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Mapping Vertical Trade

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Contents

Abstract

The paper develops a method to map global networks of production sharing and processing trade. Relying on highly detailed bilateral trade data across a matrix of 75 countries, a network index gauges countries' interdependence according to the extent of trade in parts and components for further processing and assembly of final export goods. The set of bilateral network relations is then subjected to an algorithm that lays it out for visualization as a world map of vertical trade networks. Maps are drawn in relation to processing trade across all industries, as well as for the electric/electronics and automotive industries, where such trade is most prominent. The analysis identifies three major hubs in the global networks: the People's Republic of China in connection with Japan, Germany, and the United States. Apart from Mexico (mainly because of its *maquiladoras* network ties to the United States) the analysis highlights that outside Asia, developing countries are not yet involved in global production networks to any significant degree.

I. Introduction

The progressive integration of world markets has led to the fragmentation of production across countries and the formation global supply chains. As different stages of production are typically performed in different countries, the associated cross-border trade in parts and components, and intermediate goods more broadly, has come to predominate world merchandise trade (Arndt and Kierzkowski 2001, Cheng and Kierzkowski 2001).

International trade statistics account for the gross cumulated value embodied in goods crossing international borders, not just the value added by the segment of the production process hosted by the exporting country and attributable to its resources. Official records are thus largely unsuitable to trace value added across the segments of international supply chains and overstate or "double-count" value-added trade by a factor proportional to the number of times intermediates cross an international border prior to reaching the final stage of production.

Attempts to devise methods of measuring value-added trade have emerged in the empirical literature. One such approach has been to analyze trade and investment flows within multinational firms and their foreign subsidiaries on the basis of multi-year survey data available for the United States (US) (Hanson et al. 2005) and Japan (Kimura and Baldwin 1998, Ando and Kimura 2003). Another strand of literature has developed methods to analyze sector- or product-specific global value chains, for example in relation to Apple's iPhone (Dedrick et al. 2010), the global apparel value chain (Gereffi and Frederick 2010), or Thailand's hard disk drives industry (Gourevitch et al. 2000).[1]

A more comprehensive, economywide approach to measuring value-added trade combines national input–output tables to identify the sources and destinations of value added as intermediate goods pass through global supply chains (e.g., see Hummels et al. 2001, Johnson and Noguera 2009, Daudin et al. 2009, Koopman et al. 2008 and 2010).[2]

[1] See www.globalvaluechains.org for a list of studies by researchers participating in the global value chains research initiative.

[2] For a review of the earlier empirical literature using input–output tables, see the influential paper by Hummels et al. (2001). For an overview of recent advances in the value-added literature and a description of the arguably most comprehensive empirical analysis of value-added trade to date, see Koopman et al. (2010).

Yet another approach uses finely disaggregated international trade data to distinguish parts and components from countries' final goods exports and imports.[3] Ng and Yeats (1999) were the first to compile detailed lists of parts and components trade to assess the magnitude of processing trade in East Asia, followed by Athukorala (2005 and 2010) and Kimura (2006). Compared to input–output analysis, this method is less comprehensive a gauge of processing trade and is limited to the subcategory of intermediates that are clearly recognizable as parts and components, thus disregarding processing and assembly activities characterizing vertical trade more broadly. However, it offers the advantage of parsimony, in terms of both data requirements and the methodological complexities involved.

The evidence arising out of this literature overwhelmingly points to a strong expansion of production sharing and vertical trade in the global economy, particularly since the 1990s. Nowhere has the expansion of vertical trade networks and supply chains been more pronounced than in Asia, largely in relation to the People's Republic of China's (PRC) ascension as a regional hub of assembly and global trade power. By 2007, more than half of the PRC's exports value represented value added imported from other countries (Koopman et al. 2008). Embodied in parts and components, such value added constituted more than half the value of exports of East and Southeast Asian countries positioned further upstream in the value chains linking the region's production networks (Athukorala 2010). Global value-chain analysis has found the share of foreign content of the PRC's exports to be particularly high in certain electronics products for which key components, as well as product design and brand values, originate outside the country. For example, the PRC was found to add as little as $4 in value to an Apple iPod fetching a factory gate price in the PRC of $144 (Dedrick et al. 2010).

Building on this emerging strand of literature, this paper develops a method to assess the intensity of vertical trade among all countries and industries participating in global production sharing. This measure of vertical integration among country pairs is then visualized in global maps of processing trade, displaying a production network's global structure as well as an individual country's relative position and involvement.

Central to the method proposed in this paper is a measure of the direction and intensity of countries' network relations as providers and assemblers of parts and components within the international production networks. This is achieved through the Network Trade Index (*NTI*), which is defined in this paper as a supplier country's share in parts imports by a processing industry in the hosting country, weighted by that industry's share of total final goods exports. The index is computed at the level of industries, or sectors, and for each country pair in both directions—e.g., from Japan to the PRC and vice-versa—and is then averaged and normalized to derive a more synthetic indicator for comparison across countries and industries.

[3] These studies typically rely on the United Nations' Comtrade database as a source of international trade data, either at the 5-digit classification of sectors according to the Standard International Trade Classification (SITC), or the 6-digit break-down of data in the Harmonized System (HS) nomenclature.

To create maps of country connections via processing trade, the *NTI* is subjected to an algorithm that sorts through the entire set of bilateral processing links and allocates countries within a network plane according to the intensity of vertical trade among all the countries considered in combination. This will enable the generation of network maps showing the average processing trade links including all industries, as well as maps taking special focus on the electric/electronics and automotive sectors, where vertical trade is known to be strongest.

The evidence arising out of this paper is that global processing trade centers on three major regional hubs. The first is the US, mainly through its strongly networked automotive and electric/electronics production with other member states of the North American Free Trade Agreement (NAFTA) on one hand, and its close connections to the Asian electronics production network on the other. The Asian network itself constitutes the second global hub, especially in relation to trade in parts and components within the electric and electronics industries surrounding the PRC–Japan axis, also involving a number of economies in East and Southeast Asia. The third is the European network with Germany at its center, broadly linking the common market's value chains, most notably in relation to Europe's strong automotive industry. Apart from Mexico—mainly because of its *maquiladoras* network ties to the US industries and markets—the analysis suggests that outside East and Southeast Asia, developing countries are not yet involved in global production networks to any substantial degree.

The paper is structured to first present the data set underlying the analysis, in Section II. The network trade index and its application to the data is discussed in Section III. Network maps are drawn and interpreted in Section IV. Section V discusses the value-chain dependence on Japan. Concluding thoughts and issues for further research are sketched out in Section VI.

II. The Data

The analysis relies on the Base pour L'Analyse du Commerce International (BACI) data set, compiled by the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII).[4] BACI, in turn, draws from the Comtrade database of the United Nations (UN) Statistics Division. The data is available in the 1996 revision of Harmonized System (HS) classification disaggregated at six digits, comprising more than 200 countries and 5,000 products. Compared to the underlying UN Comtrade data, BACI offers the advantage of mirrored and reconciled importer and exporter records, for a more consistent and complete world trade matrix of bilateral flows.

4 For a description of the data set, see Gaulier and Zignago (2010).

For the purpose of this analysis, only data for 2006 and 2007 are retained. This captures best the recent pattern of processing trade, just prior to the plunge in global trade associated with the global economic crisis of 2008/2009. To flatten out year-to-year fluctuations, which are characteristic of bilateral trade flows at the product level, the 2006 and 2007 panels of bilateral trade across countries and 6-digit HS product categories are collapsed in order to derive average imports and exports flows for 2006/2007.

Most of the smaller or poorer developing countries are known to have weak network connections and their role in processing trade is marginal at best. They are dropped from the data set in order to improve the readability of the network maps, without significant loss of insight. A first filter is applied to drop countries with populations smaller than 1 million; a second filter drops countries with gross domestic product (GDP) per capita in 2006/2007 smaller than US$750. After excluding all countries with missing data in either year, the data set comprises 75 countries, listed in Appendix Table 1. Included are all of the world's major trading nations, both advanced and emerging, as well as a representative number of developing countries, mainly of Asia and Latin America.

To distinguish parts and components trade among the more than 5,000 product codes populating the HS dataset at 6-digits, the exhaustive list of parts and components compiled by Athukorala (2010), based on UN Comtrade and BEC classifications, is used.[5] To circumvent the difficulty of associating imported inputs with final exports, the analysis in this paper focuses on broad sector aggregates, which are taken at the first two digits of the 6-digit product categories. For each of the sectors at the 2-digit level, bilateral export and import flows of parts and components trade are then computed (at 6 digits) as a subcategory of total trade, with the remaining trade taken to represent trade in final goods, embodying the parts and components imported within the same sector category.

Such distinction of industries only allows for an approximate association of parts imports with final goods exports, and then only for those product categories where parts and components tend to be subsumed under the same 2-digit heading. One such heading—HS category 85—corresponds to trade in electric and electronics goods. However, under this heading fall parts as diverse as "Parts of shavers/hair clippers, electric" (851090) and "Internal combustion engine spark plugs" (851110). By assigning these items to the corresponding sector at two digits (85) the analysis cannot be more ambitious than focusing on a very broad aggregate encompassing the entire range of electric and electronics products.

[5] See Athukorala (2010) for a detailed list of parts and components.

The problem of correctly assigning parts varies across sectors. For example, for the case of processing trade within the automotive industries, parts, and components are scattered across a broad range of HS categories, which complicates the task of matching intermediate and final goods. Contrary to the case of the electric/electronics industries, for which both parts and final exports are mostly subsumed under HS category 85, automotive parts are located in categories as diverse as 40, 59, 68, 70, 73, 84, 85, 86, 87, 90. Final goods exports of cars, trucks, buses and motorcycles pose less of a problem, as they are all subsumed in category 87. Fortunately, relevant parts can be identified by explicit textual reference to vehicles or combustion engines being made by the HS and corresponding Standard International Trade Classification (SITC) nomenclatures.[6] Where this is not the case, technical automotive components often can still be associated with the automotive industry by way of their functional characteristics, such as is the case for clutches or special rubber hoses. For the analysis of vertical automotive trade of the automotive sector in this paper, all the relevant auto parts had to be first identified among the more than 5,000 6-digit HS product codes.

III. The Network Trade Index

To gauge the intensity of network trade between any pair of countries, equation (1) defines *NTI* as partner *j's* share (c_s^{ij}) in reporter *i's* total imports of parts and components ($\Sigma^j\, c_s^{ij}$), weighted by the share of industry *s* in *i's* total final goods exports ($p^i_s/\Sigma i\ p^i_s$). To derive an economywide measure of vertical trade among any given country-pair, (NTI^{ij}), the index is cumulated across industries (Σ_s).

$$NTI^{ij} = \Sigma_s \frac{c_s^j}{\Sigma_i c_s^i} \frac{p_s^i}{\Sigma_i p_s^i} \qquad (1)$$

$$\widehat{NTI}^{ij} = \frac{NTI^{ij} - NTI_{min}^{ij}}{NTI_{max}^{ij} - NTU_{min}^{ij}} \qquad (2)$$

To facilitate comparability across country pairs and industries, equation (2) normalizes the *NTI* to range from 0 (no network connection between country-pairs) to 1 (the strongest connection in the entire set of country-pair permutations).

Appendix Table 2 lists the top 15 country pairs according to the index computed across all the 75 countries included in the data set. Country pairs are ranked by decreasing values of *NTI*, which is averaged across industries. Rather unsurprisingly, the world's leading exporters of manufactured goods are also those linked most strongly within the global processing networks, either in direct connection with each other, or through vertical links to a less prominent partner country.

