

# Measuring Interdependence: Specialization and Trade Motifs

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**Measuring Interdependence:  
Specialization and Trade Motifs**

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## Resumen

La mayoría de las medidas empíricas de interdependencia económica se basan en valores agregados de comercio y ocultan la arquitectura de quién comercia qué con quién. Este artículo introduce un marco de redes para medir la estructura de la interdependencia mediante “motivos comerciales” a nivel de producto. Al definir roles de exportador e importador en una red bipartita país–producto, derivamos probabilidades condicionales que separan el potencial estructural de intercambio —complementariedad y similitud— de su realización efectiva y de las interacciones con terceros países.

El marco operacionaliza conceptos clásicos de economía política. La vulnerabilidad no se mide por la concentración en socios, sino por la escasez de “opciones de salida” —sustituibilidad—, y se distingue la similitud latente de la rivalidad activa en mercados de destino específicos. Con datos armonizados para 1995–2024, mostramos que la similitud estructural predice disputas en la OMC solo cuando los competidores coinciden en destinos particulares. Una aplicación a la díada Estados Unidos–China revela un patrón de “rivalidad sistémica”: la complementariedad estructural bilateral se ha erosionado, mientras la competencia en terceros mercados se intensificó. Los indicadores resultantes ofrecen herramientas granulares para analizar la arquitectura cambiante de la geoeconomía global.

**Palabras clave:** patrones de comercio, rivalidad comercial, sustituibilidad comercial, complementariedad comercial, redes de comercio.

## Abstract

Most empirical measures of economic interdependence rely on aggregate trade values, obscuring the architecture of who trades what with whom. This paper introduces a network-based framework that measures the structure of interdependence through product-level “trade motifs”. By defining exporter and importer roles within a bipartite country–product network, we derive conditional probabilities that separate the structural potential for exchange (complementarity and similarity) from its realization and from third-country interactions.

The framework operationalizes classic political-economy concepts. It measures vulnerability not via partner concentration, but via the scarcity of “exit options” (substitutability), and it distinguishes latent similarity from active rivalry in specific third markets. Using harmonized data for 1995–2024, we show that structural similarity predicts WTO disputes only when competitors collide in particular destinations. An application to the US–China dyad reveals a pattern of “systemic rivalry”: bilateral structural complementarity has eroded even as competition in third markets has intensified. The resulting indicators offer a granular toolkit for analyzing the changing architecture of global economic statecraft.

**Keywords:** trade patterns, trade rivalry, trade substitutability, trade complementarity, trade network.

**JEL Classification Codes:** F51, F14.

# 1 Introduction

For decades, the study of economic interdependence has been shaped by a longstanding debate: is it a source of peace and cooperation, as liberal theorists argue, or a conduit for power and coercion, as realists contend? (Keohane and Nye 1977). The mixed empirical record reflects not only methodological challenges such as endogeneity, but also a persistent conceptual problem. The literature has relied almost exclusively on the value of trade to measure interdependence, treating it as a monolithic force. This paper argues that the structure of trade is a distinct and crucial dimension that reshapes the political implications of its value. The fundamental question is not only how much countries trade, but what and how they trade.

This paper introduces an analytical framework to disaggregate and understand bilateral trade relationships. The framework rests on two pillars: complementarity, which captures the potential for inter-industry trade, and similarity, which reflects the potential for intra-industry trade. From these core concepts, we derive a taxonomy of trade motifs by applying a sequence of logical restrictions. This structure clarifies how different facets of a trade relationship emerge. In line with classic trade theory, we show that realized one-way trade flows are expressions of underlying complementarity, whereas two-way trade (intra-industry) reflects similarity (Grubel and Lloyd 1975). Further restrictions on these patterns allow us to identify and measure other dimensions such as partner substitutability, involvement in production chains, and rivalry in third markets.

This framework provides the empirical means to give new life to classic theoretical insights. It allows for a clear, empirical distinction between the concepts of 'sensitivity' and 'vulnerability' interdependence, famously articulated by Keohane and Nye (1977). While sensitivity may be related to the volume of flows, vulnerability is inherently structural. Our measures directly operationalize the long-standing arguments of Hirschman (1980), who posited that a nation's foreign trade structure is a primary source of national power. Concepts such as our "partner substitutability" measure, for instance, capture the essence of vulnerability by quantifying the exit options available to a state, thereby measuring the potential costs of severing a trade tie. In doing so, our framework provides an empirical counterpart to foundational conceptual work, such as that of Baldwin (1980), which clarifies how interdependence can be leveraged as a source of state power. We offer a granular, product-informed, and directed view of this architecture, recognizing that interdependence is rarely symmetric.

By providing a structurally aware measurement of interdependence, the paper makes four contributions. First, it introduces an analytical framework that separates the potential for trade (specialization roles) from its realization and from third-party interactions. Second, it bridges

classic interdependence scholarship and network analysis by offering product-level metrics for “exit options” and “rivalry”. Third, using data for 1995–2024, it documents a systematic divergence between financial concentration and structural vulnerability, challenging standard proxies in the literature. Fourth, the application to the US–China dyad uncovers a pattern of structural decoupling and systemic rivalry that aggregate trade volumes miss, with implications for the study of global economic statecraft. These contributions speak directly to current debates on weaponized interdependence—the use of asymmetric positions in global networks to turn interdependence into coercive leverage (Farrell and Newman 2019)—on supply-chain resilience and economic security (e.g. OECD 2025a,b), and on “de-risking” strategies in global economic governance, particularly in the EU–China relationship (e.g. Brinza et al. 2024; Bermann and Fabry 2023). In this context, our approach provides a rigorous operationalization for the concept of “strategic autonomy” emphasized in recent policy-oriented literature (Méjean and Rousseaux 2024; Lefebvre and Wibaux 2024). By formalizing substitutability as a structural property of the network, we offer the analytical tool required to distinguish between benign reliance and the critical vulnerabilities that these strategies aim to mitigate.

A design choice that runs throughout the paper is that all motifs are defined in both downstream (exporter-side) and upstream (importer-side) versions. This symmetry reflects the fact that interdependence is mediated not only by the ability to sell abroad, but also by reliance on foreign supplies. However, when we connect our indicators to existing measures in the literature, most of the empirical benchmarks are export-based. As a result, the downstream side offers a natural bridge to classical indices, whereas the upstream side—closely related to questions of supply security and import dependence—is where the framework departs most sharply from established practice and, we argue, adds the greatest amount of new structure.

## 2 Measuring interdependence

This section develops a measurement framework that treats bilateral trade as a structured architecture rather than a single scalar of values or volumes. We map each dyad  $(i, j)$  into a small set of theoretically meaningful product-level motifs: basic role configurations (who exports or imports what), bilateral realizations of those potentials, avenues for third-country substitution, signatures of chain participation, and joint presence in third markets. Each motif is defined as a conditional probability—computed across products, and when relevant across third countries  $(h)$ —that makes interdependence directional and asymmetric. The framework thus translates classic concepts (complementarity, similarity, substitutability, rivalry) into observable, comparable objects for every country pair.

Operationally, we proceed by adding restrictions tier by tier. We start from role-only patterns

that depend solely on each country’s export and import baskets; we then condition on whether those potentials are actually realized in the bilateral link; we next ask whether third countries provide substitutes for the partner or for oneself; we capture chain-like configurations in which one country intermediates between the other and a third market; and we finally register matching in third markets as geography-informed versions of similarity.

## 2.1 Trade motifs

Figure 1 summarizes, at the product level, the configurations (“motifs”) through which a given product  $p$  can shape country  $i$ ’s commercial interests vis-à-vis  $j$ . Blue nodes denote the focal country  $i$  and green nodes the focal partner  $j$ ; white nodes denote third countries.<sup>1</sup>

Moving down the rows, the motifs become increasingly restrictive by imposing the constraints shown on the left margin. Setting  $(h_i, h_j) = (j, i)$  yields direct bilateral trade in  $p$ ; keeping one placeholder fixed while letting the other vary yields substitution and re-export patterns; and imposing  $h_i = h_j = h$  yields triadic configurations in which the same third country  $h$  intermediates the relationship or constitutes a common third market. Within each row, the left block corresponds to opposite-role situations (complementarity) and the right block to same-role situations (similarity), each shown in downstream and upstream versions.

A fundamental trait of our approach is that *diversification* operates as a prior, monadic layer that fixes the size of each country’s role universe. This layer determines, for each country, if product  $p$  falls within its specialization roles as exporter and as importer. Then, when country  $i$  evaluates the bilateral relation with a given country  $j$ , two broad families of situations arise: opposite roles—one side sells while the other buys (Panels A–J), and same-role situations in which both are exporters or both are importers (Panels K–S).

The second row in Figure 1 states that product  $p$  matters for a dyad if both countries are active in that product: either both as exporters (Panel K) or both as importers (Panel L), or with opposite roles (Panels A and B). When countries possess opposite roles—one specializes in exporting  $p$  and the other in importing it—they exhibit *complementarity*. When they share the same role, they exhibit *similarity*, creating the structural basis for competition or intra-industry trade.<sup>2</sup>

Beyond knowing that  $j$  imports a product that  $i$  exports, we ask whether—among all feasible partners— $j$  actually buys  $p$  from  $i$  (Panel C), and symmetrically whether  $i$  imports  $p$  from

<sup>1</sup>The  $h$  nodes indicate that a third country exists which is active in product  $p$  as an exporter or importer to  $i$  ( $h_i$ ), to  $j$  ( $h_j$ ), or both ( $h$ ).

<sup>2</sup>We use the term “similarity” in a broad sense. Because these are conditional probabilities, measures such as  $SD_{ij}$  and  $SU_{ij}$  are directional (not symmetric in  $(i, j)$ ) unlike graph-theoretic similarity indices.

$j$  (Panel D). Observed inter-industry exchanges can thus be read as bilateral realizations of complementarity, while observed intra-industry exchanges arise from similarity (Panel M), echoing the classic division between inter- and intra-industry trade. Realized flows are a selected subset of feasible links, so conditioning on roles helps avoid conflating structural alignment (who could trade with whom) with the fact that a link happens to be observed in a given period.

Panels E–H allow for outside options  $h$  that can replace either the current partner or oneself. A lost export from  $i$  to  $j$  may be partially or fully replaced by selling  $p$  to another destination  $h$  (Panel E); analogously, on the sourcing side,  $i$  can replace  $j$  by importing  $p$  from  $h$  (Panel F). We can also gauge  $i$ 's own substitutability: how often is  $j$  simultaneously supplied by another seller  $h$  (Panel G), or how often can  $j$  sell to other buyers  $h$  when  $i$  is the importer (Panel H)? Panels E–F capture partner substitution (can  $i$  switch away from  $j$  or vice versa?), whereas Panels G–H capture self substitutability (how replaceable is  $i$  as a seller/buyer). Asymmetries are informative—for instance, a high  $PSD_{ij}$  with a low  $OSD_{ij}$  signals many outside options for  $i$  but limited replaceability of  $i$  at  $j$ 's side.

Imposing the same restriction on the similarity side yields four “chain” motifs in which one country appears as an intermediate stage between the other and a third market (Panels N–Q). We refer to these as re-exports in a broad sense, allowing for transit or processing as long as the good remains within the same product line. Such chains are natural signatures of intra-industry relations and participation in global value chains (GVC), including entrepôt trade and hub-and-spoke logistics. When the data allow (e.g., HS chapters or rules of origin), one may distinguish passthrough from processing without altering the underlying motif logic.

The bottom row of [Figure 1](#) examines how  $i$  and  $j$  meet in a third market  $h$ . Complementarity here takes the form of indirect trade:  $i$  exports  $p$  to  $h$  while  $j$  imports  $p$  from  $h$  (Panels I and J), which we read as indirect exports to  $j$  and indirect imports from  $j$  through  $h$ . When both are exporters or both are importers, joint presence becomes a matching problem: they either supply the same destination  $h$  (Panel R) or source from the same origin  $h$  (Panel S). Because  $h$  is specific, these matching motifs are geography-informed versions of similarity: co-location in the same third markets has stronger strategic salience than abstract basket overlap—especially when  $h$  is a major market or a regional hub, where rivalry or alignment is most consequential.

## 2.2 Operationalization

The one-product, three-country illustration is still highly stylized: in practice, countries trade thousands of products and face close to two hundred potential partners. To assess the salience of the product-level motifs once the full set of goods and all third-country options

are considered, we define a family of measures as conditional probabilities that quantify how frequently each motif appears in the  $i$ – $j$  relationship, always from  $i$ 's point of view when evaluating  $j$  as a partner.

[Table 1](#) maps each panel of [Figure 1](#) into a probability over products (and, when relevant, over third countries  $h$ ). This organization keeps separate what is structurally feasible given roles (complementarity/similarity) from what is actually realized in observed flows, to which intensive margins can later be added as weights without altering the taxonomy.

To determine whether a country is specialized as an exporter or as an importer of product  $p$ , and to filter out marginal flows, we compute Revealed Comparative Advantage in exports for each country  $c \in \{i, j\}$  and product  $p$  ( $RCAX_{pc}$ ) as in [Balassa \(1965\)](#): a country is specialized in exporting  $p$  when the share of  $p$  in its exports exceeds the share of  $p$  in world trade. We apply an analogous notion to imports, defining Revealed Comparative Disadvantage as importer ( $RCDM_{pc}$ , [Ng and Yeats 1999](#)) when the share of  $p$  in a country's imports exceeds the share of  $p$  in world trade.

Let  $\mathcal{P}$  be the total number of products. We define diversifications (monadic base rates) as the probabilities of a country exporting a given product (downstream diversification) or importing it (upstream diversification):

$$DD_i = P(RCAX_{pi} = 1) = \frac{1}{\mathcal{P}} \sum_{p=1}^{\mathcal{P}} RCAX_{pi}; \quad DU_i = P(RCDM_{pi} = 1) = \frac{1}{\mathcal{P}} \sum_{p=1}^{\mathcal{P}} RCDM_{pi} \quad (1)$$

These proportions in  $[0, 1]$  capture, respectively, the extent of products for which country  $i$  is specialized as an exporter ( $DD_i$ ) and as an importer ( $DU_i$ ).

For country  $i$ , the Downstream Complementarity of  $j$  ( $CD_{ij}$ ) is the probability that products exported by  $i$  coincide with those for which  $j$  is specialized as an importer (Panel A). Conversely, the Upstream complementarity of  $j$  ( $CU_{ij}$ ) is the probability that products imported by  $i$  coincide with those for which  $j$  is specialized as an exporter (Panel B). These role-only conditions define the universe over which subsequent conditional probabilities are computed.

Resemblance in export baskets is captured by downstream similarity ( $SD_{ij}$ ), the probability that  $j$  exports the same products that  $i$  exports (Panel K). The import analogue is upstream similarity ( $SU_{ij}$ ), the probability that  $j$  imports the same products that  $i$  imports (Panel L). Downstream similarity reflects how close  $j$  is to  $i$  in the “product space” of [Hidalgo et al. \(2007\)](#).

These definitions are grounded in a unified structural logic. As detailed in [Appendix A](#), our framework treats the global economy as a typed bipartite network. In this context,

our Similarity motifs act as the country-level dual of the “Product Space” (Hidalgo et al. 2007), identifying structural peers through shared export roles. Simultaneously, our Complementarity motifs capture a distinct geometry: they correspond to directed paths connecting supply to demand, mapping the potential for exchange.<sup>3</sup> The appendix formally derives these two directed spaces—the “Country Space” and the “Complementarity Map”—demonstrating how product-level capabilities translate into the architecture of bilateral interdependence.

We define the realization indices as the shares of actually traded products among those in which the countries are structurally complementary to each other. The Downstream Realization Index ( $RID_{ij}$ ) is the share of complementary-destination products for which  $i$  actually exports product  $p$  to  $j$  (Panel C), while the Upstream Realization Index ( $RIU_{ij}$ ) is the share of complementary-source products for which  $i$  actually imports product  $p$  from  $j$  (Panel D). The Two-way Realization Index ( $RIT_{ij}$ ) requires that both countries are simultaneously specialized as exporter and importer and measures how often trade is realized in both directions for those products (Panel M).

