Making global value chains visible: Transnational corporations versus domestically owned firms*

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Abstract

This paper aims to advance research on transnational corporations (TNCs) and international business policy by identifying the role and influence of foreign-owned TNCs in global value chains (GVCs) compared with those of domestically owned firms. We do this by dividing the topology of trade in value added (TiVA) into three networks composed, respectively, of traditional trade, simple GVC trade and complex GVC trade, based on the OECD intercountry input-output data for 2005–2016. Our empirical results show that China's domestically owned firms have not only been supply centres of manufacturing value added, but have also risen as new regional centres of both supply and demand for services through simple GVC networks. Domestically owned firms of the United States dominate GVCs in services as a global center for both demand and supply, especially in complex GVC networks. TNCs located in Germany and the United Kingdom have a dominant presence in providing value added in manufacturing and services, respectively, through complex GVC networks. By making GVCs visible through TiVA-based network analyses, this paper significantly extends the understanding of who dominates what types of GVC. This will help policymakers better monitor and

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enhance their GVC governance and competitiveness strategies in more flexible and diversified ways.

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1. Introduction

The rise and spread of global value chains (GVCs), mainly organized by transnational corporations (TNCs), are considered among the most important features of economic globalization in the 21st century (Baldwin and Ito, 2021). From the international trade perspective, GVCs have been narrowly defined by Krugman et al. (1995) as follows: "the trend in manufacturing has been to slice up the value chain-to produce a good in a number of stages in a number of locations, adding a little bit of value at each stage". GVCs were later mainly studied in areas such as TNC policy, international business (IB) research, general management, supply chain management and operations management, and also were extensively researched in economic geography, regional development, international trade and investment, and international political economy (Antràs, 2020a; Kano et al., 2020; Inomata, 2017). GVC-related studies are also intricately linked to current international policy practice "beyond the border", ranging from regulation of commercial presence, to tax competition and even to carbon border adjustment mechanisms, especially in light of the importance of TNCs.

The reality of current GVCs is that the "made in" label typical of manufactured goods attributed to a specific economy has become an archaic symbol of a bygone era, as most manufactured goods (e.g. smartphones, autos, aircraft) are now "made in the world" (Antràs and Chor, 2021; WTO and IDE-JETRO, 2011). Eighty per cent of trade takes place in value chains linked to TNCs (UNCTAD, 2013) and "multinationals account for roughly one-half of international trade, one-third of output and GDP and one-fourth of employment in the global economy" (Cadestin et al., 2019, p. 4). Approximately 85 per cent of the market capitalization of the S&P 500 (the 500 largest firms on the United States stock market, most of which are TNCs or involved internationally) comes from intangible assets.[1] This phenomenon will pose a challenge to policymaking that relies on resident-or territory-based accounting of an economy, and it will necessitate further improvements in the measurement of GVCs from the perspective of firm heterogeneity.

[1]   Ocean Tomo, *Intangible Asset Market Value Study*, July 2020, www.oceantomo.com.

Indeed, one issue of interest to transnational and international business that appears relevant for a better understanding of GVCs in both TNC- and IB-related policy considerations has thus far not been studied in depth: the location-bound participation in value added of TNCs. This is particularly relevant to investigation of global and regional GVC orchestration and to understanding of networks and operations in diverse geographical contexts (De Marchi et al., 2020; Enderwick and Buckley, 2020). Although the study of trade in GVCs as disaggregating national and industrial sources of value added has been used for IB insights (Suder et al., 2015), with consideration of TNCs, broader and deeper cross-border direct investment has led to the involvement of a large number of foreign-owned firms in the production activities of many countries, in addition to domestically owned firms. The still predominant view of GVCs, in which TNCs are important participants, keeps the decomposition of the source of value added at the level of the country of origin without considering the real source of producers in terms of firm ownership, limiting understanding relevant for informed policymaking. For example, data from the United States Bureau of Economic Analysis show that in 2015, United States companies (including subsidiaries in China) sold $372 billion of goods and services to China, while sales of Chinese companies to the United States amounted to $403 billion. If we consider that the difference between the two is defined as the "total sales balance", the difference was $30 billion (China's surplus with the United States) that year, much smaller than the bilateral trade balance of $367 billion in the same year, which is mainly considered as context for IB research on GVC patterns. From the perspective of the United States, the difference has shifted from a deficit of $30 billion in 2015 to a surplus of $7 billion in 2016 and a surplus of $20 billion in 2017.[2] However, even if we adjust the total bilateral trade balance in terms of total sales, such as traditional bilateral gross trade, that does not take into account the formation of value added, which would provide insights into the value of the interconnections and the players' involvement.

Given the increasing complexity and importance of GVCs, more challenges have been identified by GVC researchers, policymakers and business leaders. For example:

1. Are GVCs truly global or are they more of a regional phenomenon? (Baldwin and Lopez-Gonzalez, 2015; Los et al., 2015; Mudambi and Puck, 2016; Xiao et al., 2020)

2. Which is dominant in GVCs: domestically owned firms or TNCs? (Fortanier et al., 2019; Ghauri et al., 2021)

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[2] Deutsche Bank, Annual Report 2019, https://investor-relations.db.com.

3. Whether, how and to what extent do growing uncertainties (such as geopolitical conflicts, the COVID-19 pandemic and climate change) affect GVCs? (Antràs, 2020b; Elia et al., 2021; Solingen, 2021; Suder et al., 2021; UNCTAD, 2021 and 2022)

Understanding these issues is crucial to better understanding the impacts on the world economy of the two primary directions of trade liberalization (regional versus global) and a possible decoupling of the trade–investment nexus owing to growing geopolitical risks. They also inform reflections on what better GVC governance should look like.

Academic responses to these challenges might vary greatly because of differences in approaches, measures and presentation formats used in the literature. This is why GVC research requires a more interdisciplinary approach (Kano et al., 2020). This paper contributes to a perspective rarely found in TNC and IB research, by focusing on TNCs' location participation within fragmented GVCs, compared with that of domestically owned firms. We do so by tapping into the first database to use inter-country input–output (ICIO) analyses in a way that allows such considerations, thanks to the inclusion of firm ownership information and network analysis. Through the resulting ability to make GVCs visible by network analyses of trade in value added (TiVA) with consideration of the differences between the GVC activities of domestically owned and foreign-owned firms, this paper aims to extend the understanding of which type of firm dominates which types of GVCs over time and of transnationals' role in GVC governance. Our empirical results can help policymakers better monitor and enhance their GVC governance and competitiveness strategies in more flexible and diversified ways. This could further contribute to a more nuanced analytical and policy-oriented capability and consequently to policy impact in the future.

This paper is organized as follows: we first review the recent evolution of GVC measures and the related literature about how to make GVCs visible. We then conduct a detailed analysis of the basic methods of decomposing bilateral trade into different channels of traditional trade, simple GVC trade and complex GVC trade based on an ICIO model that allows us to further consider value added creation and absorption by firm ownership, country of origin and destination. We provide the findings through visualization and explain the visualization method based on the decomposition while presenting the results as a topological relationship diagram. We analyse the centres of the current GVCs by dividing a country's enterprises into domestically owned firms and TNCs from both the supply and demand sides at sector levels (mainly manufacturing and services). The last section draws the main conclusion and offers thoughts on further research avenues based on our findings.

2. Literature review on GVC measures

Recent research (Johnson and Noguera, 2012; Koopman et al., 2014; Los et al., 2015; Los et al., 2016; Patel et al., 2019) on TiVA in the context of GVCs has led to important developments in and revisions to the concept of bilateral trade balance, revealed comparative advantage, real effective exchange rate and other trade-related measurements. One of the most important advantages of TiVA is that it avoids double counting of value added due to multiple cross-border transactions of intermediates and clearly identifies who produces what for whom in GVCs. Some follow-up studies (Borin and Mancini, 2017 and 2019; Miroudot and Ye, 2020; Nagengast and Stehrer, 2016) provided more detailed decompositions, which can be used to trace the source, transfer, absorption (sink) and double counting of value added along GVCs at the country, sector and bilateral level. More recent studies (Wang et al., 2017; Xiao et al., 2020) further trace value added in GVCs by various trading routes with consideration of the number of times that contents cross national borders. These pioneering works have provided significantly enriched insights into economic globalization and global imbalances, as well as the context of TNC and IB research, with a focus on the role of global production sharing. In recent TNC and IB research, there are growing calls for more mixed methodologies and insights from nontraditional methodologies into GVCs, including from IO (Ambos et al., 2021; Ferreira et al., 2021; Kano and Oh, 2020; Kwon 2020; McWilliam et al., 2020; Miroudot, 2020; Pla-Barber et al., 2021; Veselovská, 2020; Zhan, 2021). There are also calls to strengthen the understanding of firms therein (Kano et al., 2020).[3] This is especially relevant as some mega-risks (e.g. the COVID-19 pandemic, the United States–China trade conflict and climate change) are increasingly seen as potential tipping points in GVC theory building (Antràs, 2020b; Elia et al., 2021; Ghauri et al., 2021; Suder et al., 2021).

To provide an initial accounting of the value added formation of TNCs in GVCs, recent studies (López et.al., 2019) have combined traditional ICIO tables with data on the investment and business activities of TNCs in selected countries, such as the United States. Recently, the Organisation for Economic Co-operation and Development (OECD) constructed new ICIO tables (from the Activity of Multinational Enterprises (AMNE) database) that now also consider TNCs' activities (Cadestin et al., 2018). It further divides production activities within each country according to the country of origin of the producer, and whether the producer is domestically or foreign owned. GVC trade can be mapped in greater detail so that we now know not only the source of the country and industry but also the origin of the value added creator by firm ownership. For example, Fortanier et al. (2019) show that the

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3 Sébastien Miroudot, "Resilience versus robustness in global value chains: Some policy implications",18 June 2020, www.cerp.org/voxeu.

higher import content of exports of TNCs can go hand in hand with the creation of local backward linkages as a function of their much higher specialization in specific parts of the production process relative to domestically owned firms. Meng and Ye (2020) investigated the so-called smile curve phenomenon and identified value added gains, positions, and interdependencies of TNCs and domestically owned firms along GVCs. This new analysis provides previously inaccessible academic research and IB theory-building opportunities for a better understanding of GVCs and interpretation of bilateral trade balances, bilateral value added formation and, importantly, how to trace value added formation of TNCs around the world. This may also provide a strong basis and tools for globally coherent policy frameworks, such as the Base Erosion and Profit Shifting (BEPS) project, that are yet untapped by policy- and strategy-focused IB and TNC research into GVCs.