6 To facilitate the classification of goods, both the HS and SITC nomenclatures were used.

The PRC and Japan jointly lead the ranks, due to the reciprocal importance their production and trading structures represent: Japan as a provider of parts and components, and the PRC as an assembler and exporter of final goods. By construction, *NTI* weights equally the strength of the bidirectional link between network partners. The stronger partner in terms of its share of world trade tends to prevail also in the bilateral relationship, in the sense that it represents a more important network link to the partner than the partner does to the dominant country. In the case of Japan and the PRC— both of which count among the world's foremost trading nations—the latter prevails with an *NTI* of 0.707, confirming just how much commercial power in East Asia has shifted during the past decade or so. The index takes the value 0.585 in the opposite direction, with respect to Japan's importance to the PRC in processing trade. Taken on average, at 0.646 the intensity of the network ties between these two countries is highest out of all the 5,162 country-pair permutations populating the network (at the opposite end of the spectrum—not shown in Appendix Table 2—one would find the pair Libya and Peru, with an *NTI* of virtually zero).

Ranking second in Appendix Table 2 is the pair US–Mexico. An *NTI* of 1, its normalized maximum, classifies Mexico as the country being most strongly linked to another country within the vertical trade networks. Although depending considerably on processing trade with Mexico, the US clearly comes out as the country dominating the vertical relationship; Appendix Table 2 shows the *NTI* to take the value 0.221, in the direction from the US to Mexico. The strong vertical integration of the two economies is largely reflective of Mexico's *maquiladoras* system, which is essentially an array of tax benefits designed to foster US-owned and other foreign-owned manufacturing plants producing for exports.[7] Processing trade between these two economies was boosted further by the NAFTA, which entered into force in 1994.

Canada, also a member of NAFTA, is shown to entertain similarly strong network relations with the US, albeit the relationship between the two countries appears somewhat more balanced than the US–Mexico case.

Further down the ranks of Appendix Table 2 appears Germany, which dominates the European processing trade, followed by several Asian countries. These countries' position within the global networks will be illustrated further in the discussion of network maps below.

[7] The *maquiladoras* system was first introduced in the 1960s and experienced rapid expansion especially during the late 1990s, resulting in an array of thousands of factories allocated along the US–Mexican border. For recent accounts of the extent and economic implications of the *maquiladoras* in Mexico, see Bergin et al. (2009), Huato (2010), and Mendoza (2010).

Just before turning to the network maps, Tables 4 and 5 further clarify the structure of the *NTI* with respect to its constituent elements.[8] Appendix Table 4 ranks the top network partners within the electric/electronics industries, and Appendix Table 5 does the same for the global automotive sector. Additional detail in relation to each country pair is provided with respect to the partner's share in total parts imports (the main element of the *NTI*) and the industry's share in total exports by the assembling country (the weight component of the index).

Appendix Table 4, for example, shows that Mexico's extreme network dependence on the US is determined by a 41.7% share of parts imports from that country, out of Mexico's total imports of parts in the electric/electronics industries. For Mexico's economy as a whole, its dependence on the US gains further weight by the fact that the electric/electronics sector in 2006–2007 represented 15.7% of the country's total exports.[9] In the opposite direction, Mexico's share in the electronics parts imports of the US is a still sizeable 21.5%, but the industry constitutes only 4.1% of the merchandise exports basket of the US.

IV. Mapping Vertical Trade Networks

The *NTI* measures the intensity of vertical trade between country pairs. For a full identification of processing trade networks, the set bilateral connections needs to be set in relation to each other. To do so, we apply a suitable algorithm to sort through the data.[10] A spring-embedded algorithm works by the assumption that the nodes (countries) are connected by springs (*NTI*) that attract or repulse each other. Just like a physical system in which Hooke's law of elasticity applies, the nodes are assumed to exert a force on each other through the connecting springs, akin to magnetic repulsion or gravitational attraction. Equilibrium is reached by iteration, whereby the rings connecting the nodes are projected on to a plane while being subjected to an acceleration proportional to the various forces exerted on the edges as a whole. A state of equilibrium is reached when the total sum of forces in the system is minimized.[11]

8 Note that shares of parts imports and final goods exports are not listed in Appendix Table 1, since these are not applicable when the *NTI* is averaged across industries.

9 Note that both shares relate to totals computed among the 75 countries populating the data set, which are highly representative of but do not fully comprise world trade involving all the countries.

10 Force-directed algorithms are applied broadly in network analysis. Examples are graph clustering techniques, ubiquitous to the field of biotechnology, or the minimum cost spanning tree, a classic algorithmic solution to a vast class of optimization problems.

11 Essentially, Hooke's law states that the displacement or size of the deformation of an object is directly proportional to the deforming force. Within the logic of a spring-embedded algorithm, this is roughly equivalent to assuming that the forces in the system are proportional to the difference between the distance of the nodes and the length of the springs.

The algorithm is applied to the set of *NTI* by country-pairs outlined in the previous section. To facilitate the visualization of the *NTI*–based network, for the implementation of the algorithm we rely on Cytoscape, a software environment developed for visualizing molecular interaction networks.[12] More specifically, we apply a spring-directed algorithm to the *NTI* scores across country pairs to draw maps of vertical trade for all the sectors combined, as well as for the electric/electronics and the automotive sectors individually taken. These are now discussed in turn.

A. The Global Network of Vertical Trade

The most comprehensive map of vertical trade is drawn to represent the entire set of *NTI* values, computed across all the industries in which processing trade is observed. The *NTI* is averaged in relation to each of the 5,162 country pairs, to gauge the intensity of vertical trade links in both directions.[13] For a great majority of country pairs, vertical trade is very small, with the index taking a value close to 0. To improve the intelligibility of the network map, only the main network connections are retained. We thus drop all network relations with *NTI* smaller than 0.05, which reduces to 192 the total number of connections retained.[14]

Figure1 shows that each country in the network is presented by a circle, the coloring of which indicates whether a country pertains to developing Asia (red), the group of high-income countries (green), or developing countries outside Asia (blue). The circles' position within the network and their proximity to each other is proportional to the force of attraction countries exert on each other through the various network relations of processing trade that run directly between any pair of countries, and indirectly via third countries or country-clusters. The strength of bilateral network relations determines the width of the arcs connecting the countries.

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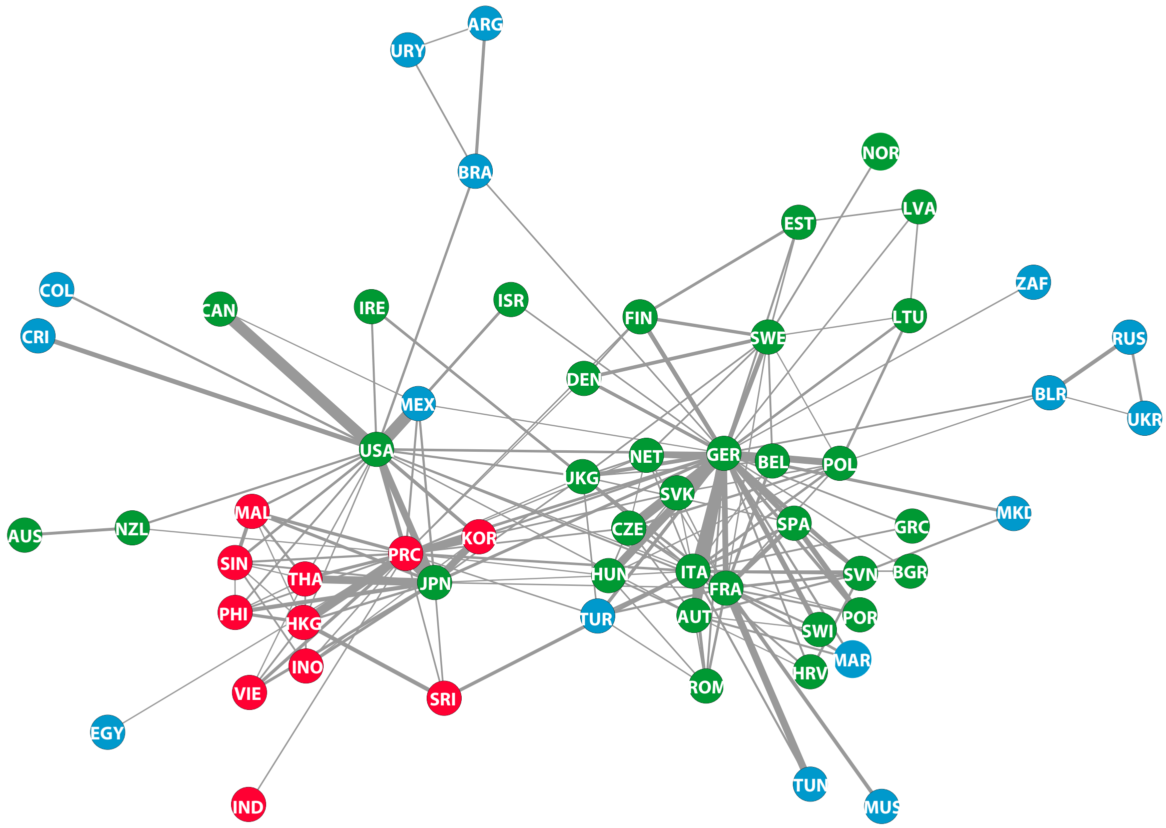
[12] Hidalgo et al. (2007) were among the first to use the open-source platform Cytoscape within the field of economics, in their case to produce a network representation of their "product space". For more information about this software, see www.cytoscape.org.

[13] For the case of some country pairs only one country imports parts and components from the other. Therefore, at 2,693 the total number of network relations identified by the average *NTI* is slightly higher than half the number of country pairs.

[14] Such cut-off is arbitrary yet necessary to facilitate the graphical rendition of what would otherwise be a picture blurred by thousands of near-zero connections among all those countries that happen to have some sort of marginal relationship with each other. Depending on whether the focus of analysis is on the central or marginal features of a network, the range of *NTI* values to be retained for mapping can be adjusted quite arbitrarily to achieve the desired results. Here, we aim at highlighting the central features of the networks, for which a 0.05 cut-off appears to be roughly appropriate, after several trials and errors. For easier comparability of the networks discussed, the 0.05 cut-off is applied throughout the paper.

Figure 1: Network Trade Index—All industries—Global



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

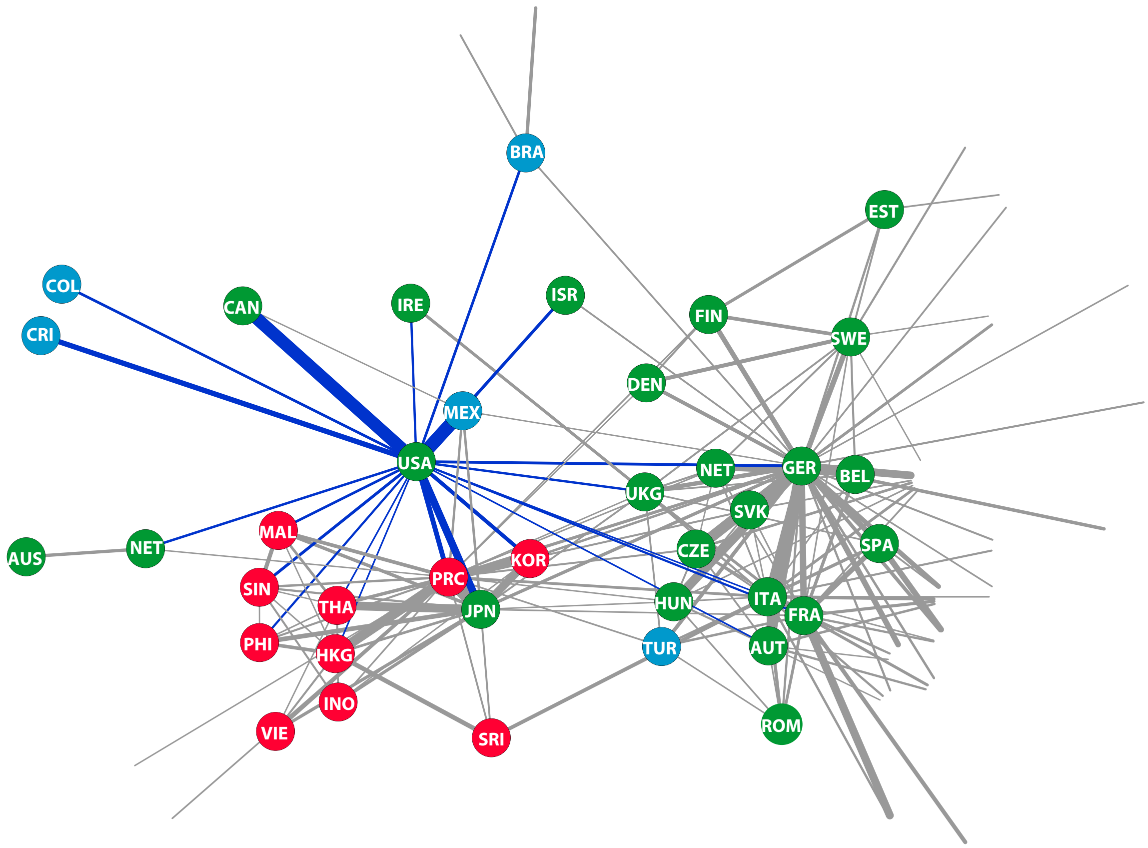
The main characteristics of global processing trade accruing from Figure 1 are highlighted as follows. Vertical trade is seen to concentrate around three global hubs, namely the US, PRC–Japan, and Germany, respectively. Although the sphere of influence of these hubs tends to be strongest within regions, it extends globally through network connections that involve hubs both directly (e.g., PRC–US) and indirectly, through a third country (e.g., PRC–Republic of Korea–US).[15]

Vertical trade with the US at its center is dominated by the country's production sharing arrangements with the other NAFTA members, Canada, and Mexico. This should come as no surprise, considering the long-standing production sharing arrangements of the US with both countries: the US–Canada Auto Pact and Mexico's extensive *maquiladoras* factories along the US borders, as will be discussed further below, in relation to the automotive and electric/electronics trade networks.

