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Research article

Measuring the environmental sustainability performance of global supply chains: A multi-regional input-output analysis for carbon, sulphur oxide and water footprints

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ABSTRACT

Measuring the performance of environmentally sustainable supply chains instead of chain constitute has become a challenge despite the convergence of the underlining principles of sustainable supply chain management. This challenge is exacerbated by the fact that supply chains are inherently dynamic and complex and also because multiple measures can be used to characterize performances.

By identifying some of the critical issues in the literature regarding performance measurements, this paper contributes to the existing body of literature by adopting an environmental performance measurement approach for economic sectors. It uses economic sectors and evaluates them on a sectoral level in specific countries as well as part of the Global Value Chain based on the established multi-regional input-output (MRIO) modeling framework. The MRIO model has been used to calculate direct and indirect (that is supply chain or upstream) environmental effects such as CO_2, SO_2, biodiversity, water consumption and pollution to name just a few of the applications. In this paper we use MRIO analysis to calculate emissions and resource consumption intensities and footprints, direct and indirect impacts, and net emission flows between countries. These are exemplified by using carbon emissions, sulphur oxide emissions and water use in two highly polluting industries; Electricity production and Chemical industry in 33 countries, including the EU-27, Brazil, India and China, the USA, Canada and Japan from 1995 to 2009. Some of the highlights include: On average, direct carbon emissions in the electricity sector across all 27 member states of the EU was estimated to be 1368 million tons and indirect carbon emissions to be 470.7 million tons per year representing 25.6% of the EU-27 total carbon emissions related to this sector. It was also observed that from 2004, sulphur oxide emissions intensities in electricity production in India and China have remained relatively constant at about 62.8 gSO_x/, respectively, $ and 84.4 gSO_x/$ although being higher than in other countries. In terms of water use, the high water use intensity in China (1040.27 L/$) and India (961.63 L/$), which are among the highest in the sector in the electricity sector is exacerbated by both countries being ranked as High Water Stress Risk countries.

The paper also highlights many advantages of the MRIO approach including: a 15-year time series study (which provides a measurement of environmental performance of key industries and an opportunity to assess technical and technological change during the investigated time period), a supply chain approach that provides a consistent methodological framework and accounts for all upstream supply chain environmental impacts throughout entire global supply chains.

The paper also discusses the implications of the study to environmental sustainability performance measurement in terms of the level of analysis from a value chain hierarchy perspective, methodological issues, performance indicators, environmental exchanges and policy relevance.

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1. Introduction

Several studies have suggested that supply chain management can contribute to solving the global sustainability challenge which has taken prominence since the publication of the Brundtland Report by the World Commission on Environment and Development (1987). Indeed, sustainability and the Triple Bottom Line (Elkington, 1997) have now become part of the political rhetoric and have been integrated across disciplines. In supply chain management, business and industrial practice, the increasing influence of sustainability has even achieved a redefinition of the operations function by necessitating the introduction of environmental protection as key operational and business strategies (de Burgos Jiménez and Lorente, 2001). It follows that sustainable supply chain management emphasizes the creation of a competitive advantage advantage through the integration of information flows and the transformation of resources within the network of activities as elaborated by Seuring and Müller (2008) and expanded upon by Crum et al. (2011) and Ageron et al. (2012). In this paper, environmentally sustainable supply chain management (sometimes described as green supply chain management) is defined as the integration of environmental thinking into the entire lifecycle processes of supply chain activities. Haines-Young et al. (2006) emphasizes that measurement of environmental sustainability in terms of environmental impacts has become very important since thresholds of indicators provide the opportunity to assess whether sufficient relative or absolute decoupling is taking place to support the conclusion that more sustainable patterns of consumption and production have been achieved.