Observed dyadic flows are coded in the binary indicator  $DX_{pij}$ , which equals one when exports of product  $p$  from  $i$  to  $j$  are positive and the link is role-consistent, i.e. when  $RCAX_{pi} = 1$  and  $RCDM_{pj} = 1$ ; otherwise  $DX_{pij} = 0$ . Realized flows are a selected subset of feasible links within the bilateral opportunity set, so conditioning on exporter-importer roles helps separate structural alignment from period-specific realizations.

Third-country relations allow us to study substitution. From the set of products currently exported from  $i$  to  $j$ , downstream partner substitutability ( $PSD_{ij}$ ) is the probability that  $i$  also ships  $p$  to an alternative destination  $h$  (Panel E), while upstream partner substitutability ( $PSU_{ij}$ ) is the probability that  $i$  can source  $p$  from an alternative supplier  $h$  instead of  $j$  (Panel F). We also consider how replaceable  $i$  is within the  $i \rightarrow j$  link: downstream own substitutability ( $OSD_{ij}$ ) asks how often  $j$  also imports  $p$  from another origin  $h$  (Panel G), while upstream own substitutability ( $OSU_{ij}$ ) asks how often  $j$  also exports  $p$  to other destinations  $h$  when  $i$  is the buyer (Panel H).<sup>4</sup>

Six *chain patterns* complete the picture, encompassing re-exports and indirect trade. On the similarity side, one country acts as an intermediate stage between the other and a third market (Panels N–Q). We use “re-exports” broadly to include pure transit (*entrepôt* trade) and processing, as long as the good remains within the same product line; where data permit

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<sup>3</sup>These measures are based on country networks proposed by Flores and Vaillant (2013) and Flores (2014).

<sup>4</sup>If the relevant role-only set is empty (e.g., no overlap between  $i$ 's exports and  $j$ 's import specializations), the denominator of the conditional probability is null; in those cases, we set the corresponding substitutability to one.

(e.g., HS chapters or rules of origin), one may distinguish passthrough from transformation without altering the motif logic. Complementarity in third markets appears as indirect trade:  $i$  exports  $p$  to  $h$  and  $h$  supplies  $j$  (Panel I), or  $j$  exports to  $h$  and  $h$  supplies  $i$  (Panel J).

Finally, joint presence in third markets turns similarity into a matching problem: when both countries are exporters, we record how often they ship  $p$  to the same destination  $h$  (Downstream Matching,  $TMD_{ij}$ , Panel R); when both are importers, we record how often they source  $p$  from the same origin  $h$  (Upstream Matching,  $TMU_{ij}$ , Panel S). Because  $h$  is explicit, these are geography-informed versions of similarity: co-location in the same third markets typically has greater strategic salience than abstract basket overlap, especially when  $h$  is a major final market or a regional hub.<sup>5</sup>

A useful corollary is that unconditional extensive-margin frequencies factor into “feasibility  $\times$  realization”. In the downstream direction, consider the event that  $i$  is specialized as an exporter and  $j$  as an importer in product  $p$  (i.e.,  $p$  belongs to the downstream opportunity set) and the event that  $i$  actually exports  $p$  to  $j$ . Because the downstream Realization Index is defined as the conditional frequency of realized exports within that opportunity set, the unconditional probability factorizes as

$$P(DX_{pji} = 1) = P(RCAX_{pi} = 1, RC DM_{pj} = 1) \times RID_{ij}.$$

An analogous expression holds upstream,

$$P(DX_{pji} = 1) = P(RCAX_{pj} = 1, RC DM_{pi} = 1) \times RIU_{ij},$$

and for two-way trade (and matching in third markets) using the corresponding opportunity sets and the two-way Realization Index  $RIT_{ij}$ . This makes explicit how our measures separate what is feasible (roles and opportunity sets) from what is realized (flows), and how they recombine multiplicatively when one is interested in unconditional frequencies.

### 2.3 Empirical strategy and data

Our empirical strategy is designed to move beyond aggregate statistics and identify the prevalence of specific micro-level trade structures within the global trade network. We treat international trade as a multi-layered network and search for recurring, theoretically meaningful subgraphs or trade motifs (Milo et al. 2002). These motifs correspond to the patterns of interdependence outlined in Figure 1.

For each ordered pair  $(i, j)$ , we quantify how frequently these motifs appear across the space

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<sup>5</sup>One could weight similarity by the ubiquity of buyers or sellers (how many countries export or import  $p$ ). We regard this as a second-order refinement and do not implement it in the baseline.

of traded products. The measures in [Figure 1](#) are computed by systematically counting motifs using the matrix algebra detailed in [Appendix B](#). For instance, detecting the “downstream match in third markets” motif (TMD)—where  $i$  and  $j$  both export the same product to a common partner  $h$ —reduces to matrix multiplication ( $DX \cdot DX'$ ). This operation counts every occurrence of the corresponding three-node, two-edge pattern across all third countries and products. By normalizing these counts over the relevant conditioning sets (e.g., products where both  $i$  and  $j$  have export specialization), we obtain the conditional probabilities that form our indicators.

The analysis is based on the BACI database provided by the Centre d’Études Prospectives et d’Informations Internationales (CEPII) ([Gaulier and Zignago 2010](#)). This dataset provides disaggregated bilateral trade data at the Harmonized System 6-digit product level, with annual frequency for the 1995–2024 period, covering over 200 polities. Our analysis restricts the sample to 182 countries observed during the whole period.<sup>6</sup> In all computations we aggregate to the HS 4-digit level, summing 6-digit flows within each 4-digit category.

### 3 The Changing Architecture of Interdependence: Global Motifs over Three Decades

This section presents the main descriptive properties of the proposed measures. We first examine their cross-sectional distributions for a recent year and then analyze their evolution since 1995 up to 2024.

[Figure 2](#) displays the distributions of all estimated measures for the full sample of country dyads in 2024. Most measures are highly right-skewed, with a large mass of observations concentrated near zero. This is particularly evident for more restrictive motifs such as Two-Way Realization Indices, all re-export patterns, and Matching in Third Markets. These complex forms of interdependence are present in the global trade network but remain rare events for the median country pair. By contrast, measures of potential—such as Complementarity—and especially Substitutability exhibit much wider and more uniform distributions. Partner Substitutability (both  $PSD$  and  $PSU$ ) often takes high values, suggesting that having alternative trade partners is a common feature of the international system.

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<sup>6</sup>BACI is constructed from the United Nations COMTRADE database but provides a crucial advantage by implementing a harmonization procedure. This procedure addresses the inconsistencies commonly found in mirror trade flows (i.e., the declared value of exports from country  $i$  to  $j$  often differs from the declared value of imports in  $j$  from  $i$ ). The methodology evaluates the reliability of each country’s reporting to provide a single, reconciled value for each trade flow, while also homogenizing quantities and adjusting values to a Free on Board (FOB) basis to account for transportation and insurance costs.

Several pairs of distributions are identical. For example, the distribution of downstream Partner Substitutability (*PSD*) is a mirror image of upstream Own Substitutability (*OSU*), and the same applies to *PSU* and *OSD*. This is an expected consequence of our measurement framework. By construction,  $PSD_{ij}$  is equivalent to  $OSU_{ji}$ . When we aggregate across all country dyads, the set of all  $(i, j)$  pairs coincides with the set of all  $(j, i)$  pairs. The overall distributions of these measures must therefore match, reflecting this inherent symmetry in the complete dyadic dataset.

Figure 3 reports the evolution of the world-average values of our indicators over the sample period. As a coarse aggregate, this average necessarily masks substantial heterogeneity across countries and dyads; its purpose is to highlight broad, long-run shifts in the architecture of trade interdependence that are common to the system as a whole. The observed trends are consistent with the progressive deepening (and partial reconfiguration) of globalization and trade interdependence over the sample period. While downstream diversification flattens and slightly declines—pointing to increasing specialization in what countries successfully place abroad—upstream diversification rises steadily, suggesting an expanding and increasingly varied set of imported inputs and origins used for production. This asymmetry is mirrored in composition: downstream similarity falls (export baskets become more differentiated), whereas upstream similarity rises (import baskets become more alike), consistent with a world in which access to a broadly shared menu of intermediate inputs, technologies, and capital goods becomes more widespread even as countries differentiate in the tasks, varieties, and stages they supply to external markets. Importantly, potential complementarity does not expand in tandem: it remains broadly stable downstream and declines upstream, indicating that globalization has not primarily operated by generating ever more idiosyncratic bilateral “fits”, but rather by thickening markets and intensifying competition among alternative suppliers within a more integrated trading system.

Against this backdrop, the realization indices increase (more clearly for one-directional than for two-way links), implying a rising ability to convert feasible matches into observed trade relationships as trade costs fall, information improves, and the policy and institutional environment facilitates cross-border exchange. These developments naturally connect to the expansion of rules-based trade and successive waves of liberalization, as well as to later episodes in which policy shifts reallocate, rather than reverse, integration patterns. Network-oriented measures reinforce this interpretation: substitutability rises in both roles, re-exports and indirect trade become more prevalent, and co-presence in third markets intensifies. Taken together, the evidence points to a densification of networked interdependence: direct bilateral dependence may become less exclusive as alternative partners proliferate, yet vulnerability and leverage can migrate toward nodes, intermediation layers, and upstream inputs that are broadly shared—features that are central to contemporary

debates on geoeconomic competition and the use of trade policy as a strategic instrument.

Finally, we verify the statistical and empirical consistency of these patterns. [Appendix C](#) presents the correlation matrix for all motifs, confirming that the complex forms of interdependence (such as substitutability and rivalry) are not merely linear functions of the baseline potentials (complementarity or similarity), but capture distinct structural information. For a more concrete view of how these motifs map onto the current global economy, [Appendix D](#) reports the top-10 country and dyadic rankings for each indicator in 2024, illustrating the empirical manifestations of these structural roles.

## 4 Links to traditional measures in the literature

This section situates our motif-based indicators within existing approaches to trade structure and economic interdependence. A key contribution of the framework is to dissect traditional aggregate indices into their structural components—roles, realizations, and third-party triadic patterns.

Our aim is twofold: to show how the concepts developed above—diversification, similarity, complementarity, realization, substitutability, chain patterns, rivalry—relate to familiar indices in the literature, and to clarify what is genuinely new in this framework. We proceed in a modular fashion: we link our country–space constructions to the product-space and other network representations of trade; relate diversification to classical concentration indices used as proxies for vulnerability; compare our complementarity indices to established value-based measures; connect our substitutability indicators to work on exit options and power asymmetries; and, finally, position realization indices, chain motifs, and rivalry measures vis-à-vis gravity-based notions of trade potential and global value-chain metrics.

For expositional reasons, and because most classical indices are defined over export structures, the discussion in this section focuses on the downstream variants of our measures (e.g.  $DD_i$ ,  $CD_{ij}$ ,  $SD_{ij}$ ,  $RID_{ij}$ ). All results, however, have direct upstream counterparts obtained by swapping exporter and importer roles (e.g.  $DU_i$ ,  $CU_{ij}$ ,  $SU_{ij}$ ,  $RIU_{ij}$  and their associated chain and matching motifs). The literature offers only fragmentary guidance on these upstream dimensions—typically through import concentration measures or occasional applications of similarity indices to import baskets—so the framework proposed here can be read as extending existing tools in a direction that is especially relevant for questions of supply security, dependence on critical inputs and “de-risking” strategies.

## 4.1 Diversification and classical concentration indices

Diversification is the starting point of our approach to economic interdependence. What matters is not only how much a country trades, but in how many product lines it can act as a competitive exporter or structurally dependent importer. Our diversification indicator summarizes this extensive-margin footprint: it counts the share of products in which a country plays a given role, capturing the breadth of its specialization pattern rather than the concentration of trade values. This role structure underpins all subsequent concepts in the framework: it determines the scope of bilateral opportunity sets, shapes the extent of possible complementarities and similarities with partners, and sets an upper bound for realization, vulnerability, and substitutability measures. Before turning to bilateral motifs, it is therefore useful to relate diversification to classical concentration indices in the interdependence literature.

Two classical measures in the interdependence literature are closely related to this notion, albeit from a complementary perspective. The first is Hirschman's *trade partner concentration index* (Hirschman 1980), originally proposed as an indicator of vulnerability to a disruption of trade relations (see [Appendix E](#) for formal definitions). A second benchmark is the *commodity concentration of exports* (Rosecrance and Stein 1973), which measures how strongly a state depends on a narrow basket of goods. As Blanchard and Ripsman (1996) emphasize, both indices have been used as indicators of trade-related vulnerability, in contrast to purely volumetric measures.

Our diversification indicator is conceptually close to these concentration measures, but differs in two important respects. First, it is defined over the role structure of the country in the product space: instead of weighting products by their export values, it classifies them according to whether the country exhibits a structural export (or import) advantage and then counts the share of products in which such roles are present. Second, it is explicitly anchored in the extensive margin: it registers in how many product lines a country is structurally positioned to trade, irrespective of how large the corresponding flows are. In this sense, the diversification index can be viewed as a structural, role-based analogue to the commodity concentration of exports: both capture how broad or narrow a country's export base is, but one does so through value shares and the other through the pattern of specialization across products.

In the empirical analysis below, we exploit this connection by computing Hirschman's trade partner concentration index and the commodity concentration of exports for each country, and then examining their correlation with our diversification indicator.

[Figure 4](#) relates our role-based downstream diversification measure (DD) to two conventional, value-based concentration indices. The figure displays a clear and approximately monotonic

(log–linear) negative association: countries with higher structural diversification as exporters tend to exhibit lower concentration, both in terms of partner dependence and commodity dependence.

This pattern is consistent with the idea that a broader portfolio of export specializations (higher  $DD$ ) is associated with less reliance on a narrow set of destinations or a small set of goods in value terms. Conversely, high concentration is primarily observed among low- $DD$  economies, indicating that narrow export role portfolios are often linked to dependence on a limited set of markets or products. Dispersion remains visible at low levels of  $DD$  (e.g.,  $DD < 0.2$ ): some specialized economies are extremely concentrated—typical of resource- or market-dependent exporters—whereas others display lower concentration despite limited structural diversification, reflecting more fragmented but small-scale export profiles. Overall, the figure suggests that extensive-margin capabilities are a strong structural correlate of classic intensive-margin proxies of vulnerability, while remaining conceptually distinct because  $DD$  is defined from specialization roles rather than mechanically from trade values.

This pattern underscores the specific contribution of our measure. While classical indices capture *realized* financial dependence (the intensive margin), our Diversification index captures *structural* capacity (the extensive margin). The fact that the measures are not perfectly correlated confirms that  $DD$  contains independent information about state resilience—specifically, the breadth of the productive portfolio—that is not visible when looking solely at aggregate export shares.

## 4.2 Other measures of trade complementarity

In this section, we situate our proposed Complementarity Downstream measure ( $CD_{ij}$ ) within the broader tradition of trade indices. Specifically, we compare our role-based approach against two established benchmarks that rely on trade values: the Trade Intensity index decomposed by [Anderson and Nordheim \(1993\)](#) and the Index of Trade Compatibility by [Michaely \(1996\)](#) (refer to [Appendix E](#) for full derivations).

The [Anderson and Nordheim \(1993\)](#) index measures *intensity* by weighing the match between export and import shares relative to the world average. A value greater than 1 implies the dyad trades more intensely in products where they have a dual advantage relative to the global norm. Conversely, [Michaely \(1996\)](#) offers a measure of *compatibility* bounded between 0 and 1, capturing the geometric intersection of trade interests. It proxies how well the supply structure of one nation maps onto the demand structure of another in value terms.

