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Production Networks and Shock Propagation in Central America and Mexico: A Comparative Analysis

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Abstract

We study how sectoral shocks propagate through production networks in Central America and Mexico. Using annual input–output matrices for 1991–2023, we construct upstream and downstream production networks for ten regional economies and quantify both the direct and indirect effects of trade shocks. Adopting a granular, network-based framework, we show that production structure plays a critical role in shaping shock transmission and amplification. Trade integration with the United States operates through distinct structural channels across countries. In economies such as Mexico, reductions in U.S. trade generate negative regional effects through supply-chain disruptions and strong upstream linkages, whereas in most other countries in the region trade shocks produce positive downstream amplification effects. The density and configuration of production networks further condition the intensity of propagation, with Mexico displaying strong upstream amplification while more enclave-type economies exhibit comparatively limited spillovers. We also identify structurally comparable benchmark countries worldwide to facilitate meaningful cross-country analysis. Taken together, our findings provide a novel empirical framework for policy analysis centered on structural transformation and trade integration in developing economies.

Keywords: Production networks; Input–output linkages; Trade shocks; Shock propagation; Central America and Mexico

JEL Codes: E32; F14; F44; C67

1. Introduction

In recent years, economics has made significant progress in understanding how idiosyncratic demand and supply shocks originating in specific sectors, regions, or firms propagate to the aggregate economy (e.g., Carvalho, 2008; Acemoglu et al., 2012; Carvalho, 2014; Acemoglu et al., 2015 a,b; Baqaee, 2015; Acemoglu et al., 2016). These advances have important policy implications for countries responding to external shocks, including international trade shocks related to tariffs and disruptions in global value chains (GVCs), as well as increases in global financial and policy uncertainty. They are also central to understanding and preparing for supply-side shocks associated with productivity, innovation, or weather-related events, and to informing the optimal design of discretionary fiscal policy.

This new body of work departs from traditional views in macroeconomics, which held that unpredictable shocks affecting individual firms or sectors largely cancel out in the aggregate (e.g., Lucas, 1977). Under the traditional perspective, the structure of interconnections among economic actors plays a limited role in shaping aggregate outcomes, including both, business cycle dynamics and long-run economic trends. This conventional view has been challenged by a more granular approach to economic analysis, which emphasizes that shocks to large individual actors can generate substantial aggregate fluctuations, particularly when the size distribution of these actors is heavy tailed (Gabaix, 2011).

In the first part of this article, we leverage these recent advances in macroeconomics that emphasize within-country sectoral input–output (IO) linkages and complex networks to develop a structural characterization of production networks in Central American countries (including Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, and Panama as well as Mexico), over the period 1991–2023, using annual IO matrices from the EORA-26 database (Lenzen et al., 2013). We then use the upstream and downstream networks estimated in the first part to quantify both direct (own) and indirect (network) effects of trade shocks affecting Central American countries and Mexico.

Our analyses draw inspiration from an influential branch of the modern literature, which shows that idiosyncratic shocks arising in a single sector, or initially affecting only a small set of economic firms, can generate spillover effects that are several orders of magnitude larger than their direct effects as conceived in the more traditional view in macroeconomics (Acemoglu et al., 2012, 2016; Carvalho, 2014). In this framework, shocks are strongly

amplified as they propagate through a country's production network on their way to final demand, consumption, and international trade.

Building on the multisector framework introduced by Long and Plosser (1983), this literature demonstrates that shocks hitting sectors that are central suppliers to the rest of the economy need not average out in the aggregate; instead, they can spread through production networks and give rise to sizable aggregate fluctuations. Hence, an accurate characterization of a country or region production IO network is fundamental for effective policy design and long-term economic planning. We show that indeed the industrial fabric is crucial for the amplification mechanisms to operate in our focus region.

From a methodological perspective, the analysis of sectoral interdependencies and the internal functioning of modern economies is naturally suited to the framework of complex networks, which we follow. Networks provide a flexible and comprehensive representation of productive structures, whether through IO relationships across sectors or through supplier–customer linkages among firms. This perspective is also closely related to the study of global value chains (GVCs), as presented by Antràs and Chor (2013, 2022) and Johnson and Noguera (2012), which can be understood as networks in which sectors, countries, and firms are embedded. Within these networks, the relative position of each actor plays a central role in determining resilience to shocks, real income, and—at the country level—the sophistication of the export basket. In this sense, the network-based characterization of production generalizes and provides a stronger theoretical foundation for the insights offered by Hidalgo et al. (2007) and Hidalgo and Hausmann (2017) in their analysis of international trade patterns.

In terms of contribution, this paper is the first to apply a granular network-based approach at a comprehensive scale with a specific focus on the extended Central American region. Our analysis covers not only the ten economies of primary interest, but also a broad set of countries worldwide for which EORA-26 data are available (187 economies in total), thereby enabling a systematic comparative assessment of production structures and shock transmission mechanisms. Our findings represent a substantial advance over the existing literature applying network theory and related methodologies to examine macroeconomic dimensions of Central America and Mexico (e.g., Leal, 2015; Lima and Banacloche, 2022; IDB, 2023; Alatriste, 2025; López and Serrano, 2025; Cardoza et al., 2025). From a more general perspective, this study proposes a novel methodological framework for monitoring the transmission of international shocks in developing economies, as well as for supporting

long-term policy design and evaluation, including industrial policies aimed at structural transformation.

Beyond the network characterization itself, which is valuable for identifying systemically important sectors and potential fragilities or bottlenecks, our methodology relies on two additional contributions. First, employing a data-driven clustering approach, we identify countries whose production network structures resemble those of Central American economies and Mexico. This classification provides a useful foundation for constructing meaningful benchmarks in counterfactual policy analyses. Second, we characterize how shocks propagate through production networks via upstream and downstream cascades among supplier and consumer sectors.

Overall, our results indicate that trade integration with the United States operates through structural complementarity rather than direct competition in countries such as Mexico, Belize, and Haiti. This contrasts with the findings for the U.S.–China case reported by Acemoglu et al. (2016) and is broadly consistent with the trade patterns observed in the region over recent decades. To our knowledge, however, this paper is the first to quantify and systematically characterize these dynamics. Reductions in U.S. trade—whether interpreted as weaker external demand or lower import penetration—generate negative economic effects in these economies, reflecting disruptions to integrated supply chains rather than gains in domestic market share arising from reduced foreign competition. By contrast, the opposite pattern emerges, particularly through downstream amplification channels, in countries such as El Salvador, Honduras, and Guatemala, where trade shocks tend to produce positive spillover effects.

Production networks play a central role in shaping these outcomes. In economies with dense domestic linkages, such as Mexico, upstream propagation substantially amplifies the initial shock, whereas less integrated economies experience limited spillovers beyond directly exposed sectors. These findings emphasize the dual role of production networks as both engines of growth and sources of vulnerability, highlighting the importance of trade diversification alongside policies that strengthen domestic supply chains.

The remainder of this document is structured as follows. Section 2 provides the regional context for our study. Section 3 presents the methodology and the results of our network characterization of the region, with a focus on explaining the network configuration and identifying structurally important sectors. Section 4 introduces the shock-propagation

framework and details the identification assumptions underlying our trade-shock analysis. Section 5 concludes with policy recommendations for the region.

2. Regional Context

In Latin America and the Caribbean region, the analytical shift described in the introduction has been particularly relevant for understanding the 'hub' sectors that drive regional growth or transmit systemic vulnerabilities. Much of the academic focus has naturally centered on Mexico due to its deep integration into North American supply chains. For instance, Leal (2015) and Alatriste (2025) utilize network-based misallocation models to identify bottleneck sectors in Mexico, arguing that the country's production density has increased while the "authority" of its manufacturing hubs has evolved in response to global trade shifts.

Beyond Mexico, multilateral organizations have led the effort to map the production structures of Central America and the Caribbean. The Inter-American Development Bank (IDB, 2023) and ECLAC (Lima and Banacloche, 2022) have utilized IO matrices to identify key forward and backward linkages in Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and the Dominican Republic. These reports highlight a high degree of dependence on imported intermediate inputs, identifying agriculture and food processing as the primary structural hubs for Northern Triangle countries, while Panama's network is uniquely dominated by services and logistics. However, a significant gap remains regarding the smaller or more data-scarce economies of Belize and Haiti.

Our study complements as well other branches of the extant literature examining spillover effects and connectivity in the markets of the region. For example, López and Serrano (2025) use a computable general equilibrium framework to model productivity spillovers and economic integration in Central America; Cardoza et al. (2025) explicitly model production networks to explain job search and matching processes in the Dominican Republic; and Gorton and Ianchovichina (2021) employ a spatial general equilibrium framework to design optimal transport networks and expansions of existing infrastructure across most Latin American countries, including those in Central America.

While these studies provide valuable starting points to the study of production networks in the region, they are often constrained by short empirical temporal and cross-sectional samples, rely on largely static representations of the network structure, and focus on traditional economic indicators that only partially characterize input–output relationships, rather than employing graph-theoretic topological metrics. Moreover, prior studies

typically do not distinguish between upstream and downstream networks or the propagation of shocks across them, even though these dimensions naturally correspond to supply and demand shocks and provide fundamentally different perspectives on the topology of domestic production, both in general and within the region.

Thus, this study advances the existing literature by providing a comprehensive, longitudinal, and global perspective on production networks that is currently absent from the regional discourse. We move beyond the regional vacuum by situating Central American networks within a global hierarchy, estimating production linkages for all 187 countries in the Eora26 database. This global benchmarking provides a comparative baseline to assess, for example, whether the network structures of countries such as Belize or Haiti are outliers or instead follow predictable developmental patterns relative to other countries in the region. It also enables a clear differentiation between Mexico's production network structure and those of Central American economies, allowing shock propagation to be estimated while accounting for these structural specificities.

3. Network Construction and Characterization in Central America and Mexico

This section consists of three parts. In the first part, we describe the construction of our networks, considering both, sectors acting as upstream suppliers and sectors as downstream customers. In the second part, we present the statistics used to characterize our production network structures at both the country level and the sector (node) level. In the third and final part, we describe the techniques used to detect grouping patterns across the full set of domestic production networks in the world.

3.1. Network Construction

The core of our networks construction involves disaggregating the global MRIO data for each year t into a set of single-country, sector-level IO tables. For a given country c, we extract the intermediate consumption matrix, $Z_{cc} \in R^{N \times N}$, where N is the number of sectors, alongside the total gross output vector, $x_c \in R^N$. The element Z_{ij} represents the value of output from sector i used as an intermediate input by sector j within country c. We use Eora26 tables, which consist of 26 sectors standardized across countries so that we can conduct meaningful comparisons.

3.1.1. Downstream Networks

The downstream networks are designed to capture the sensitivity of a given sector to supply-side shocks originating in its upstream suppliers. Typical supply shocks are TFP or

foreign patenting shocks (Acemoglu et al., 2016). We first construct the matrix of technical coefficients, $A_{cc} \in R^{N \times N}$. The element A_{ij} in this matrix is calculated as the ratio of the intermediate input from sector i to sector j (Z_{ij}) to the total output of the purchasing sector j (x_j):

$$A_{ij} = \frac{Z_{ij}}{x_j}. \quad (1)$$

The matrix A represents the cost share of input i in the production of sector j's output. Following standard practices in international IO literature (see Antrás and Chor, 2022) and the theoretical propagation channels developed by Acemoglu et al. (2016), we use the Leontief Inverse, $L_{cc} \in R^{N \times N}$, to characterize the full downstream dependence:

$$L_{cc} = (I - A_{cc})^{-1}. \quad (2)$$

The Leontief Inverse (L) is the key structural matrix for analyzing supply shocks. An element L_{ij} quantifies the total (direct and indirect) output required from sector i to satisfy a one-unit increase in the final demand of sector j. Note that, in this context, the off-diagonal elements of L are used to construct variables that measure a sector's downstream exposure to upstream productivity shocks. A higher L_{ij} implies that sector i is more critically dependent on the output of sector j, and thus more sensitive to a supply shock (for instance, think of a TFP decline) originating in sector j.

3.1.2. Upstream Networks

The upstream networks are designed to capture a sector's exposure to demand-side shocks originating in its downstream customers. In this set of shocks, we count for instance government expenditure shocks ad well as restrictions to trade shocks originating in the global economy. To analyze upstream propagation, we construct the *Allocation Matrix*, $B_{cc} \in R^{N \times N}$. The element B_{ij} is calculated as the share of sector i's total intermediate sales that go to sector j:

$$B_{ij} = \frac{Z_{ij}}{\sum_{k=1}^{N} Z_{ik}}. \quad (3)$$

where $\sum_{k=1}^{N} Z_{ik}$ is the total intermediate output sold by sector i. The matrix B is a direct empirical representation of the sales share structure. This network measures the upstream exposure of a supplying sector i to demand shocks in its purchasing sectors j. A higher B_{ij} indicates that sector i's revenue is largely concentrated on customer sector j. Therefore, a negative demand shock (e.g., a drop in domestic or foreign final demand)

experienced by sector j propagates strongly upstream to affect the output and employment of sector i.

3.1.3. Network and Centrality Statistics

To quantify the structural properties of national production networks and evaluate the systemic importance of individual industries, we employ a comprehensive set of graph-theoretic and IO metrics (see Table 1). Our methodology differentiates between node-level indicators, which capture the relative position, connectivity, and granularity of sectors within domestic supply chains, and country-level statistics, which summarize the overall topology and efficiency of the network. Together, these measures capture both the localized impact of sector-specific disturbances (such as those reflected in Betweenness and Volatility Contribution) and the economy's aggregate structural resilience, as characterized by path length and modularity.

Additional methodological details are provided in the Appendix, Section A, which documents the full set of network statistics computed, including measures such as the clustering coefficient and transitivity. These additional indicators are not reported in the main results because they exhibit limited cross-country variation and therefore provide little discriminatory power in the comparative analysis.