In the quest to enable a methodology for "how to make GVCs visible", researchers have increasingly used network analyses. Xiao et al. (2020) used the ICIO-based TiVA measure to extend existing network analyses (cf. Amador and Cabral, 2017; Cerina et al., 2015; Ferrarini, 2013; Ferrantino and Taglioni, 2014; Zhou et al., 2016; Zhu et al., 2015) and concluded that GVCs are more likely organized regionally and dominated by large countries, such as the United States, China and Germany. At the sector level, what GVCs look like depends largely on the perspective (supply or demand) and the type of networks adopted. That conclusion enriches our understanding of the topology of GVCs, providing a balanced view between that of Los et al. (2015) and Baldwin and Lopez-Gonzalez (2015). The former finds that a transition from regional production networks to the "World Factory" has appeared in almost all production chains during the years 1995–2011. The latter states more boldly that "supply chain trade is not global – it's regional" and that "the global production network is marked by regional blocks, what could be called Factory Asia, Factory North America and Factory Europe" (Baldwin and Lopez-Gonzalez, 2015, p. 1696).

Nevertheless, to the best of our knowledge, research on GVCs using ICIO models and network analysis tools looks only at country and sector; no such research explicitly considers the role of firm control (e.g. by ownership). It was argued by Mudambi and Puck (2016) that the findings presented by the regional strategy literature do not capture the full array of global activities of the TNCs, and, thus, "are likely to lead to biased interpretations using different theoretical lenses, such as the knowledge-/resource-based view, internalization theory and more general transaction cost economics" (p. 1076). Given this, our paper follows the concept of bilateral TiVA (Johnson and Noguera, 2012; Koopman et al., 2014: Suder et al., 2015) and takes advantage of the recent accounting framework by Meng and Ye (2020) for capturing GVC activities with a clear distinction between domestically owned firms and TNCs. It further uses the network-based analytical framework of Xiao et al. (2020) to remap the GVC topology and its evolution over time and

shows which type of firm (domestically owned or TNC) dominates GVCs in which way and to what extent. Our empirical results can be used to identify the real competitiveness of a country's own firms in a particular industry and to understand the locational participation of TNCs in GVCs, setting the scene for future better-informed research on location decisions and GVC governance. This paper also aims to provide policymakers with tools for better analysis, decision-making and incentives that may contribute to attracting and securing suitable sustainable trade and investment benefits.

3. Measuring value added trade in GVCs with consideration of firm ownership and trading route

The methods used to estimate TiVA by trading route are rooted in the ICIO-based models (Suder et al., 2015; Xiao et al., 2020). Without loss of generality, let us consider an ICIO model with G countries, N industries and two types of firms (D: domestically owned; and F: foreign-owned), which is consistent with the layout of the available transformed ICIO tables from the OECD AMNE, as shown in table 1 and its note (Cadestin et al., 2018).

In our model, $\mathbf{Z}^{sr}$ is a 2*N by 2*N matrix of intermediate input flows that are produced in country s and used in country r by domestically owned or foreign-owned firms (e.g. $\mathbf{Z}^{rs}_{FD}$ is the N by N matrix representing the exports of intermediates produced by foreign-owned firms located in country r used by country s's domestically owned firms). $\mathbf{Y}^{sr}$ is a 2*N by 1 vector giving final products consumed in country r and produced by domestically owned or foreign-owned firms in country s (e.g. $\mathbf{Y}^{rs}_{F}$ is the N by 1 vector representing the exports of final products produced by foreign-owned firms located in country r, used by country s). $\mathbf{X}^{s}$ and $\mathbf{VA}^{s}$ are, respectively, a 2*N by 1 and 1 by 2*N vectors of gross outputs and direct value added in country s, including domestically owned and foreign-owned firms. The input coefficient matrix (2*GN by 2*GN) can be defined as $\mathbf{A} = \mathbf{Z} \cdot \hat{\mathbf{X}}^{-1}$, where $\hat{\mathbf{X}}$ denotes a diagonalized matrix of the output vector $\mathbf{X}$; thus $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$ can be defined as the well-known global Leontief inverse matrix representing the induced output by one unit of final demand through the whole global production network. The value added coefficient vector (1 by 2*GN) can be defined as $\mathbf{V} = \mathbf{VA} \cdot \hat{\mathbf{X}}^{-1}$. Following Johnson and Noguera (2012) and Xiao et al. (2020), the definition of bilateral TiVA (forward link or supply side) by trading route and firm ownership is given as follows:

Value added exports to country r of domestically owned (D) or foreign-owned (F) firms located in country s (s≠r, similarly hereinafter) through the traditional trading route:

$$\widehat{\mathbf{V}^{s}_{D \text{ or } F}} \cdot \mathbf{L}^{ss} \cdot \mathbf{Y}^{sr}. \tag{1}$$

Table 1. Layout of the transformed OECD AMNE ICIO tables

Iutputs		Outputs						Final demand				Total output
		Intermediate use										
		1		2		...	G	1	2	...	G	
Intermediate inputs	1	Z_{DD}^{11}	Z_{DF}^{11}	Z_{DD}^{12}	Z_{DF}^{12}	...	Z_{DD}^{1G} Z_{DF}^{1G}	Y_D^{11}	Y_D^{12}	...	Y_D^{1G}	X_D^1
		Z_{FD}^{11}	Z_{FF}^{11}	Z_{FD}^{12}	Z_{FF}^{12}	...	Z_{FD}^{1G} Z_{FF}^{1G}	Y_F^{11}	Y_F^{12}	...	Y_F^{1G}	X_F^1
	2	Z_{DD}^{21}	Z_{DF}^{21}	Z_{DD}^{22}	Z_{DF}^{22}	...	Z_{DD}^{2G} Z_{DF}^{2G}	Y_D^{21}	Y_D^{22}	...	Y_D^{2G}	X_D^2
		Z_{FD}^{21}	Z_{FF}^{21}	Z_{FD}^{22}	Z_{FF}^{22}	...	Z_{FD}^{2G} Z_{FF}^{2G}	Y_F^{21}	Y_F^{22}	...	Y_F^{2G}	X_F^2
	...	...	...	...	...	...	... ...	...	...	...	...	...
	G	Z_{DD}^{G1}	Z_{DF}^{G1}	Z_{DD}^{G2}	Z_{DF}^{G2}	...	Z_{DD}^{GG} Z_{DF}^{GG}	Y_D^{G1}	Y_D^{G2}	...	Y_D^{GG}	X_D^G
		Z_{FD}^{G1}	Z_{FF}^{G1}	Z_{FD}^{G2}	Z_{FF}^{G2}	...	Z_{FD}^{GG} Z_{FF}^{GG}	Y_F^{G1}	Y_F^{G2}	...	Y_F^{GG}	X_F^G
Value added		Va_D^1	Va_F^1	Va_D^2	Va_F^2	...	Va_D^G Va_F^G					
Total input		$(X_D^1)'$	$(X_F^1)'$	$(X_D^2)'$	$(X_F^2)'$	...	$(X_D^G)'$ $(X_F^G)'$					

Source: Cadestin et al. (2018).

Value added exports to country r of domestically owned (D) or foreign-owned (F) firms located in country s through the simple GVC trading route is shown as follows:

$$\widehat{V_{D \text{ or } F}^{s}} \cdot \mathbf{L}^{ss} \cdot \mathbf{A}^{sr} \cdot \mathbf{L}^{rr} \cdot \mathbf{Y}^{rr} \qquad . \tag{2}$$

Value added exports to country r of domestically owned (D) or foreign-owned (F) firms located in country s through the complex GVC trade route is shown as follows:

$$\widehat{V_{D \text{ or } F}^{s}} \cdot \mathbf{L}^{ss} \cdot \left(\sum_{t \neq s}^{G} \mathbf{A}^{st} \cdot \sum_{u}^{G} \mathbf{B}^{tu} \cdot \mathbf{Y}^{ur} - \mathbf{A}^{sr} \cdot \mathbf{L}^{rr} \cdot \mathbf{Y}^{rr} \right), \tag{3}$$

where $\widehat{\mathbf{V}_{D}^{s}}$ is the diagonalized matrix of $\mathbf{V}_{D}^{s}$ (a 1 by 2*N row vector including only value added elements of domestically owned firms located in country s); $\widehat{\mathbf{V}_{F}^{s}}$ is the diagonalized matrix of $\mathbf{V}_{F}^{s}$ (a 1 by 2*N row vector including value added elements of foreign-owned firms located in country s); and $\mathbf{L}^{ss} = (\mathbf{I} - \mathbf{A}^{ss})^{-1}$ which represents the 2*N by 2*N domestic Leontief inverse of country s, including both domestically and foreign-owned firms (induced output of domestic products by one unit of final demand).