We computed these two benchmarks for the full universe of dyads, utilizing the same harmonized BACI data and aggregation level (HS-4 digit) employed for our structural

measures. [Figure 5](#) presents the relationship between our role-based Complementarity ( $CD_{ij}$ ) and these value-based indices.

The results reveal a robust, albeit non-linear, relationship between structure and value. The left panel shows that  $CD_{ij}$  is a strong predictor of the Michaely Compatibility Index. The relationship follows a saturation curve: at low levels of structural complementarity, small increases in overlapping roles translate into rapid gains in basket compatibility. However, as  $CD$  exceeds 0.6, the Michaely index tends to plateau. This suggests that structural complementarity is a *necessary condition* for compatibility—one cannot have overlapping value shares without overlapping roles—but once the structural potential is high, the precise value match is determined by other factors (e.g., prices, preferences).

The right panel compares  $CD_{ij}$  against the logarithm of the Anderson & Nordheim index.<sup>7</sup> Here, we observe a positive log-linear relationship. Higher structural complementarity is systematically associated with higher trade intensity relative to world trends.

Overall, these correlations validate our measure. Even though  $CD_{ij}$  ignores the value of flows and focuses solely on the extensive margin of specialization, it recovers the broad patterns of compatibility and intensity found in traditional value-based metrics. This suggests that  $CD_{ij}$  captures the underlying structural architecture that constrains and shapes observed trade flows.

### 4.3 Export Similarity: Roles vs. Values

In the literature on trade competition and political alignment, the degree to which two countries possess similar export structures is typically proxied by value-based indices. The most common is the Finger-Kreinin (FK) index ([Finger and Kreinin 1979](#)), which sums the minima of export shares for each product (see [Appendix E](#)). The FK index conflates the *intensity* of specialization (how much  $p$  dominates the basket) with the *overlap* of baskets. An alternative approach relies on the correlation of export vectors, as proposed by [Arad and Hirsch \(1981\)](#), which captures the linear association between the export baskets of countries  $i$  and  $j$ . While providing a summary statistic of structural alignment, these benchmarks differ from our Similarity Downstream ( $SD_{ij}$ ) in two fundamental ways. First, they are inherently symmetric, obscuring hierarchical “nesting” patterns. Second, they rely on continuous value shares, heavily weighting top-export products, whereas  $SD_{ij}$  operates on the extensive margin of roles as a directional conditional probability.

[Figure 6](#) relates our role-based similarity measure, Similarity Downstream ( $SD_{ij}$ ), to two

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<sup>7</sup>We use the logarithm because the raw AN93 index is highly right-skewed, with extreme values driven by thin global markets.

standard value-based benchmarks of export overlap: the Finger–Kreinin (FK) index and cosine (vector) similarity, computed at the 4-digit level. Both panels display a clear but far from one-to-one positive association. The Lowess smoothers increase steeply for small values of  $SD_{ij}$  and then flatten out, indicating that higher overlap in export roles is associated with higher value-based similarity, albeit with diminishing marginal gains.

At the same time, the scatterplots reveal substantial dispersion, especially at low  $SD_{ij}$ : dyads with limited role overlap can still exhibit moderate or even high FK/cosine similarity, consistent with the fact that these benchmarks are symmetric and heavily influenced by the intensive margin of a few top products. Conversely, high  $SD_{ij}$  is rarely accompanied by very low value-based similarity, suggesting that extensive-margin overlap in roles is a strong correlate of conventional similarity measures while remaining conceptually distinct due to its directional, role-based construction.

This pattern reveals a crucial structural feature of global trade: high structural similarity ( $SD \approx 1$ ) frequently coexists with low value similarity ( $FK \approx 0$ ). Two countries may exhibit RCA in the same set of products—inhabiting the same region of the Product Space—yet display very different export compositions in value terms. For instance, two diversified industrial economies may both be competitive in the automotive and aerospace sectors (high  $SD$ ), while one derives most export revenue from cars and the other from aircraft, resulting in low FK and cosine scores.

Our measure therefore captures the potential overlap of capabilities, serving as an indicator of structural isomorphism. Traditional indices instead capture the realized overlap of financial dependence. The lack of collinearity between these measures shows that  $SD$  provides distinct information: it identifies “structural peers” even when their current export revenues are concentrated in different sectors.

A fundamental theoretical distinction of our framework is directionality. Traditional indices like Finger-Kreinin and Vector Correlation are inherently symmetric ( $FK_{ij} = FK_{ji}$ ), implicitly assuming that similarity is a mutual property. In contrast, our conditional probability definition allows for asymmetry ( $SD_{ij} \neq SD_{ji}$ ), capturing hierarchical or “nesting” patterns common in the global economy.

For instance, a diversified industrial economy ( $i$ ) may encompass the export portfolio of a smaller, specialized neighbor ( $j$ ). In this case,  $j$ 's roles are a subset of  $i$ 's ( $SD_{ji} \approx 1$ ), but the reverse is not true ( $SD_{ij} < 1$ ). While symmetric indices average out this relationship, obscuring the hierarchy, our measure exposes the directional containment of productive capabilities. (See Appendix B for the empirical test of asymmetry).

Finally, our framework naturally extends this logic to the import side via Upstream Similarity ( $SU_{ij}$ ). Traditionally, similarity in demand structures—central to the [Linder \(1961\)](#)

hypothesis—has been proxied by differences in GDP *per capita* or by applying Finger-Kreinin to import baskets. Our *SU* measure provides a granular, role-based alternative. It identifies pairs of countries that structurally rely on the same inputs or consumer goods, creating a metric for “shared structural dependence” that, like its downstream counterpart, preserves valuable information on directionality and asymmetry that standard proxies ignore.

#### 4.4 Realization indices over the bilateral opportunity set

Our Realization Indices (downstream *RID* and upstream *RIU*) directly engage with the literature that decomposes trade flows into intensive and extensive margins (Hummels and Klenow 2005; Felbermayr and Kohler 2006). In our setting, the extensive margin is defined with respect to a bilateral opportunity set: for a given ordered pair  $(i, j)$ , we consider the products in which  $i$  has an export advantage and  $j$  has an import advantage. This opportunity set summarizes the structural scope for bilateral trade at the extensive margin.

The downstream and upstream Realization Indices provide a static measure of how much of this bilateral opportunity set is actually activated in trade at a given point in time.  $RID_{ij}$  and  $RIU_{ij}$  can be interpreted as *realization rates* of a potential extensive-margin relationship: conditional on structural complementarity between exporter and importer, they quantify the fraction of product-level opportunities that materialize as actual trade flows.

This interpretation provides a crucial distinction from aggregate trade values. A bilateral relationship can display a high total trade value (a strong intensive margin) but a low Realization Index (a weak extensive margin) if exchanges are concentrated in just a few high-volume products. Conversely, a relationship with a high Realization Index is one that is highly *complete*, in the sense that the potential for trade is realized across a wide variety of structurally complementary products. Our measures therefore isolate the extensive margin over the bilateral opportunity set, offering a structural view of the breadth of a trade relationship that is obscured when looking at total traded values alone. The two-way Realization Index,  $RIT_{ij}$ , introduced below, builds on these directional measures to provide a symmetric summary of the bilateral realization of trade potential.

Our realization indexes are conceptually related to Hausmann and Hidalgo’s density measure in the product space, which captures the share of nearby opportunities that a country has already “activated” through revealed comparative advantage. They also parallel gravity-based measures of realized trade potential and preference utilization rates in trade agreements, in that they express actual outcomes as a fraction of an underlying opportunity set. The novelty here is to construct this opportunity set at the product level for each ordered country pair, based on exporter–importer roles, and to measure the density of realized bilateral links within that structurally feasible set of extensive-margin opportunities.

#### 4.4.1 Inter-Industry Trade and Gravity: Decomposing Friction

Classical trade theory posits that differences in factor endowments create the potential for trade ( $CD$ ), but as established by the gravity literature, physical and policy frictions determine its realization ( $RID$ ) and final value (Deardorff 1998; Anderson and van Wincoop 2003). If our distinction between structure and realization is empirically valid, standard gravity variables like distance should primarily affect the latter, leaving the structural potential relatively untouched.

To test this, we estimate structural gravity models comparing the standardized determinants of three outcomes: structural Potential ( $CD$ ), extensive-margin Realization ( $RID$ ), and traditional Trade Value. Figure 7 reports the results from pooled OLS regressions with high-dimensional fixed effects (absorbing origin-year and destination-year multilateral resistances).

The results reveal a striking dichotomy. Geographic distance acts as a powerful friction on Trade Value and Realization, exhibiting large negative coefficients. In comparison, its impact on structural complementarity is minimal. This confirms that resource endowments are spatially distributed in a way that is relatively invariant to distance compared to trade flows, consistent with endowment-based theories rather than agglomeration effects. On the other hand, the activation of those links is heavily constrained by geography.

Interestingly, *contiguity* shows a positive effect on all three dimensions, but the impact on realization is significantly larger than on structure. This suggests that while neighbors may share some complementary endowments (perhaps due to regional value chains), the primary benefit of proximity lies in reducing the costs of realizing that potential.

Regarding trade policy, Regional Trade Agreements (RTAs) show a positive association across all three dimensions. The positive coefficient on Structure ( $CD$ ) likely reflects a selection effect: countries are more prone to formalize agreements when they already possess complementary endowments. However, the crucial validation of our framework lies in the contrast with the geographic variable: while policy aligns with structure, physical distance suppresses realization without altering the underlying potential.

#### 4.4.2 Intra-Industry Trade and Grubel-Lloyd: Validating RIT

The second branch of our framework addresses Intra-Industry Trade (IIT), driven by product differentiation and economies of scale. Here, the structural precondition is not difference, but similarity ( $SD$ ). The realization of this potential is captured by the Two-Way Realization Index ( $RIT$ ).

Figure 8 validates this logic against the standard Grubel-Lloyd (GL) IIT index (see Appendix E

for the formal definition). The left panel shows that structural Similarity ( $SD$ ) acts as a necessary condition: dyads with low  $SD$  systematically exhibit GL indices near zero (the empty upper-left quadrant). If two countries do not share overlapping roles in the product space, they lack the structural basis for horizontal exchange.

However, similarity is not sufficient, it represents only the potential. The middle panel shows that the realization rate ( $RIT$ , in log scale) is positively associated with observed IIT. The most powerful predictor, however, is the interaction of both dimensions. The right panel demonstrates that “Realized Similarity” ( $SD_{ij} \times RIT_{ij}$ ) serves as a robust linear predictor of the observed GL index. Just as  $RID$  activates the potential for inter-industry trade,  $RIT$  captures the activation of overlapping roles into two-way flows. By disentangling these components, our framework offers a unified micro-foundation for both inter- and intra-industry trade patterns.

#### 4.5 Substitutability, vulnerability, and exit options

The concept of vulnerability is central to the study of economic statecraft, yet its empirical measurement has remained tied to proxies that conflate flows with structure. [Hirschman \(1980\)](#) foundational analysis posits that the power of country  $A$  over country  $B$  stems from the difficulty  $B$  would face in dispensing with  $A$ ’s trade. Dependence has traditionally been operationalized through indices of partner concentration (as discussed in [subsection 4.1](#)), under the assumption that reliance on a dominant partner equates to high vulnerability. [Baldwin \(1980\)](#) and [Keohane and Nye \(1977\)](#), however, stress that true vulnerability is defined by the availability and cost of “exit options”, not by current usage alone. A country may concentrate its exports in a single market for efficiency reasons while retaining the structural capacity to shift to alternative destinations. In this view, power resides in the asymmetry of exit options rather than in the sheer volume or concentration of flows.

[Crescenzi \(2005\)](#) “economic exit” model further formalizes this logic. The political constraints of interdependence arise not from the volume of exchange, but from the inelasticity of the relationship—specifically, the costs associated with switching partners. Coercive power exists only when one side faces prohibitive exit costs. Our Partner Substitutability measure  $PSD_{ij}$  provides a direct empirical proxy for this mechanism: a low  $PSD_{ij}$  score implies a structural inability to replace partner  $j$ , creating the conditions for the political vulnerability described by Crescenzi. Conversely, high substitutability signals a structural position in which interdependence is politically benign because exit is feasible.

[Blanchard and Ripsman \(1996\)](#) seek to operationalize this distinction through a multidimensional qualitative framework. Measuring vulnerability, they argue, requires evaluating the “potential for substitution”: the availability of alternative suppliers for imports,

alternative markets for exports, and domestic capacity to replace foreign supplies. While conceptually robust, their approach relies on case-specific coding (for example, classifying goods as strategic based on domestic capacity), which limits systematic quantitative analysis across the global network.

More recently, a nascent strand of literature driven by policy concerns over “strategic autonomy” has sought to identify specific product-level dependencies, particularly within the European Union (European-Commission 2021; Bonneau and Nakaa 2020; Vicard and Wibaux 2023). Crucially, recent contributions in this vein have moved beyond simple import concentration to explicitly model substitution frictions. Méjean and Rousseaux (2024), for instance, refine vulnerability lists by incorporating the “stickiness” of trade relationships—a duration-based proxy for the difficulty of *ex-post* substitution—while Lefebvre and Wibaux (2024) extend concentration metrics to a multi-country comparison. However, these “bottom-up” approaches suffer from a reliance on ad-hoc thresholds (e.g.,  $HHI > 0.4$  or specific quantiles of stickiness) to generate binary lists of critical goods, making diagnoses sensitive to arbitrary cutoffs. Furthermore, they often require detailed domestic production data (such as *Prodcorn*) that is unavailable globally. In contrast, our framework provides a structural, continuous measure of substitutability derived solely from the topology of the global trade network, making it robust to threshold selection and applicable to any dyad without requiring granular industrial statistics.

The literature has therefore lacked a granular, scalable metric that captures exit options directly from observed trade and production patterns. Our Partner Substitutability measures ( $PSD_{ij}$ ,  $PSU_{ij}$ ) and Own Substitutability measures ( $OSD_{ij}$ ,  $OSU_{ij}$ ) provide precisely this structural quantification. By calculating the probability that a country possesses alternative partners  $h$  that are already structurally validated (matching RCA and RCD patterns), we move beyond static concentration measures. A country with high partner concentration (a high Hirschman index) but high  $PSD$  is sensitive but not structurally vulnerable, as the network offers immediate off-ramps. Conversely, low substitutability reveals a structural bottleneck. Incorporating the domestic diagonal in the opportunity set (as detailed in the methodology) allows  $OSU$  to capture the domestic resilience component emphasized by Blanchard and Ripsman—the ability to substitute imports with national production.

Figure 9 tests this distinction by plotting our Partner Substitutability measure ( $PSD$ , averaged by country) against the Hirschman Concentration Index for the year 2024. If concentration were a perfect proxy for vulnerability, we would expect a strong negative correlation (high concentration implies low options).

Instead, the data reveal that structural capacity is largely orthogonal to financial concentration. While major powers like China (CHN), the USA, and Germany (DEU) exhibit the expected

profile of high diversification and high exit options, the right-hand side of the chart reveals the distinct value of our measure.

Consider the contrast between Japan and countries like Hungary or Chile. All exhibit high partner concentration indices ( $H > 0.6$ ), indicating heavy reliance on a few dominant partners. However, Japan retains a high level of Partner Substitutability ( $PSD \approx 0.2$ ), structurally comparable to the United States. In the framework of [Keohane and Nye \(1977\)](#), Japan is sensitive due to its concentration, but structurally resilient because its diversified export roles provide latent exit options. Conversely, Hungary and Chile display low substitutability, indicating true structural vulnerability. This distinction validates  $PSD$  as a unique metric of state power that captures the latent capacity to switch partners, a dimension invisible to aggregate concentration indices.

It is worth noting that while we focus here on the export side to match Hirschman’s classic focus on market dependence, the logic applies symmetrically to the import side. Our Upstream Partner Substitutability ( $PSU$ ) measure captures “supply security”—the structural capacity to switch suppliers for critical imports—a dimension of vulnerability that has gained renewed prominence in the literature on weaponized interdependence ([Farrell and Newman 2019](#)) and supply chain resilience.