Table 1: Summary of the Network Statistics

Statistic	Description	Economic Interpretation	Level
Betweenness Centrality	The frequency with which a sector sits on the shortest path between any two other sectors.	Identifies "choke points" or critical intermediaries that control the flow of supply/demand shocks.	Node (Sector)
Aggregate Volatility Contribution- C_k	A metric quantifying a sector's predicted impact on total macroeconomic volatility.	Measures "granularity"; shocks to these sectors have a disproportionately large impact on aggregate GDP.	Node (Sector)
Eigenvector Centrality	A measure of influence based on being connected to other highly connected sectors.	Highlights sectors that are influential because they trade with other influential sectors of the economy.	Node (Sector)
PageRank	A ranking of importance where links from other important sectors carry more weight.	A robust measure of systemic relevance and global importance within the production hierarchy.	Node (Sector)
Total Strength (In- and Out-)	The sum of weighted intermediate inputs (In) and weighted output sales (Out).	Measures a sector's total scale of intermediate dependence and its role as a primary supplier.	Node (Sector)
Average Strength	The arithmetic mean of all sector strengths within a specific country.	Captures the overall intensity of connectivity and intermediate trade volume in the national economy.	Country (Global)

Average Path Length (APL)	The average number of steps required to travel between any two sectors.	Indicates network integration; lower values mean shocks spread faster across fewer hierarchical layers.	Country (Global)
Diameter (D)	The longest of all shortest paths between any two sectors in the network.	Measures network compactness; a small diameter allows shocks to traverse the entire system quickly.	Country (Global)
Modularity (Q)	The strength of the network's division into distinct, independent communities.	Indicates segregation; high modularity can limit shock spread by containing it within specific production blocs.	Country (Global)

Note: The table summarizes the network and centrality statistics used to evaluate production structures in the region. It divides indicators into node-level metrics, which identify the systemic importance and influence of individual sectors, and country-level global metrics, which characterize the overall connectivity, integration, and structural segregation of the national economy. Additional details are provided in the Appendix, Section A.

3.1.4. Hierarchical Clustering and Classification of National Networks

To classify countries based on the detailed structure of their domestic production linkages, we perform an unsupervised Hierarchical Clustering (HC) analysis for both the *Downstream* and *Upstream* network representations. In this way we aim to group countries whose domestic sectoral linkages are structurally similar. The clustering process is conducted using the following steps:

- For each country c, the full $N \times N$ domestic adjacency matrix M_c is vectorized into a single feature vector x_c, where N is the number of sectors (26 in our framework). This results in a feature vector of length $N^2 = 676$.
  - For the *downstream analysis,* M_c is the technical coefficient matrix A_{cc}.
  - For the *upstream analysis*, M_c is the normalized transactions matrix B_{cc}.
- The final matrix X is constructed by stacking all country vectors M_c. Columns corresponding to matrix entries that are zero or near-zero across all countries (variance $< 10^{-6}$) are removed to ensure numerical stability.
- The feature matrix X is then standardized using Z-score normalization (mean of zero, standard deviation of one) on each column. This outputs the standardized matrix X_{scaled}.

- Hierarchical Clustering (HC) is performed directly on the X_{scaled}. The dissimilarity between any two countries, c_1 and c_2, is quantified using the Euclidean distance on their full feature vectors. This means countries are clustered based on the element-by-element similarity of their $N \times N$ domestic network matrices:

$$d(c_1, c_2) = \sqrt{\sum_{i=1}^{N^2} \left(X_{i,c_1}^{scaled} - X_{i,c_2}^{scaled}\right)^2}. \quad (4)$$

We employ the Ward's minimum variance method to define the distance between clusters. This method minimizes the total within-cluster variance by merging the pair of clusters that results in the smallest increase in the total sum-of-squares error. The output of the HC is visualized using a dendrogram. Clusters are determined by cutting the resulting dendrogram at a fixed number of partitions ($K = 6$).

3.1.5. Input-Output Data

Our empirical analysis relies on the Eora26 Multi-Region Input–Output (MRIO) database. Eora26 is a harmonized and simplified version of the full Eora MRIO system, specifically designed to facilitate large-scale cross-country comparisons and global supply chain analysis (Lenzen et al., 2012, 2013). A key advantage of Eora26 is its global scope. Unlike other MRIO databases that focus primarily on major economies, such as WIOD or EXIOBASE, Eora26 covers virtually the entire world economy, including countries with generally missing records like Haiti and Belize, which are fundamental for our analysis. The database includes up to 190 countries, after filtering information with poor quality we retained 187 of these countries for our comparative analysis.

All national IO tables are harmonized into a common classification of 26 sectors, ensuring comparability across countries despite differences in national statistical systems. The database follows the standard Leontief IO framework. The core component is the global transactions matrix, which records intermediate exchanges of goods and services between sectors across countries. Eora26 is constructed by aggregating the high-resolution "Full Eora" model—which includes up to 15,000 sectors—into the harmonized 26-sector framework. National Supply–Use Tables are converted into symmetric product-by-product IO tables using the Industry Technology Assumption (ITA). This harmonization process ensures consistency across countries while preserving the main structural characteristics of national production systems. For analytical purposes, total (direct and indirect) production requirements associated with final demand are computed using the standard Leontief inverse.

The 26-sector classification spans primary activities such as agriculture, fishing, and mining; manufacturing sectors including food processing, textiles, chemicals, metals, machinery, and transport equipment; utilities, construction, and recycling; and a broad range of services, including trade, transport, telecommunications, finance, public administration, education, health, and other personal and community services. A residual sector is included to account for balancing items and statistical discrepancies.

3.2. Network Estimates

To visually interpret the complex structural properties of each national production network, In Figures 1 to 3 we generate two distinct sets of visualizations: a general, stylized network map and a specialized map focusing on structural bottlenecks.

In Figures 1 and 2 we generate stylized maps of the Downstream, A_{cc}, and Upstream, B_{cc} , networks to visualize their primary connectivity and scale. To ensure visual clarity and focus on the most influential relationships, the full A_{cc} or B_{cc} matrix is sparsified. Only the edges (links between sectors) with weights above the 85th percentile are retained for plotting. The resulting sparse network is rendered using a *Fruchterman-Reingold (FR)* force-directed layout. This algorithm positions highly connected nodes closer together, allowing for the visual identification of dense industrial clusters. The size of each sector (node) is scaled by its *Average Strength*—the arithmetic mean of its incoming (In-) and outgoing (Out-) weighted connections. While nodes are labeled using simplified sector names. Edge thickness (width) is directly proportional to the edge weight (the value of the flow between sectors, A_{ij} or B_{ij}), visually emphasizing the magnitude of the key economic dependencies.

3.2.1. Downstream Networks

Figure 1 presents downstream production networks for 1991, 2007, and 2023, respectively, displaying only the strongest 15 percent of intersectoral linkages. These networks capture the supply-side backbone of each economy in the region, with directed edges representing the flow of intermediate inputs from supplier sectors to purchasing sectors. Focusing on the most salient connections allows us to trace the structural evolution of domestic supply chains and identify the sectors that increasingly mediate production activity over time.

We start by describing last panel of Figure 1, Panel C, which presents the downstream network structure in 2023 for the 10 focus countries. 2023 is the last year in our sample. This year, downstream networks across all countries exhibit a pronounced hub-and-spoke topology. In every case, the financial sector emerges as the dominant supply-side hub, acting as the primary provider of intermediate services to the rest of the economy. This configuration indicates a high degree of centralization in domestic production, with financial intermediation functioning as the core mechanism through which inputs are mobilized and distributed.

Mexico displays the most integrated and diversified downstream structure in the region. While financial services clearly dominate, construction and petroleum also function as

secondary hubs, supplying inputs to multiple sectors. This pattern reflects Mexico's comparatively deep industrial base, where extractive and construction activities continue to play a meaningful role alongside services. In Panama, the downstream network is distinctive in exhibiting a dual-hub structure. Financial services remain central, but the transport sector rivals finance in importance, supplying inputs to nearly all other industries. This configuration is consistent with Panama's role as a regional logistics and transit hub.

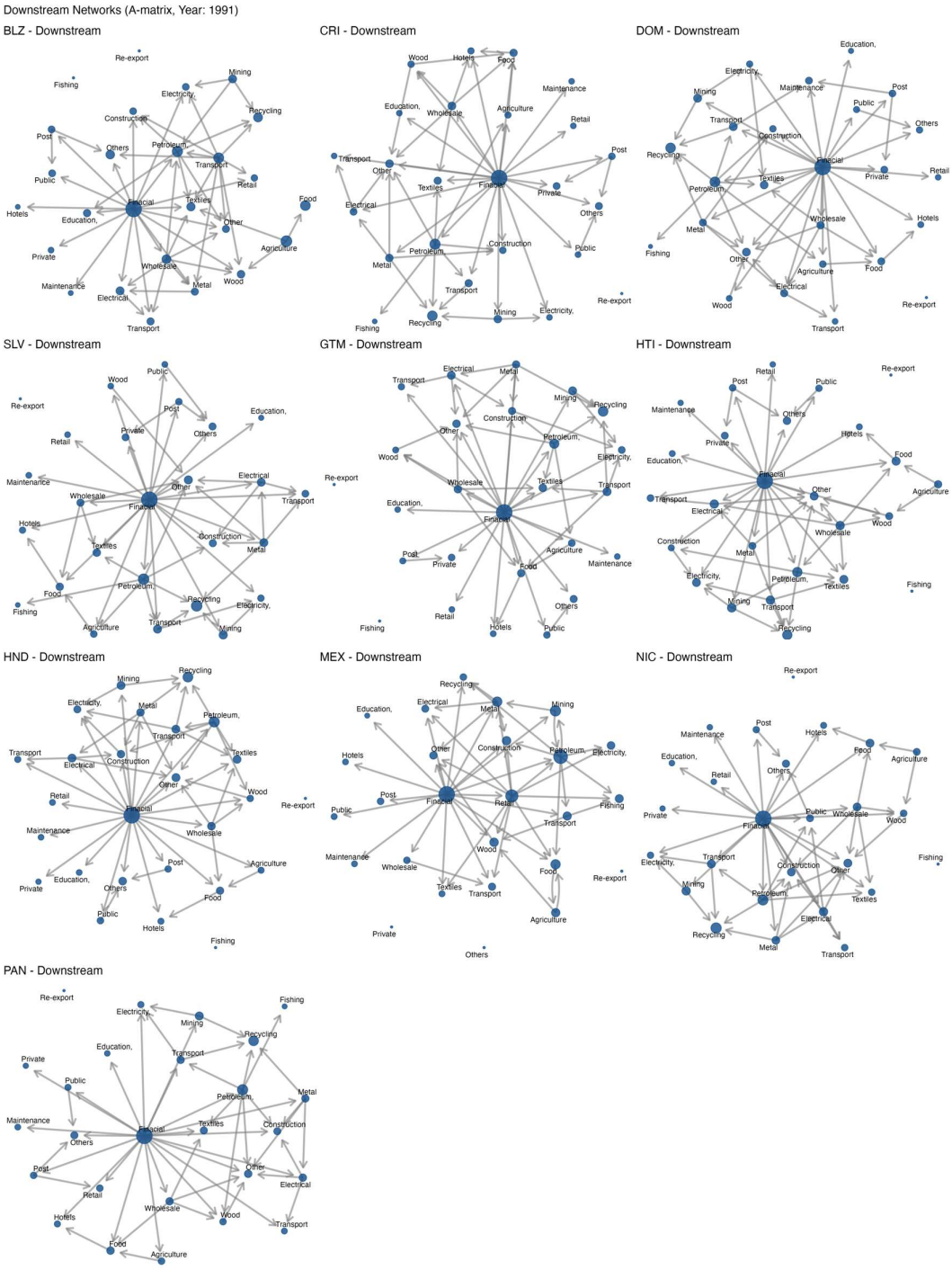
Costa Rica and the Dominican Republic present more concentrated structures led by services. In Costa Rica, financial services form a clear core, with strong outward linkages to public administration, construction, and retail. The Dominican Republic shows an even denser central cluster, with finance and wholesale trade jointly acting as the main conduits through which value is distributed to the rest of the economy.

Guatemala, El Salvador, Honduras, and Nicaragua exhibit extreme downstream centralization. In these economies, financial services overwhelmingly dominate the network, supplying inputs primarily to retail and construction. Agriculture remains visible in Nicaragua and Honduras, but only as a peripheral recipient of financial and service inputs rather than as an autonomous supplier. Haiti and Belize display the sparsest networks in the sample. In both cases, financial services constitute the sole significant hub, suggesting limited domestic supply-chain complexity and a stronger reliance on imports or weak intersectoral integration.

The comparison across 1991, 2007, and 2023 of the production networks in the region reveals a significant transformation in the organization of domestic supply chains over the last decades. In 1991, downstream networks were relatively fragmented and decentralized. Multiple sectors acted as localized hubs, particularly in agriculture- and production-oriented economies such as Honduras and Nicaragua. Strong supply relationships were more evenly distributed across sectors, and industrial or primary activities, such as petroleum in Mexico or food processing in Central American countries, played more prominent roles as suppliers.

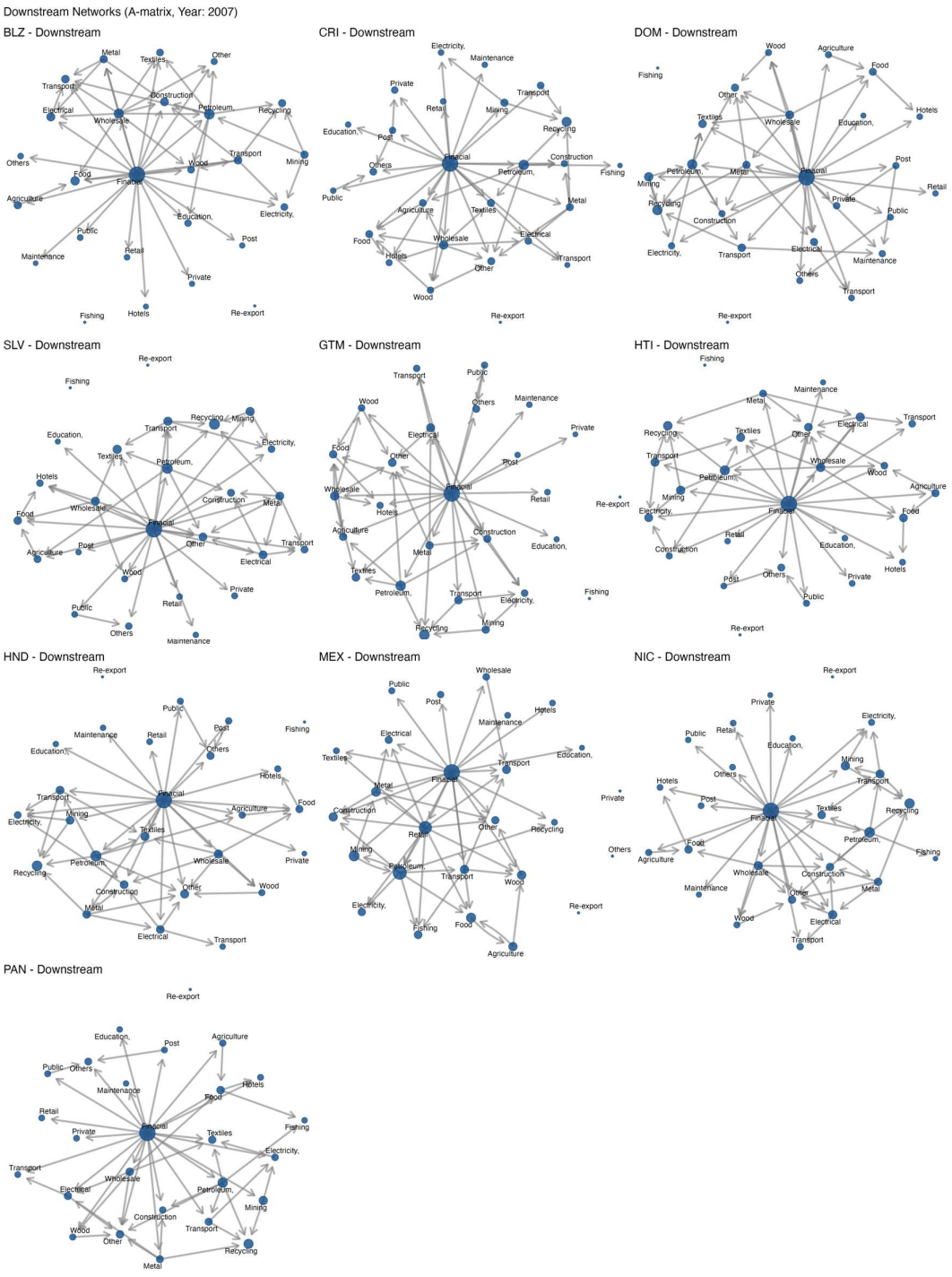
By 2007, a clear transition toward services was noticeable. Financial services expanded rapidly as a supplier of intermediate inputs, and the first signs of a star-shaped topology emerged. In Mexico, the interdependence between finance, retail, and construction crystallized into a dominant triplet, while in Panama the transport sector began to consolidate its role as a specialized logistics hub. This period coincides with broader processes of financial liberalization and modernization across the region.