Clearly, equation (1) represents a country's value added sourced in domestically owned or foreign-owned firms used to satisfy foreign final demand of country r that does not involve any crosscountry production activities. It crosses a national border for final demand usage, so is very similar to the traditional "Ricardian" type trade, i.e. "French wine in exchange for English cloth", and, thus, is identified as "traditional trade" in the paper. Equation (2) represents the value added of domestically owned or foreign-owned firms in country s embodied in intermediate exports that are used by the trading partners of domestically owned or foreign-owned firms to produce its final domestic products, which are then consumed in the direct importing country r. In this case, the domestic value added sourced in domestically owned or foreign-owned firms crosses a national border only once (relatively simple production sharing across countries), with no indirect exports to third countries or re-export activities involved; thus, it is identified in this paper as "simple GVC trade". The first part in equation (3) represents the value added of domestically owned or foreign-owned firms in country s, respectively, that is induced by the final demand of country r for imports from a third country u. This implies that the value added by country s must first be embodied in its intermediate products that are exported directly to country t (including country r), which will be further used directly and indirectly by domestically owned or foreign-owned firms in country u (including country r) to produce final products to satisfy the final demand of country r. With the second part, which is equals to minus equation (1), it can be seen that equation (3) represents the value added of domestically owned or foreign-owned firms in country s that is absorbed by country r through third countries. In this case, the factor contents move across country borders at least twice (relatively complex production sharing across countries); thus, it is defined as a case of "complex GVC trade" in this paper.

This decomposition of GVCs by different trading routes is simply illustrated in figure 1 using China's value added creation in the metal industry as an example. This decomposition provides a better understanding of how global production is fragmented and, thus, of the relative position (upstream or downstream) of a specific country in GVCs as well as the complexity (partly reflecting the level of technology embodied in intermediate goods) and length of GVCs involving different types of firms.

Figure 1. Value added creation and absorption along GVCs by trading route

Source: Meng et al. (2023).
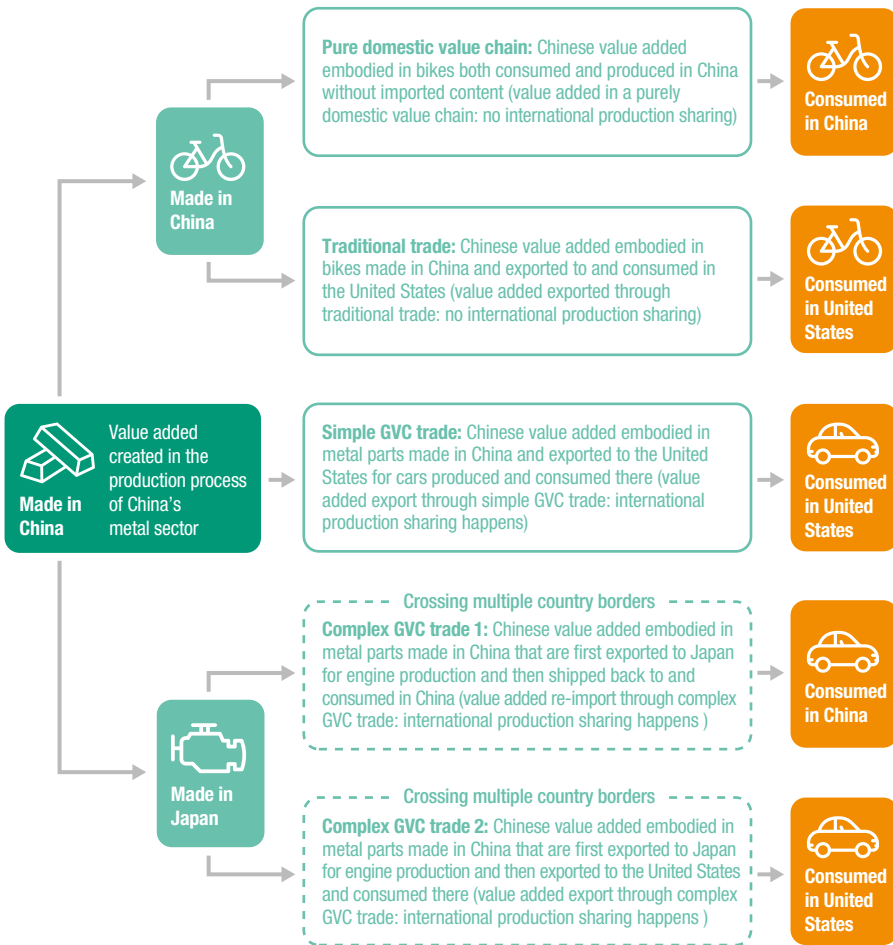
This approach follows the forward industrial linkage. Therefore, it can be used to investigate how a specific firm or industry's value added is embodied in all downstream production stages and finally absorbed by a country's final demand through various trading routes. This approach is suitable for analysing GVC networks from the point of view of a supplier (value added creating firm or industry). Similarly, we can also follow the backward industrial linkage to investigate how the final demand for a specific good or service induces value added along upstream value chains, which could provide a demander's view of GVCs, as shown in the following equations.

Induced value added by domestically owned (D) or foreign-owned (F) firms in country r by country s's final demand for a specific product made in country r (r≠s, similarly hereinafter) through the traditional trading route is shown as follows:

$$\mathbf{V}^r_{D \text{ or } F} \cdot \mathbf{L}^{rr} \cdot \widehat{\mathbf{Y}^{rs}}. \tag{4}$$

Induced value added by domestically owned (D) or foreign-owned (F) firms in country r by country s's final demand for a specific product made in country s through the simple GVC trading route is shown as follows:

$$\mathbf{V}^r_{D \text{ or } F} \cdot \mathbf{L}^{rr} \cdot \mathbf{A}^{rs} \cdot \mathbf{L}^{ss} \cdot \widehat{\mathbf{Y}^{ss}}. \tag{5}$$

Induced value added by domestically owned (D) or foreign-owned (F) firms in country r by country s's final demand for a specific product made in third countries through the complex GVC trading route is shown as follows:

$$\mathbf{V}^r_{D \text{ or } F} \cdot \mathbf{L}^{rr} (\sum_{t \neq s}^{G} \mathbf{A}^{rt} \cdot \sum_{u}^{G} \mathbf{B}^{tu} \cdot \widehat{\mathbf{Y}^{us}} - \mathbf{A}^{rs} \cdot \mathbf{L}^{ss} \cdot \widehat{\mathbf{Y}^{ss}}), \tag{6}$$

where $\widehat{\mathbf{Y}^{rs}}$ is the diagonalized matrix of $\mathbf{Y}^{rs}$.

4. Method for visualizing networks of TiVA in GVC analysis

The ICIO data used is from the OECD AMNE database[4], wherein firms are categorized according to their ownership (domestically and foreign-owned) over the period 2005–2016, with 60 economies (appendix) and 34 industries in the

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[4] Main data sources used in compiling the OECD AMNE ICIO tables include the OECD ICIO tables, OECD AMNE statistics, national accounts and other national sources, trade by enterprise characteristics and services trade by enterprise characteristics, and micro-level databases. For other options, refer to the UNCTAD-Eora Global Value Chain Database (Casella et al., 2019), the World Input-Output Database (www.wiod.org), and the ADB-MRIO (https://mrio.adbx.online), which provide different country, sector and year coverage.

ISIC Rev. 4 classification at the basic price[5]. It should be noted that foreign-owned firms are defined as foreign affiliates that have at least 50 per cent foreign ownership and that domestically owned firms include both domestic TNCs (domestic firms with foreign affiliates) and domestic firms not involved in international investment.

To simplify the identification of the relationship between peripheral and core countries of various networks from the perspectives of importers and exporters of value added, separately, networks can be presented in two ways. The first uses a specific country as a supply centre if the majority of value added imports by other countries are from that country. The second uses a specific country as a demand centre if the majority of value added exports from other countries go to that country. In the network figures, a bubble's size represents the share of a country's value added exports or imports of the world total. The shares of value added flowing through trading partners are represented by the thickness of an arrow. The point of the arrow shows the direction of the value added flow.

Note that whether an arrow appears in the network depends on two standards. In the visualization of networks, we use the following criteria: (1) if country A takes the largest share of value added imports from country B, an arrow will lead from A to B; or (2) if country A's share of country B's value added imports is larger than 25 per cent, an arrow will lead from A to B. The first standard is the so-called top 1 threshold, which is widely used in network analyses to identify the most important arcs or links.[6] The second standard is used to adjust the density of the network and, thus, avoids omitting other important links. We must emphasize that the arrows between nodes in the GVC trade networks are not about the relationship of any direct bilateral trade partners. Instead, they are used to explore the complexity of the whole structure of interactions among countries that are indirectly linked with each other in terms of TiVA through third countries.[7]

5. Empirical results

The empirical results show very large variations of networks given the high diversity of dimensions used (including year, time, sector, supply side vs. demand side, trading route and firm ownership). For ease of explanation, we focus on the manufacturing and services sectors for the years 2005 to 2016.

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[5] According to the definition of Eurostat (see https://ec.europa.eu/eurostat/statistics-explained/index. php?title=Glossary:Basic_price), the basic price is the amount receivable by the producer from the purchaser for a unit of a good or service produced as output minus any tax payable, and plus any subsidy receivable, by the producer as a consequence of its production or sale. It excludes any transport charges invoiced separately by the producer.

[6] We checked for robustness by way of the choice of threshold (5–40 per cent) and found that 25 per cent yields a stable situation for the number of links in selected core countries.

[7] For details, see Xiao et al. (2020).

5.1 Centres of TiVA in manufacturing GVC networks by trading route and firm ownership

GVCs involving both domestically owned firms and TNCs in the manufacturing sector can be divided into three subnetworks: traditional trade, simple GVC trade and complex GVC trade. As shown in figure 2, from the supply side, between 2005 and 2016, value chains involving domestically owned firms around the world increasingly developed into three regions centred on China, Germany and the United States, through both traditional trade (figure 2a) and simple GVC trade (figure 2b). There appeared to be a pattern of dual centres in Germany and in China through complex GVC trade (figure 2c). At the country level, relatively rapid changes in network topology can be observed as follows.

First, China took over Japan's position, and its share of value added creation in the manufacturing sector GVC began to exceed that of Germany. China is more likely a global centre with more surrounding countries, especially through both simple and complex GVC trade. This is highly consistent with the recent literature on the success story of China's domestic industrial upgrading.[8] Namely, China is not only the largest final goods provider in the world, but also supplies relatively more high-tech intermediate goods to serve its downstream countries directly through simple GVC trade and indirectly through complex GVC trade.