## 4.6 Chain Motifs and Global Value Chains

The fragmentation of production across borders has been a defining feature of international trade in recent decades ([Baldwin 2016](#)). The literature on Global Value Chains (GVCs) typically analyzes this phenomenon using Inter-Country Input-Output (ICIO) tables to trace value-added flows ([Koopman et al. 2014](#); [Johnson and Noguera 2012](#)). While indispensable for understanding income distribution, these accounting frameworks often operate at high levels of sectoral aggregation, obscuring the precise routing of goods. Our framework complements this value-based view with a topological perspective based on gross trade patterns at the product level.

Our “chain motifs” (Panels N-Q and I-J in [Figure 1](#)) identify specific triangular sequences of trade flows that are signatures of GVC activity. Specifically, they capture the extent to which a bilateral relationship serves as a bridge to third markets rather than a final destination.

In GVC terminology, “forward participation” refers to a country providing inputs that are processed by a partner and exported to a third country. Our Partner Re-Exports Downstream measure ( $PRD_{ij}$ ) captures the gross-trade extensive margin of this phenomenon. It measures the probability that, when country  $i$  exports product  $p$  to  $j$ , country  $j$  also exports that same product  $p$  to a third destination  $h$ . High values of  $PRD$  indicate that  $j$  acts as a hub or processing center for  $i$ ’s goods. While our measure relies on the same HS code (and thus

captures re-exportation, distribution, or intra-industry processing rather than cross-sector transformation), it provides a granular proxy for the logistical “middleman” role in value chains. We expect countries with high average  $PRD$  to exhibit high “Domestic Value sent to third economies” in TiVA data.

Conversely, “backward participation” involves using foreign inputs for exports. Our Indirect Trade Upstream ( $ITU_{ij}$ ) and Indirect Trade Downstream ( $ITD_{ij}$ ) motifs capture the triangulation where goods flow from an origin  $h$  to a partner  $j$ , and then to  $i$  (or from  $i$  to  $h$  to  $j$ ). This effectively maps the dependency on intermediaries. A relationship characterized by high Indirect Trade suggests that the dyad is not self-contained but relies on the logistical or productive contribution of third parties to connect supply and demand.

Finally, the Domestic Re-Exports ( $DRD_{ij}$  and  $DRU_{ij}$ ) motifs measure a country’s own propensity to act as an intermediary. A country  $i$  with high  $DRD$  systematically imports goods from various origins  $h$  and re-exports them to  $j$ . This is the structural definition of an *entrepôt* or a distribution hub (e.g., Singapore, Netherlands). Unlike TiVA measures which might net out these transient flows, our topological approach highlights them, acknowledging that the logistical capability to connect markets is a distinct form of structural power in the global network. Identifying these hubs is critical because, as recent general equilibrium analyses have shown, a country’s contribution to global welfare is increasingly determined by its capacity to intermediate value added rather than solely by its own production (Bosker and Westbrook 2024). Our motif-based measures provide a direct, topological identification of these structural intermediaries.

We validate our “Chain Motifs” by comparing them against benchmarks from the OECD Trade in Value Added (TiVA) database (Borin and Mancini 2019). We focus on two structural roles central to the GVC literature: originators (suppliers) and intermediaries (hubs). Forward integration typically involves exporting inputs that are then embodied in third countries’ exports; our downstream chain measures ( $DC_{ij}$ ,  $DRD_{ij}$ ) capture precisely the propensity to supply such inputs that subsequently reach other destinations. Conversely, backward integration—importing intermediates that feed into own exports—is reflected in upstream chain motifs ( $UC_{ij}$ ,  $DRU_{ij}$ ). Figure 10 (left panel) reveals a strong, systematic association between these motif-based indicators and TiVA-style forward/backward participation measures, suggesting that our topological approach recovers key GVC roles while preserving product-level granularity.

Conversely, “backward participation” refers to the foreign value added embedded in exports. Our Domestic Re-Exports Downstream ( $DRD$ ) motif captures the topological equivalent: the propensity to import and re-export goods within the same category. This is the structural definition of a logistic hub. As shown in Figure 10 (right panel),  $DRD$  correlates strongly with

the share of Foreign Value Added (FVA) in exports. This confirms that countries identified topologically as re-exporters are indeed those dependent on foreign content, validating *DRD* as a high-frequency proxy for downstream GVC integration without the lag of input-output tables.

#### 4.7 From Similarity to Rivalry: Matching in Third Markets

While similarity indices (like our *SD* or the traditional Finger-Kreinin index) capture the potential for competition based on overlapping export portfolios, they remain spatially agnostic. In the lexicon of political economy, similarity represents latent rivalry. However, for trade competition to manifest as political friction, actors must not only produce the same goods but collide in the same specific markets.

Our Match in Third Markets motif (*TMD*) operationalizes this active rivalry. This distinction is crucial for unbundling the mechanisms linking trade to conflict (Goenner 2004). Two nations may possess identical endowments (high *SD*) yet serve disjoint regions of the global economy, effectively segmenting the market and minimizing friction. Conversely, structurally dissimilar nations may collide intensely if their few overlapping sectors are concentrated in the same strategic battleground markets.

We propose that *TMD* is a more precise predictor of trade politicization than aggregate similarity. High values of *TMD* imply a zero-sum contest for market share in specific jurisdictions, increasing the incentives for defensive trade remedies or formal adjudication. To test this hypothesis, we examine the determinants of formal trade disputes at the World Trade Organization (WTO).

We construct a panel dataset of directed dyads covering the period 1995–2024. Our dependent variable,  $Dispute_{ijt}$ , is a binary indicator that equals one if country  $i$  (the complainant) initiates a WTO dispute against country  $j$  (the respondent) in year  $t$ . We sourced the complete history of disputes from the WTO official registry, identifying 1,023 active dispute-year onsets after expanding European Union cases to its member states to match our bilateral trade data structure.

Our identification strategy relies on estimating the probability of a dispute onset as a function of the structural motifs. We employ a Firth Logit estimator to account for the rarity of trade disputes relative to the universe of peaceful trading relations. All explanatory variables are standardized (Z-scores) and lagged by one year ( $t - 1$ ) to mitigate simultaneity concerns.

We estimate three models to test our theoretical mechanism. Model 1 (Baseline) includes trade volume and structural similarity (*SD*). Model 2 (Rivalry) adds our rivalry measure (*TMD*). Model 3 (Mechanism) introduces an interaction term ( $SD \times TMD$ ) to test whether the effect of rivalry depends on structural similarity.

Table 2 reports Firth Logit estimates as odds ratios. In the baseline specification (Column 1), trade volume is a strong positive predictor of dispute onset (OR = 4.473,  $p < 0.01$ ), while structural similarity is statistically indistinguishable from unity (OR = 1.030). Absent controls for specific competitive dynamics, the abstract overlap of productive capabilities does not appear to drive trade disputes.

Column 2 introduces our key explanatory variable: third-market rivalry ( $TMD$ ). The effect of similarity remains insignificant (OR = 0.967), whereas rivalry emerges as a powerful and highly significant predictor. A one-standard-deviation increase in  $TMD$  raises the odds of a WTO dispute by about 19% (OR = 1.191,  $p < 0.01$ ). This pattern suggests that similarity acts as a noisy proxy for rivalry in parsimonious models: it is not generic structural isomorphism that matters for conflict, but concrete collisions in specific third markets.

Column 3 provides evidence for the interaction mechanism. Both constitutive terms—similarity (OR = 1.160) and rivalry (OR = 1.338)—are positive and significant, while the interaction term  $SD \times TMD$  falls below unity (OR = 0.928,  $p < 0.01$ ). Substantively, the marginal impact of rivalry on the probability of dispute onset is strongest at intermediate levels of structural similarity and attenuates when countries become near-twins. Third-market competition is thus most combustible when states are neither fully specialized nor perfectly alike, but face each other as partially overlapping competitors in global markets.

Theoretical interpretation suggests that while rivalry is generally destabilizing, high levels of structural similarity might be correlated with deeper intra-industry integration or shared global value chains, which raise the opportunity costs of formal dispute initiation. Consequently, rivalry appears most particularly combustible not when countries are twins, but when they face high competition in third markets despite having somewhat distinct export structures.

## 5 Application: The United States and China

In this section, we apply our motif-based framework to one of the most consequential bilateral relationships in the contemporary global economy: the United States and China. Moving beyond aggregate trade values, which can be distorted by price effects and inertia, our structural measures reveal the underlying architecture of their interdependence.

### 5.1 Diverging Specialization Patterns

Figure 11 displays the Diversification indices ( $DD$  and  $DU$ ) for both nations. Far from converging, the monadic view reveals a striking pattern of structural divergence that accelerates after the mid-2000s.

In the mid-1990s, both powers started with roughly comparable levels of diversification. However, since roughly 2005, their trajectories have moved in opposite directions, creating a mirror image. The United States (blue line) has progressively specialized its export portfolio (declining  $DD$ ), shedding marginal export roles, while simultaneously broadening its import basket (rising  $DU$ ). This profile characterizes an economy that acts as a “buyer of last resort”, sourcing a wide variety of goods globally while concentrating its export advantages in fewer sectors.

China (red line), by contrast, displays the opposite dynamic. It has dramatically expanded its export diversification (rising  $DD$ ), cementing its role as the “factory of the world” capable of exporting across the entire product spectrum. Simultaneously, its import diversification has collapsed (falling  $DU$ ). This suggests a successful drive towards import substitution: China likely stopped importing a broad range of final goods (replacing them with domestic production) and concentrated its import structure on specific critical inputs and raw materials. The result is not convergence, but a sharp differentiation in global roles.

## 5.2 The Structural Architecture of the Relationship

Figure 12 turns to the dyadic motifs. The evolution of the structural indicators reveals a relationship undergoing a fundamental transformation, characterized by widening asymmetry and a shift from direct integration to global rivalry.

A fundamental shift is visible in the Complementarity (CD/CU) panels. While US capabilities have remained broad, the structural fit with China has deteriorated: US exports act less as a complement to Chinese imports today than they did in the early 2000s.

Crucially, the Partner Substitutability (PSD) motif reveals a growing asymmetry in power. Since 2010, the US has steadily increased its “exit options” when exporting to China, reducing its structural vulnerability (Baldwin 1980). China, conversely, has not achieved a comparable diversification of alternative partners for its sourcing from the US. The rising PSD for the US reflects a structural success in “derisking”: the US has effectively diversified its export destinations, reducing the leverage of any single partner, consistent with recent policies of strategic autonomy.

Finally, while direct complementarity falters, the “chain motifs”—including Domestic Re-exports ( $DRD$ ) and Indirect Trade ( $ITD$ )—point to persistent entanglement through third countries. Despite political tensions, the topological signatures of value-chain intermediation remain high, suggesting that indirect linkages are robust even as direct dependence is managed. The Match in Third Markets ( $TMD$ ) indicator also rises steadily over the period, indicating that the two powers increasingly collide as competitors in global markets.

### 5.3 Testing for Structural Decoupling

Is the US-China separation merely political, or is it structural? [Figure 13](#) compares the US metrics towards China against the US average towards the rest of the world. The Complementarity Downstream (CD) panel offers the strongest evidence of structural decoupling. While US structural complementarity with the world has remained relatively stable, its complementarity with China has collapsed since the mid-2000s. This implies that the baskets of goods the US exports and China imports are diverging fundamentally, independent of tariffs or trade wars.

Furthermore, the Match in Third Markets (TMD) motif displays a marked upward trend that mirrors the global average but at higher levels. This pattern signals a transformation in the nature of the relationship: US–China ties are shifting from bilateral integration to systemic rivalry. As direct structural ties erode (decoupling), competitive collisions in third markets intensify. Rather than simply separating, the two economies are becoming more deeply engaged in competition for global market share.

Finally, the Realization Index (RID) shows a notable divergence. While the US realizes a high share of its potential trade with the world average, its realization rate with China has historically been lower and shows signs of stagnation. This “missing trade”—potential links that are structurally feasible but inactive—may capture the friction of non-tariff barriers and geopolitical distance.

These aggregate trends indicate a shift towards managed dependence, but aggregate metrics can obscure sector-specific risks. To demonstrate the diagnostic flexibility of the framework, [Appendix F](#) applies the logic of the substitutability motif to construct a “Vulnerability Matrix” for the dyad. This application serves as an example of how the product-level components of our indicators can be used to identify critical products or partners in any of the proposed interdependence measures.

## 6 Conclusions

This paper has argued that interdependence is not a monolithic scalar of trade values but a complex architecture of roles, realizations, and third-party interactions. By decomposing trade into a set of structural motifs, we provide a unified framework that disentangles the potential for exchange from its realization and distinguishes simple sensitivity from structural vulnerability.

Our empirical findings challenge several conventions. We show that a large family of theoretically meaningful trade motifs can be computed efficiently from standard bilateral trade data using matrix algebra, treating international trade as a typed bipartite network between

countries and products. This approach recovers and extends several established constructs. Country-space similarity and complementarity measures are the dual of the original product space, while remaining fully compatible with it. Our realization indices provide a structural analogue to gravity-based notions of trade potential and to density measures in the product space. Chain motifs and indirect trade patterns offer a high-frequency, topological counterpart to value-added metrics from input-output tables. Substitutability measures implement, in a scalable and transparent way, the theoretical emphasis on exit options and power asymmetries that has long been central to the interdependence literature.

We document a set of empirical regularities that reshape how we think about vulnerability and rivalry. At the global level, complex forms of interdependence—such as two-way realization, chain motifs, and matching in third markets—remain rare for the median dyad but have become systematically more prevalent over the last three decades. Measures of potential (complementarity and, especially, partner substitutability) are much more widely distributed, indicating that the international system is characterized by a dense architecture of latent options even when realized ties are sparse. Classical concentration indices are, at best, noisy proxies for structural vulnerability: high partner concentration can coexist with ample exit options when a country's role structure is broad, while genuinely vulnerable states are those that combine concentrated flows with low substitutability. Likewise, traditional measures of export similarity often conflate structural overlap with realized value composition. Our role-based similarity indices reveal that countries can be “structural peers” in terms of capabilities even when their export revenues are concentrated in different sectors.

The paper provides a bridge between our motif-based indicators and existing measures in trade economics and international political economy. We show that role-based complementarity strongly predicts value-based compatibility and trade intensity, but in a non-linear fashion: structural potential is a necessary condition for high compatibility, yet once this potential is high, the distribution of values is shaped by other forces such as prices and preferences. Gravity exercises confirm that geographic frictions like distance primarily affect realization and trade value, while leaving structural complementarity largely untouched, whereas trade agreements are associated with both structure and realization. Our two-way realization index, combined with similarity, offers a unified micro-foundation for intra-industry trade as measured by Grubel-Lloyd indices. Chain motifs are systematically related to TiVA-style indicators of forward and backward participation in global value chains. Finally, matching in third markets proves to be a powerful predictor of WTO dispute onset: once we condition on rivalry in specific destinations, generic similarity loses explanatory power, and the combination of similarity and third-market matching sharply increases the probability of formal trade conflict.

The application to the United States-China relationship illustrates the substantive leverage

of this framework. Monadic diversification indices reveal not convergence but structural divergence: the United States increasingly specializes as an exporter while broadening its import base, whereas China expands its export roles and narrows its import structure. Dyadic motifs show that structural complementarity between the two powers has eroded even as their rivalry in third markets has intensified. Partner Substitutability measures indicate that the United States has progressively increased its exit options vis-à-vis China, while China's asymmetric dependence persists in several dimensions. Together, these patterns suggest that what is often described as “decoupling” is better understood as a reconfiguration toward managed direct dependence alongside heightened systemic rivalry.