Figure 1 (Panel A): Downstream Network Representation for Central America and Mexico, 1991



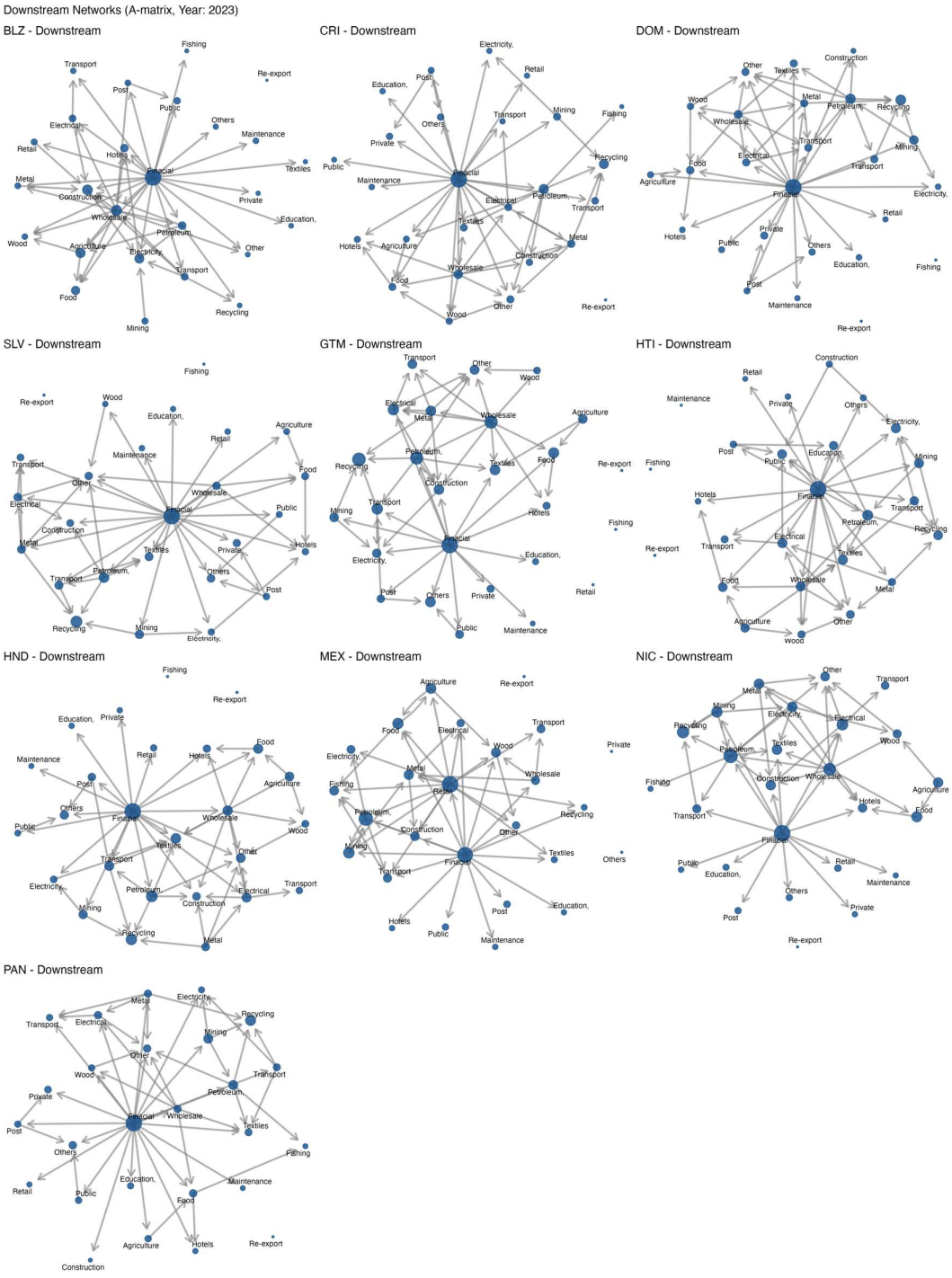
Note: The figure presents a schematic representation of the downstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 1991, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's sensitivity to supply-side shocks originating from its upstream suppliers, as measured by the Leontief inverse (Equation 2). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

Figure 1 (Panel B): Downstream Network Representation for Central America and Mexico, 2007



Note: The figure presents a schematic representation of the downstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 2007, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's sensitivity to supply-side shocks originating from its upstream suppliers, as measured by the Leontief inverse (Equation 2). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

Figure 1 (Panel C): Downstream Network Representation for Central America and Mexico, 2023



Note: The figure presents a schematic representation of the downstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 2023, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's sensitivity to supply-side shocks originating from its upstream suppliers, as measured by the Leontief inverse (Equation 2). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

By 2023, the transition to a fully financialized supply structure was complete in the region. Downstream networks became markedly clearer as financial services absorbed an overwhelming share of the strongest intersectoral linkages, effectively replacing other sectors from the top tier of the distribution. Domestic production systems converged towards more financialized structures, in which the production and circulation of goods increasingly depend on the intermediation and coordination provided by financial and professional services.

Several common patterns characterize the region by the end of the sample period. Financial services dominate downstream networks in all ten countries, acting as the primary supplier of intermediate inputs. Retail trade, construction, and public administration consistently appear as the main recipients of these flows, emphasizing their role as key transmission points in domestic supply chains. At the same time, direct supply linkages among manufacturing or primary sectors have become less prominent, reflecting a relative sparsification of industrial interconnections. Despite this convergence, important differences remain. Mexico retains the greatest industrial depth, evidenced by the persistence of secondary hubs such as petroleum, retail and metals. In contrast, Haiti, Guatemala and Belize exhibit somehow lower levels of domestic connectivity, with fewer high-intensity supply relationships outside the central financial node. Together, these results illustrate both the shared trajectory toward financialized production networks and the enduring heterogeneity in economic structure across the region.

3.2.2. Upstream Networks

Figure 2, Panels A–C present the upstream, or allocation, networks for 1991, 2007, and 2023, constructed from the B-matrix of allocation coefficients (Equation 3). In these networks, a directed edge from sector i to sector j indicates that a large share of sector i's total output is sold to sector j. Centrality in this context therefore reflects demand-side importance: hubs are sectors that act as primary destinations for the output of many other domestic industries. Focusing on the top 15 percent of allocation linkages highlights the dominant customers that organize domestic demand.

By 2023, upstream networks across the region display a high degree of tertiary consolidation. Domestic production is no longer primarily absorbed by other manufacturing or primary sectors but, instead, flows toward a small set of distributional and service hubs. Retail, wholesale, finance, and, in some cases, education dominate as the final domestic destinations of economic value.

Mexico exhibits a complex upstream structure in the sample. Electrical sector and transport, together with financial services, form the principal demand hubs. Wholesale and petroleum sectors direct a large share of their output toward these nodes, indicating that production is increasingly intermediated through domestic trade and financial channels before reaching final demand. Panama presents a somehow distinct configuration in which education and construction emerge as a co-dominant hub alongside finance.

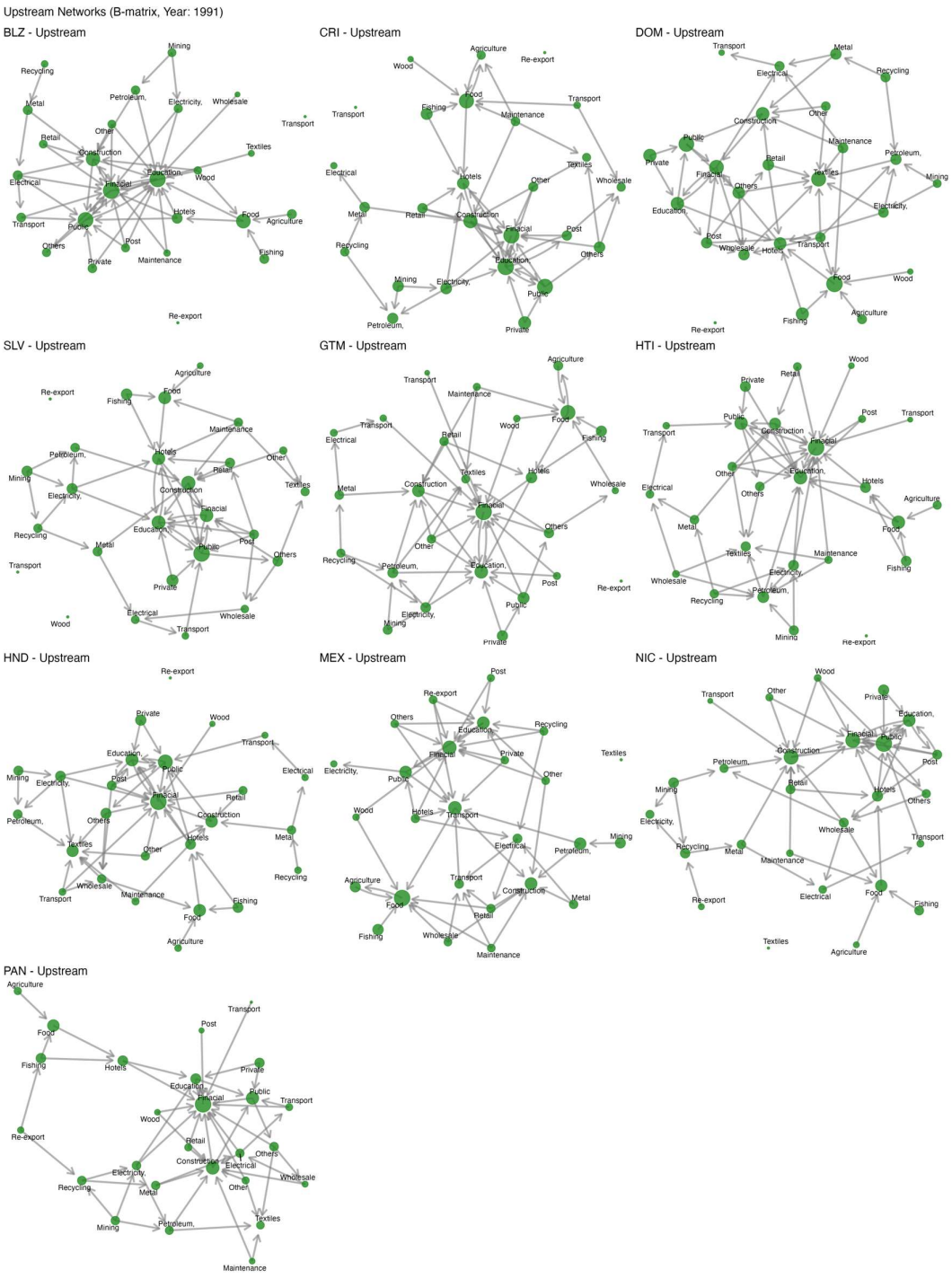
In Costa Rica and the Dominican Republic, education and public administration absorb a substantial share of domestic output, suggesting that demand is increasingly organized around service provision rather than intermediate industrial use. In these economies, the upstream network points to a reorientation of domestic markets toward consumption, public services, and non-tradable activities like construction.

A different form of centralization characterizes Guatemala, El Salvador, Honduras, and Nicaragua. In these countries, construction functions as the overwhelming hub, receiving the strongest output flows from nearly all industrial and agricultural sectors. Guatemala retains some residual allocation from agriculture to food and beverages, but these links are secondary relative to the dominant retail absorption. Nicaragua represents one of the most centralized cases, with an upstream structure in which value from across the economy is channeled almost exclusively into construction and public sector activities.

In Haiti, financial services, education and public activities are the three sectors with the strongest internal allocation links, suggesting that much of domestic production either bypasses intermediate domestic customers—flowing directly to final consumption—or is exported in a minimally processed form. Belize exhibits a similarly thin structure, pointing to limited domestic demand integration and a narrow set of internal buyers based mainly on public sector and construction activities.

