Fragmentation, Corridor Dependence, and Originâ€“Destination Coupling in Global Value Chain Layers

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Author: Shuning Chen
Co-Authors: Marius Vila, Mateu Sbert

A persistent limitation in global value chain (GVC) research is that summary indicators compress multi-country, multi-sector production networks into scalar shares. While these indices show cross-border value-added (VA) involvement, they poorly diagnose how intermediate-production linkages are organized. Rising fragmentation indicators often occur while the measured "GVC share" remains minor in total trade, as the system can expand by scaling limited corridors rather than broadening link diversity. This study develops an information-theoretic framework treating each GVC matrix as a "system" of normalized distribution over originâ€“destination linkages, enabling measurement of concentration and coupling structure in intermediate-export VA networks. We focus on VA embodied in intermediate exports and construct three GVC matrices where each row represents an origin node and each column represents a destination node. The matrices differ in path-based definition: GVC1 captures intermediate-export VA crossing borders once, GVC2 represents full intermediate-export VA from origin to destination, and GVC3 isolates intermediate-export VA sent to destinations that subsequently re-export. These matrices are analyzed as layers of the global intermediate-export system. Our objective is to characterize how each layer's structure evolves over time and changes under aggregation from country to region and sectors, integrating origin and destination organization at policy-relevant scales.
Methodologically, for each year (t) and each trade layer (k\in1,2,3), we take the nonnegative matrix (F_t^{\left(k\right)}\left(i,r\right)) and normalize it into a joint probability distribution over links: (p_t^{\left(k\right)}\left(i,r\right)=F^{\left(k\right)}t\left(i,r\right)/\sum{i,rF_t^{\left(k\right)}\left(i,r\right)}).
This yields marginals for origins (p_t^{\left(k\right)}\left(i,\cdot\right)) and destinations (p_t^{\left(k\right)}\left(\cdot,r\right)), and conditional routing profiles (p_t^{\left(k\right)}\left(r\mid i\right)). On this system representation we compute: (1) entropy of source (H\left(X\right)), summarizing origin-side concentration; (2) entropy of channel (H\left(Y\middle| X\right)), summarizing destination diversification conditional on origin; (3) joint entropy (H(X,Y)), summarizing link-level dispersion; (4) mutual information (I\left(X;Y\right)), summarizing originâ€“destination coupling (the extent to which destinations â€œrevealâ€• origins and vice versa); and (5) two normalized mutual information measures, (I/H\left(X\right)) and (I/H\left(X,Y\right)), which scale coupling by origin diversity and by total link complexity. We complement these static summaries with time-series analysis of structural change, including year-to-year differences and distributional distances between successive normalized matrices, and we evaluate how aggregation alters both levels and trends. Aggregation is implemented by mapping countries into regions and detailed sectors into major sectors, then re-aggregating flows and re-normalizing; the difference between fine and aggregated metrics provides an interpretable measure of information loss and indicates whether the systemâ€™s meaningful structure is primarily micro-level (countryâ€“subsector) or macro-level (regionâ€“major sector).
The framework decomposes system structure into three components: (i) source entropy for origin dominance, (ii) channel entropy for destination portfolio diversification, and (iii) mutual information for origin-destination pairing structure. Early results show high dispersion in origin and destination marginals with low mutual information, indicating substantial global mixing despite distinctive destination profiles. The study demonstrates that "fragmentation" comprises separable propertiesâ€”backbone concentration, routing diversification, and coupling intensityâ€”which evolve differently across GVC layers. These diagnostics describe system-level dependence, corridor structure, and modular organization, remaining meaningful under aggregation for cross-scale comparison.

This work enhances IO/GVC analysis by providing implementable system metrics complementing standard participation measures. By distinguishing between "mass" and "shape," the approach reveals how intermediate-export systems expand through link diversity or concentrated corridors, offering a framework for comparing structural organization across layers and time.