Taken together, these results carry implications for how we theorize the relationship between interdependence, power, and conflict. First, they highlight the importance of distinguishing sensitivity from vulnerability and of measuring each at the appropriate level. High trade volumes or high concentration can signal exposure, but vulnerability depends on the structure of exit options captured by partner substitutability and own substitutability. States may willingly accept sensitivity when their structural position ensures that interdependence remains reversible. Second, the findings clarify that export similarity is not inherently destabilizing. Only when similarity is translated into matching in specific third markets does rivalry become politically salient, as countries collide over concrete jurisdictions rather than abstract product spaces. Third, our chain motifs underscore that power increasingly operates through control over logistical and network positions – hubs, intermediaries, and gatekeepers – rather than solely through bilateral dependence.

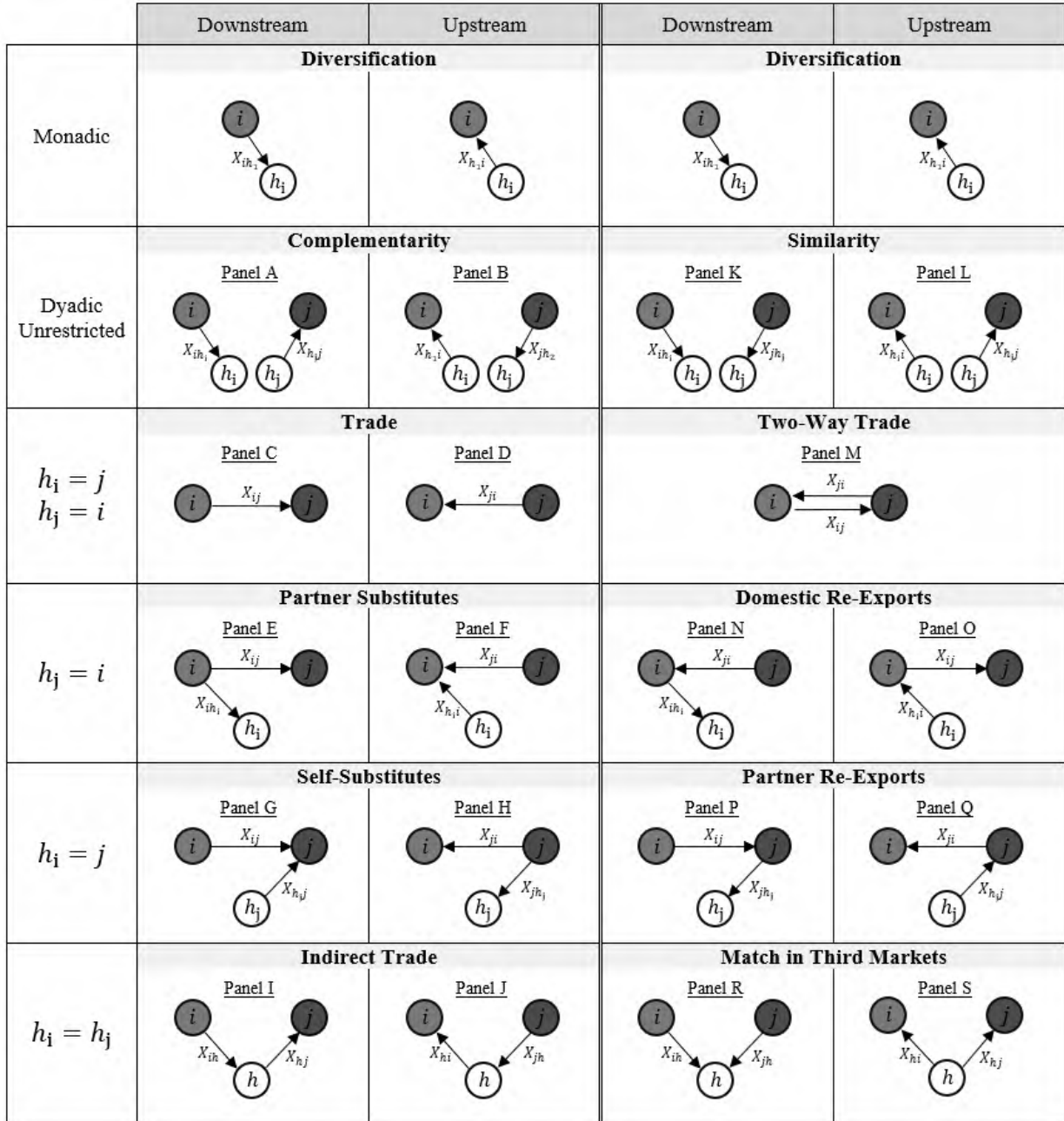
The framework also opens a number of avenues for future research. One natural extension is to embed these motif-based measures systematically into models of cooperation and conflict beyond WTO disputes, including alliance formation, sanctions, and crisis bargaining. A second is to exploit the temporal dimension of the data to study how shocks—financial crises, pandemics, regional wars—reconfigure the architecture of interdependence: which motifs are most brittle, which rewire quickly, and which generate persistent “scars” in the network. A third direction is to integrate firm-level or sectoral data, when available, to link the macro-network motifs documented here with micro-level strategies of multinational firms, state-owned enterprises, and global supply chain coordinators. Finally, the approach could be extended to services trade and to digital flows, where questions of interdependence and control are becoming central but measurement is even more challenging.

In sum, the analysis suggests that contemporary debates about globalization, decoupling, and weaponized interdependence cannot be adjudicated with aggregate trade values alone. What matters is not only how much countries trade, but how their specialization roles, outside options, and third-market interactions are structured across products and partners. By providing a coherent, empirically tractable language for these patterns, the framework

developed here aims to make the structure of interdependence—and the power it enables—an observable object, open to systematic comparison and theoretical scrutiny.

Finally, the framework we develop here opens several avenues for future work. One natural extension is to incorporate economically meaningful weights into the realization measures—for example by weighting products by trade value, by their strategic importance, or inversely by their global ubiquity—thereby linking the topology of diversification to questions of economic security and supply-chain resilience. A second direction is to restrict the analysis to critical product sets, such as minerals, dual-use goods, or bottleneck intermediate inputs, which would allow analysts to trace more precisely the sources of vulnerability underlying current debates on weaponized interdependence and de-risking. Beyond these extensions, the framework can also support country-level policy diagnostics by decomposing each measure into its product-level contributors, identifying which goods drive a country's realized diversification, its reliance on narrow upstream options, or its exposure to third-market rivalry. Finally, dynamic or country-product-partner versions of the measures would enable the study of how these patterns evolve in response to shocks, policy interventions, or the shifting architecture of global value chains. Altogether, these extensions underscore that the indices proposed here are not only descriptive tools but a flexible analytical framework for diagnosing the structure and strategic consequences of interdependence in the world economy.

Figure 1. Product-level trade relations and the role of third countries

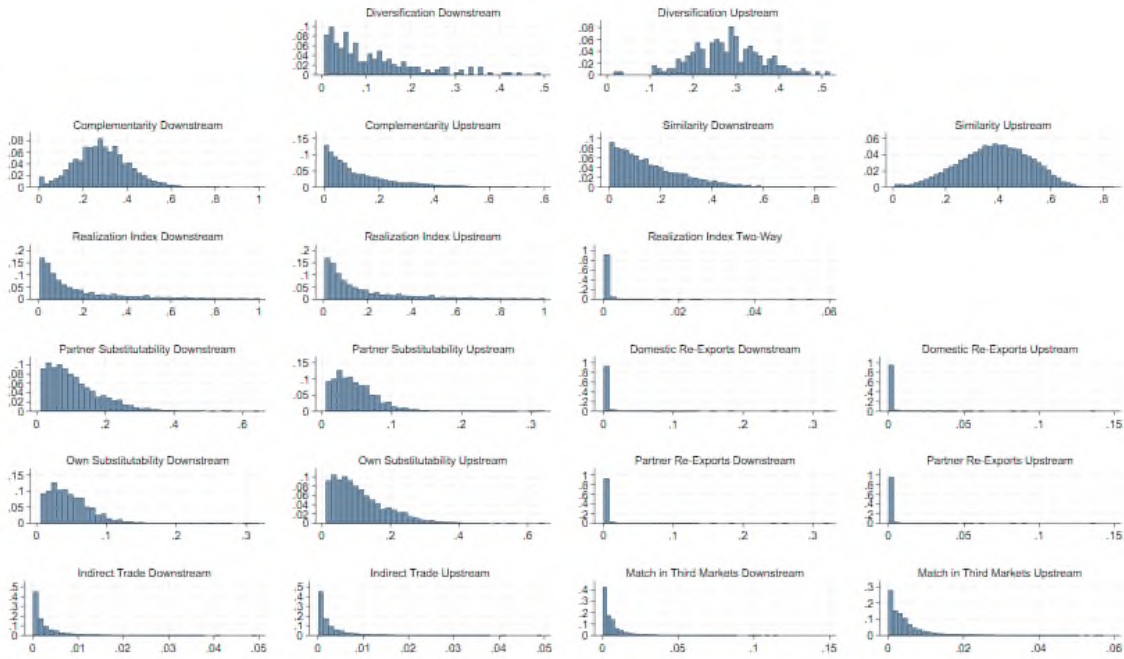


Source: Own elaboration.

Table 1. **Descriptive Measures of Trade Patterns**

	Downstream Diversification	$DD_i = P(RCAX_{pi} = 1)$ <i>Share of products for which <math>i</math> is specialized as an exporter</i>
	Upstream Diversification	$DU_i = P(RCDM_{pi} = 1)$ <i>Share of products for which <math>i</math> is specialized as an importer</i>
A	Downstream Complementarity	$CD_{ij} = P(RCDM_{pj} = 1 \mid RCAX_{pi} = 1)$ <i>If <math>i</math> is specialized as an exporter in <math>p</math>, how often is <math>j</math> specialized as an importer in the same <math>p</math>?</i>
B	Upstream Complementarity	$CU_{ij} = P(RCAX_{pj} = 1 \mid RCDM_{pi} = 1)$ <i>If <math>i</math> is specialized as an importer in <math>p</math>, how often is <math>j</math> specialized as an exporter in <math>p</math>?</i>
C	Realization Index Downstream	$RID_{ij} = P(DX_{pij} = 1 \mid RCDM_{pj} = 1, RCAX_{pi} = 1)$ <i>Among products where <math>j</math> is a complementary destination for <math>i</math>, in what share does <math>i</math> actually export <math>p</math> to <math>j</math>?</i>
D	Realization Index Upstream	$RIU_{ij} = P(DX_{pji} = 1 \mid RCAX_{pj} = 1, RCDM_{pi} = 1)$ <i>Among products where <math>j</math> is a complementary source for <math>i</math>, in what share does <math>i</math> actually import <math>p</math> from <math>j</math>?</i>
E	Partner Substitutability Downstream	$PSD_{ij} = P(DX_{pih} = 1 \mid DX_{pij} = 1, RCDM_{pj} = 1, RCAX_{pi} = 1)$ <i>If <math>i</math> currently exports <math>p</math> to <math>j</math>, how often does <math>i</math> also ship <math>p</math> to an alternative destination <math>h</math>?</i>
F	Partner Substitutability Upstream	$PSU_{ij} = P(DX_{phi} = 1 \mid DX_{pji} = 1, RCAX_{pj} = 1, RCDM_{pi} = 1)$ <i>If <math>i</math> currently imports <math>p</math> from <math>j</math>, how often can <math>i</math> source <math>p</math> from an alternative supplier <math>h</math>?</i>
G	Own Substitutability Downstream	$OSD_{ij} = P(DX_{phj} = 1 \mid DX_{pij} = 1, RCDM_{pj} = 1, RCAX_{pi} = 1)$ <i>If <math>i</math> exports <math>p</math> to <math>j</math>, how often does <math>j</math> also import <math>p</math> from another country <math>h</math>?</i>
H	Own Substitutability Upstream	$OSU_{ij} = P(DX_{pjh} = 1 \mid DX_{pji} = 1, RCAX_{pj} = 1, RCDM_{pi} = 1)$ <i>If <math>i</math> imports <math>p</math> from <math>j</math>, how often does <math>j</math> also export <math>p</math> to other destinations <math>h</math>?</i>
I	Indirect Trade Downstream	$ITD_{ij} = P(DX_{pih} = 1, DX_{phj} = 1 \mid RCDM_{pj} = 1, RCAX_{pi} = 1)$ <i>How often does <math>i</math> export <math>p</math> to a country <math>h</math> which in turn exports <math>p</math> to <math>j</math>?</i>
J	Indirect Trade Upstream	$ITU_{ij} = P(DX_{phi} = 1, DX_{pjh} = 1 \mid RCAX_{pj} = 1, RCDM_{pi} = 1)$ <i>How often does <math>i</math> import <math>p</math> from a country <math>h</math> which in turn imports <math>p</math> from <math>j</math>?</i>
K	Downstream Similarity	$SD_{ij} = P(RCAX_{pj} = 1 \mid RCAX_{pi} = 1)$ <i>If <math>i</math> is specialized as an exporter in <math>p</math>, how often is <math>j</math> also specialized as an exporter in the same <math>p</math>?</i>
L	Upstream Similarity	$SU_{ij} = P(RCDM_{pj} = 1 \mid RCDM_{pi} = 1)$ <i>If <math>i</math> is specialized as an importer in <math>p</math>, how often is <math>j</math> also specialized as an importer in the same <math>p</math>?</i>
M	Realization Index Two-way	$RIT_{ij} = P(DX_{pij} = 1, DX_{pji} = 1 \mid RCAX_{pi} = 1, RCDM_{pi} = 1, RCAX_{pj} = 1, RCDM_{pj} = 1)$ <i>Among products where <math>i</math> and <math>j</math> are specialized as importers and exporters, how often is trade realized in both directions?</i>
N	Domestic Re-Exports Downstream	$DRD_{ij} = P(DX_{pih} = 1 \mid DX_{pji} = 1, RCAX_{pi} = 1, RCAX_{pj} = 1)$ <i>Among products <math>p</math> where <math>i</math> and <math>j</math> are specialized as exporters and <math>j</math> exports <math>p</math> to <math>i</math>, how often <math>i</math> exports <math>p</math> to other countries?</i>
O	Domestic Re-Exports Upstream	$DRU_{ij} = P(DX_{phi} = 1 \mid DX_{pij} = 1, RCDM_{pi} = 1, RCDM_{pj} = 1)$ <i>Among products <math>p</math> where <math>i</math> and <math>j</math> are specialized as importers and <math>i</math> exports <math>p</math> to <math>j</math>, how often <math>i</math> imports <math>p</math> from other countries?</i>
P	Partner Re-Exports Downstream	$PRD_{ij} = P(DX_{pjh} = 1 \mid DX_{pij} = 1, RCAX_{pi} = 1, RCAX_{pj} = 1)$ <i>Among products <math>p</math> where <math>i</math> and <math>j</math> are specialized as exporters and <math>i</math> exports <math>p</math> to <math>j</math>, how often <math>j</math> exports <math>p</math> to other countries?</i>
	Partner Re-Exports Upstream	$PRU_{ij} = P(DX_{phj} = 1 \mid DX_{pji} = 1, RCDM_{pi} = 1, RCDM_{pj} = 1)$

Figure 2. Distribution of the estimated measures in 2024



Source: Own elaboration using BACI.