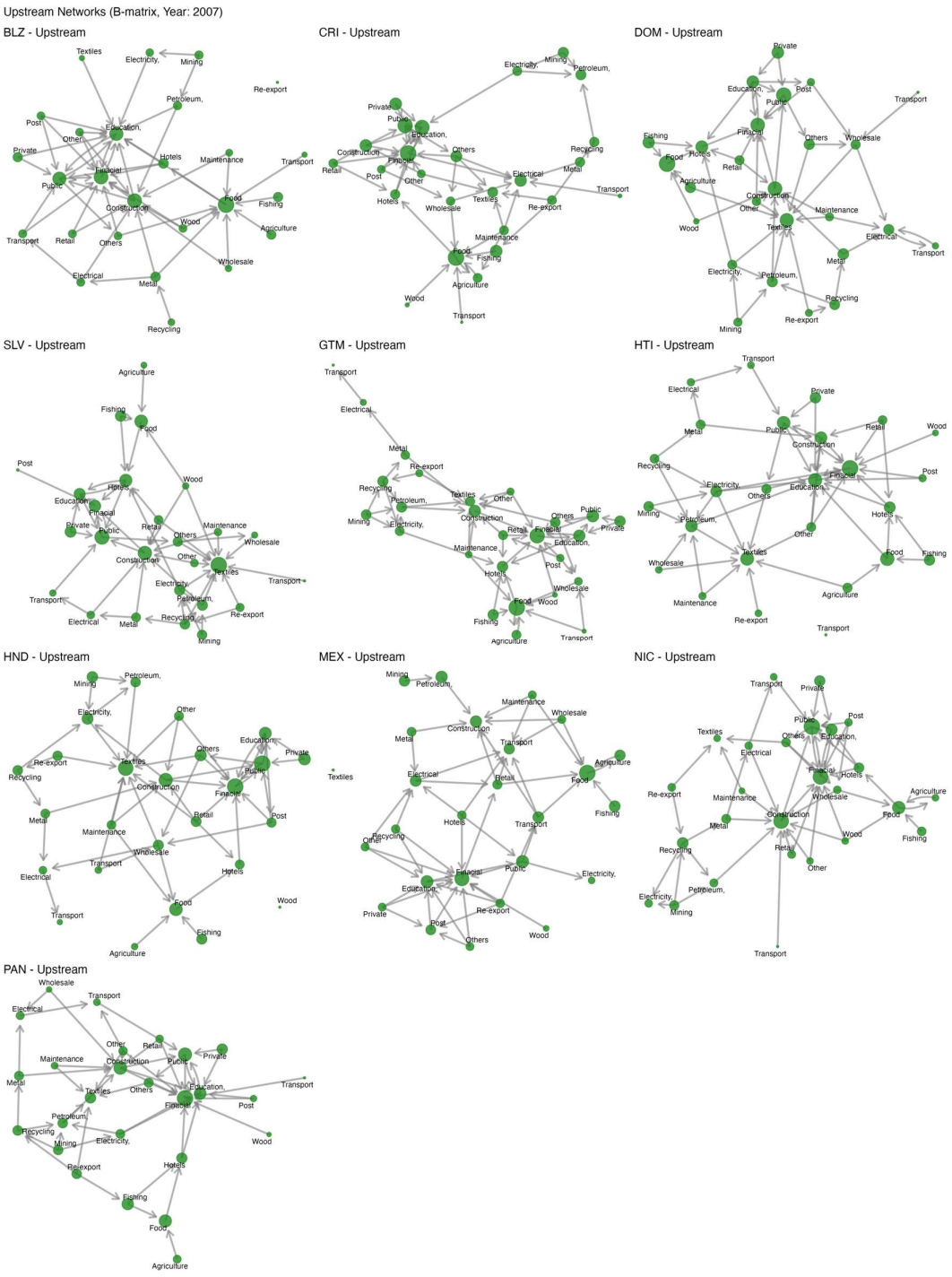
The evolution of upstream networks over the past three decades reveals a process of domestic de-industrialization (e.g., Sinha, 2023). In 1991, allocation networks were more distributed and resembled production chains rather than stars. Output flowed more frequently from primary to manufacturing sectors, for example, from agriculture to food processing or from mining to metals, resulting in a flatter structure with less pronounced hubs.

Figure 2 (Panel A): Upstream Network Representation for Central America and Mexico, 1991



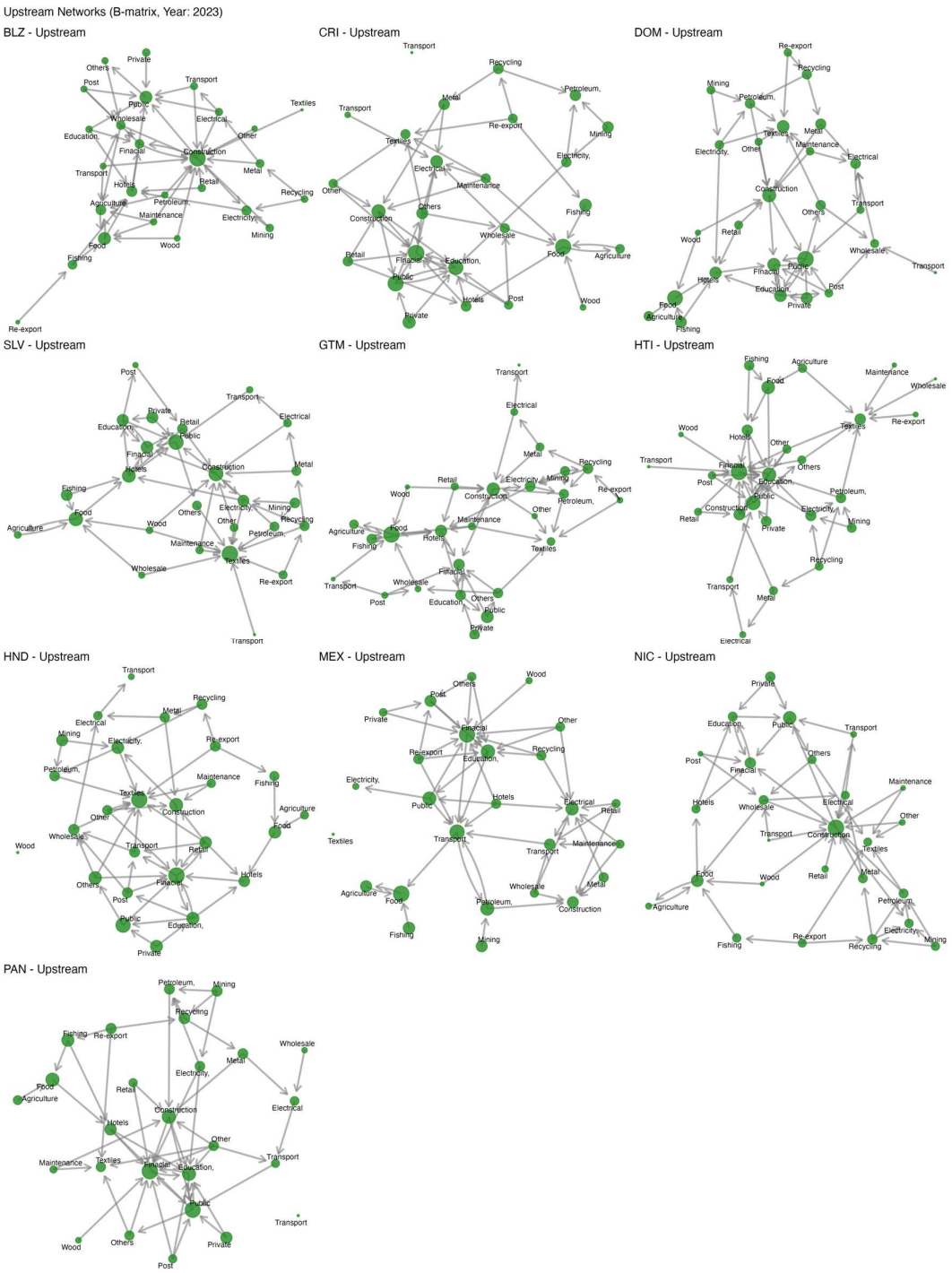
Note: The figure presents a schematic representation of the upstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 1991, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's exposure to demand-side shocks originating in its downstream customers, as measured by the Allocation (Equation 3). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

Figure 2 (Panel B): Upstream Network Representation for Central America and Mexico, 2007



Note: The figure presents a schematic representation of the upstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 2007, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's exposure to demand-side shocks originating in its downstream customers, as measured by the Allocation (Equation 3). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

Figure 2 (Panel C): Upstream Network Representation for Central America and Mexico, 2023



Note: The figure presents a schematic representation of the upstream networks of Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama for 2023, based on the EORA26 database. Each node represents one of the 26 sectors, while edges capture a sector's exposure to demand-side shocks originating in its downstream customers, as measured by the Allocation (Equation 3). To facilitate visualization, only edges above the 85th percentile of the weight distribution are included.

By 2007, this configuration began to shift. Following the trade liberalizations of the 1990s and early 2000s, wholesale trade and transport gained prominence as domestic customers, with output increasingly redirected away from industrial-to-industrial use and toward trade and logistics nodes. This transition marks a reorientation of domestic demand toward the movement, commercialization, and distribution of goods rather than their transformation.

By 2023, the process was largely complete. Financial and retail sectors had fully captured domestic output flows in almost all countries, although construction also emerges as a demand engine of the region. Regardless of whether value originated in agriculture, manufacturing, or extractive activities, the strongest allocation links now pointed toward services or non-tradeable sectors. The upstream structure thus reflects a domestic economy organized around consumption and financial intermediation, with services acting as the primary absorbers of value.

At the same time, important differences can be noted., for instance related to the diverse role of sectors such as construction, education or public administration. Overall, these results indicate that while Mexico retains features of a more complete and diversified domestic economy, most Central American and Caribbean countries have converged toward a service-hub model in which domestic demand is dominated by the distribution, financing, and commercialization of goods rather than their integrated production.

3.2.3. Country Networks Topology Metrics

In what follows, we present network metrics at both the country and node (sectoral) levels. The analyses in this section situate the production network structure of Central America and Mexico within a global context by comparing the topology of downstream and upstream networks in the region to those observed in the rest of the world. Table 2 summarizes the cross-country distribution of the standardized network metrics for year 2023.

All metrics have been normalized to have a mean of zero and a standard deviation of one in the global sample. For each metric, the minimum and maximum values observed across all countries are reported. The remaining columns present the average values for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama (Region 10), followed by the corresponding average computed for the same set of countries excluding Haiti, Belize, and Mexico (Region 7).

Table 2 Selected Standardized Network Metrics in the World

Panel A: Downstream Network	*Min*	*Max*	*Avg. 10*	*Avg. 7*
Avg. Strength	-0.350	13.480	-0.100	-0.080
Avg. Path Length	-0.250	12.600	-0.110	-0.070
Diameter	-0.190	11.120	-0.150	-0.140
Modularity	-3.200	3.080	0.040	0.190
Panel B: Upstream Networks				
Avg. Strength	-3.100	2.540	-0.060	-0.300
Avg. Path Length	-0.450	9.600	-0.080	-0.060
Diameter	-0.320	12.620	-0.110	-0.110
Modularity	-5.460	3.550	-0.160	-0.170

Note: The table reports the minimum and maximum values of the standardized metrics listed in column 1 for the cross section of countries in 2023. By construction, the metrics have a mean of zero and a variance of one across all countries. Subsequent columns report the average values of each metric for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama (Average 10). The final column reports the average for the same group excluding Haiti, Belize, and Mexico (Average 7).

Table 2 suggests that the region exhibits a structural configuration that differs systematically from the global average. In the downstream network (Panel A), the negative values for Average Strength, Average Path Length, and Diameter observed for both the "Average 10" and "Average 7" country groupings indicate production systems that are, on average, less dense in terms of intermediate trade intensity but relatively compact in their network topology. From an economic perspective, shorter path lengths imply that shocks can traverse the network with relatively few intermediation steps, potentially accelerating their propagation. At the same time, this tendency is mitigated by positive modularity, most notably for the Region 7 group, indicating that downstream production is organized into relatively well-defined clusters. Such modular structures can act as buffers, limiting the diffusion of supply-side shocks across otherwise weakly connected industrial blocks and enhancing aggregate resilience at the cost of a less dense industrial fabric.

Table 3 presents standardized values of key network metrics for the countries listed in the first column (Region 10). Again, all metrics are normalized with respect to the global sample. Results are reported separately for downstream networks in Panel A and upstream networks in Panel B. In line with our previous analysis, it is revealed a substantial cross-country variation within the region, particularly with respect to the degree of shock containment implied by network modularity. In the downstream network, countries such as Guatemala and El Salvador display relatively high positive modularity, consistent with strongly segmented production structures that may inhibit the cross-sectoral transmission

of supply disturbances. In contrast, Belize, Mexico and Costa Rica combine negative modularity with short path lengths, characterizing more integrated and horizontally connected production systems. While such configurations may support efficiency and scale economies, they also imply a higher potential for economy-wide contagion following sector-specific shocks.

Table 3 Selected Standardized Network Metrics for the Focus Region

	Avg. Strength	Avg. Path Length	Diameter	Modularity
Panel A: Downstream Network				
BLZ	-0.170	-0.180	-0.170	-0.750
CRI	-0.060	0.110	-0.060	-0.490
DOM	-0.080	0.070	-0.100	0.280
SLV	-0.110	-0.210	-0.180	0.360
GTM	-0.100	0.090	-0.100	0.610
HTI	-0.080	-0.200	-0.180	0.150
HND	-0.090	-0.140	-0.150	0.340
MEX	-0.150	-0.250	-0.190	-0.360
NIC	-0.060	-0.220	-0.180	0.000
PAN	-0.100	-0.170	-0.180	0.220
Panel B: Upstream Networks				
BLZ	1.680	0.090	-0.050	-0.510
CRI	-0.930	0.000	0.000	-0.410
DOM	-0.040	-0.170	-0.110	-0.070
SLV	-0.390	-0.050	-0.060	-0.270
GTM	0.510	-0.080	-0.090	0.260
HTI	-0.020	-0.070	-0.040	-0.410
HND	-1.270	-0.100	-0.170	0.040
MEX	-0.180	-0.330	-0.290	0.540
NIC	0.260	0.010	-0.180	-0.580
PAN	-0.230	-0.070	-0.130	-0.150

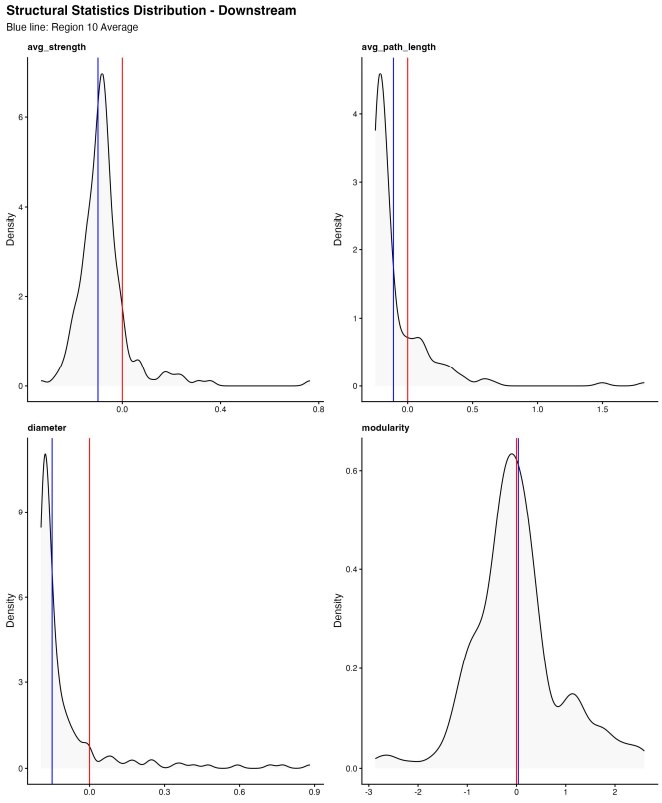
Note: The table reports values of selected network metrics—average strength, average path length, diameter, and modularity—for 2023 across the countries listed in the first column. All network metrics are standardized across the global sample of countries. Panel A corresponds to downstream networks while Panel B corresponds to upstream networks.