[15] See Appendix Table 1 for a correspondence of country names with three-letter ISO codes.

Beyond its sphere of influence within North America, US vertical trade is strongest with Japan and the PRC, as well as with the Republic of Korea and the other countries pertaining to the tightly intertwined Asian networks (see Figure 2).

Figure 2: Network Trade Index—All Industries—United States

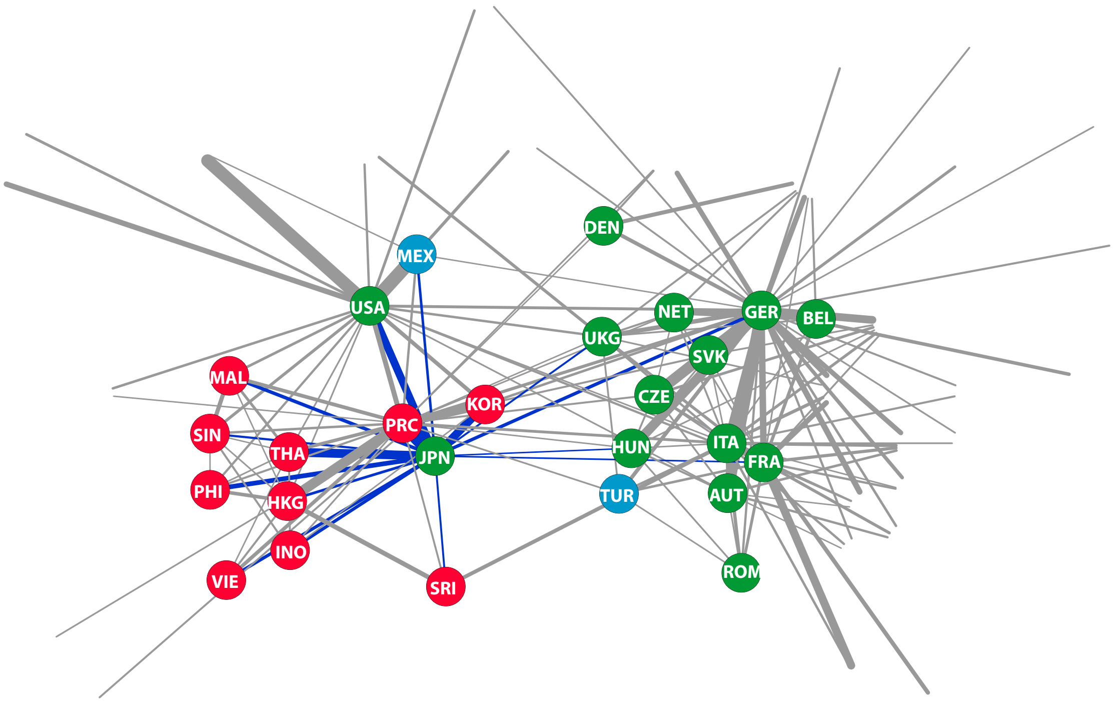


Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

The US' network links with Germany and the rest of Europe appear to be far less pronounced. The same is true for US vertical trade with countries in Latin America. Colombia and Costa Rica can be seen at the outer margins of the global network, while Brazil is located somewhat more centrally, in between the US and European hubs and triangulating also with Argentina and Uruguay. Except for Mexico, which has direct ties with the US and also maintains network connections with Asian and European hubs, Latin America appears not to be strongly involved in global network trade, nor does the extent and intensity of vertical trade among its economies resemble anything close to the Asian networks.

South of the US on the network map, the extensive Asian network is shown to extend around the PRC–Japan axis, involving a web of tightly connected East and Southeast Asian economies (see Figures 3 and 4). Often referred to as "factory Asia", fragmented production activities scattered across the region typically involve the provision of high value-added parts and components by leading economies, such as Japan and the Republic of Korea, further processing in countries such as Malaysia and the Philippines, and final assembly in countries involving low labor costs and value added, predominantly in the PRC.[16]

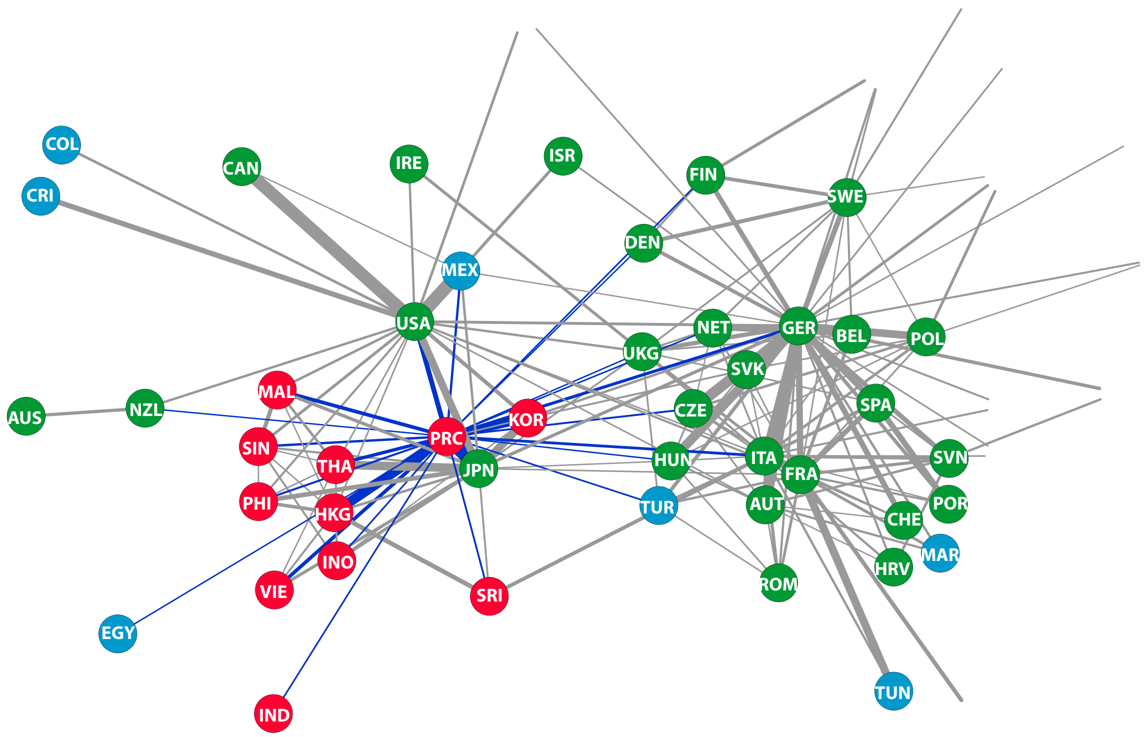
Figure 3: Network Trade Index—All Industries—Japan



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

16 The Asian network and the individual network relations involved are listed in Appendix Table 3, for country pairs with *NTI* >0.05.

Figure 4: Network Trade Index—All Industries—People's Republic of China



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

The Asian network as a whole and its countries individually are clearly drawn to the US through a range of network connections. By contrast, Asian networks appear to be largely disconnected from Australia and New Zealand. This reflects the nature of trade between Asia's networked economies and the Pacific, involving mostly final consumer goods in exchange for primary commodities.

Within the Asian networks, countries' position in relation to each other sheds further light on the configuration and intensity of vertical trade links. For example, the proximity of the PRC and Japan testifies to the exceptionally strong vertical linkages between these two economies. Both countries are tightly linked to the main actors of factory Asia. Together, they lay at the crossroads of the major network axes spanning from East and Southeast Asia to Europe and the US. Contrary to Japan, however, the position of the PRC needs to be interpreted also in the light of Hong Kong, China's role as an entrepôt for the mainland. Consequently, much of the PRC's network trade with Hong Kong, China represents transshipments, including mainland processing trade with the region and the rest of the world. Hong Kong, China's relative position within the Asian network may thus be interpreted as partly representing the PRC's, which could thus be thought of as being located closer to the cluster of Asian countries it relates to as the region's assembly hub.[17]

The Republic of Korea, by contrast, stands out as being less broadly connected to the Asian network, which it interacts with mainly through the PRC and, to a lesser extent, Japan. Whereas the Republic of Korea's location on the map shows a close relation with its East Asian neighbors and with the US, its looser ties with the other countries of Asia explain its position at the outskirts of the regional networks.

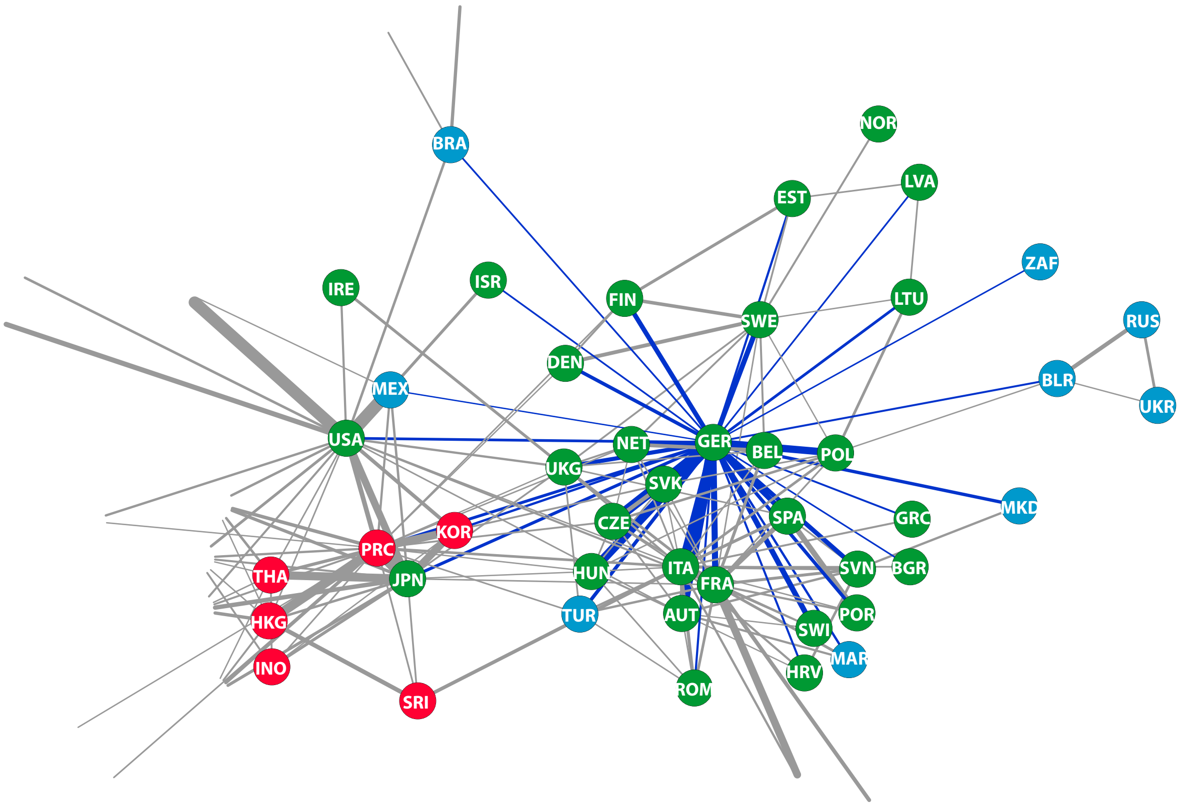
Among the Asian countries represented on the map, India appears most marginalized in the global trade networks, as it relates exclusively to the PRC and certainly is not yet part of factory Asia. Sri Lanka, on the other hand, is positioned rather well, with connections to the PRC; Hong Kong, China; and Japan, and a foothold into the European networks through Italy.

