Decoding Environmental Impacts of Machinery and Equipment in Europe: Integrating National Production Recipes into EXIOBASE

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Machinery and equipment (ME) are among the major contributors to greenhouse gas (GHG) emissions and metal consumption associated with capital stock formation, ranking second only to construction. Due to their long service lifetimes and rapidly evolving technological requirements, investment decisions in ME can lead to unsustainable development patterns, including technological lock-in or premature asset abandonment. Improving understanding of production technologies and supply-chain dependencies for specific ME categories, such as agricultural machinery, rather than relying on highly aggregated representations of general machinery, can therefore help inform future investments and balance technological progress with environmental concerns.

Despite their importance, the representation of ME in environmental input-output (IO) analysis remains limited. Most existing studies had used the multi-regional input-output (MRIO) model EXIOBASE to examine the role of ME in environmental impact analysis, in which ME are aggregated into only seven broad product categories, reflecting the detail available in European national accounts. While MRIO models capture global supply chains and trade effects, this high level of aggregation obscures heterogeneity in production technologies across different types of ME. As a result, estimated environmental impacts may be overly homogenized, limiting their relevance for policy and investment decision-making. In contrast, several major ME manufacturing countries, including China, Japan, South Korea and the United States, periodically publish national IO tables with significantly finer sectoral detail for ME.

Against this background, the research question of this study is: How does integrating detailed national production recipes for specific ME categories into EXIOBASE alter the estimation of ME-related environmental impacts in European economies?

To address this question, the study follows a two-step approach. Using the path extraction (PEX) method, we first investigate production recipes for selected ME categories across countries and datasets to assess the degree of structural consistency. Inputs are grouped into materials, energy, and transport services (MET). Major suppliers of non-MET inputs are identified using a structural path algorithm applying 0.5% cut-off. Second, we integrate detailed national ME production recipes into EXIOBASE using a hybrid IO approach, linking national foreground production structures with MRIO background supply chains .

The analysis focuses on GHG emission multipliers for ME. It examines how the proposed integration reshapes estimates of ME impacts in European capital formation. It thus serves to test the usefulness of PEX for studying the production of manufactured capital. The results highlight the extent to which aggregation in conventional MRIO models masks variation in ME-related emissions across product categories and countries. For agricultural machinery, we find substantial cross-country differences in production recipes particularly in the contributions of material inputs, transport services, and direct emissions. Using Germany as an illustrative case, the integration shows that embedding national production recipes within a common European supply-chain background smooths part of the variability observed, while upstream supply-chain effects play a larger role in shaping agricultural machinery emission multipliers. By revealing differences in ME impacts, the study expects to demonstrate how integrating national production detail can materially provide more insights for specific products. By linking national account with MRIO data, this study

provides new insights into the composition of ME impacts in Europe and improves the representation of ME in environmental IO models, supporting more robust climate and industrial policy decision-making and enlightening the investment decisions.