The upstream network (Panel B) presents a contrasting picture. Whereas downstream modularity is generally positive, upstream modularity is predominantly negative at the regional level, suggesting that input provision and raw material sourcing are more uniformly interconnected and less compartmentalized. Belize emerges as a notable outlier, exhibiting a markedly high upstream Average Strength, indicative of a concentrated or unusually intensive pattern of demand-side linkages relative to its economic size. By

contrast, several countries, such as Honduras and Costa Rica, show strongly negative upstream strength, pointing to a more limited role for domestic inter-industry supply chains. This pattern is consistent with greater reliance on imported inputs or a comparatively less complex production base.

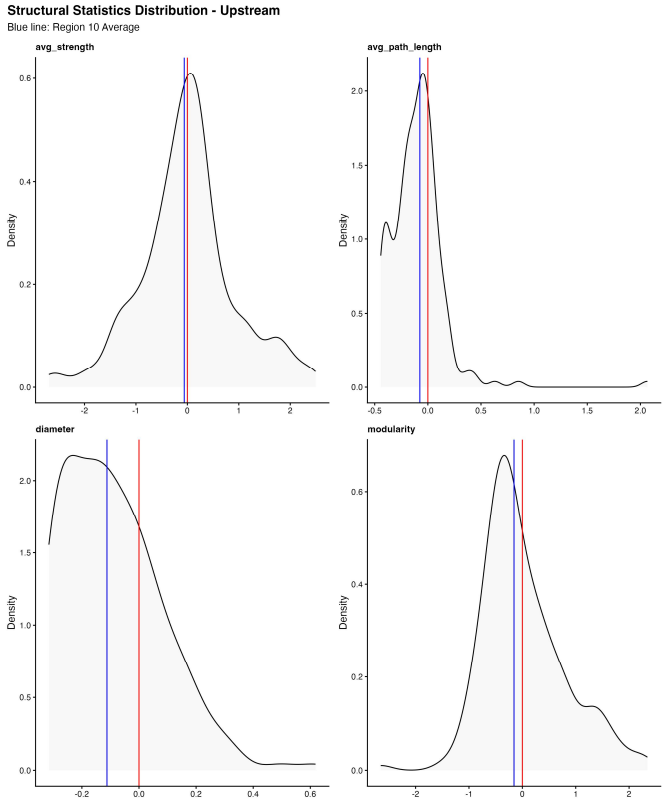
Figure 4 presents the probability density functions of four standardized network metrics—average strength, average path length, diameter, and modularity—computed for a global sample of countries (187 in total) in 2023. Panel A reports the distributions for downstream production networks, while Panel B reports those for upstream, demand networks. In each subplot, the vertical red line denotes the standardized world mean (zero), and the vertical blue line marks the average value for the focus region (Belize, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama). Observations to the left of the red line correspond to values below the global average, whereas those to the right indicate above-average values.

Figure 4 (Panel A): Distribution of Downstream Networks Characteristics, 2023.



Note: The figure shows the global distribution of selected downstream network metrics for 2023: average strength, average path length, diameter, and modularity. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

Figure 4 (Panel B): Distribution of Upstream Networks Characteristics, 2023.



Note: The figure shows the global distribution of selected upstream network metrics for 2023: average strength, average path length, diameter, and modularity. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

The distributions presented in Figure 4 (Panel A) indicate that the focus region's downstream production networks are characterized by relatively high structural segmentation. The region clearly lies below the global mean in terms of average strength, path length, and diameter, while its average modularity is slightly positioned to the right of the world benchmark. From an economic perspective, this combination implies production systems that are structurally compact, such that shocks can, in principle, traverse the network through relatively few intermediation layers, yet partitioned into distinct and weakly connected production modules. Elevated downstream modularity therefore functions as a stabilizing feature, potentially constraining the diffusion of demand-side shocks across otherwise semi-autonomous industrial blocks.

By contrast, Figure 4 (Panel B) highlights a somehow different configuration in the region's upstream networks. In this case, the regional average for modularity lies to the left of the global mean, indicating a lower degree of structural segregation on the demand side. This

pattern is reinforced by comparatively low average strength and shorter path lengths relative to global peers. Taken together, these indicators describe upstream demand structures that are more uniformly interconnected and less reliant on compartmentalized domestic chains. While such integration may enhance efficiency, it also implies heightened exposure to the rapid transmission of demand-side disturbances, including fiscal and trade shocks.

3.2.4. Sectors (Nodes) Topology Metrics

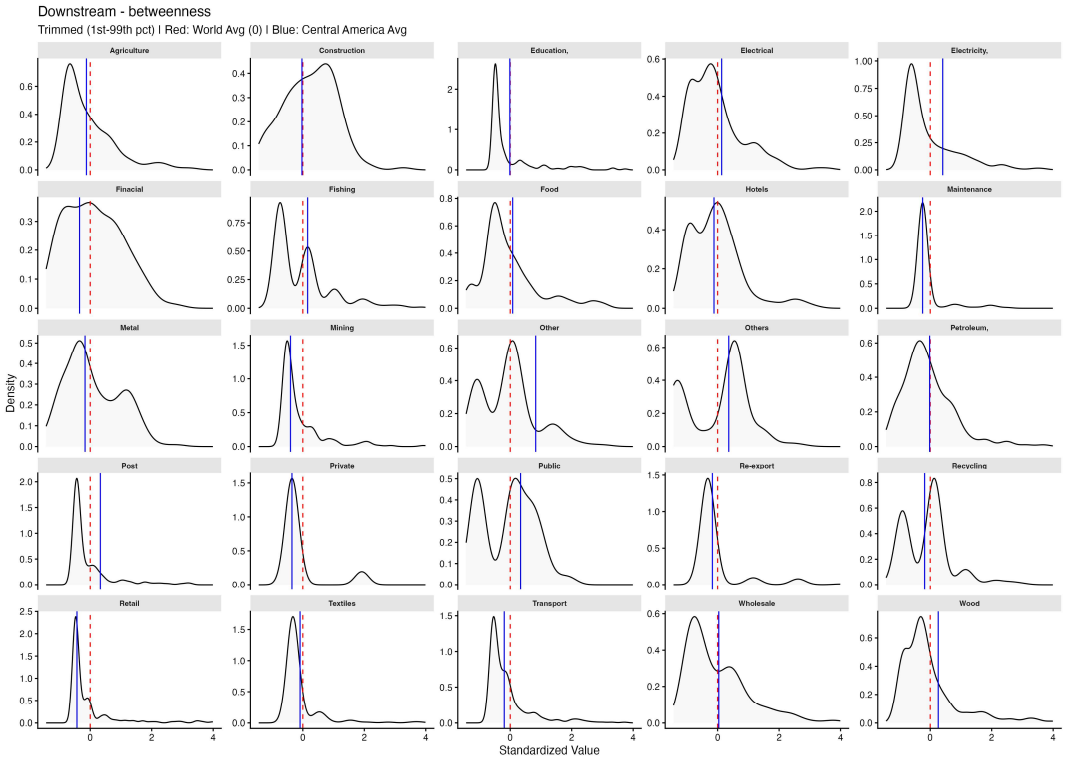
As an alternative proposal to identify economic sectors that play a relatively more central role in national production systems in the region, compared with the rest of the world, in this section, the analysis is extended to node-level centrality metrics (see Figure 5). The distributions of indicators such as Betweenness Centrality and PageRank are used to highlight sectors that function as critical "choke points" or influential hubs within the production downstream networks. In addition, the Aggregate Volatility Contribution is employed to assess the economy's degree of granularity, capturing the extent to which shocks originating in individual industries can generate aggregate macroeconomic fluctuations. This sector-level perspective makes it possible to distinguish whether resilience may arise primarily from the overall network topology or from the dominance of a small number of key sectors.

Figure 5 presents the standardized distributions of sector-level network statistics for 2023 across our global sample of countries, offering a detailed view of the structural properties of production networks. Each panel corresponds to a distinct centrality or importance indicator: Betweenness (Panel A), Aggregate Volatility Contribution (Panel B), Eigenvector Centrality (Panel C), PageRank (Panel D), and Total Strength (Panel E). In all panels, the vertical red line denotes the standardized world mean (normalized to zero), while the blue line indicates the average value for the focus region. The distributions are reported for 25 broad industrial sectors (we excluded transport equipment in this figure for a better visualization in a 5×5 matrix of plots, excluding transport complementary activities). Observations to the right of the red line signal above-average systemic relevance and those to the left indicate below-average connectivity, influence, or macroeconomic relevance. Here, we focus on downstream networks while results for upstream networks are available upon request.

Taken together, the five panels reveal a consistent pattern in which most sectors in the focus region occupy positions to the left of the global mean across multiple dimensions of

network centrality. In terms of Betweenness Centrality, this implies that regional production networks are generally less reliant on complex internal intermediaries than the global average, with industrial flows requiring fewer sectoral “choke points” to connect upstream and downstream activities. A notable exception is the electricity sector, whose regional average lies to the right of the world benchmark. This identifies electricity as a critical systemic bottleneck: disruptions in this sector are more likely to propagate widely through the economy than in comparable global networks. Sectors such as construction and transport are close to the global mean, suggesting that they play a more conventional intermediation role in linking stages of production. By contrast, other sectors, such as education and financial services, appear relatively less important within the regional supply-chain structure, despite the central role of finance identified in the domestic network analysis shown in Figure 1.

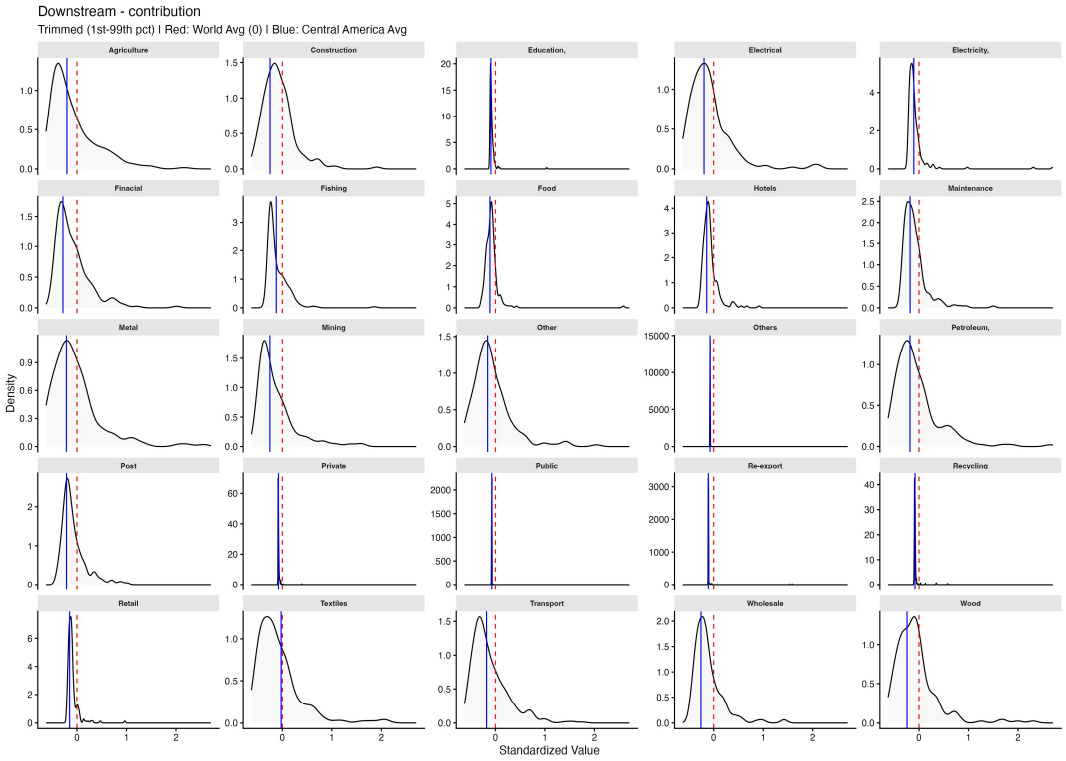
Figure 5 (Panel A). Distribution of Betweenness Centrality Statistics for Downstream Networks, 2023



Note: The figure displays the distribution of sectoral betweenness centrality in downstream networks for 2023. All network metrics are standardized across the global sample of countries, so positive values indicate levels above the world mean and negative values indicate levels below the world mean. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

A similar leftward shift is evident in the distribution of Aggregate Volatility Contributions. Across nearly all sectors, the focus region exhibits values well below the global average, indicating a comparatively low degree of economic granularity. From a macroeconomic perspective, this implies that idiosyncratic shocks originating in individual industries are unlikely to generate substantial aggregate fluctuations in output (relatively speaking). Instead, systemic volatility in the region is more plausibly driven by common external disturbances, such as global demand shifts or international price shocks, rather than by failures in single, dominant domestic sectors.