Table 2. The Impact of Third-Market Rivalry on WTO Dispute Onset

	(1) Baseline	(2) Rivalry	(3) Mechanism
xb			
Trade Volume (Log, t-1)	4.668*** (0.200)	3.661*** (0.160)	3.260*** (0.144)
Similarity (SD, t-1)	1.019 (0.020)	0.950** (0.021)	1.149*** (0.030)
Rivalry (TMD, t-1)		1.205*** (0.016)	1.356*** (0.021)
Interaction (SD x TMD)			0.926*** (0.008)
Observations	960596	960596	960596
Wald Chi2	1537.95	2166.37	2347.95

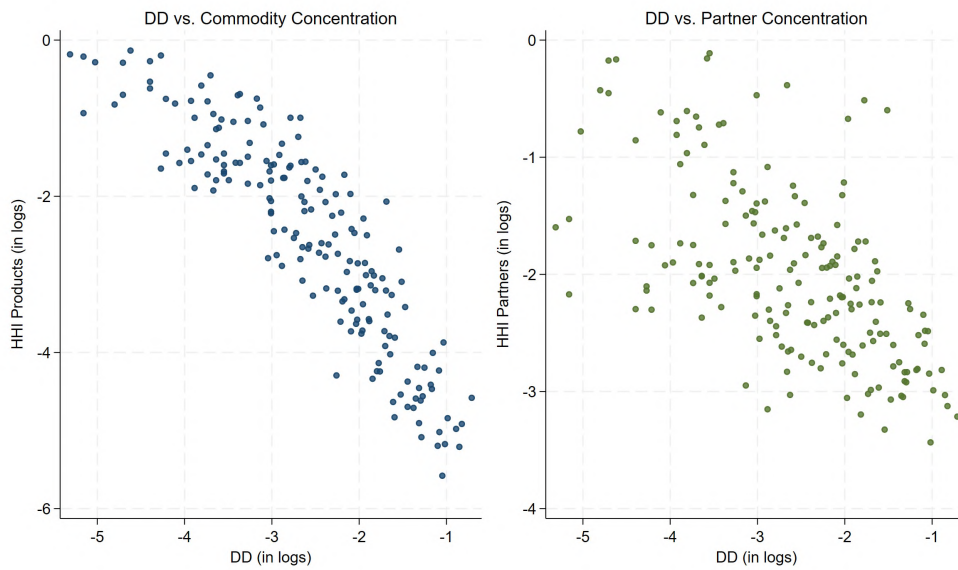
*Notes:* Firth Logit estimates reported as Odds Ratios. Standard errors in parentheses. All independent variables are standardized (Z-scores) and lagged by one year ( $t - 1$ ). Significance levels: \* 10%, \*\* 5%, \*\*\* 1%.

Figure 3. Evolution of the estimated measures (world average, 1995–2024)



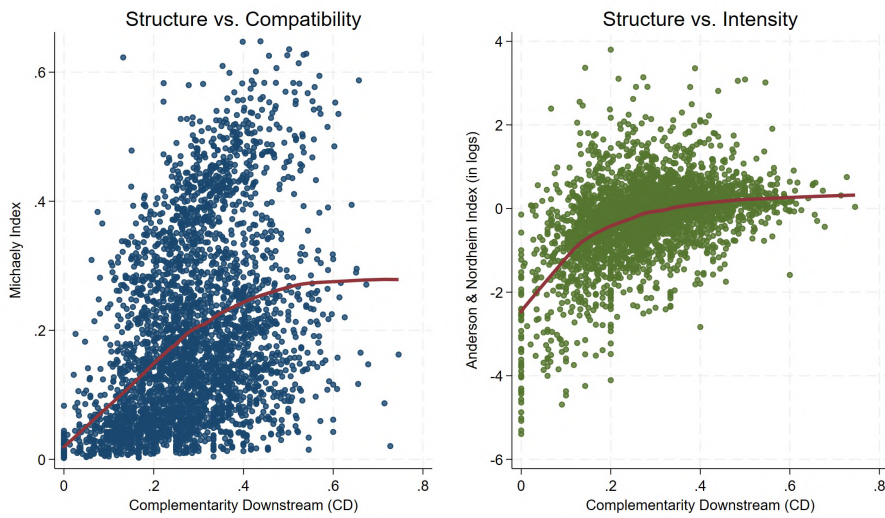
Source: Own elaboration using BACI.

Figure 4. Downstream Diversification vs. Value Concentration in 2024



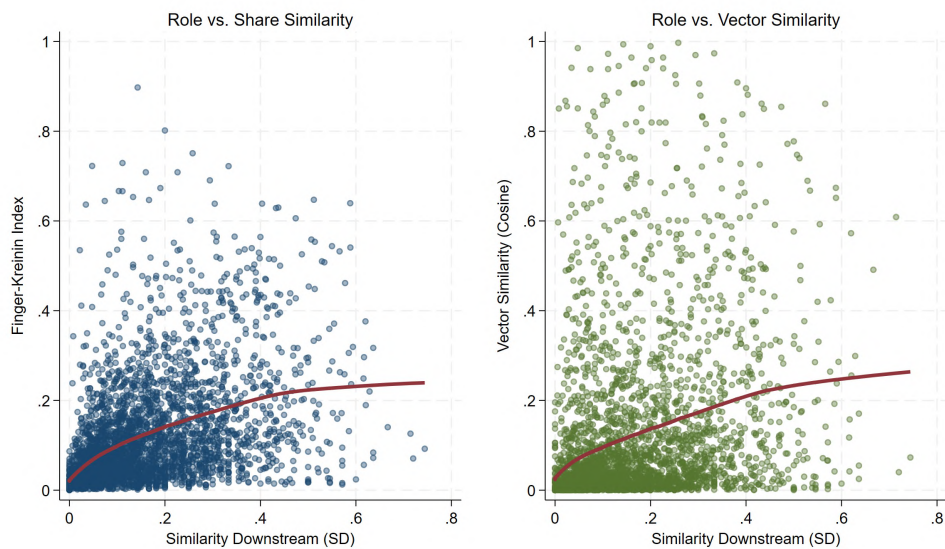
Source: Own elaboration using BACI. Each dot represents a country.

Figure 5. Comparison with Complementarity Benchmarks in 2024



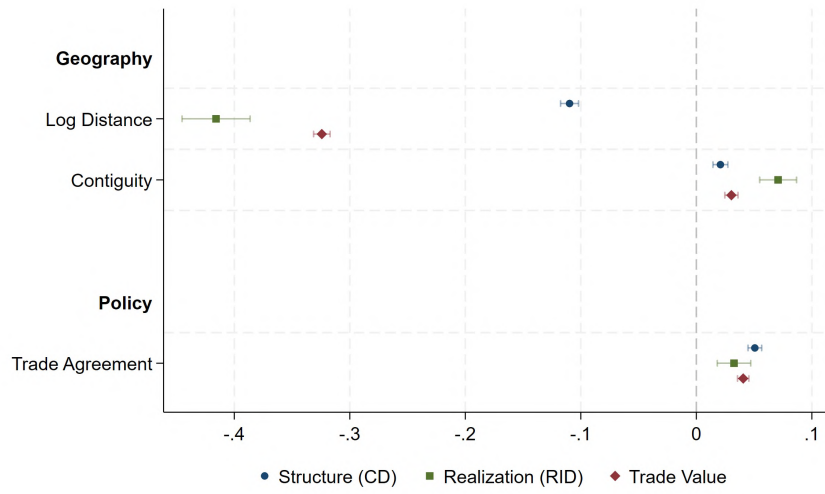
Source: Own elaboration using BACI. Each dot represents a dyad. Red lines are Lowess smoothers.

Figure 6. Comparison with Similarity Benchmarks in 2024



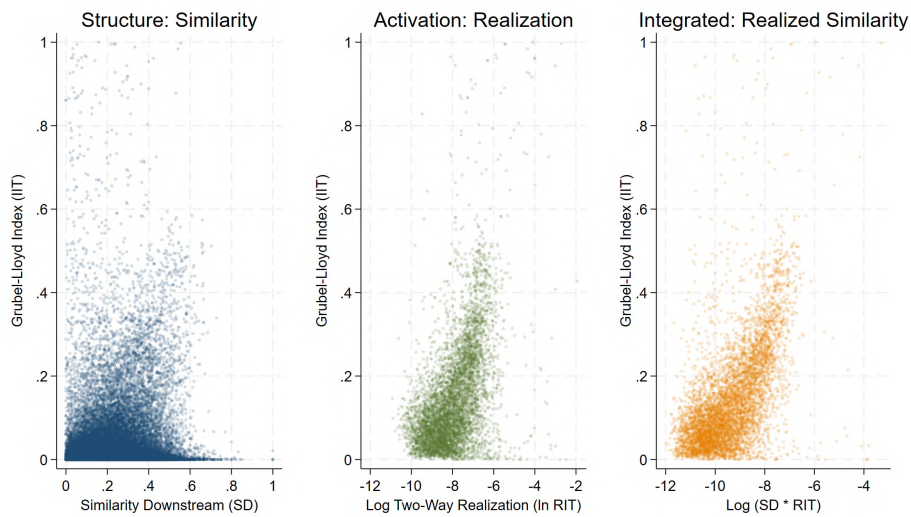
Source: Own elaboration using BACI. Each dot represents a dyad. Red lines are Lowess smoothers.

Figure 7. Gravity Decomposition



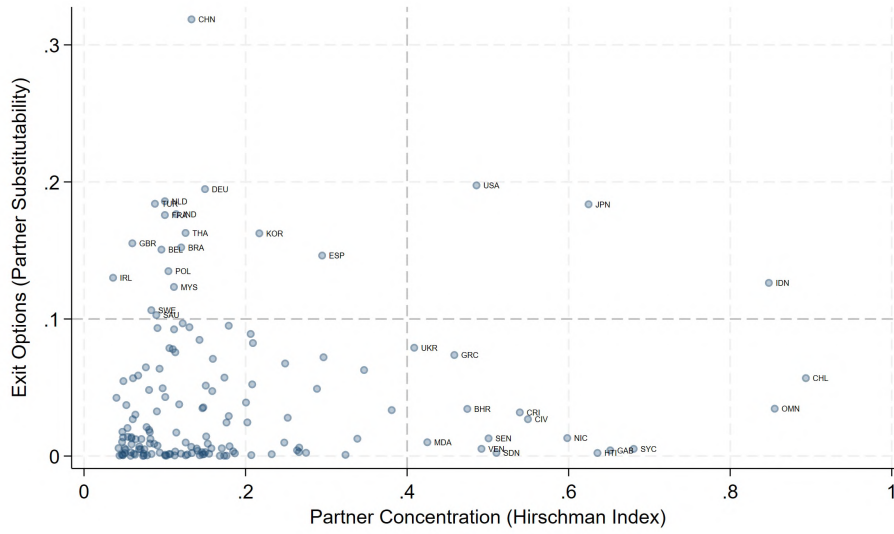
Source: Own elaboration using CEPII's BACI and Gravity databases (Conte et al. 2022). Standardized coefficients from structural gravity models with high-dimensional fixed effects, estimated using *reghdfe* in Stata (Correia 2016).

Figure 8. Structural Determinants of Intra-Industry Trade



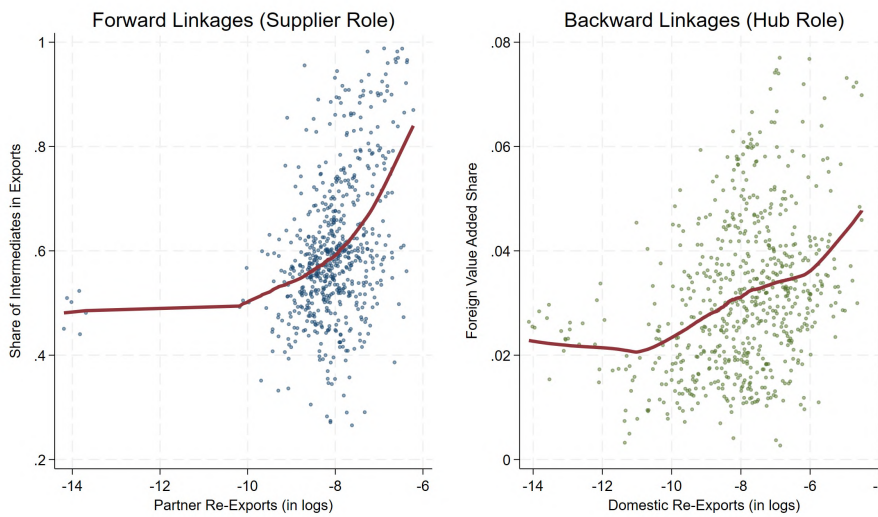
Source: Own elaboration using BACI.

Figure 9. Vulnerability: Concentration vs. Exit Options (2024)



Source: Own elaboration using BACI.

Figure 10. Topological Signatures of GVCs



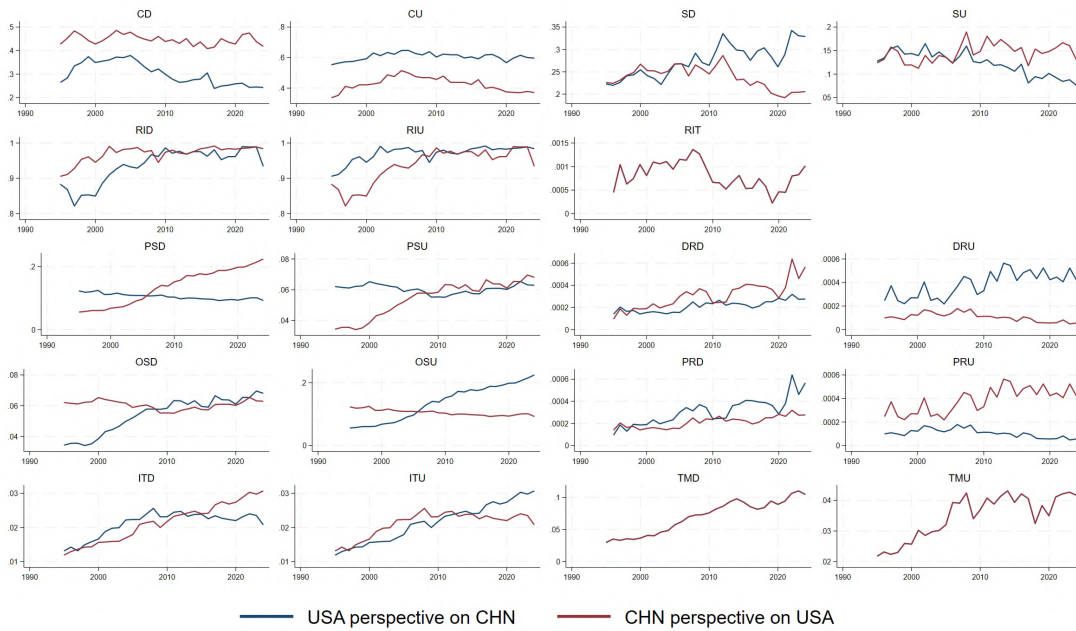
Source: Own elaboration using BACI. Notes: Pooled sample of all available years: 2000, 2005, 2010, 2015 and 2020.

Figure 11. Comparative Capabilities: Downstream and Upstream Diversifications



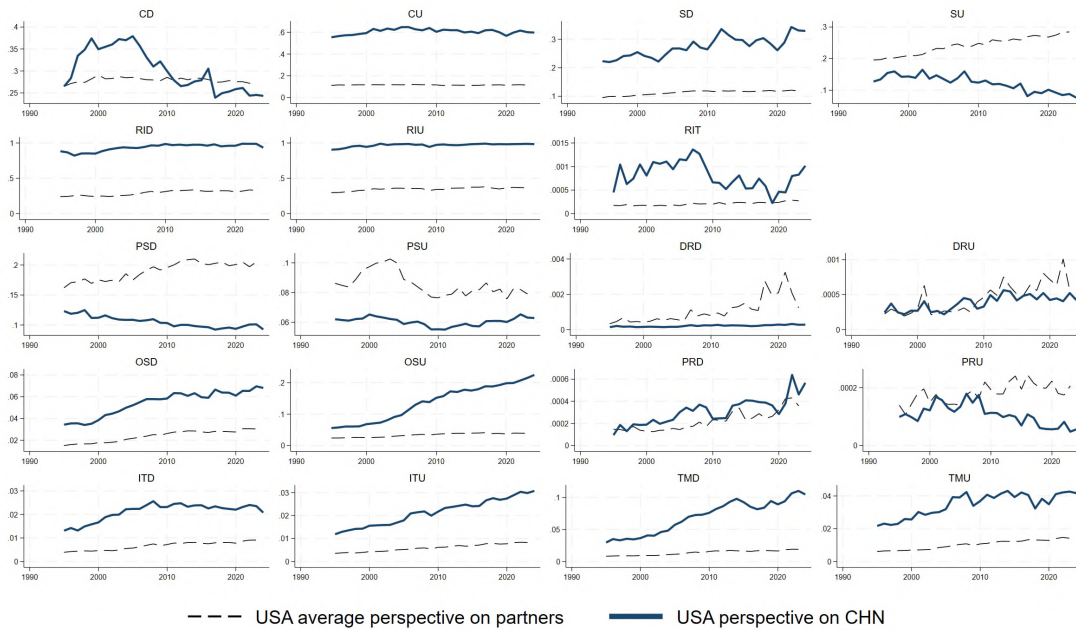
Source: Own elaboration using BACI.