Moving on to Europe (Figure 5), Germany is seen dominating the region's processing trade, much in line with its status as one of the world's top industrial and trading powers. Facilitated by the ease with which parts and components are allowed to cross national borders within the European Union's single market, vertical trade can be seen forming a tight web of links among many of its member countries. Network trade is strongest between Germany and its neighbors, Austria, France, and Italy. The latter two countries themselves are closely networked within Europe and the major world hubs, as well as with the developing world. France, for example, displays strong ties to francophone Africa, including Tunisia and Mauritius.[18] The United Kingdom (UK), by contrast, figures rather marginally within the network, broadly reflecting its fading status as an industrial power within Europe. Moreover, the country's proximity to the US on the network map is reflective of its deep Atlantic alliance, including its industrial and foreign direct investment structures. Indeed, the *NTI* reckons the UK's ties to the US to be nearly as strong as those it has with Germany.

[17] To emphasize the special connection between the PRC and Hong Kong, China, the data panels in relation to the two countries could simply be collapsed into one, as frequently is done in empirical analysis taking focus on the PRC's external trade.

[18] It will be recalled that the index underlying the maps averages the two unidirectional values of the *NTI* characterizing any pair of countries. As a result, countries such as Tunisia are drawn onto the map mainly because of their strong dependence on a stronger network partner, which is almost never reciprocated beyond a certain degree. For example, the *NTI* of Tunisia toward France is 0.700, whereas it is only 0.019 in the opposite direction.

Figure 5: Network Trade Index—All Industries—Germany



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

Further testimony to Germany's central role as Europe's hub is its outreach to providers of parts and components well outside the region, such as Brazil, Mexico, and South Africa. Moreover, jointly with Sweden, Germany acts as a hub to the Scandinavian and northern European networks, spanning from Denmark, to Estonia, Latvia, Lithuania, and Poland.

To the East, Germany is shown to link the Russian Federation and Ukraine through Belarus, albeit the marginal position of these countries suggests that none of them fully pertains to the European, let alone global, processing networks as such.

Developing countries outside Asia are poorly represented on the network map. Of Latin America, only Mexico and Brazil are involved with global value chains. African countries are largely cut off from global networks, apart from sporadic connections to individual countries within the network's core. This is true for South Africa, the continent's most industrialized country, as much as for Egypt and for Mauritius, Morocco, and Tunisia, the only African countries with a strong enough *NTI* to make it onto the map.

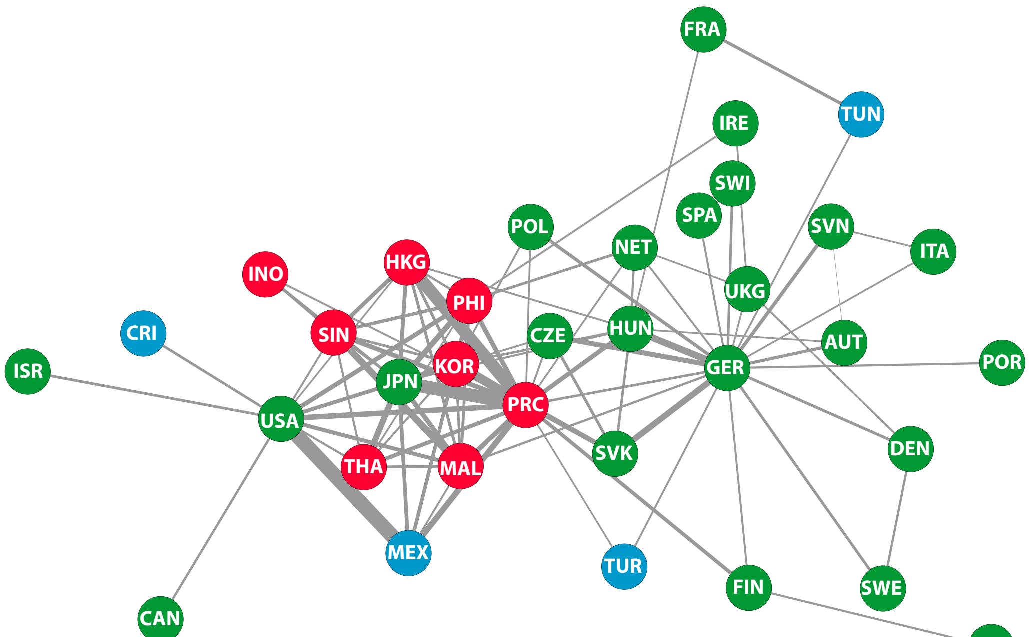
Also the CIS countries are relegated to the outer borders of the vertical trade networks. This is because their trade baskets tend to be heavily concentrated in natural resources, rather than networked manufacturing, and also because the Russian Federation, the regional hub, only weakly integrates with the world trading system.

In sum, network analysis based on the *NTI* across industries indicates that the global distribution of vertical trade is heavily concentrated in Northern America, East and Southeast Asia, and Europe. By this measure, developing countries outside Asia are not yet integrated with the international production networks to any substantial degree.

B. The Global Network of the Electric/Electronics Sector

Figure 6 shows the map of vertical trade within the electric and electronics sectors, defined by the broad category No. 85 of the HS nomenclature. Again, only country pairs with the strongest links (*NTI* >0.05) enter the algorithmic transformation underlying the map. Out of the 2,599 country pairs identified within the sector, only 93 are retained. Appendix Table 4 ranks the top 15 among these country pairs, which correspond to the countries connected by the boldest arcs in Figure 6.

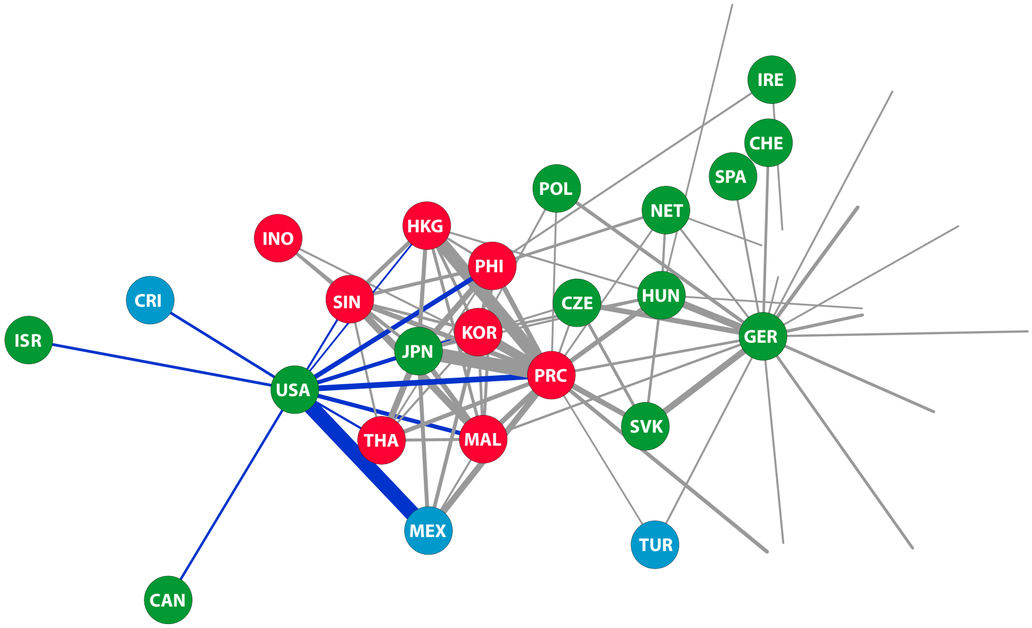
Figure 6: Network Trade Index—Electric/Electronics Industries—Global



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

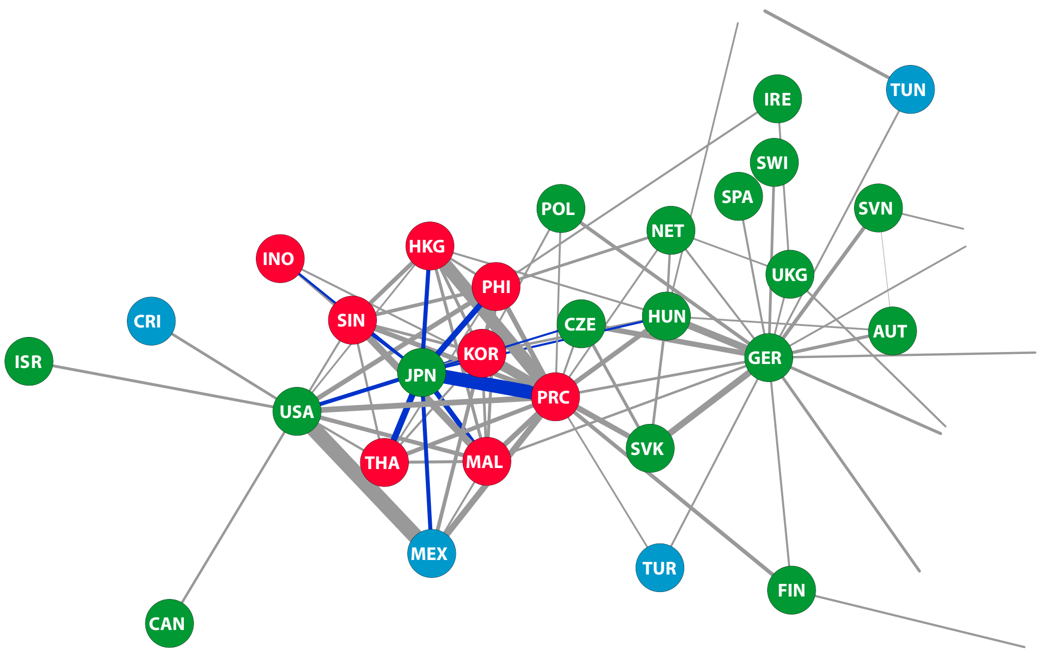
Compared to the map across industries discussed in the previous section, the electronics network is more sparsely populated, as several of the developing countries outside Asia fall below the 0.05 threshold value of the *NTI*. Mexico is the notable exception, which, paired with the US, ranks at the top of the entire network (Appendix Table 4) and also has extensive connections to the PRC, Japan, and other countries within the Asian networks (Figure 7).