Second, the United States maintained its position as a regional supply centre of value added, mainly for the members of the Agreement between the United States of America, Mexico and Canada (USMCA), but its presence declined relatively, especially in complex GVC networks, in terms of the number of surrounding countries. Nevertheless, the United States has become more interdependent with China, which can be seen from the growing thickness of the United States–China connection in the figure. This is caused on the one hand by the hollowing out of United States low-technology manufacturing industries (offshored to low-technology, low-wage countries) and on the other, by the enhancement and specialization of United States high-technology manufacturing industries (Meng, Ye and Wei, 2020). Third, Germany's position as a regional centre in Europe has been relatively stable over time, while the Germany–United States connection has been largely replaced by the Germany–China connection.

For GVCs involving TNCs, the overall network topology and evolution over time are similar to GVCs involving domestically owned firms, but significant differences can be identified at the country level. For example, during the period, TNCs in Germany show a much larger presence as a centre to create value added than those in China, especially in complex GVC networks. At the same time, TNCs

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[8] For example, see Xing (2020).

Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016

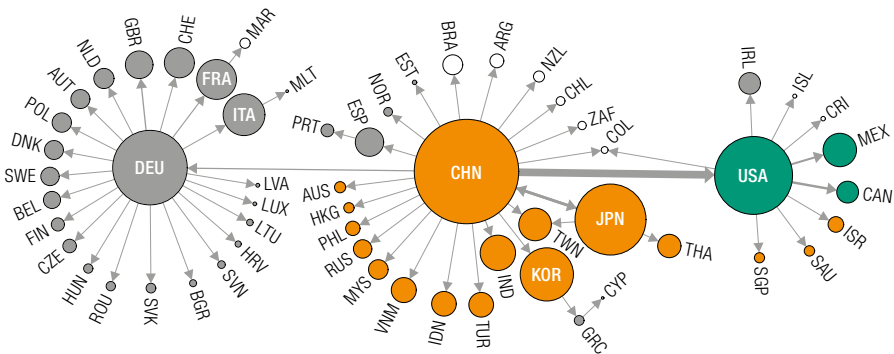2a. Traditional trade networks, domestically owned firms
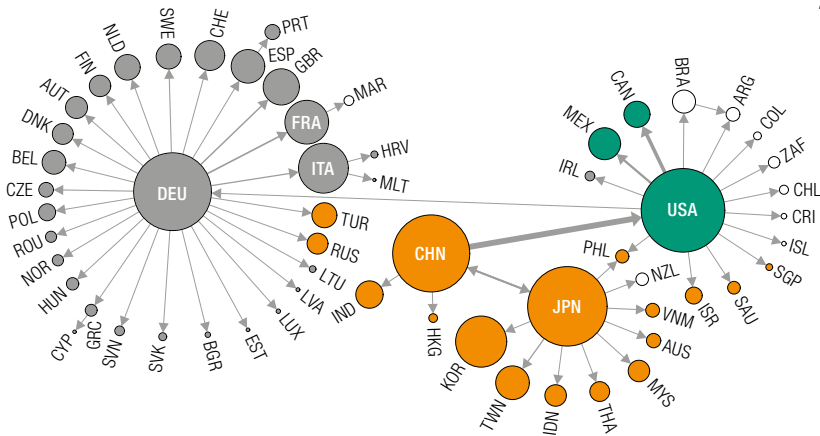
Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)
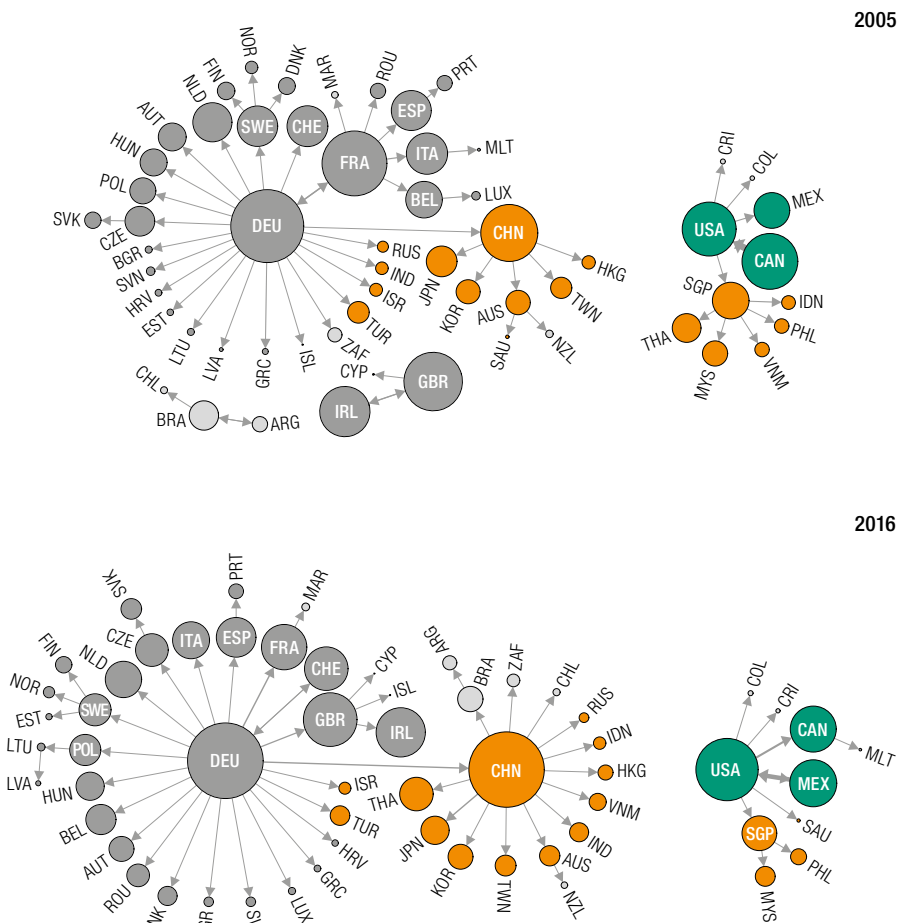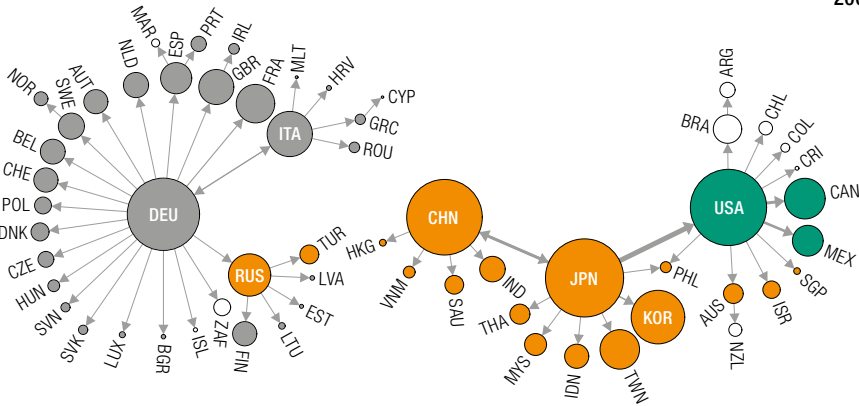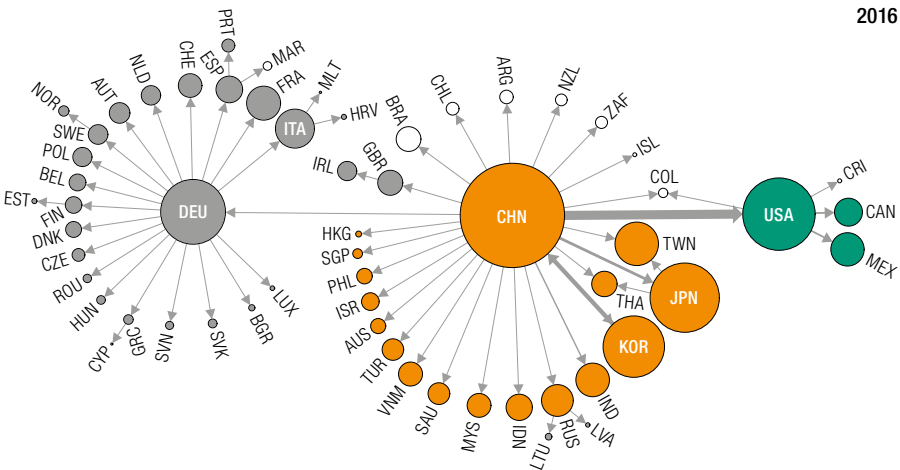
2a. Traditional trade networks, TNCs

