across nations, resulting in greater overall environmental and natural resources degradation (Hoekstra and Mekonnen, 2012; Moran et al., 2013; Peters et al., 2011).

Inter-relational quantitative assessments incorporating socio-economic systems and the natural environment have gained attention with respect to global international trade. The major international trade assessment metrics and environmental indicators are called “embodied flows” (Bruckner et al., 2012; Giljum et al., 2011). Embodied flows quantify the natural resource or environmental quantities required directly or indirectly to make a product or provide a service. Embodied flows analysis helps identify and illustrate environmental burden shifts associated with raw materials extraction and processing, and product manufacture. Further analyses help to identify international trade balances. An important line of research focuses on “unequal ecological exchange” amongst nations.

To date, studies on trade-based embodied flows typically focus on either environmental or resources dimensions, based on different methods, such as Input-Output Analysis (IOA), Material Flow Analysis (MFA) and other relevant methods. These studies also aim to identify driving factors influencing embodied flows transfer, so that more appropriate policies can be raised to help address resources and environmental losses from trade (Caro et al., 2014; Davis et al., 2011; Tukker and Dietzenbacher, 2013; Steinberger et al., 2010; Wu et al., 2016; Guan et al., 2008).

However, due to the short period of this nascent field, publications related to embodied flows have not been comprehensively reviewed from either a quantitative or qualitative perspective. Although a number of reviews have been completed related to specific tools for embodied flows (Bruckner et al., 2015; Wiedmann, 2009; Wiedmann et al., 2007) or for specific types of embodied flows (embodied carbon, virtual water) (Liu et al., 2016; Zhang et al., 2017b); no research review has considered all the embodied flows, tools, and regions. A comprehensive integrative review provides insights into what topics have been covered and the reasons for these studies. It can also help identify research gaps and determine some consensus findings that policy makers can utilize.

In order to fill this gap in the literature and help to advance the field, this study applies bibliometric and complex network analysis for a systematic review of embodied flows associated with international trade. Systematic literature reviews are completed through an iterative process of defining appropriate search keywords, searching the literature and completing the analysis (Higgins and Green, 2009). Systematic reviews differ from traditional narrative reviews in that they employ a replicable, scientific and transparent process that minimizes the selection bias through exhaustive literature search (Vrabel, 2015).

The goals of this study include: (1) identifying trends and features of international trade embodied flows research for the period of 1997–2016; (2) summarizing contributions based on country, institutions, authors and journals and collaborative efforts to determine the perspectives and potential biases; (3) uncovering emergent research fields extracted from keywords through co-citation relationships; and (4) providing future directions for embodied flows and international trade research.

The remainder of this paper includes discussion of the methodology and data collection in Section 2. Section 3 presents the main results. Section 4 provides a discussion and critical analysis of the results. Conclusions and future directions drawn from analysis are presented in the final section, Section 5.

## 2. Methods, data collection and treatment

### 2.1. Methods

Systematic bibliometric literature reviews follow a series of steps. Initially topically relevant keywords are needed for electronic database

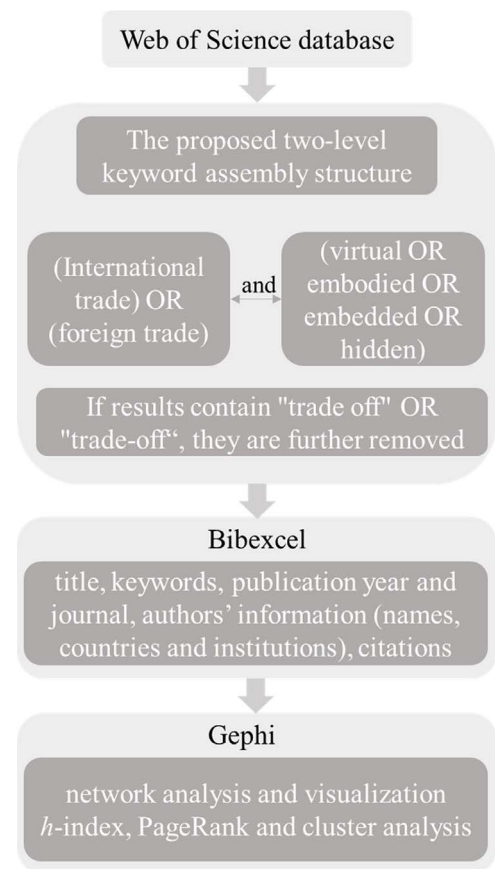


Fig. 1. The general flow chart for the systematic literature analysis.

searches. Typical databases include the Web of Science or Scopus databases. Secondly some literature analysis tools (such as Bibexcel (Persson, 1986), in this study) are applied for identifying basic features of the selected papers. These data are then exported and processed for further analysis. The third step is the application of a network analysis tool. Network analysis provides insights into complex relationships amongst the publications and their various characteristics. In this regard, Gephi (Heymann, 2014) is used for network analysis and visualization of these networks. Various bibliometric statistics such as *h*-index, PageRank and cluster analysis could further help researchers identify the key roles of publications. The general flow chart for the systematic literature analysis used in this study is shown in Fig. 1. More details on these methodological steps and tools are now provided.

Bibexcel is a bibliometric toolbox offering the user significant flexibility in data management and analysis. It is helpful in evaluating the research status and trends of various disciplines and topics. It is also helpful for identifying future research directions (Persson, 1986; Zheng et al., 2015). Bibexcel allows for modifying and adjusting data fields which can be imported from various electronic publication databases including Web of Science and Scopus. It can be integrated with other bibliometric and statistical software such as Pajek, Excel, SPSS, and Gephi (Fahimnia et al., 2015). Bibexcel extracts basic information from each publication, such as title, keywords, publication year, journal, authors' information (names, countries and institutions), and citations. Additional information on Bibexcel operations and capabilities can be found in Šubelj et al. (2014a,b) and Persson (1986).

Network analysis helps evaluate various relationships among interacting units. Relations defined by linkages among units are a fundamental component. Network analysis evaluates observed attributes of social actors, such as race, ethnicity, size, and productivity of collective bodies such as cooperation or nation-states, as examples. It seeks to understand relationship patterns or structures amongst the units of

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