Figure 5 (Panel B). Distribution of Contribution Statistics for Downstream Networks, 2023

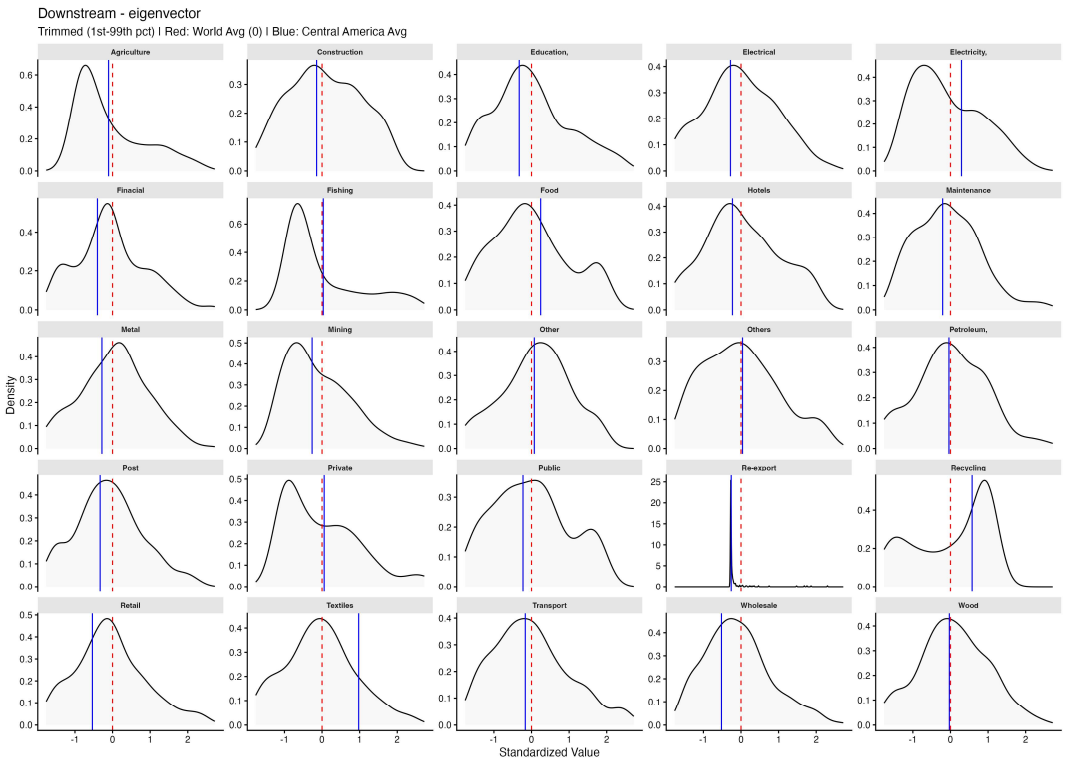


Note: The figure displays the distribution of sectoral contribution in downstream networks for 2023. All network metrics are standardized across the global sample of countries, so positive values indicate levels above the world mean and negative values indicate levels below the world mean. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

The results for Eigenvector Centrality further reinforce this characterization, with most industries displaying lower influence relative to global benchmarks. However, textiles stand out as an exception, exhibiting elevated eigenvector centrality within the regional network. This suggests that this sector is embedded in particularly influential portions of

the production system, such that disruptions affecting them may carry disproportionate systemic consequences. In contrast, sectors such as retail or mining appear weakly connected to other influential industries and therefore play a more limited role in shaping aggregate network dynamics.

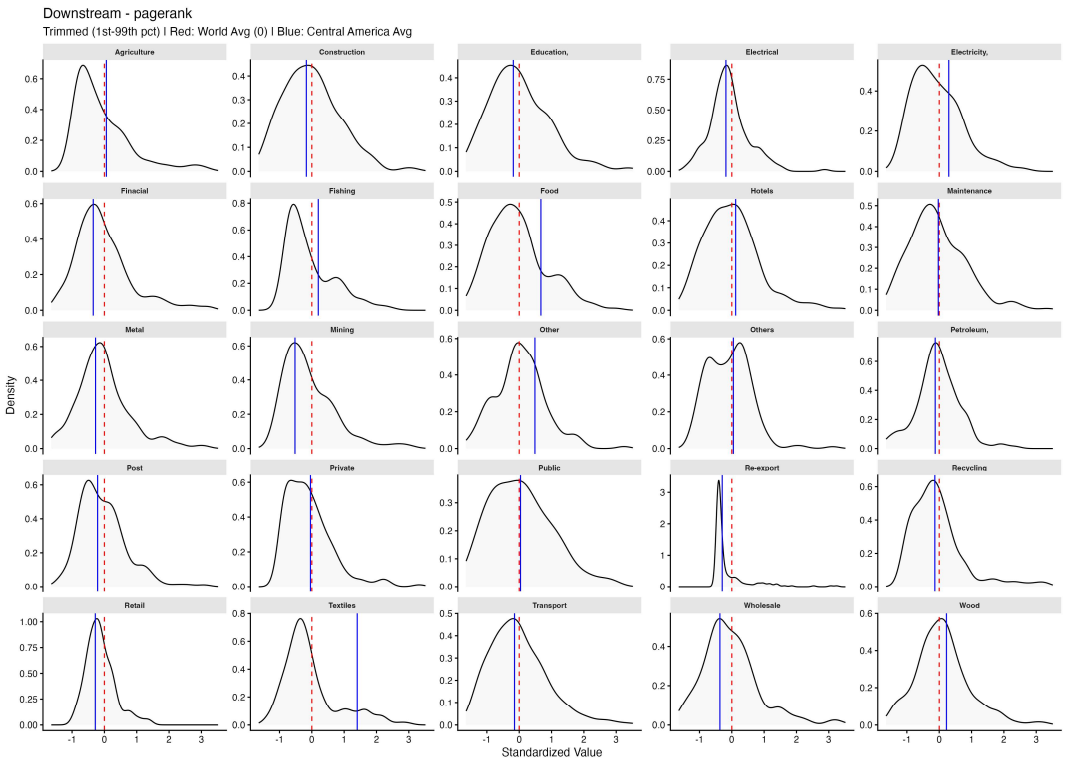
Figure 5 (Panel C). Distribution of Eigenvector for Downstream Networks, 2023



Note: The figure displays the distribution of sectoral Eigenvector in downstream networks for 2023. All network metrics are standardized across the global sample of countries, so positive values indicate levels above the world mean and negative values indicate levels below the world mean. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

PageRank statistics provide a complementary view of systemic importance by emphasizing connections to other important sectors. Here food and textiles emerge as the primary anchors of the regional production network, with average values that meet or exceed the global mean. Despite the overall lower density of inter-sectoral linkages, these industries function as key drivers of rank and influence, reflecting the region's reliance on utility-intensive activities and agricultural processing within its production structure.

Figure 5 (Panel D). Distribution of PageRank Statistics for Downstream Networks, 2023

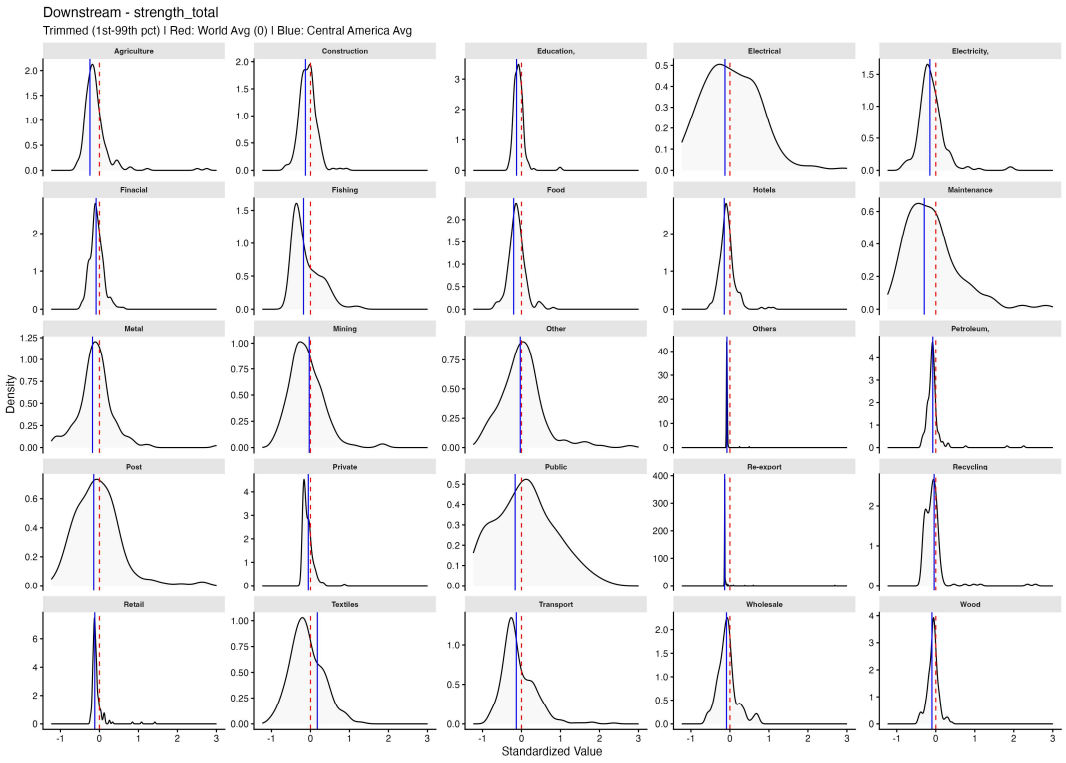


Note: The figure displays the distribution of sectoral PageRank in downstream networks for 2023. All network metrics are standardized across the global sample of countries, so positive values indicate levels above the world mean and negative values indicate levels below the world mean. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

Finally, the distribution of Total Strength (which is the average of In- and Out- Strength) highlights the relatively low intensity of domestic inter-industry trade across the region. Nearly all sectors lie to the left of the global mean or in the global mean, underscoring the "thin" nature of regional production networks. This pattern is consistent with limited domestic intermediate input use and a greater dependence on imported inputs, as well as a production orientation toward final goods rather than deeply integrated domestic supply chains.

All in all, evidence from Figure 5 indicates that while the region's production networks are characterized by low granularity and limited internal complexity, systemic importance remains concentrated in a small number of key sectors, with electricity and textiles representing a critical point of vulnerability, in relative terms.

Figure 5 (Panel E). Distribution of Strength Total (Average In- and Out-) for Downstream Networks, 2023



Note: The figure displays the distribution of sectoral Strength (average In- and Out Strength) in downstream networks for 2023. All network metrics are standardized across the global sample of countries, so positive values indicate levels above the world mean and negative values indicate levels below the world mean. For each metric, the average value for Belize, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama is indicated by a vertical blue line, while the world average is shown by a vertical red line.

Upstream sectoral analysis is reported in Figure A1 of the Appendix, Section B. This figure reveals that the focus region's supply-side production networks are generally less centralized and less internally intensive than the global average. Most industries exhibit below average betweenness, closeness, and total strength, indicating a relatively flat and segmented upstream structure with limited domestic intermediation and relatively low volumes of inter-industry input flows. This configuration implies that supply shocks originating in individual sectors tend to propagate more slowly and encounter greater structural friction, which can act as a partial buffer against rapid economy-wide contagion. At the same time, the thinness of upstream linkages points to a production system that relies heavily on imported intermediates or the direct export of primary inputs, rather than on deeply integrated domestic supply chains.

Despite this overall fragmentation, the analysis identifies a small set of sectors that play a disproportionately important role in the upstream network. Textiles, food, and electricity emerge as key demand-side anchors, exhibiting relatively high eigenvector centrality and PageRank compared to global benchmarks. These sectors are closely connected to other influential sectors and therefore occupy critical positions within the regional markets. As a result, disruptions affecting these sectors have the potential to generate significant upstream effects that outweigh the generally low level of inter-sectoral integration, highlighting them as focal points for demand resilience to fiscal and external shocks.

3.2.5. Global Network Clustering

Figure 6, Panel A, presents a circular dendrogram that hierarchically clusters 187 national production networks according to the structural similarity of their downstream linkages. The analysis in this section focuses on downstream propagation, whereby a supply-side shock affecting a producer transmits to its direct customers and subsequently cascades through their customers along global value chains. Note that, clustering countries according to this criterion identifies groups of economies that share similar *supply-side signatures*: nations that serve as suppliers to comparable sectors within each economy and would propagate supply disruptions in structurally similar ways.

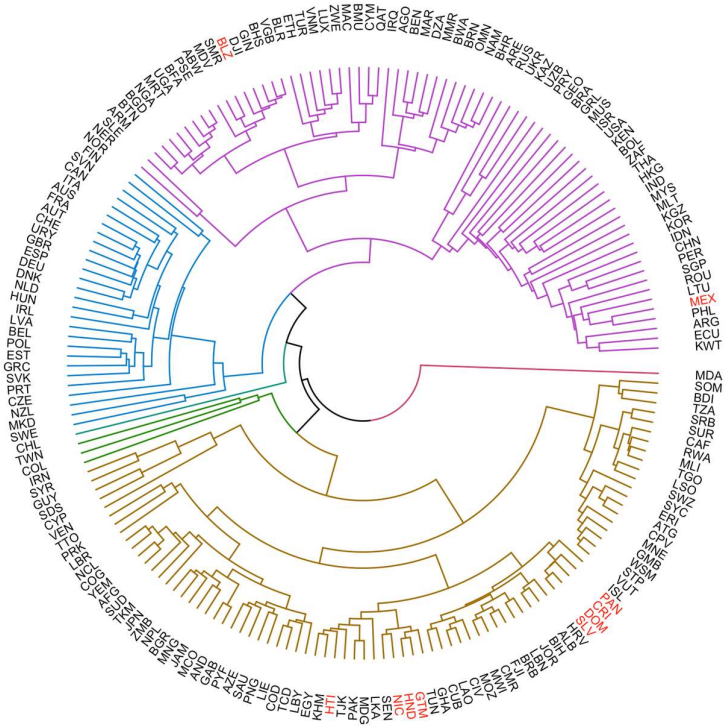
Within this global taxonomy, Mexico occupies a distinctive position. It is embedded in the violet cluster, which contains many of the world's major manufacturing and technological hubs. In the context of Acemoglu et al.'s (2016) framework, this placement implies that Mexico exhibits downstream propagation patterns characteristic of a hub economy. Mexico's structural signature is therefore closer to that of "global factory" economies such as the Czech Republic or the Philippines than to that of its immediate Central American neighbours.

In contrast, most Central American economies, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Dominican Republic, Haiti and Panama, form a tightly clustered subgroup within the gold branch of the dendrogram. The proximity of these countries along the clustering hierarchy indicates a high degree of homogeneity in their downstream network architectures. These economies tend to supply similar downstream industries, such as U.S.-oriented retail channels, textile and apparel wholesalers, or specific agricultural processors. From a shock-propagation perspective, a supply-side disruption in any one of these countries would be expected to follow nearly identical transmission paths,

underscoring a shared regional exposure to sector-specific shocks and external demand fluctuations.

