

Product-level value chains from firm data: mapping trophic levels into economic growth

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Value chains represent the backbone of the economy, operating the continuous transformation of raw

materials into final products. Traditionally, their structural analysis has centered on the concepts of upstreamness and downstreamness, which measure how far a product is from final consumers or basic

goods, respectively [1]. However, due to data limitations, most studies have relied on industry-level Input-

Output tables, which provide a distorted picture of the actual input-output relationships happening at the micro-level [2].

In this work, we move beyond sectoral aggregation by constructing a statistically validated, directed input-output network of 5000 products. To do this, we leverage firm-level trade data from the Italian Institute of Statistics (ISTAT), which provide granular product-level information on yearly volumes of imports and exports (measured in US\$) reported by Italian firms, with products classified according to

the Harmonized Systems classification at the 6-digit level.

To quantify the hierarchical organization of the reconstructed network, we use the concept of trophic levels [3] - a metric borrowed from the ecological network literature that generalizes the concepts of upstreamness and downstreamness by positioning each product along the value chain, from basic inputs

- i.e. products with no incoming link - to final products - i.e. products with no outgoing link (see Figure

1, left panel). Our analysis reveals that the network displays a statistically significant trophic structure,

measured through the related concept of trophic coherence. This result holds with respect to two different

null models accounting for both network density and nodes' in- and out-degrees. Statistical significance

is however lost upon aggregating products into broader industrial sectors, thus confirming the necessity

of a granular description of the system in order to be able to properly characterize its structure.

We then leverage UN-COMTRADE data on global imports and exports of products to map our analysis at the country level. Our findings indicate that more diversified countries tend to import more

upstream goods, reflecting their ability to process raw materials into higher-value products. This general

trend, however, highlights clear differentiation, among the most diversified economies, between more

manufacturing-oriented countries (e.g. China, India, Italy), which tend to display the most upstream import baskets, and more service- and outsourcing-oriented ones (e.g. the United States and several

European countries), which instead display more downstream imports.

Conversely, less diversified countries are more likely to import downstream goods, highlighting their dependence on finished or semi-finished products imported from more industrially developed nations,

a trend we name trophic barrier. This general pattern also exhibits notable outliers, including poorly diversified countries that display unusually upstream import baskets (e.g. Bangladesh), likely reflecting

their role as assembly hubs or outsourcing destinations in global production networks.

Furthermore, we uncover a strong positive correlation between export diversification and trophic jump

- i.e. the difference between the average trophic level of a country's exports and imports (see Figure 1,

right panel), which suggests that industrial diversification enables nations to cover larger portions of the

value chain, effectively transforming basic inputs into final products.

By providing a systematic framework for analyzing value chains at the product level, our findings offer

a novel insight into the drivers of economic growth and industrial development at different scales, thus

paving the way for future research on global production networks.

[1] Antràs et al., American Economic Review 102, 3 (2012).

[2] Diem et al. PNAS Nexus 3, 3 (2024).

[3] MacKay et al. Royal Society open science 7, 9 (2020).

Figure 1: Left: small subgraph of the network, with trophic level on the vertical axis: the hierarchy induced by trophic levels orders products from basic inputs (polyesters fibres), to increasingly complex

components (radio navigational aid, electric motors) up to products for final consumption (floating or submersible platforms). Right: export diversification of countries vs average trophic jump. There is a strong and significant positive correlation between the two quantities, signaling that more industrially proficient countries operate a bigger transformation on the imported products.