Framework for disaggregating multi-region input-output tables with an application to critical minerals

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Multi-region input-output (MRIO) tables serve as a powerful analytical tool to model interregional supply chains and explore associated socio-economic and environmental issues. However, the lack of sectoral granularity in existing MRIO tables makes it challenging to analyze numerous emerging topics. Furthermore, the absence of a systematic methodology framework for MRIO disaggregation has hindered progress in refining these datasets. Here, we present a novel, comprehensive framework for disaggregating MRIO tables. Our approach strikes a balance between incorporating detailed, bottom-up information about specific sectors of interest and maintaining consistency with the original MRIO system. The framework adheres to a principle of minimal disturbance, such that only the sectors in focus undergo refinement while all others remain unchanged. Moreover, our method embraces flexibility in reconciling information inconsistencies based on bi- and tri-dimensional matrix balancing techniques.

The proposed framework aims to leverage bottom-up, techno-economic data of sectors under study to disaggregate top-down, MRIO tables. One of the most widely used methods to compile a MRIO table is to link national input-output tables through international trade. Thus, the disaggregation process starts with splitting the inputs and outputs of national input-output tables, followed by reconciling competitive and non-competitive input-output structures towards harmonized, disaggregated international trade flows, and ends with coupling all disaggregated national tables into a new global MRIO system with improved granularity. To deal with discrepancies between bottom-up and top-down information, data reconciliation strategies are tailored for each stage, based on entropy-based nonlinear programing approaches. The proposed framework establishes a methodology benchmark for sectoral disaggregation in MRIO tables and can be extended to regional and temporal disaggregation, enabling timely response to rapidly evolving global challenges.

We demonstrate the framework by incorporating granular, bottom-up critical mineral details into a time series of global MRIO tables. Critical mineral supply chains have been an increasingly important focus in the context of clean energy transitions. However, there is a lack of representation of critical minerals in existing MRIO tables, where mineral sectors are lump into a small number of highly aggregated sectors, making it impossible to capture the detailed nuances of critical mineral supply chains. As countries ramp up efforts to deploy clean energy technologies, it is important to have the analytical capacity for modeling worldwide critical mineral supply chains.

Addressing this gap, we split the single aggregated mineral sector in the GTAP Power database into 38 distinct mineral sectors. The resultant mineral-focused MRIO tables offer granular details for minerals that are central to clean energy technologies, including lithium, nickel, cobalt, and rare earth elements, among others. To achieve this high-resolution dataset, we draw on a diverse array of data sources. In addition to national input-output tables and international trade metrics from the GTAP database, we incorporate production values, input structures, and output structures from the UNIDO database and official input-output tables for representative countries; production quantities and price data from WBMS, S&P Global, USGS, and BGS databases; and mineral trade flows from the BACI database. This refined dataset equips researchers, policymakers, and stakeholders around the world to investigate the socio-economic and environmental impacts along critical mineral supply chains, enabling more informed decision-making in the pursuit of sustainable and secure energy transitions.