2005

2016

Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)
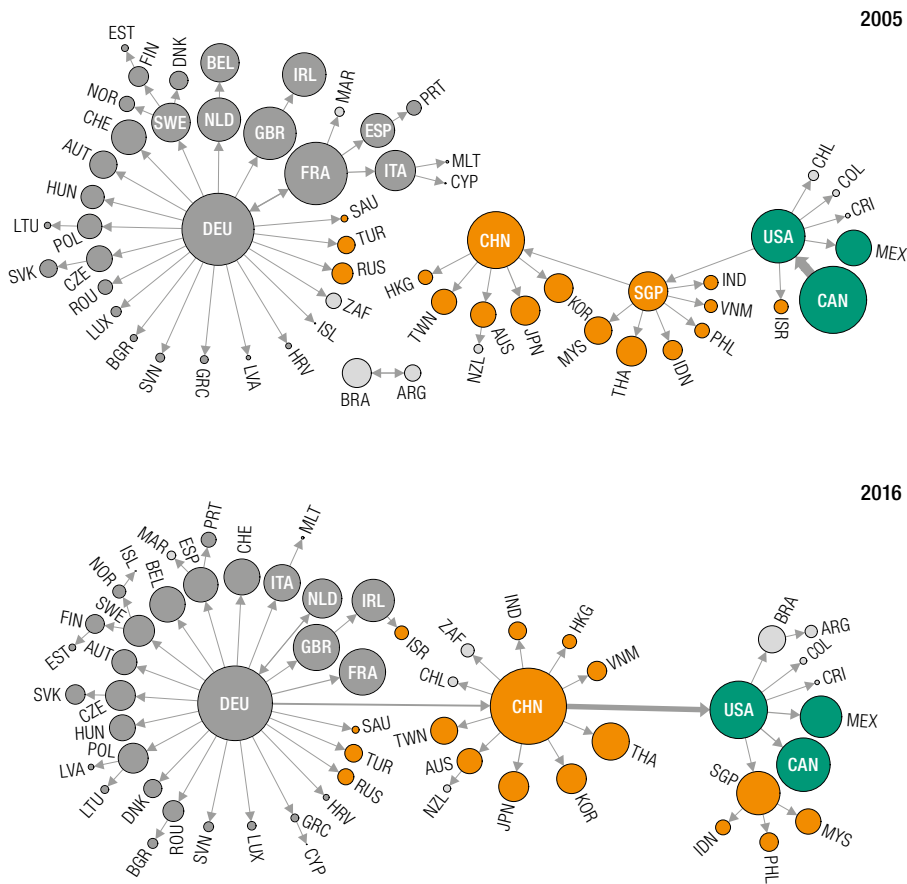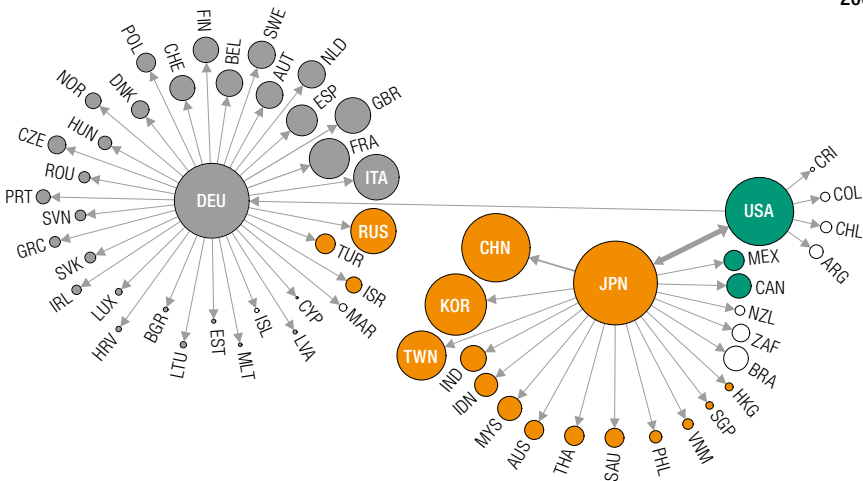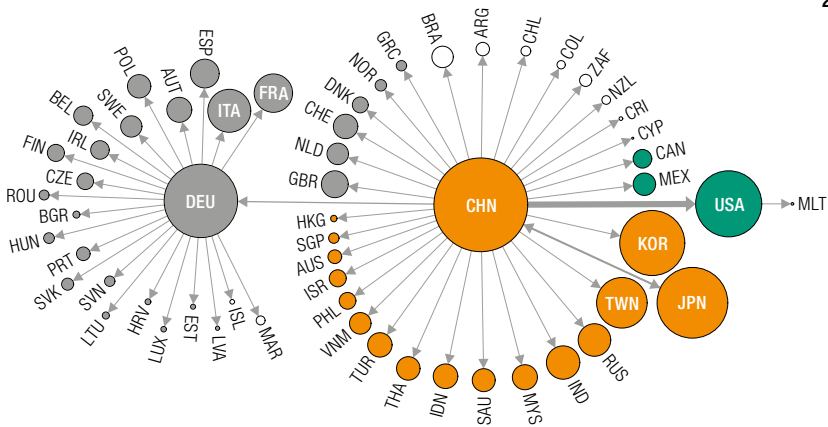
2b. Simple GVC trade networks, domestically owned firms


2005

2016

Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

2b. Simple GVC trade networks, TNCs

2005

2016

Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

2c. Complex GVC trade networks, domestically owned firms

2005

2016

Figure 2. Supply centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Concluded)

2c. Complex GVC trade networks, TNCs
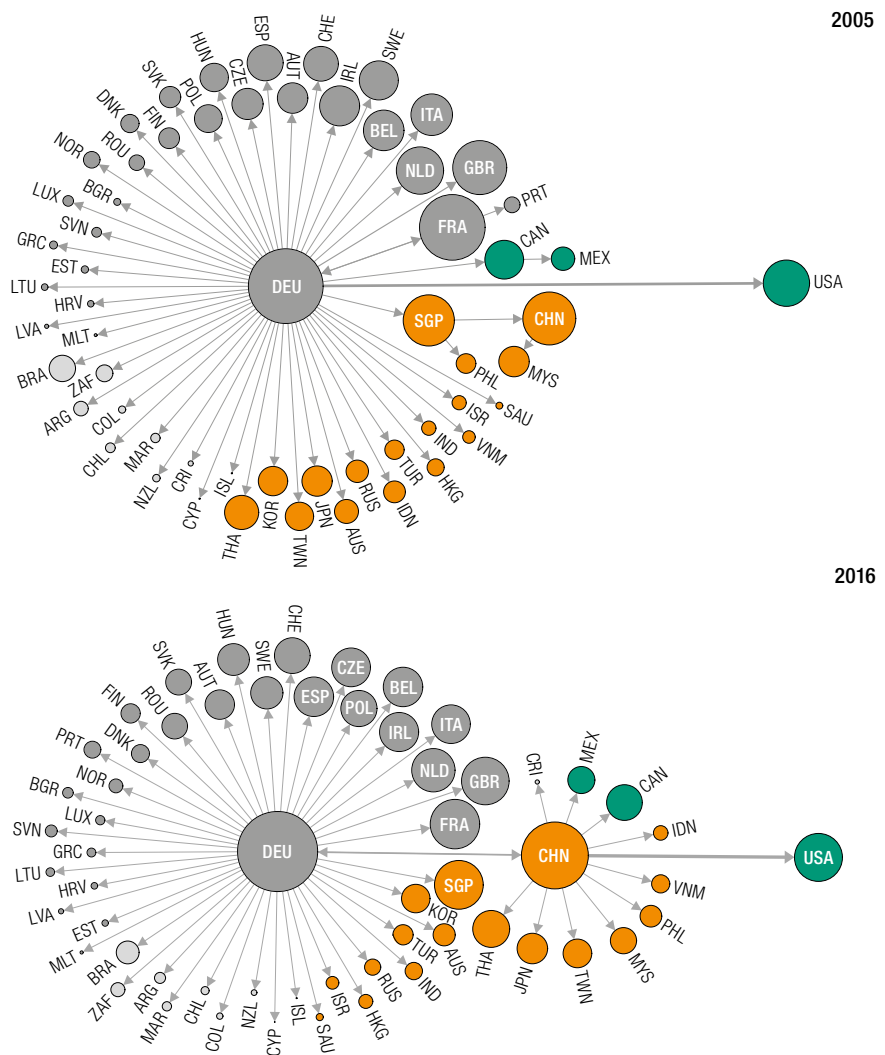
Note: A bubble's size represents the share of a country's value added exports or imports of the world total. The shares of value added flowing between two countries are represented by the thickness of the arrow. The point of the arrow shows the direction of the value added flow. Country and economy codes appear in the appendix.

located in the United States were isolated in both traditional and simple GVC trade, forming a region that included the economies of the USMCA and Singapore. In the complex value chain network involving TNCs, the United States was always on a relatively independent periphery, receiving supply through direct connections with Germany in 2005 and with China in 2016. It seems that TNCs have enhanced their FDI capacity in China and tend to provide more sophisticated intermediate goods through GVCs to serve more countries, most of them in Asia but also including Canada and Mexico, especially through complex trade.

From the demand side, the United States has been the global centre of the GVC network through final demand for manufacturing goods, in terms of both the various value chain channels and the distinction between domestically owned firms and TNCs (figure 3). In traditional trade (figure 3a) and simple value chain trade (figure 3b), Germany has been the regional demand centre in Europe. France and Italy lost their central positions in Europe, absorbed by Germany in 2005, but by 2016 had become surrounding countries that provide value added mainly to the United States. In complex value chain trade (figure 3c), however, Germany is linked to the United States as a separate economy and as of 2016 was no longer the centre of the regional value chain. In contrast to Germany, China has traditionally traded directly with the United States, providing value added to fulfil final demand in the United States for manufacturing goods.

A more significant change can be seen in the rapid rise of demand in China through simple value chains. In 2005, China absorbed value added from its neighbouring Asian countries, but by 2016, it had evolved into a global hub by attracting value chains from neighbouring Asian countries, some European countries, the United States and Latin American countries. It is for this reason that China's relative volume in simple value chain trade has approximated that of the United States in value added absorption. In complex value chains, the United States' long-time dominance as a global demand centre has enhanced its connection with China. These findings reflect the huge absorption power of the United States' final demand for manufacturing goods in GVCs and also imply that GVCs ending in the United States are much longer and more complex. At the same time, China not only functions as the world's factory, but has also become a regional demand centre, particularly through simple GVCs, given the growing strength of its final domestic demand.

