Disaggregation of the Steel Sector in MRIO: Global Supply Chain Differences between BFâ€“BOF and EAF Routes

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Steel products are indispensable to modern society, with 52% used in buildings and infrastructure and 12% in the automotive sector. In 2023, approximately 280 million tons of steel products were traded internationally, accounting for 15% of global steel use, indicating that steel production and consumption are deeply embedded in global supply chains (GSCs). Meanwhile, the steel sector is a major source of greenhouse gas emissions, with direct COâ‚‚ emissions reaching 2.6 gigatons in 2020, or 7% of global emissions. These emissions are induced not only by production activities but also by diverse domestic and international final demands, particularly from construction and automotive sectors. Given the scale and interconnected nature of these emissions, identifying COâ‚‚ emission hotspots within steel-related GSCs is essential for effective decarbonization strategies.
Many studies have analyzed GSC-related emissions using multiregional inputâ€“output (MRIO) models. Although MRIO-based environmentally extended inputâ€“output analysis (EEIOA) is suitable for tracing emissions along international supply chains, it faces structural limitations due to sectoral aggregation. Data from heterogeneous firms and technologies are averaged during MRIO construction, which may introduce aggregation bias, especially in sectors with strong technological heterogeneity. In most MRIO frameworks, crude steel and steel products are combined into a single â€œbasic iron and steelâ€• sector, obscuring differences between the blast furnaceâ€“basic oxygen furnace (BFâ€“BOF) route and the electric arc furnace (EAF) route. These routes differ substantially in raw materials, energy use, environmental burdens, and supply chain configurations, suggesting that treating steel as a single sector may distort emission analyses.

This study aims to clarify (1) structural differences in GSC configurations between BFâ€“BOF and EAF routes and (2) cross-country variations among countries using similar technologies. To address aggregation bias, we disaggregate the â€œbasic iron and steelâ€• sector in the GLORIA MRIO database (164 countries, 120 sectors; 2021 edition) for six major steel-producing countriesâ€”China, India, Japan, South Korea, Russia, and the United Statesâ€”into four subsectors: pig iron, converter (BOF), electric arc furnace (EAF), and steel products. The disaggregation uses multiple datasets, including global steel statistics, production shares, Japanâ€™s detailed inputâ€“output table, trade data, IPCC guidelines, energy data, and plant-level cost information from TransitionZeroâ€™s Global Steel Cost Tracker (GSCT), enabling the construction of process-sensitive input structures.
The results reveal several robust patterns. Pig iron production in all countries is dominated by iron ore inputs, accounting for more than half of intermediate inputs, while converter production is largely dependent on pig iron, confirming the structural linkage between upstream and downstream processes. In contrast, substantial cross-country heterogeneity appears in the EAF sector. In Japan, the main inputs are wholesale and retail trade services (27%), the EAF sector itself (14%), and electricity (12%), reflecting reliance on scrap and the importance of scrap collection and distribution systems. In India, quarrying of stone, sand, and clay (17%) dominates, followed by wholesale and retail trade (14%) and hard coal mining (9%), reflecting the prevalence of AC-type EAFs with higher electrode consumption and refractory replacement needs.

This study makes a novel contribution by incorporating plant-level cost data to disaggregate steelmaking processes within a global MRIO framework, enabling process-level analysis of supply chain structures across countries. Overall, the findings demonstrate that BFâ€“BOF and EAF routes differ fundamentally in input structures and that even within the same technology, national production systems vary due to differences in resource sourcing, technology, and industrial organization. These results indicate that aggregated steel sectors in conventional MRIO models fail to capture process-level heterogeneity. By explicitly disaggregating steelmaking processes, this study provides a more accurate representation of supply chains and a foundation for identifying process-specific emission drivers, which is crucial for designing targeted decarbonization policies and improving GSC-based carbon footprint assessments.