Measuring environmental performance of a product, process or activity across the entire supply chain is a challenge. Lehtinen and Ahola (2010) and Hassini et al., (2012) have reiterated that there exist incompatibilities between the known principles of performance measures and supply chains. Indeed, despite the fact that sustainability performance measurements remain fundamental in the shift of the operations function towards sustainable supply chains, Schaltegger and Burritt (2014) recently reported that existing methods and possible approaches to measure and manage sustainability performance of supply chains such as at the industry level are lacking although performance measurement is of great importance for effective supply chain management (Yang et al., 2011). This can be attributed to many factors; amongst them the existence of multiple and sometimes conflicting measures that characterize the performance of the supply chain (Liang et al., 2006), the focus on reporting green supply chain management initiatives implementation rather than performance outcomes (Zhu et al., 2008), the fact that supply chains are dynamic in nature (Gunasekaran et al., 2004) and that environmental problems are multi-faceted (Hubbard, 2009) and the result of inconsistent methodologies as expounded upon by Font and Harris (2004).

In addition, environmental evaluations of supply chains have only recently become an issue (Hoekstra and Wiedmann, 2014), especially in relation to Scope 3 emissions attributed to indirect supply chain activities which is based on the Accounting and Reporting Standard of the GHG Protocol addressing carbon leakage (Scott and Barrett, 2015). As a result, they envisage a future in which such environmental sustainability assessments are implemented by companies and at the national level using consistent analytical frameworks with broad but not overlapping coverage of environmental pressures to measure performance of both operations and supply chains. This study therefore seeks to contribute to performance measurement in this regard.

Further to these, this research is motivated by the recent Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), which reported that industry-related greenhouse gas (GHG) emissions have continued to increase and are higher than GHG emissions from other end-user sectors (Fischedick et al., 2014). The need for a deeper level of understanding of the environmental performances of industries especially those considered to be heavy industry sectors across different regions and across time must be studied and fully understood. As such, in an attempt to help address global environmental sustainability issues, the paper adopts an industry-level perspective of the global supply chain and provides insight using exemplar cases of how environmental sustainability performance models can be developed and systematic measurements undertaken in key industries and regions and across a range of environmental indicators. (Gereffi et al., 2005).

This paper therefore seeks to contribute to the growing body of knowledge in this research area by addressing some of these pertinent issues. To this end, we argue that an environmental sustainability performance measurement approach based on a consistent MRIO framework implemented at the industrial level of the value chain across a range of environmental indicators over a time series addresses some of the issues identified in the literature including multiple indicators and conflict between measures (Liang, et al., 2006); inconsistent methodologies (Font and Harris, 2004) and performance frameworks (Gunasekaran et al., 2004; Zhu et al., 2008); lack of research and possible approaches to measure and manage sustainability performance of supply chains (Schaltegger and Burritt, 2014) and lack of consistent analytical frameworks (Hoekstra and Wiedmann, 2014).

The paper reports on the MRIO model results for two heavy polluting industries; Electricity production and Chemical industry. These industries were chosen because such heavy industrial sectors received special attention in the recently published Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC, 2014). The analysis was carried out in the following countries and regions the 27 European Union member countries (EU-27), Canada, USA and Japan and some major emerging economies or BIC nations (Brazil, India and China). The BIC nations were chosen because of growing international concerns on environmental damages associated with accelerated industrial growth of these countries (Lai and Wong, 2012). The EU-27 and G7 member countries, on the other hand, represent some of the most developed economies, with some of these countries having very stringent environmental policies, which should be reflected in their environmental performance of their industries but may not always be the case. Additionally, in terms of a consumption-based perspective of performance measurement, EU-27 and G7 member countries are responsible for significant environmental impacts (usually in developing and industrialized nations such as BIC countries) because of the high consumer demand for goods and services in these countries.

The assessment is based on a time-series analysis undertaken over a 15-year period from 1995 to 2009 enabling the performance over time to be evaluated because country specific regulations (e.g. emission standards) evolve through time and countries do not always share the same level of technological progress in key industries e.g. coal power plants in China vs. Europe may have different operating efficiencies. Multiple sustainability performance measures for carbon dioxide emissions, sulphur oxide emissions and water usage are used. Carbon dioxide emissions, (sulphur oxide emissions and water usage were chosen as indicators because they respectively characterize different environmental sustainability dimensions of climate change, pollution and resource extraction. In addition, the indicators are consistent with the objective of “Transforming our World: The 2030 Agenda for Sustainable Development” which has been set out by the United Nations Commission's Sustainable Development Framework

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