Figure 12. Bilateral Structural Dependence: USA-CHN



Source: Own elaboration using BACI.

Figure 13. Structural Decoupling Test



Source: Own elaboration using BACI.

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## Appendix

### A Country Spaces from a Typed Bipartite Network: Similarity and Complementarity

This appendix details the formal derivation of the Similarity and Complementarity motifs as dual projections of the bipartite country-product network, establishing the theoretical link with the Product Space framework discussed in the main text.

We take the product space of [Hidalgo et al. \(2007\)](#) as our conceptual starting point. In their framework, the world economy is represented as a bipartite country-product structure, and analysis proceeds via the one-mode projection onto the product layer. Proximity between two products  $p$  and  $p'$  is defined as the minimum of two conditional probabilities that a country exhibits revealed comparative advantage in one product given advantage in the other:

$$\phi_{pp'} = \min \left\{ P(RCAX_{cp'} = 1 \mid RCAX_{cp} = 1), P(RCAX_{cp} = 1 \mid RCAX_{cp'} = 1) \right\}.$$

This construction uncovers the geometry of productive capabilities by asking which products tend to be co-exported across countries.

We adopt the same bipartite substrate but project onto the country layer. Let  $X_{pi} = \mathbb{1}\{RCAX_{pi} = 1\}$  denote export specialization and  $M_{pi} = \mathbb{1}\{RCDM_{pi} = 1\}$  its import-side analogue.<sup>8</sup> Write  $\mathcal{S}_i^X = \{p : X_{pi} = 1\}$  and  $\mathcal{S}_i^M = \{p : M_{pi} = 1\}$ .

Our first pair of measures mirrors this logic but for countries. Let  $X_{pi} = \mathbb{1}\{RCAX_{pi} = 1\}$  denote export specialization and  $M_{pi} = \mathbb{1}\{RCDM_{pi} = 1\}$  its import-side analogue. Define  $S_i^X = \{p : X_{pi} = 1\}$  and  $S_i^M = \{p : M_{pi} = 1\}$ . We then obtain downstream and upstream similarity as

$$SD_{ij} \equiv P(X_{pj} = 1 \mid X_{pi} = 1) = \frac{\sum_p X_{pi} X_{pj}}{\sum_p X_{pi}} = \frac{|\mathcal{S}_i^X \cap \mathcal{S}_j^X|}{|\mathcal{S}_i^X|},$$

$$SU_{ij} \equiv P(M_{pj} = 1 \mid M_{pi} = 1) = \frac{\sum_p M_{pi} M_{pj}}{\sum_p M_{pi}} = \frac{|\mathcal{S}_i^M \cap \mathcal{S}_j^M|}{|\mathcal{S}_i^M|}.$$

Both measures are directed and asymmetric, capturing one-sided containment of export and import specialization, respectively.

Symmetric counterparts analogous to  $\phi_{p,p'}$  are given by the minima of the two directions:

$$\psi_{ij}^D = \min\{SD_{ij}, SD_{ji}\}, \quad \psi_{ij}^U = \min\{SU_{ij}, SU_{ji}\}.$$

Hence, while [Hidalgo et al. \(2007\)](#) quantify proximity among products via co-export across countries, we quantify proximity among countries via co-specialization across products—a dual projection on the same bipartite logic.

---

<sup>8</sup>Formal definitions of  $RCAX$  and  $RCDM$  appear in [Section 2](#).

The bipartite structure naturally supports a second family of measures that has no direct analogue in the original product space but is fully consistent with its logic. If we allow two edge types (export  $X$  and import  $M$ ), we can count typed two-step paths  $i \xrightarrow{X} p \xrightarrow{M} j$  and  $i \xrightarrow{M} p \xrightarrow{X} j$ . These yield directed complementarities:

$$CD_{ij} \equiv P(M_{pj} = 1 \mid X_{pi} = 1) = \frac{\sum_p X_{pi} M_{pj}}{\sum_p X_{pi}} = \frac{|\mathcal{S}_i^X \cap \mathcal{S}_j^M|}{|\mathcal{S}_i^X|},$$

$$CU_{ij} \equiv P(X_{pj} = 1 \mid M_{pi} = 1) = \frac{\sum_p M_{pi} X_{pj}}{\sum_p M_{pi}} = \frac{|\mathcal{S}_i^M \cap \mathcal{S}_j^X|}{|\mathcal{S}_i^M|}.$$

$CD_{ij}$  reads as the degree to which  $j$ 's import specialization matches  $i$ 's export basket, and  $CU_{ij}^{M \rightarrow X}$  reverses roles. For symmetry, we may also define:

$$\chi_{ij} = \min\{CD_{ij}, CU_{ji}\}.$$

Let  $X, M \in \{0, 1\}^{P \times C}$ , and  $D_X = \text{diag}(X^\top \mathbf{1})$ ,  $D_M = \text{diag}(M^\top \mathbf{1})$  (country-level basket sizes). Then

$$S^X = D_X^{-1} X^\top X, \quad S^M = D_M^{-1} M^\top M, \quad CD = D_X^{-1} X^\top M, \quad CU = D_M^{-1} M^\top X.$$

To reduce the influence of ubiquitous products, counts can be replaced by  $X^\top W X$ ,  $M^\top W M$ ,  $X^\top W M$ ,  $M^\top W X$  with  $W = \text{diag}(w_p)$  and  $w_p$  decreasing in product ubiquity.

$SD_{ij}$  (and  $SU_{ij}$ ) coincide with the overlap coefficient (Szymkiewicz–Simpson) of the respective baskets, endowed with a direct probabilistic interpretation. The [Hidalgo et al. \(2007\)](#) proximity  $\phi_{pp'}$  and our symmetric  $\psi_{ij}^D$  (or  $\psi_{ij}^U$ ) share the same “minimum-of-conditionals” principle but swap the projection side of the bipartite graph. The cross-typed complementarities  $CD$  and  $CU$  extend this logic to supply-demand matching along typed two-step paths, yielding a pair of directed “country complementarity maps” that complement the two directed “country similarity maps”.

For a given year  $t$ , we define four directed graphs on countries with adjacency matrices  $S^X(t)$  and  $S^M(t)$  (export and import country spaces) and  $CD(t)$  and  $CU(t)$  (complementarity maps). For layout, we compute node positions from the symmetric backbone (e.g.,  $\frac{1}{2}(S + S^\top)$ ), then render the top- $k$  outgoing links per node. A statistical backbone (e.g., hypergeometric filtering conditional on row/column sums) can be used to prune non-salient intersections before plotting.

Overall, this dual-plus-cross projection retains the core specialization logic of the product space while translating it into two directed country spaces (export and import) and two directed complementarity layers that speak directly to bilateral interdependence.

## B Computing patterns of trade descriptive measures

Each probability is obtained as an element-wise division of the sums across products for the numerator ( $N$ ) and denominator ( $D$ ).<sup>9</sup> For a generic measure  $W$  in period  $t$  (sub index

<sup>9</sup>Following usual notation in statistical packages, we use the symbol ‘./’ for element-wise matrix divisions.

omitted):

$$W_{ij} = \sum_p W_{N \cdot} / \sum_p W_D \quad (2)$$

Where  $C$  is the total number of countries,  $RCAX$  and  $RCDM$  are binary ( $C \times 1$ ) vectors signaling the cases in which a country has revealed comparative advantage as exporter or disadvantage as importer in the product, respectively (product sub index is omitted).  $DX$  is a binary ( $C \times C$ ) matrix signaling the cases in which bilateral exports from  $i$  (rows) to  $j$  (columns) in product  $p$  are positive and role-consistent, i.e.  $RCAX_{pi} = 1$  and  $RCDM_{pj} = 1$ .  $\iota_c$  is a unitary ( $C \times 1$ ) vector. Hence, all the measures in the table come exclusively from the data on bilateral exports by product.

Table B.1. Computing trade patterns descriptive measures

	Downstream	Upstream	Downstream	Upstream
Unrestricted	Complementarity (C)		Similarity (S)	
	$CD_N = RCAX \cdot RCDM'$ $CD_D = RCAX \cdot \iota_c'$	$CU_N = RCDM \cdot RCAX'$ $CU_D = RCDM \cdot \iota_c'$	$SD_N = RCAX \cdot RCAX'$ $SD_D = RCAX \cdot \iota_c'$	$SU_N = RCDM \cdot RCDM'$ $SU_D = RCDM \cdot \iota_c'$
$h_1 = j$ $h_2 = i$	Trade Probability (TP)		Two-Way Trade Probability (TW)	
	$TPD_N = DX \odot CD_N$ $TPD_D = CD_N$	$TPU_N = DX' \odot CU_N$ $TPU_D = CU_N$	$TWD_N = DX \odot DX' \odot SD_N \odot SU_N$ $TWD_D = SD_N \odot SU_N$	
$h_2 = i$	Partner Substitutability (PS)		Domestic Re-Exports (DR)	
	$PSD_N = \left[ \left( DX \cdot \frac{1}{C} \cdot \iota_c \right) \cdot \iota_c' \right] \odot TPD_N$ $PSD_D = TPD_N$	$PSU_N = \left[ \left( DX' \cdot \frac{1}{C} \cdot \iota_c \right) \cdot \iota_c' \right] \odot TPU_N$ $PSU_D = TPU_N$	$DRD_N = \left[ \left( DX \cdot \frac{1}{C} \cdot \iota_c \right) \cdot \iota_c' \right] \odot DX' \odot SD_N$ $DRD_D = DX' \odot SD_N$	$DRU_N = \left[ \left( DX' \cdot \frac{1}{C} \cdot \iota_c \right) \cdot \iota_c' \right] \odot DX \odot SU_N$ $DRU_D = DX \odot SU_N$
$h_1 = j$	Own Substitutability (OS)		Partner Re-Exports (PR)	
	$OSD_N = \left[ \iota_c \cdot \left( \iota_c' \cdot \frac{1}{C} \cdot DX \right) \right] \odot TPD_N$ $OSD_D = TPD_N$	$OSU_N = \left[ \iota_c \cdot \left( \iota_c' \cdot \frac{1}{C} \cdot DX' \right) \right] \odot TPU_N$ $OSU_D = TPU_N$	$PRD_N = \left[ \iota_c \cdot \left( \iota_c' \cdot \frac{1}{C} \cdot DX \right) \right] \odot DX \odot SD_N$ $PRD_D = DX \odot SD_N$	$PRU_N = \left[ \iota_c \cdot \left( \iota_c' \cdot \frac{1}{C} \cdot DX \right) \right] \odot DX' \odot SU_N$ $PRU_D = DX' \odot SU_N$
$h_1 = h_2$	Indirect Trade Probability (IT)		Match in Third Markets (TM)	
	$ITD_N = (DX \cdot DX) \odot CD_N$ $ITD_D = CD_N$	$ITU_N = (DX' \cdot DX') \odot CU_N$ $ITU_D = CU_N$	$TMD_N = (DX \cdot DX') \odot SD_N$ $TMD_D = SD_N$	$TMU_N = (DX' \cdot DX) \odot SU_N$ $TMU_D = SU_N$

Source: Own elaboration.

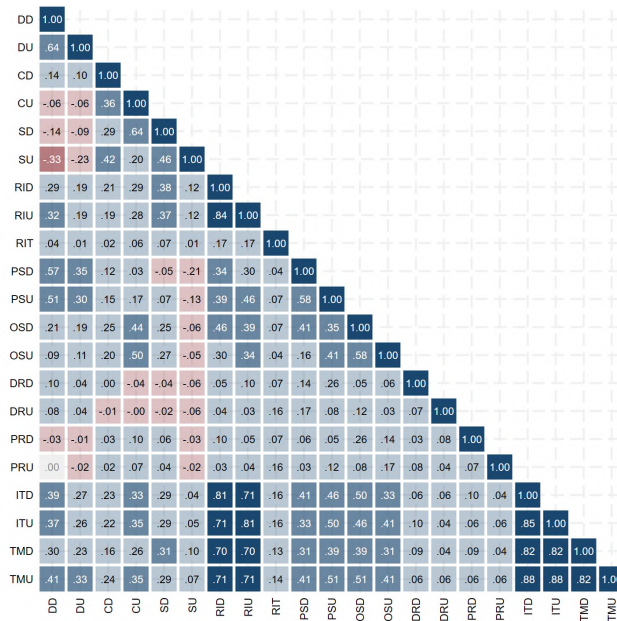
Note that Realization Indices and Indirect Trade Probabilities are computed as shares of Complementarities, while Substitutabilities are in a second level, defined as shares of Realization Indices.

Regarding restrictions on Similarities, the probabilities of Match in Third Markets are defined as shares of the corresponding Similarities, while Two-Way Trade is defined over a combination of both upstream and downstream Similarities, and Re-Exports over the subset of the corresponding Similarities that is effectively traded with country  $j$ .

## C Correlations among trade motifs

To assess the relationships and potential redundancies among the set of proposed indicators, we computed pairwise correlations for all 21 measures across the entire sample (1995–2024). Figure C.1 presents the resulting correlation matrix as a heat map, where numerical values indicate the Pearson correlation coefficient and cell colors represent the sign and magnitude of the relationship (blue for positive, red for negative; gray for non-significant correlations at the 5% level).

Figure C.1. Correlation Matrix of Trade Motifs



Note: Pairwise Pearson correlation coefficients for all dyadic measures (1995–2024). Colors indicate direction and strength: Blue hues denote positive correlations, while red hues denote negative correlations. Gray cells indicate non-significant correlations at the 5% level.

The matrix reveals distinct clusters of interrelation that validate the theoretical structure of our framework. First, we observe a robust positive correlation ( $\rho = 0.35$ ) between Downstream (*CD*) and Upstream Complementarity (*CU*). This finding is critical for the political economy of trade negotiations: it implies a structural tendency towards reciprocity. When country  $i$  has an export interest in  $j$ , it is relatively likely that  $j$  also has an export interest in  $i$ , facilitating the exchange of market access concessions that underpins most preferential trade agreements. If this correlation were negative, trade relations would be characterized by structural imbalances and one-way dependence, making cooperative outcomes significantly harder to achieve.

Second, measures within the same conceptual family tend to be positively correlated but distinct. For instance, the Realization Indices (*RID*, *RIU*) show a strong positive association with the indirect trade motifs (*ITD*, *ITU*) and matching in third markets (*TMD*, *TMU*), suggesting that dyads with high extensive-margin realization are also more deeply embedded in complex triangular trade networks.

Third, a notable block of negative correlations appears between Upstream Similarity (*SU*) and

several downstream performance measures (e.g., *DD*, *DU*, *RID*). This structural divergence reflects the asymmetric nature of global trade roles: countries that are highly similar as importers often occupy competitive positions that do not translate into complementary bilateral flows.

Finally, the relatively low correlations between the Substitutability measures (*PSD*, *PSU*) and the foundational role-based metrics (*CD*, *CU*) confirm that our measures of “exit options” capture a dimension of interdependence—vulnerability—that is orthogonal to simple structural complementarity. This independence supports the utility of measuring substitutability separately to understand the political economy of trade leverage.

## D Top-10 Dyads by Measure (2024)

The following tables present the top 10 countries (for monadic measures) or country-pairs (for dyadic measures) for each indicator in 2024. These rankings illustrate the empirical manifestations of the structural motifs discussed in the text.