Figure 7: Network Trade Index—Electric/Electronics Industries—United States



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

Figure 8: Network Trade Index—Electric/Electronics Industries—Japan



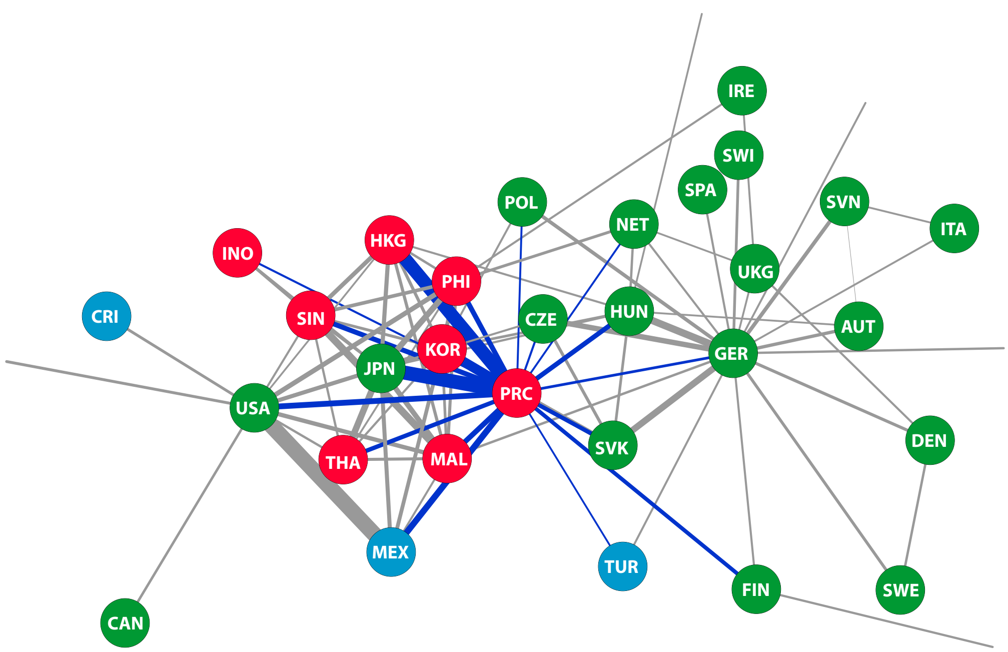
Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

The three hubs—PRC/Japan, Germany, US—are still distinguishable, but are now more proximate to each other. Factory Asia can be seen dominating vertical trade within the global electric/electronics industries (Figure 9). Japan (Figure 8) confirms its central position as a provider of parts and components, and through production sharing is strongly interlinked with the PRC and the rest of Asia, as well as with the North American networks.

The PRC itself is positioned at the inner corner of the Asian network and takes central position with respect to the global networks. The PRC's extensive web of connections within Asia is mirrored by the multiple connections of the US with Asian countries. Both countries involve heavily in vertical trade with all the countries gravitating around the PRC–Japan–US axis dominating global activities. In contrast to the US, however, the PRC also vertically integrates with the more distant European network, including Germany and the eastern outposts, such as the Czech Republic, Hungary, and the Slovak Republic.

Within factory Asia, relatively minor changes characterize the electric/electronics network compared to the broader map across industries, discussed in the previous section. For example, the Philippines now takes a more prominent position, due to its strong vertical integration with Japan's electronics industries.[19] Viet Nam, on the other hand, does not show on the map, because its strongest connection (with Japan, *NTI* =0.046), falls just short of the arbitrary *NTI* cut-off level imposed. Similarly, India fails to show up on the map, but its *NTI* with the PRC reaches a respectable 0.041.

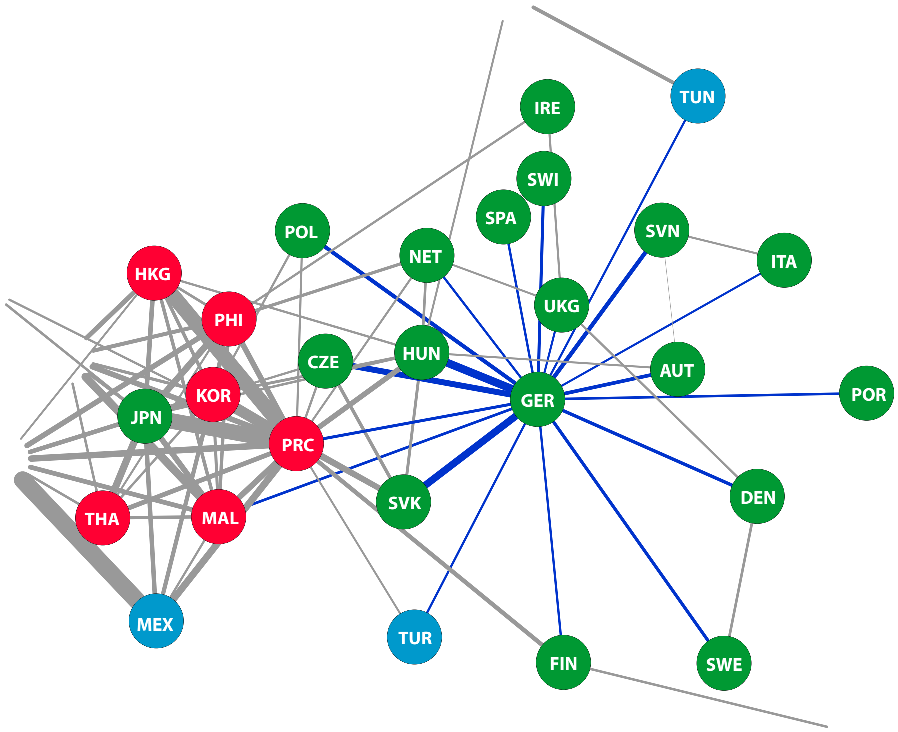
Figure 9: Network Trade Index—Electric/Electronics Industries—People's Republic of China



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

[19] In 2006/2007, 17.9% of the Philippines' intermediate electronics imports originated in Japan, and the electronics industry constituted 11.7% of the country's manufacturing exports (Appendix Table 4).

Figure 10: Network Trade Index—Electric/Electronics Industries—Germany



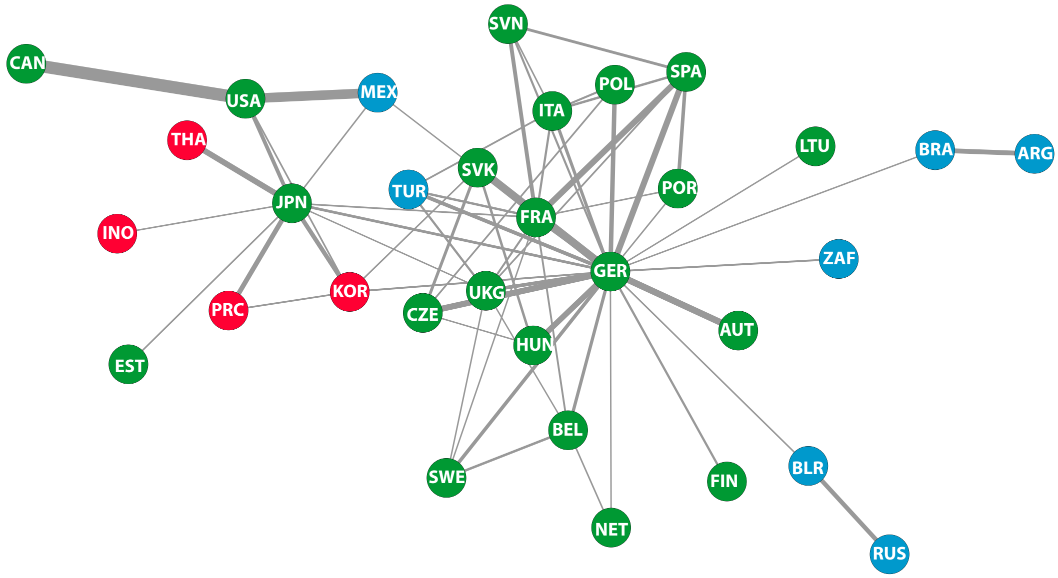
Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

In sum, the *NTI* -based network map of the electric/electronics networks provides strong evidence that production sharing and processing trade centers mainly around factory Asia with the PRC and Japan at its center, and involves a range of close trans-Pacific connections between Asia, Mexico, and the US. Far less substantial is vertical trade in Europe (Figure 10), which is mostly concentrated within the region itself. Outside Asia and apart from Mexico, developing countries are not yet part of the global networks or only marginally so (Costa Rica, Tunisia, and Turkey).

C. The Global Network of the Automotive Sector

Weights are distributed differently within the global network of automotive processing trade compared to the electric/electronics sector. Among the usual three main hubs emerging from the map, it is now Germany taking the driver's seat, followed by the vertically integrated North American automotive industries. By comparison, Asia's industrial network is relatively less developed (Figure 11).

Figure 11: Network Trade Index—Automotive Industries—Global



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

Europe's network of automotive industries (Figure 12) involves the continent's leading auto producers, namely France, Germany, and Italy. These three countries' industries integrate with countries operating either upstream or downstream, by either providing the auto parts or hosting the assembly processes (e.g., Austria, Czech Republic, Poland, Slovak Republic, Spain). Germany is clearly the driving force at the center of the European auto industry and also integrates with important emerging markets, such as Belarus, Brazil, South Africa, and Turkey.

Canada, Mexico, and the US form a second network axes, characterized by strong vertical integration of the automotive industries within NAFTA (Figure 13). This should come as no surprise, considering the long history of North American integration of this industry, going back to the 1965 Auto Pact between Canada and the US.[20]

In stark contrast to the closely tied electronics industry, there are virtually no direct connections between the American and European auto hubs. However, they are both connected with the Asian network cluster around Japan.

Japan's automotive industry positions itself at the center of Asia's networks, as a prime source of auto parts and components (Figure 14). Japan's strongest network partner is

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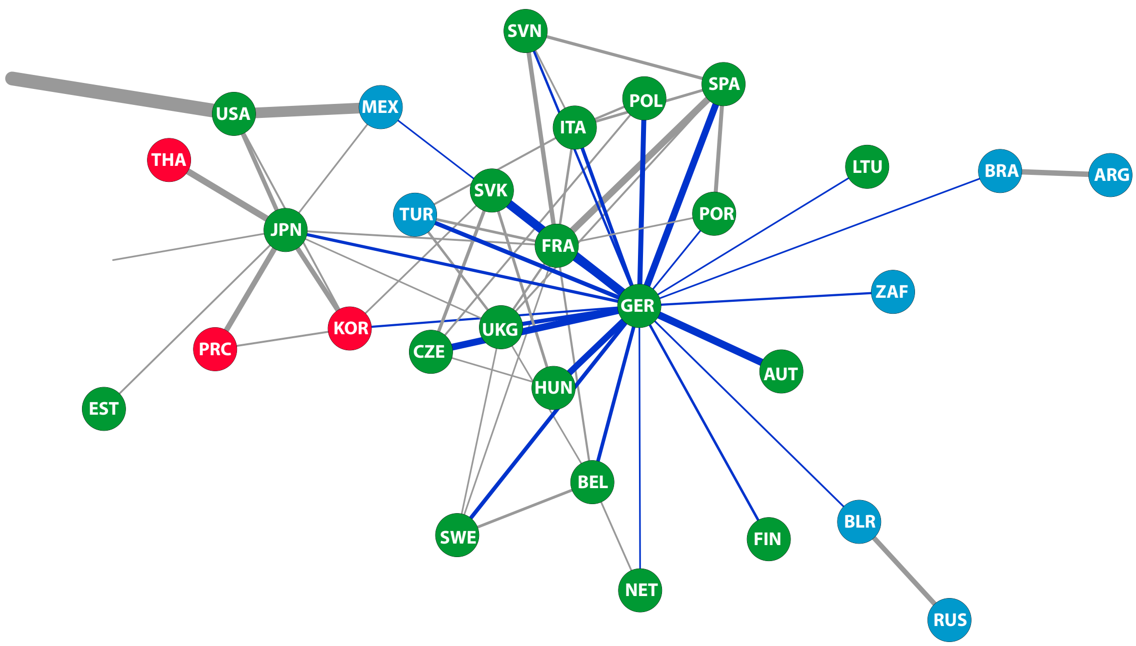
[20] The 1965 Canada–US Automotive Agreement (commonly known as the 1965 Auto Pact) marked the first postwar trade agreement between the two countries, and cleared the way for the 1989 Canada–US Free Trade Agreement. Later, NAFTA brought in also Mexico, leading to a broad regional integration of the auto industry in North America.

