CO2 Reduction Potential of Global Supply Chain Networks: An MRIO Approach Incorporating Maritime Network Structures

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The global supply chain (GSC) structure has significantly developed over the past few decades driven by the expansion of international trade. 23% of global CO2 emissions are embodied in traded goods through GSCs, making the reduction of CO2 emissions from GSCs a matter of significant concern for achieving carbon neutrality worldwide. Environmentally Extended Multi-Regional Input-Output (EE-MRIO) models are one of the most powerful tools for tracing GSCs and allocate emissions from production to consumption across countries.

In Input-Output Analysis, Multi-Regional Input-Output (MRIO) tables describe inter- and intra-industry dependencies within and between countries by modeling GSC as a multidimensional space defined by country, commodity, and industry. However, MRIO tables do not provide insights into the domestic and international transportation systems used for these trade flows, as the path through physical space is not explicitly defined.

On the other hand, it is important to note that the development of the GSCs has led to the geographic separation of production areas and consumption areas, which makes the GSC highly dependent on international shipping. To more accurately evaluate the environmental impact of global supply chains, it is essential to develop analytical methods that incorporate physical dimensions. Accordingly, this study aims to establish a new framework for analyzing GSCs by integrating maritime network structures into an MRIO approach.

In this study, we first estimated direct and indirect input (dollar) induced by world final demand in 2019 using Global Environmentally-Extended Multi-Region Input-Output Database (GLORIA). Next, we calculated the ratio (%) of container transport by industry and country based on trade statistics data and estimated Japanâ€™s import value (dollar) by container transport using an MRIO approach. Additionally, we utilized big data on international container shipping to calculate offshore CO2 emissions (t-CO2) from container shipping and identified the most effective container shipping routes based on Graph theory to allocate offshore CO2 emissions (t-CO2) to countries. Finally, we calculated offshore CO2 emission intensity (t-CO2/dollar) for international container shipping based on big data and estimated total offshore CO2 emission (t-CO2) based on an MRIO approach.

Results showed that container ships traveling from Europe to Japan typically stop at Amsterdam, the Suez Canal, Singapore, and Hong Kong, while those traveling from the Americas stop at the Panama Canal. These container ships emit more CO2 than those operate within East Asia and Southeast Asia because of longer distances. Identifying the specific countries where container ships stop is challenging using only the MRIO approach. One of the key contributions of this study is the development of a novel method to allocate offshore CO2 emissions to countries. This approach highlights that not only import and export countries involved in GSCs but also hub countries where ships make stops (e.g., Singapore, Panama, etc.) should share responsibility for offshore CO2 emissions. These countries should also consider developing sub-global environmental policies to address the environmental impact of international shipping.