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016

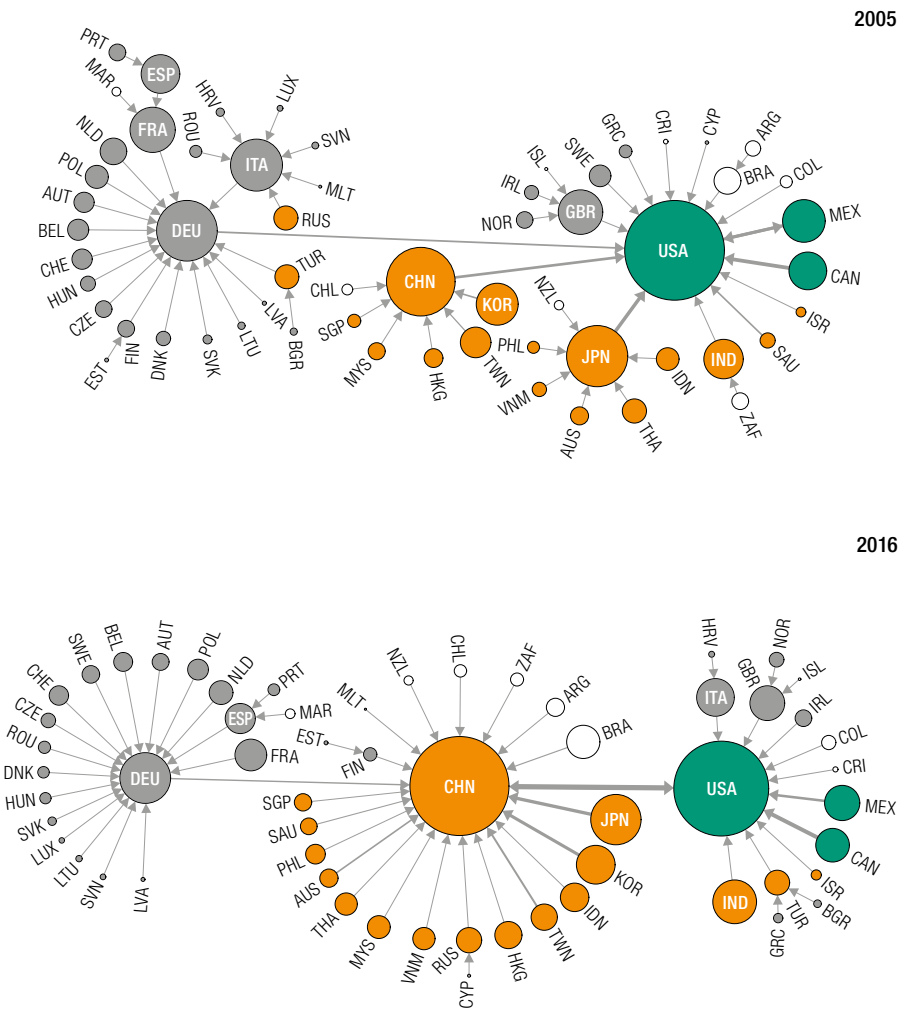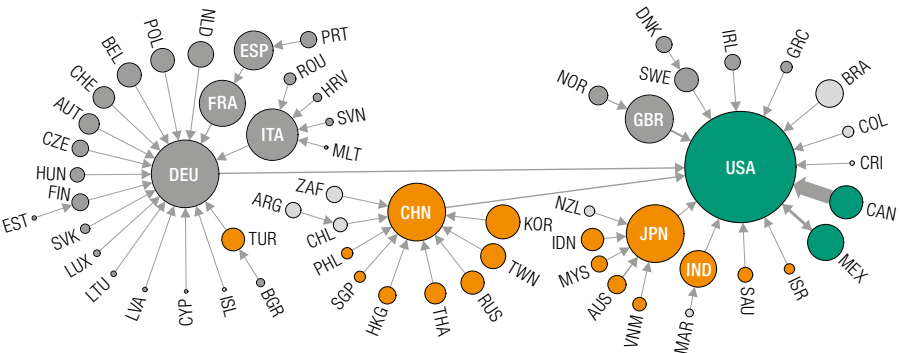3a. Traditional trade networks, domestically owned firms

2005

2016

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

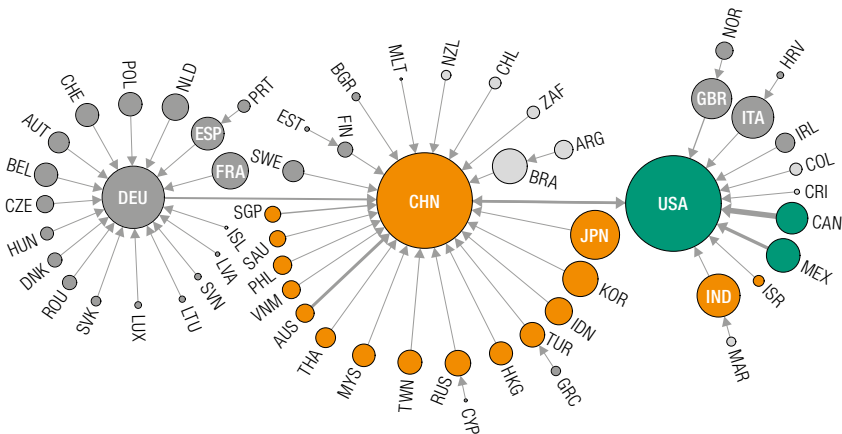3a. Traditional trade networks, TNCs

2005

2016

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

3b. Simple GVC trade networks, domestically owned firms

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

3b. Simple GVC trade networks, TNCs

2005

2016

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Continued)

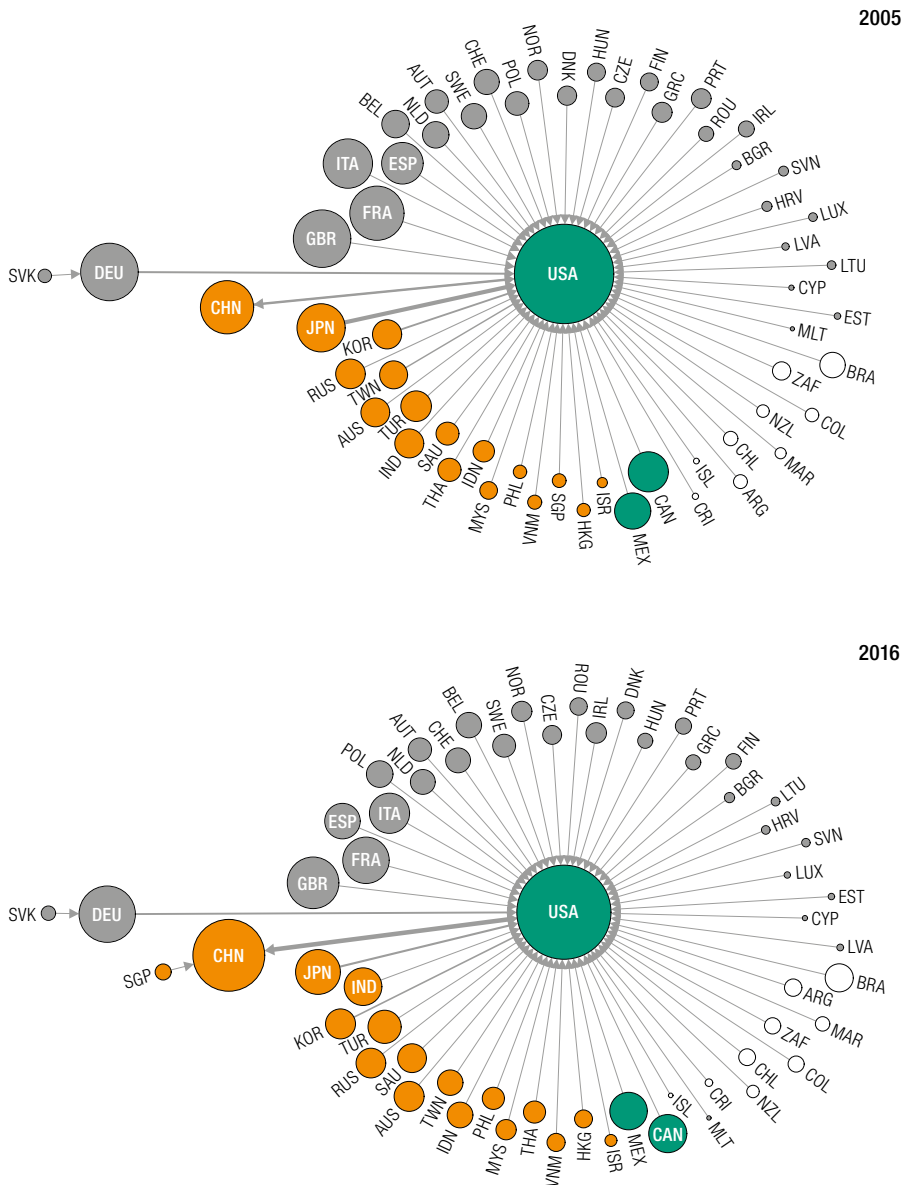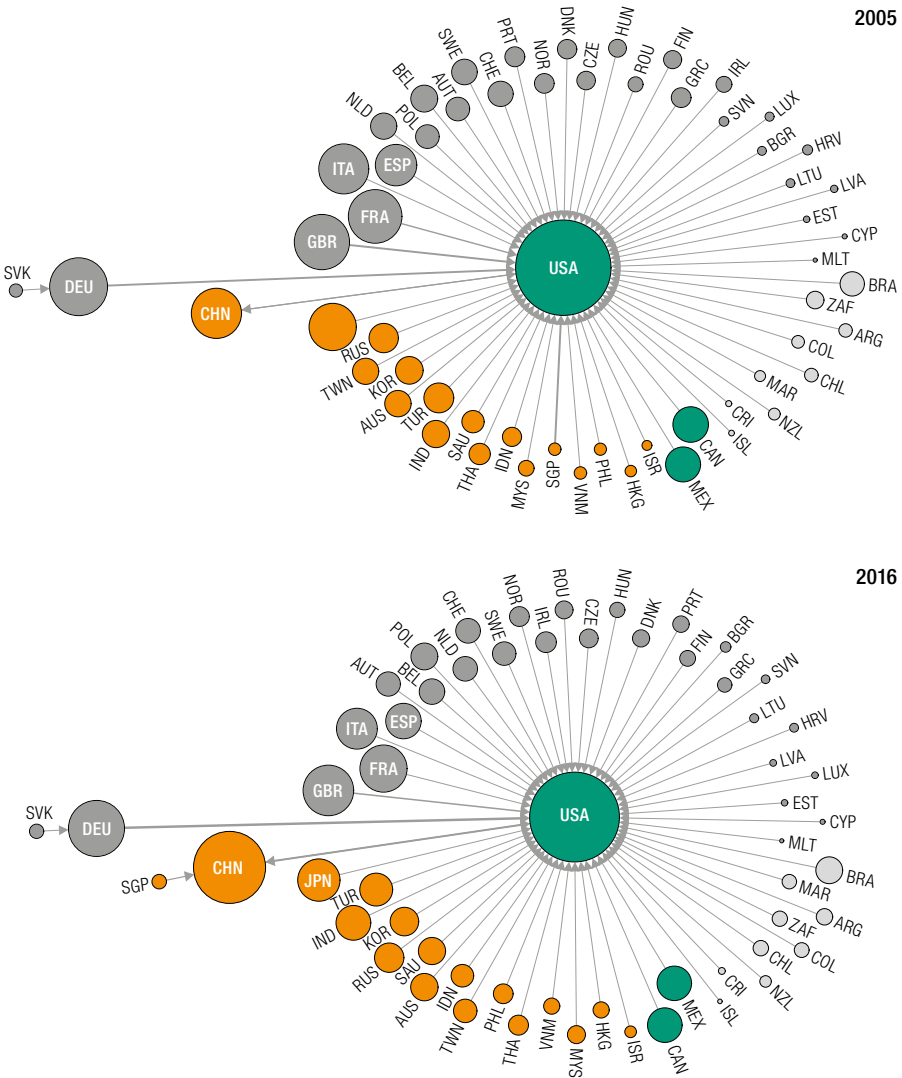3c. Complex GVC trade networks, domestically owned firms