Belize stands out as a notable exception. Rather than clustering with its regional peers, it appears within a different branch alongside a set of small, highly specialized economies, including commodity exporters and island states. This placement suggests that Belize's downstream linkages differ fundamentally from those of the rest of Central America. Whereas neighbouring countries are embedded in manufacturing-oriented or transit-based supply chains, Belize's production network appears concentrated in narrower niches—such as specialized commodity exports or tourism-related services—that transmit shocks in a distinctive way. Our results in this section highlight pronounced heterogeneity in downstream propagation patterns within the region.

Figure 6 (Panel A): Global Clustering of Downstream Networks, 2023.



Note: The figure shows the structural similarity of 187 national production networks based on their downstream linkages. Proximity in the dendrogram indicates that countries serve as suppliers in a similar way across domestic sectors. Focus countries are highlighted in red. Different colours correspond to the different main countries.

Figure 6, Panel B, reports the hierarchical clustering of national production networks based on the structural similarity of their upstream linkages. Using the same methodology as in the downstream analysis, this figure organizes countries according to their allocation networks, which capture how demand-side shocks propagate through the economy.

Upstream networks trace the transmission of demand disturbances, therefore, clustering countries along this dimension groups economies with similar input-sourcing profiles and, consequently, similar exposure to demand-side disruptions.

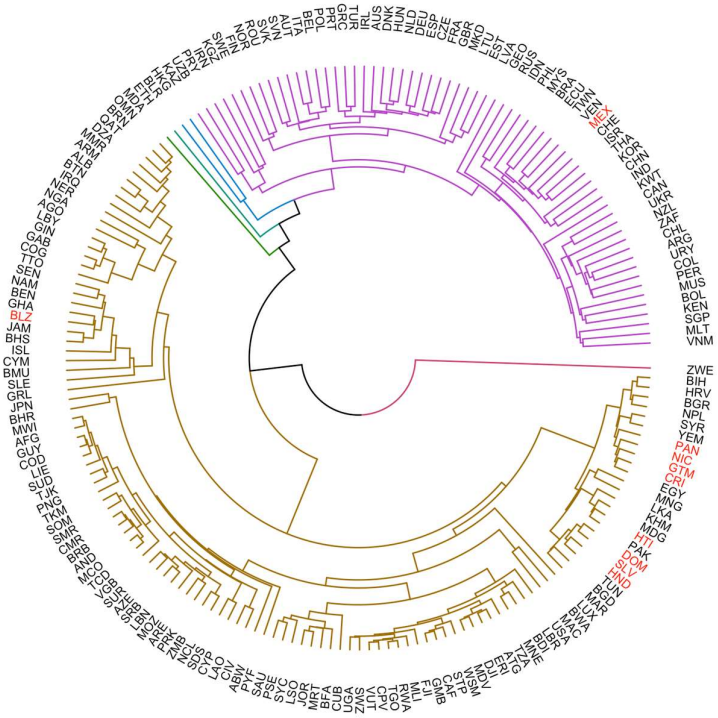
A striking result is the consistency of Mexico's position across both dimensions of analysis. Once again, Mexico appears within the blue cluster, alongside advanced manufacturing hubs such as the Czech Republic, Taiwan, and the Philippines. This placement indicates a strong degree of structural symmetry in Mexico's participation in global value chains. Not only does Mexico propagate supply shocks in a manner like other "global factory" economies, but it also relies on comparable upstream suppliers for its intermediate inputs. As a result, Mexico's upstream vulnerability is closely tied to fluctuations in global demand for complex manufactured goods rather than to regional or commodity-specific demand shocks.

Central American economies, including Honduras, Guatemala, Nicaragua, El Salvador, the Dominican Republic, Panama, Haiti, and Costa Rica, again form a tightly knit group within the gold cluster. In the upstream dimension, their proximity is even more pronounced than in the downstream case, pointing to an especially high degree of homogeneity in their input dependency structures. For instance, a contraction in demand from a major external market, particularly the United States, would propagate upstream through these economies in nearly identical ways. This pattern underscores a shared vulnerability rooted in limited diversification of sourcing strategies and a synchronized integration into global demand channels.

Belize remains a clear outlier. As in the downstream clustering, it appears within another branch of the gold cluster alongside resource-rich and various island nations. This suggests that Belize's upstream network is structurally distinct from the manufacturing- and transit-oriented input structures that characterize its regional neighbors. Its sourcing patterns are likely more heavily oriented toward services or specialized commodity-related inputs, reinforcing its isolation from the dominant industrial configuration observed elsewhere in Central America.

Comparing the downstream and upstream clustering results reveals a notable degree of stability. Countries consistently remain in the same clusters regardless of whether supply-side or demand-side propagation is considered.

Figure 6 (Panel B): Global Clustering of Upstream Networks, 2023.



Note: The figure shows the structural similarity of 187 national production networks based on their upstream linkages. Proximity in the dendrogram indicates that countries serve as suppliers in a similar way across domestic sectors. Focus countries are highlighted in red. Different colours correspond to the different main countries.

4. Trade Shock Measurement

To analyze shock propagation within the focus region we use as our main explanatory variable a sector specific trade shock that captures exposure to imports from the United States. For each sector i in country c and year t, the own trade shock is defined as the change in real imports from the United States relative to the industry's baseline real value added:

$$\text{Shock}_{ict}^{own} = -\frac{\Delta M_{ict}^{US}}{VA_{ic,0}}, \tag{5}$$

where, ΔM_{ict}^{US} denotes the change in real imports from the United States and $VA_{ic,0}$ is real value added in a pre-determined base year, 0. This normalization accounts for differences in sector size and reflects the interpretation of import competition as a negative demand shock to domestic producers, as indicated by the sign of the right-hand-side expression.

4.1. Network Propagation of Shocks

To capture indirect effects, the direct (own) shocks are propagated through the production network using an input–output structure derived from Eora. Let A denote the matrix of input coefficients, where a_{ij} a ij represents the share of inputs from sector i used by sector j.

Upstream exposure reflects shocks transmitted from an industry's customers to the industry itself, consistent with demand-side propagation (Acemoglu et al., 2016). The upstream network shock is defined as:

$$\text{Shock}_{ict}^{up} = \sum_j A_{ij} \text{Shock}_{jct}^{own}. \quad (6)$$

Downstream exposure captures shocks transmitted from suppliers to consumer at the sector level and it is given by:

$$\text{Shock}_{ict}^{down} = \sum_j B_{ij} \text{Shock}_{jct}^{own}. \quad (7)$$

These measures allow the total exposure of an industry to be decomposed into direct effects and indirect effects operating through upstream and downstream production linkages.

One point is worth emphasizing at this stage. While Acemoglu et al. (2016) interpret trade shocks from China as import-competition shocks, in our setting although trade shocks originating from the United States also represent demand shocks, they are likely complementary to domestic production. That is, although we retain the negative sign convention to maintain direct comparability with Acemoglu et al. (2016), we expect qualitatively different results. For countries highly integrated with the United States, the shock may reflect both demand- and supply-side transmission, leading to distinct propagation patterns through production networks as well as differences in the relative magnitudes of the own, upstream, and downstream shock components.

4.2. Instrumental Variables Estimates

A key identification concern in our context is that observed import flows may respond endogenously to domestic demand or productivity shocks, rather than external trade shocks, although this is partially mitigated in our case by the small economy assumption, we address this concern directly by employing an instrumental-variables approach. Our estimator exploits variation in U.S. exports to third country "peer". These peers are selected to be economically comparable to the target country but plausibly unaffected by its industry-specific shocks.

Formally, U.S. exports to peer countries predict import exposure in the target country through common supply-side factors in U.S. export behavior, while remaining orthogonal to contemporaneous shocks to domestic value added. This approach mirrors standard shift-share identification strategies used in the trade and networks literature and in particular follows closely Acemoglu et al. (2016).

In the original paper, trade shocks from China are instrumented using other advanced economies import penetration from China in countries such as Austria, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland. In our case to estimate the effects on each individual economy except for Mexico, we use the flows of the other peer economies in the region. For Mexico, we use peers like China, Vietnam, Poland, Thailand and Turkey, acknowledging its difference in terms of production networks with Central American countries. We also provide additional specifications in the Appendix that use peer countries identified through the hierarchical clustering results in Section 3.

4.3. Econometric Specification

The main estimating equation relates changes in industry-level real value added to lagged trade shocks:

$$\Delta \ln VA_{ict} = \beta^{own} \text{Shock}^{own}_{ic,t-1} + \beta^{net} \text{Shock}^{net}_{ic,t-1} + \mu_t + \varepsilon_{ict}, \quad (8)$$

where, Shock^{net} represents either upstream, downstream, or combined network exposure, μ_t denotes year fixed effects, and ε_{ict} is an error term. All regressions are weighted by baseline real industry size to reflect the relative economic importance of economic sectors, and standard errors are clustered at the sector level to allow for within-sector correlation over time.

The empirical analysis is implemented under two alternative specifications that differ in the year used to fix the production network before estimation to attenuate reserve-causality concerns. In the baseline specification, the input–output network and associated weights are fixed using 1991 data, and the estimation sample spans the period from 1992 to 2023. As a robustness exercise, the network is instead fixed using 2006-year data, with the corresponding estimation period running from 2007 to 2023. In both cases, annual trade flow data from 1991 to 2023 are used to construct the underlying panel, and all monetary values are converted into real terms using a U.S. GDP deflator, with prices expressed in constant 2010 dollars.

Table 4 reports the results from the baseline econometric specification analysing how U.S. trade shocks propagate across Central American economies and Mexico through IO sector networks. Columns correspond to countries in our focus region, while rows report lagged growth (dependent variable), lagged own effects, and lagged upstream and downstream effects. All regressions include lagged variables to further mitigate endogeneity concerns and are estimated separately for each country.

Panel A presents results using trade networks fixed in 1991, with regressions estimated over the 1992–2023 period. Across countries, lagged growth is generally positive when explaining current growth and significant, indicating persistence in economic growth dynamics. Own effects are negative and statistically insignificant for most countries, while downstream amplification is generally significant and sizable, suggesting that indirect exposure to U.S. trade shocks does play an important role in shaping domestic growth outcomes. The magnitude of these effects varies considerably, with Mexico exhibiting particularly strong explanatory power, as reflected in a high adjusted R^2 of 0.863, while smaller economies such as Guatemala, Panama and Belize display substantially lower R^2 values.

The network propagation of shocks uncovers a heterogeneous pattern across countries. Upstream effects, capturing shocks transmitted from supplier relationships, are negative and statistically significant for Belize and Mexico, indicating that adverse shocks affecting their downstream trading partners can meaningfully depress domestic growth. In line, downstream effects—reflecting shocks from customer linkages—are generally positive and significant, suggesting that exposure through export destinations can partially offset negative spillovers in some cases. This is not the case of Mexico and Belize, which alongside Haiti again present a significant contraction after the shock.

Panel B re-estimates the model using trade networks fixed in 2006, covering the shorter 2007–2023 period as a robustness exercise. While the overall structure of the results remains consistent, several coefficients change in magnitude and significance, reflecting an evolving nature of regional trade integration in the region. Notably, downstream effects become stronger and more statistically significant for most countries. This pattern suggests that, in the more recent period, shocks transmitted through buyer relationships (demand shocks) have become a more important channel for economic growth.

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Table 1. Panel A (Baseline Specification): Analysis of US Trade Shocks, Network from 1991, Estimation 1992-2023

	MEX	GTM	HND	SLV	NIC	CRI	PAN	BLZ	DOM	HTI
Growth(t-1)	**0.110***	0.042	**0.134+**	**0.116***	0.173	**0.066****	0.122	**0.108****	**0.123+**	**0.154****
	-0.047	-0.03	-0.072	-0.049	-0.115	-0.025	-0.169	-0.034	-0.072	-0.052
Own Effects(t-1)	−0.644	0.265	−1.831	−2.254	−4.330	−1.510	−2.989	−1.449	−1.947	−0.901
	-0.761	-1.375	-2.222	-2.172	-3.816	-0.917	-4.831	-0.952	-1.48	-4.623
Upstream Effects (t-1)	**−0.439***	−0.161	−0.306	0.284	0.555	−0.079	0.027	**−1.262*****	−0.451	−1.156
	-0.175	-0.275	-0.399	-0.437	-1.007	-0.168	-0.523	-0.272	-0.412	-1.763
Downstream Effects (t-1)	**−1.403+**	**4.453***	**2.672***	**3.112***	**3.126+**	0.704	5.72	**−2.169+**	**1.965+**	**−10.833****
	-0.784	-2.002	-1.303	-1.551	-1.721	-0.823	-6.283	-1.162	-1.021	-3.813
Num.Obs.	806	806	806	806	806	806	806	806	806	806
R2	0.868	0.251	0.406	0.419	0.368	0.651	0.303	0.326	0.614	0.487
R2 Adj.	0.863	0.218	0.38	0.394	0.34	0.636	0.272	0.296	0.597	0.465
AIC	5502.5	6424.8	6090	6440.2	6151.6	5379.8	6640.4	6130.7	5996.9	7131.9
BIC	5671.4	6593.7	6258.9	6609.2	6320.5	5548.7	6809.3	6299.6	6165.9	7300.8
RMSE	12.86	14.44	12.93	31.23	11.5	12.16	14.34	11.76	10.72	19.86
Std.Errors Cluster	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector

Note: This table reports the results of the model in equation (4) for the ten countries in the target region. For all countries, the instruments consist of U.S. import flows to the rest of the region, except for Mexico, for which the instruments are constructed using import flows to similar countries, including China, Vietnam, Thailand, Poland, and Turkey. In the baseline specification (Table 1, Panel A), networks are fixed in 1991 to propagate the shock, while the regressions use data from 1992 to 2017. The table reports lagged own effects, as well as lagged downstream and upstream effects, to further mitigate endogeneity concerns. + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001.

