

Enterprise-level mapping reveals supply-chain emissions hotspots and mitigation paths in global oil refinery sector

Topic: Global MRIO Modelling and Applications for Emerging Economies

Author: Jinglei Wang

Research question: Refining enterprises are pivotal actors in global supply-chain decarbonization, yet their upstream (Scope 3) emissions remain poorly measured due to incomplete disclosures, complex supplier networks, and the lack of a unified, enterprise-resolved accounting framework. We firstly compile an enterprise-level multi-regional input-output (EMRIO) for global 586 refiners, which merges available firm-level production with 3,951 stakeholders and 28,751 transactions, creating a globally consistent account of purchases and sales across refining enterprises. This enterprise-resolved framework enables finer-grained assessment of supply-chain environmental impacts. Using this framework, the results show that total refiners' supply-chain emissions account for ~5.3% of global emissions, of which, 0.47 Gt (1.4% of global volume) of emissions are locked if key suppliers to just top 20 of the world's biggest refining enterprises, nearly equal to annual emissions of Turkey. Supply chains reveal markedly heterogeneous upstream intensity, key paths and drivers among domestic refiners, revealing three patterns of emissions in these refiners. Most of enterprises saw a decrease of varying degrees in emissions, driven by better energy efficiency and improvements in procurement structure. Furthermore, multinationals hold the key to scale up emissions reductions by leveraging diverse portfolios to shift exposure away from carbon-intensive pathways across hubs. Our research fill gaps in current EMRIO data and can improve the understanding of how heterogeneous refiners' emissions embodied supply chains and sustainable pathways.

Method & Data used: The basic idea of the EMRIO table is to disaggregate sector-level MRIO into enterprise-level, which begins from a balanced global MRIO and involves a variety of data sources. The key advantage of EMRIO is its alignment with the existing framework of sector-level IOTs. This alignment ensures that EMRIO maintains the structural integrity and analytical strengths of traditional MRIO models while introducing an unprecedented level of detail. By breaking down the economic interactions into sub-segments corresponding to specific MRIO sectors, EMRIO offers a more precise and comprehensive understanding of the production and transaction patterns within companies.

At the first stage of data collection, company data includes total revenue, headquarter, NAICS 4-digit code and entity ID obtained from FactSet, Capital IQ and Bureau van Dijk (Osiris) database. We obtain business-to-business transaction data from FactSet database. Furthermore, we collect ownership structure of each refinery and crude oil refining capacity from CEADs-GREI v2.035 and map refinery-company based on ownership. Data at the multi-regional input-output table from EMERGING database³⁶ provides national economic links between sectors and international trades among different regions sourced from national IOTs and supply-use tables (SUTs) and UN Comtrade.

When mapping the company to the industry categories, we utilize NAICS 4-digit code to identify its primary industry instead of disaggregating into segments. Although a segment is a subnet within a company, a single company often encompass multiple production commodities and engages in diverse industries. Given the small sample size, only 108 refining enterprises were available in the FactSet database, and the boundary standards for segment classification varied. Therefore, in our study, no segment processing was conducted for the refining enterprises.

Novelty: We have developed the EMERGING-GREI framework, which is an enterprise-resolved, globally balanced multi-regional input-output (MRIO) for oil refining. Specifically, we compiled 1,196 refineries worldwide, consolidated them into 586 refining enterprises, and matched 28,751

customerâ€™supplier transactions linking 3,951 firms with the EMERGING economy-sector structure. These micro-level linkages were integrated into the global MRIO using consistent macro constraints, enabling the first enterprise-level representation of supply-chain carbon flows in the refining sector. We applied Structural Path Analysis (SPA) and Structural Path Decomposition (SPD) to identify critical paths of supply chains and dominant drivers to the changes of path-level emissions at the enterprise level. The results enable the identification of differentiated mitigation pathways, providing actionable insights for enterprise-level operations toward strengthened climate commitments.