2005

2016

Figure 3. Demand centres of TiVA in various networks for the manufacturing sector, 2005 and 2016 (Concluded)

3c. Complex GVC trade networks, TNCs

Source: Authors' estimations.

Note: A bubble's size represents the share of a country's value added exports or imports of the world total. The shares of value added flowing between two countries are represented by the thickness of the arrow. The point of the arrow shows the direction of the value added flow. Country and economy codes appear in the appendix.

5.2 Centres of TiVA in GVC service networks by trading route and firm ownership

From the supply side, the service industry exhibits the characteristics of a dual centre involving the United States and Europe (figure 4). In the supply of services from TNCs, Europe occupies a very important position in GVCs. Whereas Germany has always been the European supply centre for services, the United Kingdom has also played a very important role through TNCs as a value added provider, whether in traditional trade (figure 4a), simple value chain trade (figure 4b) or complex value chain trade (figure 4c). In fact, the United Kingdom was the core of the value chain of global TNCs in 2005, and it was only in 2016 that Germany and the United States joined the United Kingdom to form a triumvirate of complex value chains in global services trade. TNCs in Singapore and Hong Kong (China) also play an important role in the entire Asian region through traditional trade and simple value chain trade. Domestically owned firms in the United States have always been an important source of supply for the three kinds of trade. The centre of supply for simple value chain trade in services for domestically owned firms in Asia gradually changed from Japan in 2005 to China in 2016.

In GVC services networks, China is in general better able to participate through links with the United States. Although in traditional and simple value chain trade, domestically owned Chinese firms have increasingly played the role of regional service trade supply centres, from the perspective of TNCs, China still needs to be globally connected through links with Hong Kong (China) or with the United States. In terms of complex value chain trade, in 2005, China's domestically owned firms still needed to pass through Japan to connect to the United States-centric GVC services network, whereas by 2016, China was more directly connected to the United States in participating in this network. However, TNCs in the services sector have no outstanding presence in China compared with TNCs in the manufacturing sector. This partly reflects the fact that market openness for services in China is still low.

Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016

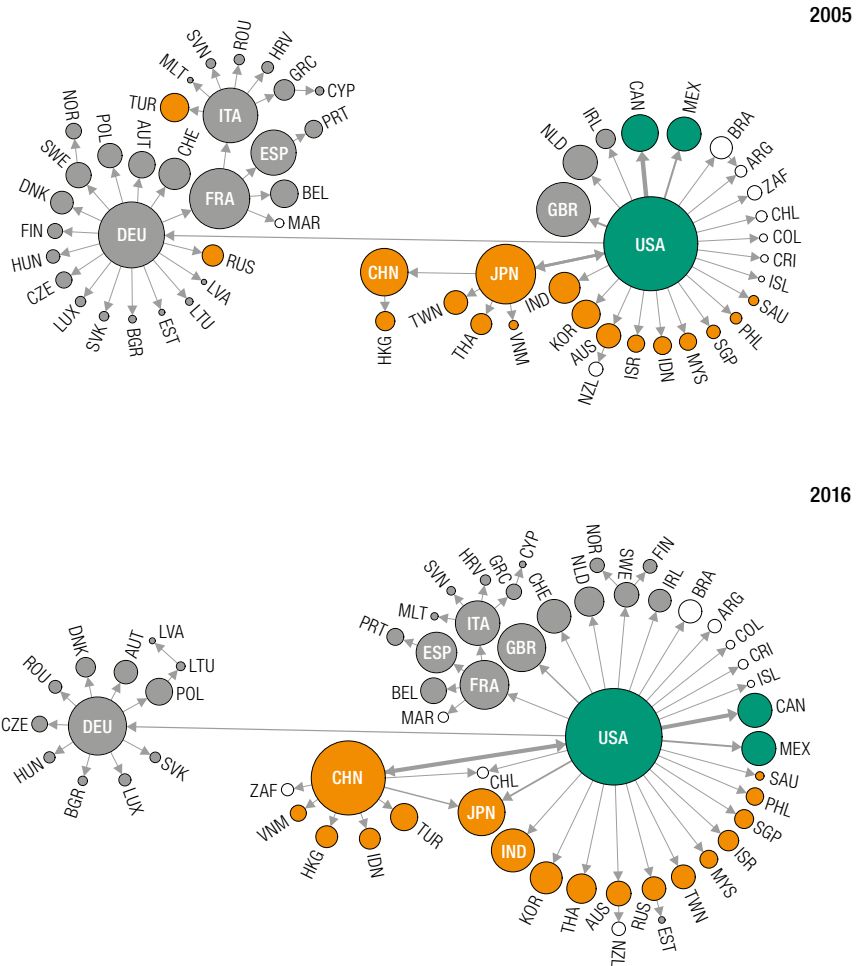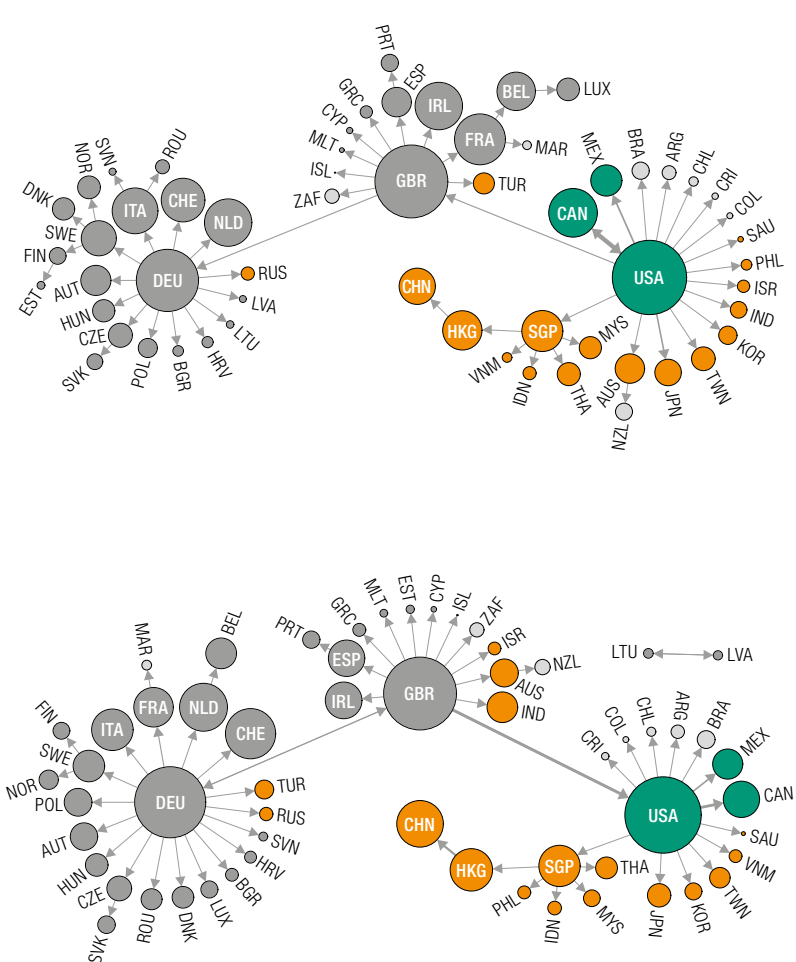**4a. Traditional trade networks, domestically owned firms**