Thailand, which sources 67.5% of its automotive parts from Japan (Appendix Table 5).[21] Other relevant partners within the Southeast Asian region are Indonesia, and to a lesser extent the Philippines, which with an *NTI* of 0.03 in connection to Japan however fails to pass the 0.05 *NTI* threshold.

Figure 12: Network Trade Index—Automotive Industries—Germany

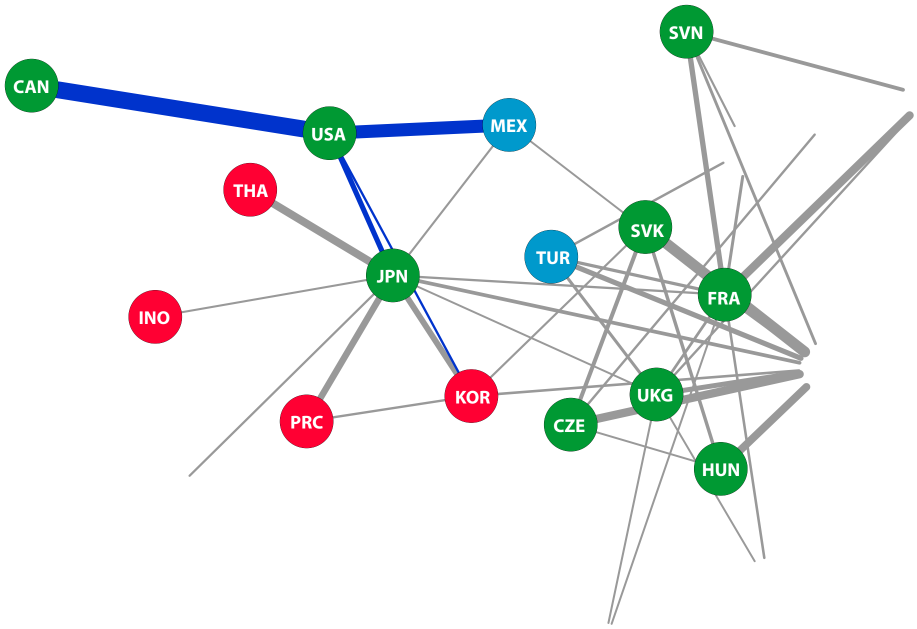


Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

The PRC has not yet reached a status of major influence in the regional automotive industries. Nevertheless, in 2006/2007 the country represented the second-largest regional network leg, in connection with Japan, and also integrates strongly with the Republic of Korea's auto industry. The Republic of Korea itself represents a more significant element in the Asian networks, and also has significant relations to the German and the US hubs.

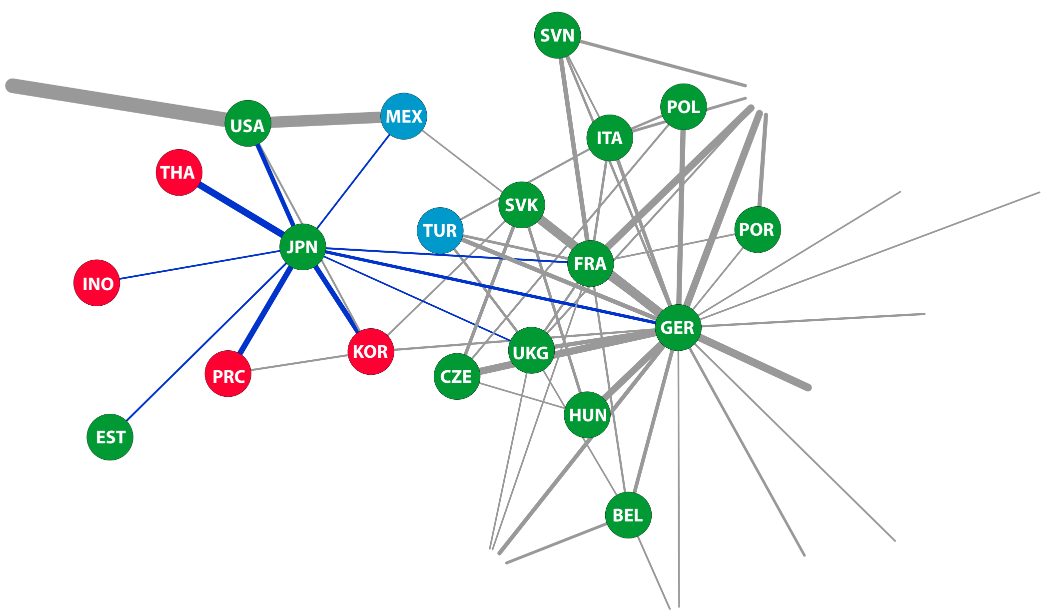
[21] Among all the country pairs, this share is higher only for Canada, which source 81% of its parts from the US. The network relations being also significant in the opposite direction, the two paired countries rank highest based on *NTI* specific to the automotive industry (Appendix Table 5).

Figure 13: Network Trade Index—Automotive Industries—United States



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

Figure 14: Network Trade Index—Automotive Industries—Japan



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

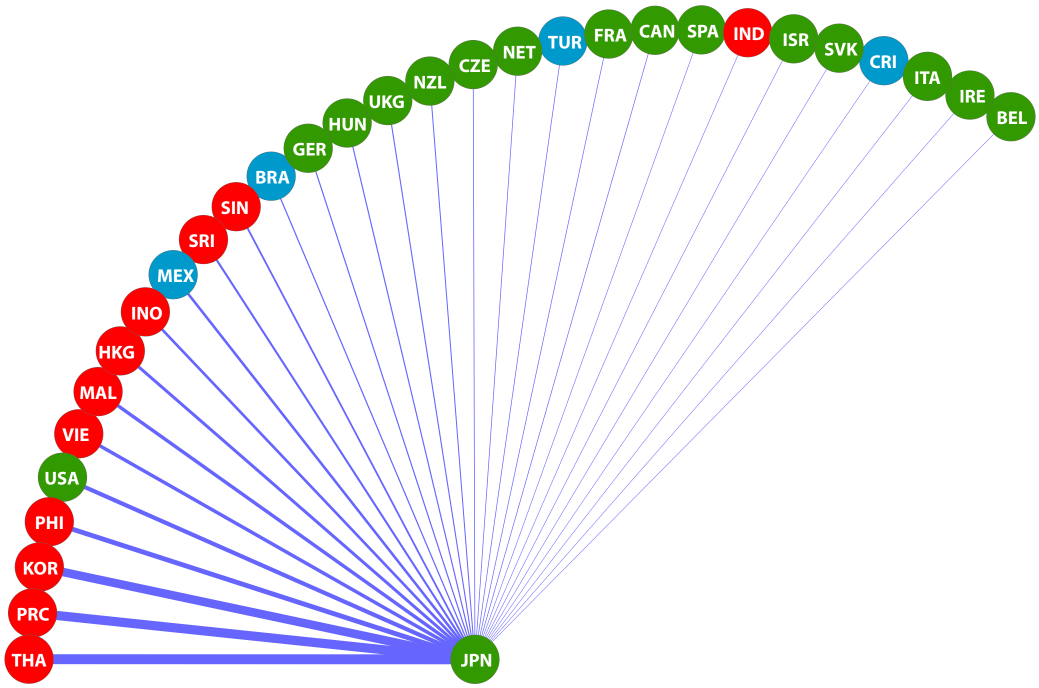
Similar to the other industries characterized by global processing trade, developing countries are poorly represented in the automotive networks. Exceptions are Mexico and Turkey, which are well integrated with Europe. Among the other emerging economies, only Belarus, Brazil, and South Africa have substantial direct connections with a global hub. Argentina and the Russian Federation are shown to integrate only regionally.

V. Value-Chain Dependence on Japan

The *NTI* provides a measure of dependence of any one country on another in terms of the provision of parts and components as inputs for a certain export sector. For a practical application of this property of the index, consider the case of Japan, where disruptions to some of its production activities caused by the devastating earthquake and tsunami of 11 March 2011 have raised fears about this supply shock propagating throughout the global electronics and automotive supply chains. The *NTI* can provide clues as to whether or not such fears may be justified according to Japan's role upstream, as a provider of parts and components for both these global value chains.

Supply dependence is assessed by the *NTI* directed toward Japan, instead of considering the average value of countries' *NTI* from and to Japan, as is done in the network maps. Figure 15 and Appendix Table 6 rank Japan's network partners across all the industries, according to descending values of these countries' *NTI* directed toward Japan. Thailand tops the list, classifying it as the country most vulnerable to a potential disruption in Japan's supply of parts and components. Next in line are the PRC, the Republic of Korea, followed by the Philippines. Besides the US, which ranks fifth, Asian countries as a group appear to be most exposed to Japan's production disruptions across the networked industries.

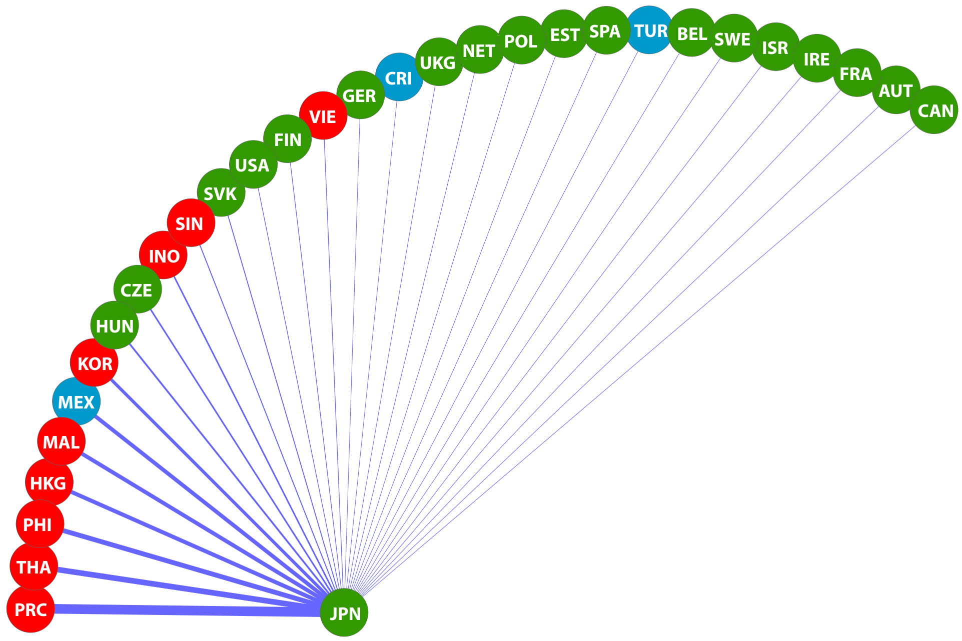
Figure 15: Network Trade Index—Uni-Directed toward Japan—Top 30 Dependencies—All Industries



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

Figure 16 and Appendix Table 7 rank countries according to their dependence on Japan's supply of electric and electronics parts and components. Unsurprisingly, Japan's central position within the regional production networks makes Asian buyers the most vulnerable to potential disruptions in the supply chain. Comparably less exposed is the US, which has the benefit of greater reliance on sources other than Japan for its electronic parts and components, most notably Mexico (Figure 7).