Table D.1. Top 10 DD      Table D.3. Top 10 CD      Table D.5. Top 10 SD      Table D.7. Top 10 RID

Country	Val
CHN	0.491
DEU	0.439
ITA	0.426
ESP	0.411
FRA	0.373
TUR	0.362
IND	0.356
POL	0.351
PRT	0.339
NLD	0.338

Org	Dst	Val
GNQ	LTU	1.000
GNQ	IND	0.857
ERI	ESP	0.800
GAB	NLD	0.778
LBY	IND	0.765
MDV	ESP	0.760
FSM	VNM	0.750
FSM	KOR	0.750
NRU	NOR	0.750
TTO	VCT	0.746

Org	Dst	Val
IRQ	USA	0.857
GNQ	CAN	0.857
TCD	SDN	0.833
TCD	MLI	0.833
AGO	IND	0.800
BGD	CHN	0.744
VNM	CHN	0.728
GIN	PAN	0.727
GIN	PER	0.727
CHE	DEU	0.722

Org	Dst	Val
GUY	HTI	1.000
GIN	FRA	1.000
AGO	COG	1.000
NGA	GNQ	1.000
IRQ	BGR	1.000
GIN	IRL	1.000
IRQ	TUR	1.000
LBY	ARG	1.000
AGO	CHN	1.000
IRQ	KOR	1.000

Table D.2. Top 10 DU

Country	Val
AUT	0.518
FRA	0.485
PRT	0.464
DNK	0.457
POL	0.453
ROU	0.443
DEU	0.435
ESP	0.426
RUS	0.422
NLD	0.415

Table D.4. Top 10 CU

Org	Dst	Val
DJI	CHN	0.744
CMR	CHN	0.693
ETH	CHN	0.686
TJK	CHN	0.684
RUS	CHN	0.676
VNM	CHN	0.675
PRK	CHN	0.674
GIN	CHN	0.673
SLE	CHN	0.669
VEN	CHN	0.666

Table D.6. Top 10 SU

Org	Dst	Val
MHL	PNG	0.842
MHL	MDV	0.842
MHL	SYC	0.842
LBR	GAB	0.829
LCA	GRD	0.827
LCA	ATG	0.821
HND	GTM	0.800
GIN	GHA	0.796
AUS	NZL	0.793
MHL	VCT	0.789

Table D.8. Top 10 RIU

Org	Dst	Val
CHL	GNQ	1.000
MDG	COD	1.000
TUR	LBY	1.000
CHN	COD	1.000
TUR	IRQ	1.000
CHN	IRQ	1.000
FRA	LBY	1.000
IND	IRQ	1.000
GRC	IRQ	1.000
FRA	GNQ	1.000

Table D.9. Top 10 RIT

Org	Dst	Val
ITA	MHL	0.056
MHL	ITA	0.056
MHL	FRA	0.050
FRA	MHL	0.050
LBR	KOR	0.025
KOR	LBR	0.025
MHL	GBR	0.024
GBR	MHL	0.024
MHL	CYP	0.020
CYP	MHL	0.020

Table D.13. Top 10 OSU

Org	Dst	Val
TUV	CHN	0.648
FSM	CHN	0.555
BLR	USA	0.549
VCT	CHN	0.541
TON	CHN	0.509
VUT	CHN	0.489
SYC	CHN	0.486
PNG	DEU	0.484
ATG	DEU	0.484
BLZ	DEU	0.484

Table D.17. Top 10 PRU

Org	Dst	Val
PLW	TUR	0.137
SLE	SGP	0.091
SLB	SGP	0.091
SLB	KOR	0.082
LBY	HRV	0.060
TGO	ECU	0.060
TKM	GEO	0.055
TUN	SEN	0.049
WSM	SGP	0.045
NIC	SGP	0.045

Table D.21. Top 10 TMU

Org	Dst	Val
USA	DEU	0.057
DEU	USA	0.057
FRA	DEU	0.055
DEU	FRA	0.055
GBR	DEU	0.055
DEU	GBR	0.055
DEU	POL	0.053
POL	DEU	0.053
DEU	ITA	0.052
ITA	DEU	0.052

Table D.10. Top 10 PSD

Org	Dst	Val
CHN	TUV	0.648
CHN	FSM	0.555
USA	BLR	0.549
CHN	VCT	0.541
CHN	TON	0.509
CHN	VUT	0.489
CHN	SYC	0.486
DEU	PNG	0.484
DEU	ATG	0.484
DEU	BLZ	0.484

Table D.14. Top 10 DRD

Org	Dst	Val
SGP	TGO	0.324
SGP	TKM	0.324
SGP	NER	0.324
SGP	IRQ	0.324
SGP	WSM	0.324
ITA	GIN	0.258
GRC	IRQ	0.247
CHE	UGA	0.181
CHE	KEN	0.181
CHE	CUB	0.181

Table D.18. Top 10 ITD

Org	Dst	Val
IRQ	SAU	0.049
ITA	DEU	0.040
POL	DEU	0.038
DEU	GBR	0.037
DEU	USA	0.037
CHN	DEU	0.037
CZE	DEU	0.036
FRA	DEU	0.036
DEU	FRA	0.035
HUN	DEU	0.035

Table D.11. Top 10 PSU

Org	Dst	Val
CHN	YEM	0.319
CHN	HTI	0.319
CHN	CYP	0.319
IND	DJI	0.313
IND	JAM	0.313
IND	HND	0.308
IND	CPV	0.305
IND	SYC	0.297
IND	BRB	0.297
CHN	HND	0.272

Table D.15. Top 10 DRU

Org	Dst	Val
TUR	PLW	0.137
SGP	SLB	0.091
SGP	SLE	0.091
KOR	SLB	0.082
ECU	TGO	0.060
HRV	LBY	0.060
GEO	TKM	0.055
SEN	TUN	0.049
SGP	NIC	0.045
SGP	WSM	0.045

Table D.19. Top 10 ITU

Org	Dst	Val
SAU	IRQ	0.049
DEU	ITA	0.040
DEU	POL	0.038
GBR	DEU	0.037
USA	DEU	0.037
DEU	CHN	0.037
DEU	CZE	0.036
DEU	FRA	0.036
FRA	DEU	0.035
DEU	HUN	0.035

Table D.12. Top 10 OSD

Org	Dst	Val
YEM	CHN	0.319
CYP	CHN	0.319
HTI	CHN	0.319
JAM	IND	0.313
DJI	IND	0.313
HND	IND	0.308
CPV	IND	0.305
BRB	IND	0.297
SYC	IND	0.297
HND	CHN	0.272

Table D.16. Top 10 PRD

Org	Dst	Val
IRQ	SGP	0.324
TKM	SGP	0.324
NER	SGP	0.324
WSM	SGP	0.324
TGO	SGP	0.324
GIN	ITA	0.258
IRQ	GRC	0.247
CUB	CHE	0.181
UGA	CHE	0.181
ETH	CHE	0.181

Table D.20. Top 10 TMD

Org	Dst	Val
CHN	DEU	0.115
DEU	CHN	0.115
DEU	ITA	0.109
ITA	DEU	0.109
CHN	USA	0.104
USA	CHN	0.104
CHN	ITA	0.100
ITA	CHN	0.100
TUR	CHN	0.097
CHN	TUR	0.097

## E Definition of traditional measures

This appendix provides the formal definitions of the established trade indices used as benchmarks in Section 4.

### Concentration Indices

To proxy for vulnerability, we utilize [Hirschman \(1980\)](#)'s trade partner concentration index. Let  $X_{ij}$  denote exports from  $i$  to  $j$  and  $s_{ij} = X_{ij}/\sum_k X_{ik}$  be the share of partner  $j$  in  $i$ 's total exports. The Herfindahl-Hirschman index (HHI) is defined as:

$$H_i^{\text{partner}} = \sum_j s_{ij}^2 \quad (3)$$

Similarly, the commodity concentration of exports ([Rosecrance and Stein 1973](#)) measures dependence on specific products. Let  $u_{ip} = X_{ip}/\sum_q X_{iq}$  be the share of product  $p$  in  $i$ 's total exports:

$$H_i^{\text{commodity}} = \sum_p u_{ip}^2 \quad (4)$$

### Complementarity and Intensity

[Anderson and Nordheim \(1993\)](#) propose a measure of trade intensity. Defining  $x_i^p$  as the share of product  $p$  in country  $i$ 's total exports,  $m_j^p$  as the share of  $p$  in country  $j$ 's imports, and  $t_W^p$  as the share of  $p$  in world trade (net of  $i$ 's trade):

$$\text{complAN93}_{ij} = \sum_{p=1}^{\mathcal{P}} \frac{x_i^p m_j^p}{t_W^p} \quad (5)$$

[Michaely \(1996\)](#)'s index of trade compatibility assesses the overlap between the export basket of the source and the import basket of the destination:

$$\text{complM96}_{ij} = 1 - \frac{1}{2} \sum_{p=1}^{\mathcal{P}} |m_j^p - x_i^p| \equiv \sum_{p=1}^{\mathcal{P}} \min(x_i^p, m_j^p) \quad (6)$$

### Export Similarity

The Finger-Kreinin index ([Finger and Kreinin 1979](#)) measures the similarity of export structures between countries  $i$  and  $j$ :

$$FK_{ij} = \sum_p \min\left(\frac{X_{ip}}{X_i}, \frac{X_{jp}}{X_j}\right) \quad (7)$$

Alternatively, [Arad and Hirsch \(1981\)](#) propose the correlation of export vectors. Let  $x_{ip}$  and  $x_{jp}$  be the export shares of product  $p$  for countries  $i$  and  $j$ , respectively:

$$AH_{ij} = \frac{\sum_p (x_{ip} - \bar{x}_i)(x_{jp} - \bar{x}_j)}{\sqrt{\sum_p (x_{ip} - \bar{x}_i)^2} \sqrt{\sum_p (x_{jp} - \bar{x}_j)^2}} \quad (8)$$

## Intra-Industry Trade

To validate our Two-Way Realization Index (*RIT*), we compare it against the standard [Grubel and Lloyd \(1975\)](#) index of intra-industry trade. Aggregated at the bilateral level for the set of traded products, the index is defined as:

$$GL_{ij} = 1 - \frac{\sum_p |X_{pij} - X_{pji}|}{\sum_p (X_{pij} + X_{pji})} \quad (9)$$

where  $X_{pij}$  denotes exports of product  $p$  from  $i$  to  $j$  and  $X_{pji}$  denotes the reverse flow.

## F Economic Security: A Granular Diagnostic of Strategic Vulnerabilities

This appendix illustrates the practical utility of the proposed framework as a diagnostic tool for economic statecraft, using the Partner Substitutability motif as a case study. While we focus here on export exit options, an analogous diagnostic could be performed for supply security or third-market rivalry. By decomposing the aggregate substitutability index into its product-level components, we provide a granular map of structural vulnerability.

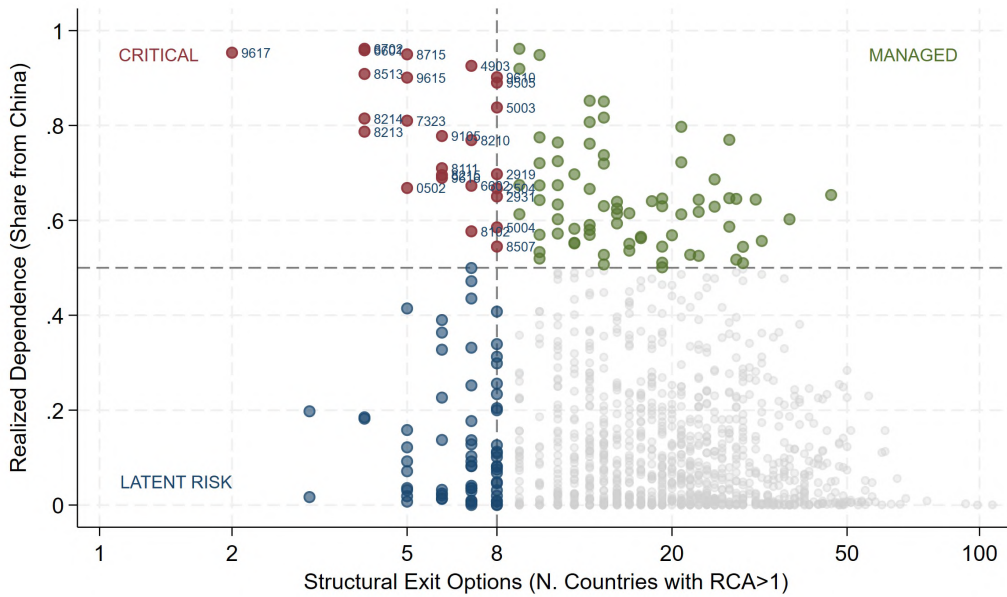
We construct a “Vulnerability Matrix” for the US-China dyad in 2024. We classify each HS-4 digit product imported by the United States from China along two dimensions: (i) Realized Dependence (Intensive Margin) is the share of total US imports of product  $p$  sourced from China, which captures the immediate cost of a potential disruption; and (ii) Structural Exit Options (Extensive Margin) is the number of alternative supplier countries  $h$  (excluding the US and China) that possess a Revealed Comparative Advantage ( $RCA \geq 1$ ) in product  $p$ , and captures the structural capacity of the global network to substitute the partner.

[Figure F.1](#) displays the results. We delineate four quadrants based on a dependence threshold of 50% and a structural scarcity threshold of 8 alternative suppliers (indicating oligopolistic global supply).

The diagnostic reveals three key insights for policymakers. First, the majority of high-dependence products fall into the “Managed Dependence” quadrant. This confirms that for most traded goods, high reliance on China is a choice driven by price or efficiency rather than a structural constraint, as numerous alternative exporters exist.

Second, the “Critical Vulnerability” quadrant validates the framework’s ability to identify strategic bottlenecks. The measure correctly isolates well-known choke points such as Electric Accumulators (HS 8507, vital for the EV transition), Rare Earth metals (HS 2805), and Natural Graphite (HS 2504).

Figure F.1. Matrix of Structural Vulnerability: US Imports from China (2024)



**Note:** Selected products in the Critical Vulnerability quadrant include:

*Strategic Inputs:* **8507** Electric accumulators (incl. Li-ion batteries); **2805** Alkali or alkaline-earth metals (incl. rare earths);

**2504** Natural graphite; **2846** Compounds, inorganic or organic, of rare-earth metals; **8111** Manganese and articles thereof.

*Scale Monopolies:* **9617** Vacuum flasks; **6702** Artificial flowers; **6601** Umbrellas and sun umbrellas; **9105** Other clocks.

Third, and perhaps most notably, the critical quadrant also contains non-strategic consumer goods such as Vacuum Flasks (HS 9617) and Artificial Flowers (HS 6702). This highlights a distinct form of vulnerability driven by “scale monopolies”. In these sectors, extreme industrial agglomeration in China has eroded the comparative advantage of other nations, creating a monopoly of efficiency rather than technology. For a policymaker, distinguishing between these two types of criticality—strategic inputs versus consumer scale monopolies—is essential for designing targeted de-risking instruments.

Finally, the “Latent Risk” quadrant identifies products where current dependence is low, but the global market is structurally thin (few alternative suppliers). This effectively maps the “supplier of last resort” risks, where a future shift in demand could rapidly expose the importer to unmanageable dependency.

This distinction highlights the analytical advantage of our topological framework over traditional concentration measures. A standard HHI or a simple import-share threshold would flag all products in the upper half of Figure F.1 equally as “high dependence”. However, from a political economy perspective, a high market share in a product with abundant structural exit options (high Extensive Margin) represents a commercial choice, whereas high share combined with structural scarcity constitutes a strategic vulnerability. By interacting realized flows with structural motifs, the framework filters out “managed dependence” from true security risks, a nuance that value-based indices inherently miss.

# documentos de trabajo



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