Table 4. Panel B (Alternative Specification): Analysis of US Trade Shocks, Network from 2006, Estimation 2007-2023

	MEX	GTM	HND	SLV	NIC	CRI	PAN	BLZ	DOM	HTI
Growth(t-1)	**0.133+**	**0.151+**	**0.192***	**0.103***	0.222	**0.060+**	0.065	0.097	**0.152***	0.106
	-0.068	-0.078	-0.097	-0.043	-0.136	-0.034	-0.166	-0.06	-0.076	-0.068
Own Effects(t-1)	−0.774	−1.492	−3.187	−2.093	−6.105	**−2.170+**	−1.080	−1.347	**−3.456***	−1.781
	-0.985	-3.02	-3.874	-2.285	-5.173	-1.2	-8.695	-1.164	-1.694	-9.124
Upstream Effects (t-1)	**−0.641+**	−0.581	−1.228	0.622	0.777	−0.079	**−1.451+**	**−1.412****	−0.244	−1.213
	-0.347	-0.651	-0.75	-0.579	-1.263	-0.215	-0.803	-0.521	-0.549	-3.47
Downstream Effects (t-1)	**−2.606****	**5.725*****	**3.382*****	**4.844***	**7.664+**	0.905	−0.449	−2.865	**4.050***	**−5.925+**
	-0.872	-1.643	-0.994	-1.903	-4.206	-0.943	-9.943	-1.943	-1.856	-3.189
Num.Obs.	416	416	416	416	416	416	416	416	416	416
R2	0.768	0.192	0.27	0.265	0.259	0.596	0.239	0.276	0.225	0.399
R2 Adj.	0.757	0.154	0.235	0.23	0.224	0.577	0.202	0.241	0.187	0.37
AIC	3113.6	3566.4	3393	3565.4	3429.8	3025.9	3702.7	3321.7	3383.7	3947.7
BIC	3198.3	3651	3477.7	3650	3514.4	3110.6	3787.3	3406.4	3468.4	4032.4
RMSE	17.74	19.49	17.6	43.56	16.05	16.89	19.62	14.64	15.01	27.32
Std.Errors Cluster	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector	by: sector

Note: This table reports the results of the model in equation (4) for the ten countries in the target region. For all countries, the instruments consist of U.S. import flows to the rest of the region, except for Mexico, for which the instruments are constructed using import flows to similar countries, including China, Vietnam, Thailand, Poland, and Turkey. In the alternative specification (Table 1, Panel B), networks are fixed in 2006 to propagate the shock, while the regressions use data from 2007 to 2023. The table reports lagged own effects, as well as lagged downstream and upstream effects, to further mitigate endogeneity concerns. + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Results in Table 4 emphasize the importance of trade network structure in shaping how U.S. trade shocks affect growth across the region. While direct exposure to U.S. trade remains a key driver of economic outcomes in the most recent period for countries such as Costa Rica and the Dominican Republic, upstream linkages also play a nontrivial amplifying role in Panama, Mexico, and Belize. Nonetheless, downstream linkages appear to be more important in explaining the region's heterogeneous trade dynamics. Some countries experience a negative downstream amplification of trade shocks, as in the cases of Mexico and Haiti, whereas others exhibit positive amplification effects, including Guatemala, Honduras, El Salvador, Nicaragua, and the Dominican Republic. Costa Rica stands out as the only country for which neither upstream nor downstream linkages generate significant amplification effects

5. Conclusions

This study provides a detailed structural characterization of production networks in Central America and Mexico over the period 1991–2023, documenting profound transformations in the organization of domestic supply chains and their systemic implications. By exploiting sectoral input–output linkages and network-based metrics, the analysis has identified key sectoral hubs, patterns of interdependence, and sources of vulnerability, situating the region's production structures within a broader global context. The results point to a long-run process of structural transformation across Central America, accompanied by a reconfiguration of economic activity toward service-oriented and increasingly financialized network architectures.

From a downstream, supply-side perspective, production networks evolved from relatively fragmented and decentralized structures in the early 1990s into highly centralized hub-and-spoke configurations by 2023. Financial services emerged as the dominant downstream hub in all countries in the sample, assuming a central intermediation role in the provision of intermediate inputs. As this process unfolded, traditional manufacturing and primary-sector linkages became progressively less prominent within domestic production hierarchies. This shift reflects both a reallocation toward services and a streamlining of domestic production structures, as financial intermediation progressively replaces dense industrial linkages as the primary mechanism coordinating economic activity.

Upstream, demand-side networks have consolidated toward service and distribution. Financial services and construction now dominate as the final domestic destinations for sectoral output, reflecting a reorientation toward consumption and non-tradable activities.

The combined downstream and upstream dynamics point to a regional production model that is less internally articulated and more reliant on external inputs and final demand.

When benchmarked against global production networks, the region's systems appear structurally "thin", exhibiting lower trade intensity and reduced internal complexity. Most sectors are less central than their global counterparts, suggesting limited capacity to act as autonomous drivers of domestic production. Nevertheless, a small number of sectors retain systemic importance. Electricity and textiles consistently stand out as a critical, in relative terms, reflecting their indispensable role in sustaining intersectoral flows. In addition, food processing continues to function as an influential anchor within the regional production hierarchy, owing to their deep integration into both domestic and external value chains.

These structural features translate into a distinct and asymmetric risk profile. On the supply side, downstream networks display relatively high modularity, indicating a degree of compartmentalization that may help contain localized supply-disruptions and reduce the likelihood of cascading failures. In contrast, upstream networks are characterized by low modularity and relatively short path lengths, implying that demand-side shocks—such as abrupt changes in fiscal policy, trade conditions, or external demand—can propagate rapidly throughout the system. As a result, while the region may exhibit some resilience to sector-specific supply shocks, it remains highly exposed to synchronized contractions driven by external or macroeconomic forces.

The network-based clustering analysis further reinforces this interpretation. Most Central American economies form highly homogeneous cluster, sharing nearly identical upstream and downstream signatures. This homogeneity points to synchronized structural exposure, particularly to fluctuations in external demand, and limits the scope for diversification-driven resilience within the region. Mexico, by contrast, occupies a clearly distinct position, clustering with global manufacturing hubs rather than with its Central American neighbors. Its production network is more diversified and internally articulated, with secondary hubs in petroleum and metals that complement its role in global manufacturing chains. At the other extreme, Belize exhibits the sparsest networks, characterized by limited domestic complexity and heavy reliance on single hubs.

One particularly informative result, which appears counterintuitive at first glance, emerges when we first identify the financial sector as the dominant supply-side hub within Central American production networks, only for later showing that finance is relatively less

important when benchmarked against the global average. This contrast yields a key structural insight: although finance has played an increasingly central role in coordinating domestic production within the region, its network centrality remains modest relative to the highly developed financial hubs of more advanced economies. Taken together, these findings highlight both the internal importance of finance in Central America and the limits of finance as a driver of development and as a systemic catalyst compared with other economies.

All in all, these findings portray a regional trajectory marked by increasing financialization, structural convergence, and some degree of vulnerability. The simplification of domestic production networks and their growing dependence on service-sector hubs have reduced internal complexity but heightened exposure to external demand shocks.

In section 4, which contains the second part of our results, we examine how trade shocks originating in the United States propagate through the production networks of Central America and Mexico, emphasizing the interaction between direct trade exposure and domestic input–output linkages. By combining sector-level panel regressions with and instrumental variable approach, the analysis provides a unified picture of how external shocks translate into aggregate economic outcomes. The consistency between the regression coefficients and the dynamic responses shown in the corresponding figures confirms that differences across countries in total economic exposure are driven primarily by the strength of domestic upstream linkages rather than by direct trade exposure alone.

A central finding is that trade integration with the United States is best characterized by structural complementarity rather than substitution in cases such as Mexico, Haiti and Belize. That is, although the trade shock is defined as a change in U.S. import penetration and follows the sign convention of Acemoglu et al. (2016), the resulting responses are generally negative across these three countries. This apparent contrast reflects a fundamental difference in economic relationships. In this context, a reduction in trade with the United States, even when it implies less import competition, does not generate gains for domestic producers. Instead, it signals a weakening of tightly integrated supply chains, leading to contractions in domestic value added. The negative responses therefore highlight the dependence of these economies on the United States as both a source of final demand and a critical node in regional production networks. For the rest of the economies, especially for the most recent sample analysis (2007-2023) positive and significant amplification via downstream propagation of the trade shocks are observed, which directly addresses the different patterns highlighted by the cluster analysis.

Our findings emphasize the heterogeneity of trade integration across Central America and Mexico. Economies with dense domestic production linkages or dependence on natural resources face greater aggregate vulnerability to external trade disruptions, while those with limited backward linkages are partially insulated from network spillovers. This heterogeneity has important policy implications. Efforts to strengthen domestic supply chains and increase local value added can enhance long-run development prospects, but they also increase exposure to external shocks when trade is highly concentrated on a single partner.

Our analysis focuses exclusively on trade shocks measured by annual variations in sectoral imports from the United States across the economies under study. Given the structure of domestic production networks documented here, other types of shocks may propagate very differently, particularly if they disproportionately affect highly connected nodes within the network, such as the public sector in the case of fiscal policy shocks or the financial sector in the case of macroprudential interventions. Analysing such mechanisms would require data of substantially higher granularity and is therefore left for future research.

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APPENDIX

Section A

Network and Centrality Statistics

We compute a comprehensive set of statistics aiming to characterize our production network structures at the country and sector levels. In this way, we capture the structural properties of each national production network and the relative importance of each sector (node) in each case.

Node-Level statistics:

Sector-level statistics measure the relative position of sector k within the national network structure. Among this set of indicators, we have:

A. Leontief-Derived Centrality (Downstream Only)

This set of indicators, derived from the Leontief Inverse (L) , includes:

Output Multiplier ($\sum_i L_{ik}$): Derived from the Leontief Inverse (L), this is the column sum of L.

$$Multiplier_k = \sum_{i=1}^{N} L_{ik}. \quad \text{(A1)}$$

This statistic represents the total increase in national output caused by a one-unit increase in the final demand for the output of sector k. It is a standard measure of sector k's backward linkages and its ability to spur economic activity across the rest of the economy.

Aggregate Volatility Contribution (C_k): Following Acemoglu et al. (2012), this metric quantifies a sector's predicted contribution to aggregate macroeconomic volatility, assuming idiosyncratic, independent shocks of unit variance:

$$C_k = \left(\sum_{i=1}^{N} L_{ik}\right)^2. \quad \text{(A2)}$$

This indicator measures the centrality of sector k in propagating supply shocks. Sectors with a high C_k are deemed granular and their idiosyncratic shocks are expected to have a disproportionately large impact on overall economic aggregates (e.g., aggregate GDP/Output).

B. Degree and Strength Metrics:

We calculate the weighted and unweighted (in- and out-degrees) using the Downstream (A_{cc}) and Upstream (B_{cc}) matrices, with zeroed diagonals to capture only inter-sectoral dependence. We count the following statistics in this category:

Downstream In-Degree ($\mathrm{In-Degree}_A$): The column sums of the non-diagonal A matrix ($\sum_{i \neq k} A_{ik}$). Measures the total weighted intermediate input reliance of sector k.

Downstream Out-Degree ($\mathrm{Out-Degree}_A$): The row sum of the non-diagonal A matrix $\left(\sum_{j \neq k} A_{kj}\right)$. Measures the total weighted intermediate output sales of sector k (normalized by customer output).

Upstream In-Degree ($\mathrm{In-Degree}_B$): The column sums of the non-diagonal ($\sum_{i \neq k} B_{ik}$). Measures the total weighted customer concentration on sector k as a supplier.

Upstream Out-Degree ($\mathrm{Out-Degree}_B$): The row sum of the non-diagonal B matrix $\left(\sum_{j \neq k} B_{kj}\right)$. Measures the total weighted sales concentration of sector k to its customers.

C. Topological Centrality Measures:

These metrics assess a sector's importance and influence within the overall network structure.

Clustering Coefficient: Measures the degree to which nodes in a graph tend to cluster together. A high clustering coefficient suggests tight-knit industrial clusters, which can both isolate shocks (if the cluster is weakly linked to the rest of the economy) or amplify them (if the shock is contained within the cluster).

Betweenness Centrality: Measures the number of times a sector lies on the shortest path between two other sectors. Sectors with high betweenness act as critical choke points or intermediaries in the supply chain.

$$\text{Betweenness}_k = \sum_{i \neq j \neq k} \frac{\sigma_{ij}(k)}{\sigma_{ij}}. \quad \text{(A3)}$$

The term σ_{ij} represents the total number of shortest paths (geodesics) that exist between sector i and sector j in the network. Sector i is the starting sector (the origin of the flow or shock). Sector j is the ending sector (the destination). $\sigma_{ij}(k)$ represents the number of those shortest paths between sector i and sector j that pass-through sector k. A sector with high betweenness has significant control over the resources flow between other sectors.

Closeness Centrality: Measures how quickly a sector can reach, or be reached by, all other sectors. Sectors with high closeness are well-positioned for rapid interaction and less reliant on intermediaries.

$$\text{Closeness}_k = \frac{N-1}{\sum_{i \neq k} d(k,i)}. \quad \text{(A4)}$$

Eigenvector Centrality: Measures a sector's influence based on its connection to other highly connected sectors.

PageRank: A robust measure of a sector's global importance, where connections from important sectors contribute more to a sector's rank.

Country-Level (Global) Statistics

Country-level statistics capture the overall connectivity and scale of the national network.

Average Metrics: these metrics are the arithmetic means of their node-level counterparts, summarizing the typical sector profile in the country. There are both weighted and unweighted versions which refers to strength and degree respectively

Topological and Efficiency Metrics (Unweighted): These metrics are primarily computed on the binary (unweighted) network to assess structure and efficiency. In this subcategory we have the following indicators:

- *Network Density:* Measures the fraction of possible links that are active in the network (applied to the binary version of A or B).

$$Density_A = \frac{\sum_i \sum_{j \neq i} \mathbb{I}(A_{ij} > \tau)}{N(N-1)}. \quad \text{(A5)}$$

  A higher density indicates a more highly interconnected economy where sectors depend on a larger number of other sectors, potentially leading to faster shock propagation.

- *Average Path Length (APL):* The average number of steps required to travel between any two sectors in the network (computed on the binary version of A). A lower *APL* suggests a more integrated network with fewer hierarchical layers, implying that shocks can spread throughout the economy more quickly.

$$APL = \frac{1}{N(N-1)} \sum_{i \neq j} d(i,j). \quad \text{(A6)}$$

  Where, $d(i,j)$ is the length of the shortest path between i and j.

- *Diameter* (D): The longest of all the shortest paths between any two sectors. A small diameter means the network is very compact, allowing shocks to traverse the entire system quickly.

Structural Metrics:

Transitivity Global: This is the global version of the Clustering Coefficient, measuring the degree to which nodes in a graph tend to cluster together. A high clustering coefficient suggests tight-knit industrial clusters, which can both isolate shocks or amplify them, in the same way described before.

Modularity (Q)*:* Measures the strength of division of a network into distinct communities or production modules. A high Q means the national network is highly segregated into independent production blocs, potentially limiting inter-module shock spread.