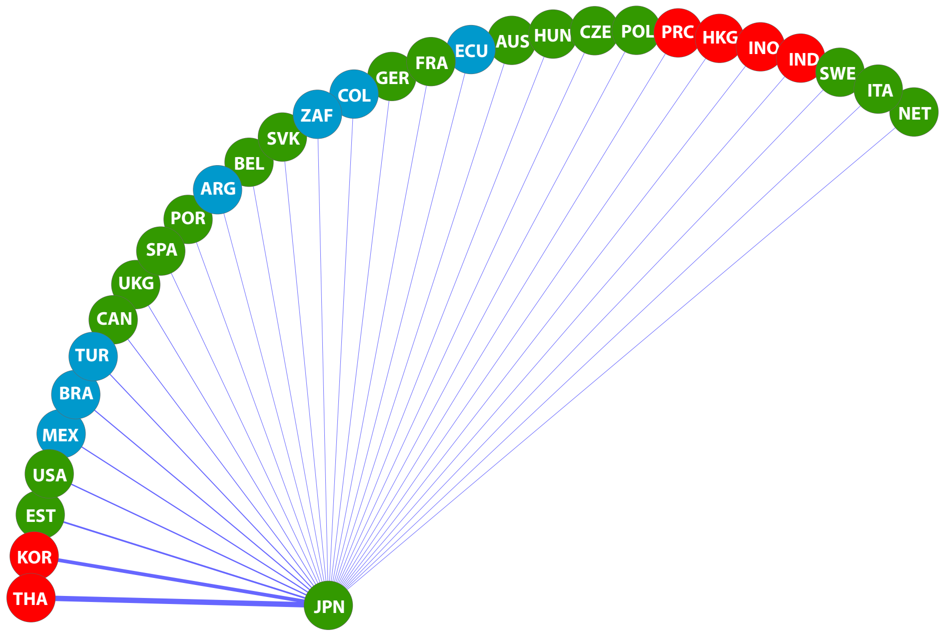
Figure 16: Network Trade Index—Uni-directed toward Japan—Top 30 dependencies—Electric/electronics industries



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

More vulnerable to disruptions in Japan appears the US' automotive industry, as can be evinced from Figure 17 and Appendix Table 8. More generally, vulnerability seems to extend beyond the Asian region, to countries such as Estonia, Mexico, and Turkey. However, generally lower average *NTI* values indicate that supply dependency tends to be generally weaker in the auto industry compared to the electric/electronics supply chains.

Figure 17: Network Trade Index—Uni-Directed toward Japan—Top 30 Dependencies—Automotive Industries



Note: See Appendix Table 1 for definitions of country codes.
Source: Author's calculation.

In sum, the analysis here suggests that Japan's position upstream in the global supply chains does create a certain degree of apprehension about the effects of potential disruptions affecting production downstream. Most likely to be affected are those countries relying most heavily on Japan's provision of electronics parts, such as the PRC, Thailand, and the Philippines. However, it must be emphasized that the network dependencies highlighted by the *NTI* are defined as involving relative large volumes and shares of countries' total parts imports. Therefore, for potential disruptions to affect a partner country's processing industry, these would have to be sufficiently large to render it impossible for the importing country to source the shortfall of parts from alternative providers, including those in Asia. Disruptions of such entity appear to be a most unlikely scenario in the case of Japan, where fears about potential disruptions relate mostly to its continued capacity to provide some highly specialized, high-value added electronics parts, such as smart cards, and is more generally restricted to very few markets where Japan holds a disproportionate share of global production.

VI. Conclusions

This paper develops a method that gauges the complex network relationships in world processing trade and leads to a plausible representation in the form of network maps. The paper finds that global processing trade centers on three major regional hubs. The first is the US, mainly through its strongly integrated automotive and electric/electronics production networks with the other NAFTA member states on one hand, and its close connections to the Asian electronics production networks on the other.

The Asian network itself constitutes the second global hub, especially in relation to trade in parts and components within the electric and electronics industries surrounding the PRC–Japan axis, which also involves a number of economies in East and Southeast Asia.

The third major hub is the European network with Germany at its center, broadly linking the single market's value chains, most notably in relation to Europe's strong automotive industry.

Apart from Mexico—because of its *maquiladoras* network ties to the US—the analysis suggests that outside East and Southeast Asia, developing countries are not yet involved in global production networks to any substantial degree. There is no equivalent to factory Asia in Latin America, let alone Africa.

Concerning the methodology underlying this paper, there is of course a margin for improvement of both the network index and the data set. As for the *NTI*, its properties and performance could be subjected to further evaluation by considering alternative weighting and standardization methods.

Concerning the data set, the use of monthly data would allow identification of network effects of a more dynamic nature, which are particularly relevant for processing trade in relation to just-in-time production. Further insights could also be gained through the use of volume data and unit values for within-product classifications, to further distinguish partners' share in parts and components imports according to different classes of unit values within 6-digit HS product lines.

Finally, network maps can be drawn in relation to all the years available in the data underlying this analysis (1998–2007). Preliminary analysis shows that the evolution of processing trade since 1990 provides interesting aspects on the formation of production clusters in Asia. Due to space constraints, these maps will be the subject of discussion of a follow-up paper.

Appendix

Appendix Table 1: List of Countries/Economies

Code	Country	Code	Country	Code	Country
DZA	Algeria	ITA	Italy	ZAF	South Africa
ARG	Argentina	JPN	Japan	SPA	Spain
AUS	Australia	HKG	Hong Kong, China	SRI	Sri Lanka
AUT	Austria	KAZ	Kazakhstan	SWE	Sweden
AZE	Azerbaijan	KOR	Korea, Rep. of	SWI	Switzerland
BLR	Belarus	KWT	Kuwait	THA	Thailand
BEL	Belgium	LVA	Latvia	TUN	Tunisia
BOL	Bolivia	LBY	Libya	TUR	Turkey
BRA	Brazil	LTU	Lithuania	TKM	Turkmenistan
BGR	Bulgaria	MKD	Macedonia	UKR	Ukraine
CAN	Canada	MAL	Malaysia	UKG	United Kingdom
CHL	Chile	MUS	Mauritius	USA	United States
PRC	China, People's Rep. of	MEX	Mexico	URY	Uruguay
COL	Colombia	MON	Mongolia	VEN	Venezuela
CRI	Costa Rica	MAR	Morocco	VIE	Viet Nam
HRV	Croatia	NET	Netherlands		
CZE	Czech Rep.	NZL	New Zealand		
DEN	Denmark	NGA	Nigeria		
ECU	Ecuador	NOR	Norway		
EGY	Egypt	PRY	Paraguay		
EST	Estonia	PER	Peru		
FIN	Finland	PHI	Philippines		
FRA	France	POL	Poland		
GER	Germany	POR	Portugal		
GRC	Greece	ROM	Romania		
HUN	Hungary	RUS	Russian Federation		
IND	India	SAU	Saudi Arabia		
INO	Indonesia	SIN	Singapore		
IRE	Ireland	SVK	Slovak Rep.		
ISR	Israel	SVN	Slovenia		

Note: List of 75 economies underlying the network trade index computations. Three-digit International Organization for Standardization (ISO) codes are used, except for certain member economies of the Asian Development Bank, for which the Bank's country codes or country names are used.

Source: Author's listing.

Appendix Table 2: Network Trade Index—All Industries

Code	Country	Code	Country	Network Trade Index	Network Trade Index (average)
JPN	Japan	PRC	China, People's Rep. of	0.707	0.646
PRC	China, People's Rep. of	JPN	Japan	0.585	0.646
MEX	Mexico	USA	United States	1.000	0.611
USA	United States	MEX	Mexico	0.221	0.611
CAN	Canada	USA	United States	0.881	0.579
USA	United States	CAN	Canada	0.277	0.579
AUT	Austria	GER	Germany	0.892	0.507
GER	Germany	AUT	Austria	0.122	0.507
CZE	Czech Rep.	GER	Germany	0.813	0.489
GER	Germany	CZE	Czech Rep.	0.164	0.489
HKG	Hong Kong, China	PRC	China, People's Rep. of	0.764	0.443
PRC	China, People's Rep. of	HKG	Hong Kong, China	0.122	0.443
HUN	Hungary	GER	Germany	0.750	0.422
GER	Germany	HUN	Hungary	0.094	0.422
THA	Thailand	JPN	Japan	0.626	0.395
JPN	Japan	THA	Thailand	0.164	0.395
PRC	China, People's Rep. of	KOR	Korea, Rep. of	0.393	0.375
KOR	Korea, Rep. of	PRC	China, People's Rep. of	0.356	0.375
KOR	Korea, Rep. of	JPN	Japan	0.543	0.363
JPN	Japan	KOR	Korea, Rep. of	0.182	0.363
TUN	Tunisia	FRA	France	0.700	0.359
FRA	France	TUN	Tunisia	0.019	0.359
SVK	Slovak Rep.	GER	Germany	0.651	0.349
GER	Germany	SVK	Slovak Rep.	0.047	0.349
POL	Poland	GER	Germany	0.597	0.348
GER	Germany	POL	Poland	0.099	0.348
JPN	Japan	USA	United States	0.407	0.342
USA	United States	JPN	Japan	0.278	0.342
ITA	Italy	GER	Germany	0.409	0.288
GER	Germany	ITA	Italy	0.167	0.288

Note: Top 15 country pairs ranked by decreasing network trade index.
Source: Author's calculation.

Appendix Table 3: Network Trade Index (All Industries)—Asian Economies

Code	Country	Code	Country	Network Trade Index	Network Trade Index (average)
JPN	Japan	PRC	China, People’s Rep. of	0.707	0.646
PRC	China, People’s Rep. of	JPN	Japan	0.585	0.646
HKG	Hong Kong, China	PRC	China, People’s Rep. of	0.764	0.443
PRC	China, People’s Rep. of	HKG	Hong Kong, China	0.122	0.443
THA	Thailand	JPN	Japan	0.626	0.395
JPN	Japan	THA	Thailand	0.164	0.395
PRC	China, People’s Rep. of	KOR	Korea, Rep. of	0.393	0.375
KOR	Korea, Rep. of	PRC	China, People’s Rep. of	0.356	0.375
KOR	Korea, Rep. of	JPN	Japan	0.543	0.363
JPN	Japan	KOR	Korea, Rep. of	0.182	0.363
PHI	Philippines	JPN	Japan	0.318	0.202
JPN	Japan	PHI	Philippines	0.087	0.202
SRI	Sri Lanka	HKG	Hong Kong, China	0.399	0.200
HKG	Hong Kong, China	SRI	Sri Lanka	0.001	0.200
MAL	Malaysia	SIN	Singapore	0.219	0.180
SIN	Singapore	MAL	Malaysia	0.141	0.180
MAL	Malaysia	PRC	China, People’s Rep. of	0.264	0.157
PRC	China, People’s Rep. of	MAL	Malaysia	0.051	0.157
VIE	Viet Nam	PRC	China, People’s Rep. of	0.298	0.155
PRC	China, People’s Rep. of	VIE	Viet Nam	0.013	0.155
PHI	Philippines	HKG	Hong Kong, China	0.276	0.151
HKG	Hong Kong, China	PHI	Philippines	0.025	0.151
MAL	Malaysia	JPN	Japan	0.232	0.144
JPN	Japan	MAL	Malaysia	0.056	0.144
THA	Thailand	PRC	China, People’s Rep. of	0.234	0.144
PRC	China, People’s Rep. of	THA	Thailand	0.054	0.144
VIE	Viet Nam	JPN	Japan	0.234	0.136
JPN	Japan	VIE	Viet Nam	0.037	0.136
INO	Indonesia	JPN	Japan	0.185	0.134
JPN	Japan	INO	Indonesia	0.083	0.134
MAL	Malaysia	THA	Thailand	0.117	0.111

continued.

