Refining product resolution of multi-regional input-output tables using parameterised production functions

Topic: Sustainable Production and Consumption Policies
Author: Albert Kwame Osei-Owusu
Co-Authors: Stefano MERCIAI, Mathieu Thierry Delpierre, Maddalen Ayala, Philip Holger Lindholt Coenen, Jannick Schmidt

Environmentally-extended multi-regional input-output (MRIO) databases offer valuable insights for evaluating the sustainability of global supply chains and providing policy-relevant information to achieve sustainable production and consumption of goods and services (SDG 12). These databases provide trade-linked impacts of global consumption, complementing national input-output tables. However, their highly aggregated product/industry dimension is a limitation that restricts their application in assessing the socio-economic and environmental impacts of specific products or industries at national or global levels. While some studies suggest using proxy information to disaggregate industries/products can improve the accuracy of input-output multipliers, others introduce hybrid input-output life cycle assessment (IO LCA) databases that combine the high product resolution of LCA databases and the completeness of IO tables to address the issue of highly aggregated IO tables. However, these approaches have limitations related to data uncertainty and modelling assumptions required to estimate inter-industry use of production and input use by the disaggregated product/industry.

The present study introduces a novel procedure and algorithm that uses parameterised production functions (PPFs) to disaggregate MRIO tables. This method involves characterising the production processes of products, considering all inputs and outputs across their entire life cycle. By adjusting the parameters, we can analyse various scenarios, such as the influence of changes in input requirements or production conditions on production volumes and emissions.
Our method for disaggregating IO databases differs from previous approaches by providing country-specific production recipes that account for nuanced differences in production technologies, feedstock requirements, and other factors. Our approach considers primary product substitution and by-products for treatment, which are not inherent in traditional IO tables based on industry technology assumptions. To demonstrate our method, we introduce a PPF for methanol and show its practical application in providing country/region-specific input recipe data for the 'chemicals not elsewhere classified' product/industry within the EXIOBASE database.

Focusing on product-level disaggregation, The study utilises the hybrid EXIOBASE global MRIO database version 3.3.18 4, which comprises production recipes for 164 products across 44 countries and five regions. The research is a part of the Getting the Data Right project, which aims to create a unique open-source climate footprint calculator based on an upgraded hybrid EXIOBASE that includes global supply chain data and environmental extensions for over 1000 products and all countries, including sub-national regions. By examining various benchmark indicators, such as carbon footprint and direct input coefficients, we identify and shortlist more than 30 products for disaggregation. Key products include non-metallic minerals like cement, chemicals like methanol and ethylene, metals like aluminium and steel, and plastics such as polyethylene and polyvinyl chloride.

Our PPF algorithm relies on information from the IPCC Guidelines for National Greenhouse Gas Inventories, industry reports, scientific literature, and life cycle inventory or LCA databases. We use pertinent mathematical equations and models derived from these sources to encode the input-output relationships to produce products in Python programming language. The processes in this study are based on physical units, and carbon and mass balances are determined following the guidelines established by the Intergovernmental Panel on Climate Change (IPCC) or conventional methodologies. The PPF systematically evaluates the carbon content of inputs and outputs and the wet weights of product flows. Additionally, we compute carbon emissions associated with production using Life Cycle Assessment (LCA) and IPCC-recommended equations.

Disaggregating input-output tables is crucial for revealing nuanced product and industry environmental hotspots, capturing complex inter-industry and country interdependencies, simulating scenarios for sustainable transitions, and informing policies. However, securing sufficient granular data for disaggregation poses confidentiality, consistency, and modelling challenges. Therefore, it is essential to choose an appropriate level of disaggregation that balances informative detail with practical feasibility. Additionally, product-level and geographic disaggregation of IO tables should be considered, as some major producing/consuming countries may be hidden in the highly aggregated Rest of the World (RoW) of EXIOBASE.