Environmental footprint manageability of global supply chains

Topic: Input-Output Analysis: Industrial policies (3)
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Today, industries worldwide face growing demands to reduce their environmental footprints embodied in global supply chains (GSCs) induced by their production activities. Many studies have analyzed environmental footprints in GSCs using environmentally-extended multi-regional input output analysis (EE-MRIOA) and have provided useful insights into designing strategies for industries to reduce their environmental footprints by revealing environmental burden hotspots in GSC structures.

Here, it is important to note that such environmental footprints are generated in complex GSC structures that consist of multi-tiered and multi-regional production networks. As a result, for industries at the endpoint of relevant GSCs (i.e., the GSC-managing industries), the manageability of the footprints differs depending on where and how burdens are generated within GSCs. Identifying critical parts in GSCs that are not solely based on footprint magnitude is essential for industries to effectively manage and mitigate their footprints. However, there are few attempts to analyze environmental footprints of relevant GSCs reflecting their manageability.

Based on the above, this study proposes an MRIOA framework that evaluates the manageability of environmental footprints induced in specific GSCs to address the following question: Where are critical policy targets for mitigating environmental footprints in relevant GSCs considering both magnitude and manageability of the footprints? Specifically, this study evaluates the footprint manageability of relevant GSCs with a footprint structure of environmental burdens induced in the GSCs in which each transaction is weighted by the propagation distance and border barrier between supplying and consuming sectors, and highlights key factors affecting the footprint manageability of relevant GSCs. The novelty of this study is to integrate the concept of footprint manageability into the conventional context of magnitude-based hotspot analysis using EE-MRIOA.

First, this study estimated the footprint intensity (FI) of environmental burdens induced by a unit of output of a specific industry through GSC. Second, this study calculated the manageability-adjusted FI (MAFI) by weighing the footprint generated in each sector included in relevant GSCs by the depth of the propagation tier of the footprint and the border barriers between countries of the footprint-generating industries and the GSC-managing industry. This study applied the average passthrough length as the weighting factor of the propagation depth and the Novyâ€™s implied trade costs as the weighing factor of the border barrier. Third, this study developed the comparable footprint manageability (CFM) index of relevant GSCs, which can be decomposed into three factors affecting the footprint manageability: the technology structure (i.e., the footprint intensity itself) of the GSCs, the depth of burden generating industries in the GSCs and the border barriers between those industries and the GSC-managing industry.

To demonstrate the framework, focusing on the carbon footprints of GSCs based on the OECD-ICIO database, this study estimated FI and MAFI of GSCs of five aggregated sectors in 77 countries in 2019. The results showed that MAFI of each industryâ€™s GSCs was approximately 1.5-8 times larger than the corresponding FI, which indicates that the difference between FI and MAFI varies among the GSCs reflecting the manageability of their carbon footprints.

To explore this difference, from the results of the CFM index of each industryâ€™s GSCs, this study highlighted the relative manageability of carbon footprints among the GSCs and identified critical factors affecting their manageability. For example, this study found that the CFM indexes of Chinese

and Indian manufacturing GSCs were higher than those of manufacturing GSCs in developed countries because of their greater contributions of the technology structure factor, suggesting that the carbon footprints of Chinese and Indian manufacturing GSCs are less manageable because of their higher footprint intensities.

However, the results focusing on the depth and border factors revealed a different trend reflecting the features of each countryâ€™s manufacturing GSCs. For instance, USA manufacturing GSCs showed a relatively small contribution of the border barrier factor because a large share of their foreign carbon footprints occurred in Canada and Mexico, which have trade agreements with the USA. On the other hand, German and French manufacturing GSCs exhibited relatively high contributions of both the depth and border factors due to their highly fragmented production networks within the EU region and their larger carbon footprints in countries with relatively high border barriers such as China and Russia.

Finally, based on the findings, this study suggested policy implications to address critical targets for managing and mitigating carbon footprints of relevant GSCs.