Appendix Table 3: *continued.*

Code	Country	Code	Country	Network Trade Index	Network Trade Index (average)
THA	Thailand	MAL	Malaysia	0.106	0.111
HKG	Hong Kong, China	JPN	Japan	0.207	0.108
JPN	Japan	HKG	Hong Kong, China	0.010	0.108
SIN	Singapore	PRC	China, People's Rep. of	0.109	0.097
PRC	China, People's Rep. of	SIN	Singapore	0.085	0.097
SIN	Singapore	JPN	Japan	0.131	0.086
JPN	Japan	SIN	Singapore	0.042	0.086
PHI	Philippines	PRC	China, People's Rep. of	0.104	0.081
PRC	China, People's Rep. of	PHI	Philippines	0.059	0.081
VIE	Viet Nam	HKG	Hong Kong, China	0.159	0.081
HKG	Hong Kong, China	VIE	Viet Nam	0.003	0.081
INO	Indonesia	SIN	Singapore	0.107	0.081
SIN	Singapore	INO	Indonesia	0.054	0.081
INO	Indonesia	THA	Thailand	0.093	0.075
THA	Thailand	INO	Indonesia	0.058	0.075
SRI	Sri Lanka	JPN	Japan	0.149	0.075
JPN	Japan	SRI	Sri Lanka	0.001	0.075
SRI	Sri Lanka	PRC	China, People's Rep. of	0.146	0.073
PRC	China, People's Rep. of	SRI	Sri Lanka	0.000	0.073
INO	Indonesia	PRC	China, People's Rep. of	0.115	0.065
PRC	China, People's Rep. of	INO	Indonesia	0.014	0.065
IND	India	PRC	China, People's Rep. of	0.118	0.064
PRC	China, People's Rep. of	IND	India	0.010	0.064
THA	Thailand	KOR	Korea, Rep. of	0.092	0.059
KOR	Korea, Rep. of	THA	Thailand	0.027	0.059
PHI	Philippines	THA	Thailand	0.069	0.058
THA	Thailand	PHI	Philippines	0.047	0.058
HKG	Hong Kong, China	SIN	Singapore	0.086	0.057
SIN	Singapore	HKG	Hong Kong, China	0.027	0.057
VIE	Viet Nam	THA	Thailand	0.094	0.054
THA	Thailand	VIE	Viet Nam	0.014	0.054
INO	Indonesia	KOR	Korea, Rep. of	0.099	0.054
KOR	Korea, Rep. of	INO	Indonesia	0.008	0.054
MAL	Malaysia	HKG	Hong Kong, China	0.068	0.053
HKG	Hong Kong, China	MAL	Malaysia	0.037	0.053
PHI	Philippines	SIN	Singapore	0.081	0.051
SIN	Singapore	PHI	Philippines	0.021	0.051
THA	Thailand	SIN	Singapore	0.063	0.050
SIN	Singapore	THA	Thailand	0.037	0.050

Note: Network relations among Asian country pairs with *NTI* >0.05.
Source: Author's calculation.

Appendix Table 4: Network Trade Index—Electric/Electronics Industries

Country 1	Country 2	Parts Imports from Country 2 (%)	Industry Share of Country 1 Exports (%)	Network Trade Index	Network Trade Index (average)
Mexico	USA	41.7	15.7	1.000	0.567
USA	Mexico	21.5	4.1	0.135	0.567
PRC	Japan	26.2	15.5	0.619	0.506
Japan	PRC	30.5	8.4	0.392	0.506
Hong Kong, China	PRC	42.2	13.3	0.854	0.478
PRC	Hong Kong, China	4.3	15.5	0.102	0.478
PRC	Korea, Rep. of	19.4	15.5	0.459	0.347
Korea, Rep. of	PRC	24.8	6.2	0.235	0.347
Malaysia	Singapore	17.9	11.8	0.323	0.253
Singapore	Malaysia	21.0	5.7	0.183	0.253
Hungary	Germany	21.8	14.3	0.476	0.252
Germany	Hungary	5.3	3.6	0.029	0.252
Slovak Rep.	Germany	20.4	14.3	0.443	0.225
Germany	Slovak Rep.	1.4	3.6	0.008	0.225
Thailand	Japan	28.4	8.6	0.370	0.223
Japan	Thailand	5.9	8.4	0.076	0.223
Mexico	PRC	17.6	15.7	0.422	0.216
PRC	Mexico	0.4	15.5	0.009	0.216
Korea, Rep. of	Japan	22.8	6.2	0.216	0.211
Japan	Korea, Rep. of	16.1	8.4	0.207	0.211
Philippines	Japan	17.9	11.7	0.318	0.203
Japan	Philippines	6.8	8.4	0.088	0.203
PRC	USA	11.0	15.5	0.260	0.200
USA	PRC	22.1	4.1	0.139	0.200
Czech Rep.	Germany	28.9	7.6	0.336	0.184
Germany	Czech Rep.	5.7	3.6	0.031	0.184
Malaysia	PRC	13.1	11.8	0.237	0.179
PRC	Malaysia	5.1	15.5	0.121	0.179
Slovak Rep.	Korea, Rep. of	16.4	14.3	0.356	0.178
Korea, Rep. of	Slovak Rep.	0.0	6.2	0.000	0.178

PRC = People's Republic of China, USA = United States.

Note: Top 15 country pairs—Share of Country 1's parts and components imports sourced from Country 2, and industry's share of total exports of Country 2.

Source: Author's calculation.

Appendix Table 5: Network Trade Index—Automotive Industries

Country 1	Country 2	Parts Imports from Country 2 (%)	Industry Share of Country 1 Exports (%)	Network Trade Index	Network Trade Index (average)
Canada	USA	81.0	13.1	1.000	0.559
USA	Canada	22.5	5.6	0.119	0.559
Mexico	USA	65.3	12.2	0.751	0.429
USA	Mexico	20.4	5.6	0.107	0.429
Slovak Rep.	Germany	39.0	18.0	0.659	0.354
Germany	Slovak Rep.	3.6	14.0	0.048	0.354
Austria	Germany	57.2	8.4	0.451	0.291
Germany	Austria	10.0	14.0	0.132	0.291
Czech Rep.	Germany	45.0	9.8	0.415	0.269
Germany	Czech Rep.	9.3	14.0	0.123	0.269
Spain	Germany	28.6	16.6	0.445	0.265
Germany	Spain	6.4	14.0	0.084	0.265
Spain	France	24.9	16.6	0.388	0.264
France	Spain	16.4	9.1	0.140	0.264
Thailand	Japan	67.5	5.3	0.339	0.253
Japan	Thailand	9.9	18.0	0.167	0.253
Hungary	Germany	62.5	6.4	0.374	0.249
Germany	Hungary	9.5	14.0	0.125	0.249
Argentina	Brazil	52.5	6.9	0.341	0.209
Brazil	Argentina	13.3	6.2	0.078	0.209
Japan	PRC	23.3	18.0	0.393	0.208
PRC	Japan	36.0	0.7	0.023	0.208
Poland	Germany	38.8	7.9	0.288	0.192
Germany	Poland	7.3	14.0	0.096	0.192
Belarus	Russian Federation	44.8	8.9	0.376	0.190
Russian Federation	Belarus	7.2	0.7	0.005	0.190
France	Germany	27.5	9.1	0.235	0.189
Germany	France	10.9	14.0	0.143	0.189
Korea, Rep. of	Japan	27.5	9.3	0.242	0.186
Japan	Korea, Rep. of	7.8	18.0	0.131	0.186

PRC = People's Republic of China, USA = United States.

Note: Top 15 country pairs—Share of Country 1's parts and components imports sourced from Country 2, and industry's share of total exports of Country 2.

Source: Author's calculation.

Appendix Table 6: Network Dependence on Japan—Across Industries

Code	Country	Network Trade index
THA	Thailand	0.626
PRC	China, People's Rep. of	0.585
KOR	Korea, Rep. of	0.543
PHI	Philippines	0.318
USA	United States	0.278
VIE	Viet Nam	0.234
MAL	Malaysia	0.232
HKG	Hong Kong, China	0.207
INO	Indonesia	0.185
MEX	Mexico	0.179
SRI	Sri Lanka	0.149
SIN	Singapore	0.131
BRA	Brazil	0.095
GER	Germany	0.093
HUN	Hungary	0.092
UKG	United Kingdom	0.088
NZL	New Zealand	0.082
CZE	Czech Rep.	0.068
NET	Netherlands	0.064
TUR	Turkey	0.064
FRA	France	0.063
CAN	Canada	0.062
SPA	Spain	0.055
ISR	Israel	0.053
IND	India	0.053
SVK	Slovak Rep.	0.052
CRI	Costa Rica	0.051
ITA	Italy	0.050
IRE	Ireland	0.047
BEL	Belgium	0.045

Note: Top 30 countries ranked by decreasing network trade index.
Source: Author's calculation.

Appendix Table 7: Network Dependence on Japan—Electric/Electronics Industries

Code	Country	Parts Imports from Japan (%)	Industry Share of Exports (%)	Network Trade Index
PRC	China, People's Rep. of	26.2	15.5	0.619
THA	Thailand	28.4	8.6	0.370
PHI	Philippines	17.9	11.7	0.318
HKG	Hong Kong, China	13.4	13.3	0.270
MAL	Malaysia	14.8	11.8	0.266
MEX	Mexico	11.0	15.7	0.263
KOR	Korea, Rep. of	22.8	6.2	0.216
HUN	Hungary	6.1	14.3	0.132
CZE	Czech Rep.	10.3	7.6	0.120
INO	Indonesia	18.3	4.1	0.115
SIN	Singapore	9.4	5.7	0.082
SVK	Slovak Rep.	3.6	14.3	0.077
USA	United States	10.0	4.1	0.063
FIN	Finland	7.1	5.7	0.062
VIE	Viet Nam	21.5	1.9	0.062
GER	Germany	6.4	3.6	0.035
CRI	Costa Rica	9.8	2.1	0.031
UKG	United Kingdom	4.7	3.9	0.028
NET	Netherlands	3.6	5.0	0.028
POL	Poland	2.8	5.9	0.025
EST	Estonia	4.9	3.3	0.025
SPA	Spain	4.5	3.5	0.025
TUR	Turkey	3.3	4.5	0.023
BEL	Belgium	7.1	1.8	0.020
SWE	Sweden	2.0	6.3	0.019
ISR	Israel	2.5	5.0	0.019
IRE	Ireland	3.6	2.8	0.015
FRA	France	3.6	2.4	0.013
AUT	Austria	2.2	3.0	0.010
CAN	Canada	4.5	1.5	0.010

Note: Top 30 countries ranked by decreasing network trade index.
Source: Author's calculation.

Appendix Table 8: Network Dependence on Japan—Automotive Industries

Code	Country	Parts Imports from Japan (%)	Industry Share of Exports (%)	Network Trade Index
THA	Thailand	67.5	5.3	0.339
KOR	Korea, Rep. of	27.5	9.3	0.242
EST	Estonia	22.2	5.9	0.123
USA	United States	18.7	5.6	0.099
MEX	Mexico	7.7	12.2	0.089
BRA	Brazil	14.5	6.2	0.085
TUR	Turkey	6.4	12.8	0.077
CAN	Canada	5.3	13.1	0.066
UKG	United Kingdom	7.3	8.5	0.058
SPA	Spain	3.5	16.6	0.054
POR	Portugal	8.0	6.9	0.052
ARG	Argentina	7.4	6.9	0.048
BEL	Belgium	5.4	9.5	0.048
SVK	Slovak Rep.	2.8	18.0	0.047
ZAF	South Africa	10.9	4.6	0.047
COL	Colombia	14.4	3.0	0.041
GER	Germany	2.6	14.0	0.034
FRA	France	3.8	9.1	0.032
ECU	Ecuador	15.1	2.3	0.032
AUS	Australia	18.7	1.6	0.029
HUN	Hungary	4.3	6.4	0.026
CZE	Czech Rep.	2.7	9.8	0.025
POL	Poland	3.4	7.9	0.025
PRC	China, People's Rep. of	36.0	0.7	0.023
HKG	Hong Kong, China	23.0	1.0	0.021
IND	India	13.2	1.7	0.021
INO	Indonesia	41.3	0.5	0.020
SWE	Sweden	2.2	9.5	0.020
ITA	Italy	3.9	5.1	0.019
NET	Netherlands	5.0	3.1	0.015

Note: Top 30 countries ranked by decreasing network trade index.
Source: Author's calculation.

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About the Paper
Benno Ferrarini maps global networks of production sharing and processing trade. The analysis identifies three major hubs in the global networks: the People's Republic of China in connection with Japan, Germany, and the United States. The analysis highlights that, outside Asia, developing countries are not yet involved in global production networks to any significant degree.

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