2005

2016

Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

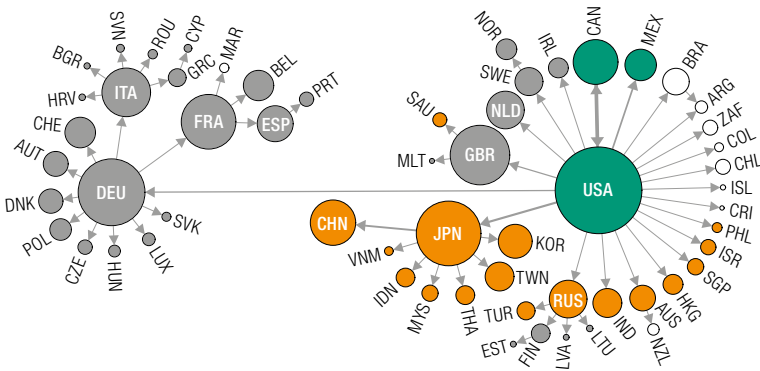### 4a. Traditional trade networks, TNCs

2005

2016

Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

4b. Simple GVC trade networks, domestically owned firms

Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

4b. Simple GVC trade networks, TNCs

2005

2016

Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

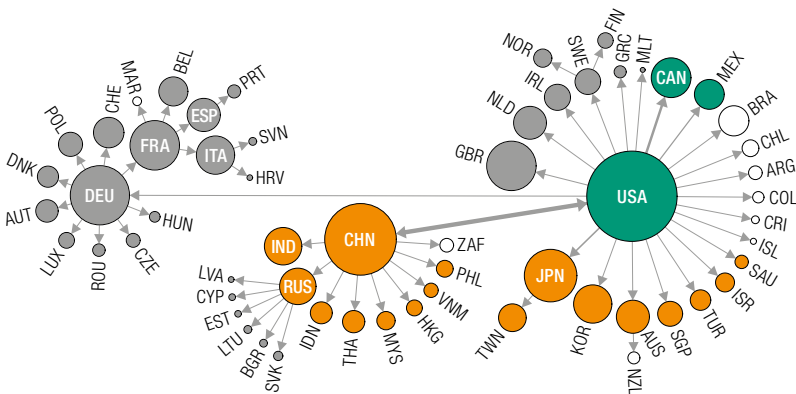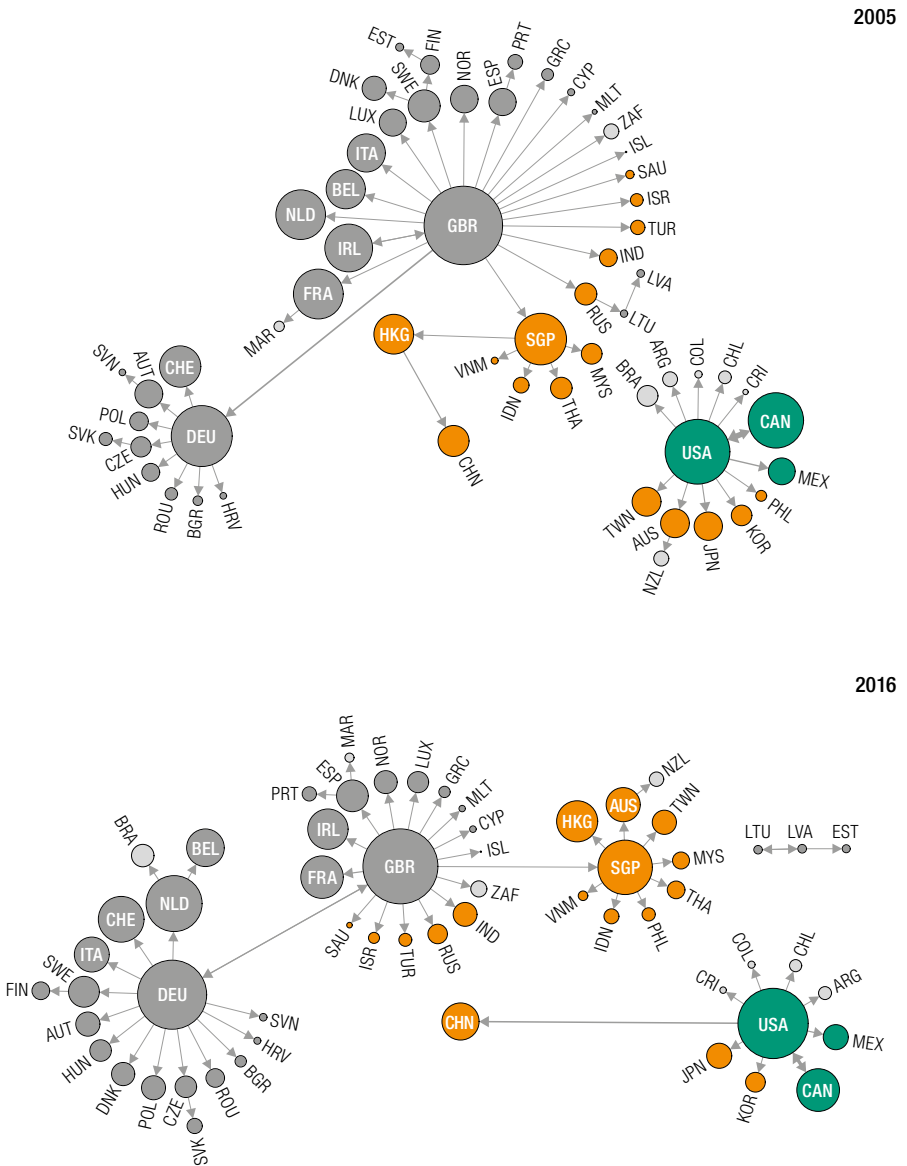4c. Complex GVC trade networks, domestically owned firms
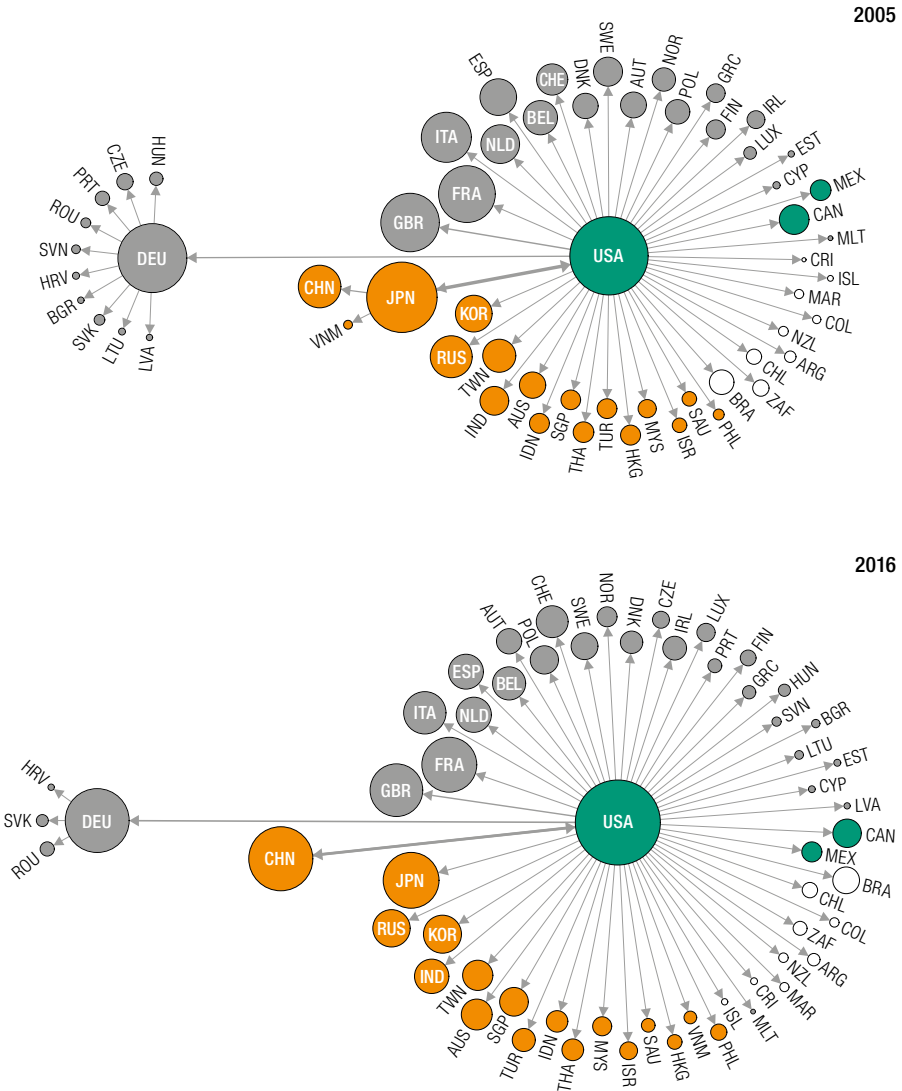
Figure 4. Supply centres of TiVA in various networks for the services sector, 2005 and 2016 (Concluded)

4c. Complex GVC trade networks, TNCs

Source: Authors' estimations.

Note: A bubble's size represents the share of a country's value added exports or imports of the world total. The shares of value added flowing between two countries are represented by the thickness of the arrow. The point of the arrow shows the direction of the value added flow. Country and economy codes appear in the appendix.

Similar to the demand side of manufacturing, the United States has always been the core of GVCs for services (see figure 5). Other economies, including Germany and China, participate in the complex value chains of global trade in services through direct links with the United States, and both domestically owned firms and TNCs exhibit similar basic characteristics.

In traditional trade (figure 5a), the United States and Germany maintained their dominance as both global and regional demand centres, whereas domestically owned firms and TNCs in Switzerland and China matured and began to play a role in North Europe and Asia, respectively, as small demand centres. In the simple trade value chain (figure 5b), China by 2016 had attracted a large number of Asian regional economies to meet their services needs – including Japan, which was a demand sub-centre in 2005, directly connected with the United States. This is evident not only in China's domestic corporate value chains, but also in the services trade value chains of China-centric TNCs, reflecting China's growing importance in simple value chains trade in services. In complex value chain trade (figure 5c), in 2016 the United States' dominance as the global centre remained stable, while Germany had matured and functioned as the European centre, attracting the value added of more TNCs. Unlike the significant role of a regional centre played by TNCs in the United Kingdom from the supply side, the United Kingdom had no significant presence on the demand side and was merely attracted by the United States as a value added provider.

Figure 5. Demand centres of TiVA in various networks for the services sector, 2005 and 2016

5a. Traditional trade networks, domestically owned firms

2005

2016

Figure 5. Demand centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

5a. Traditional trade networks, TNCs

Figure 5. Demand centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

5b. Simple GVC trade networks, domestically owned firms

**Figure 5. Demand centres of TiVA in various networks for the services
        sector, 2005 and 2016** (Continued)

5b. Simple GVC trade networks, TNCs
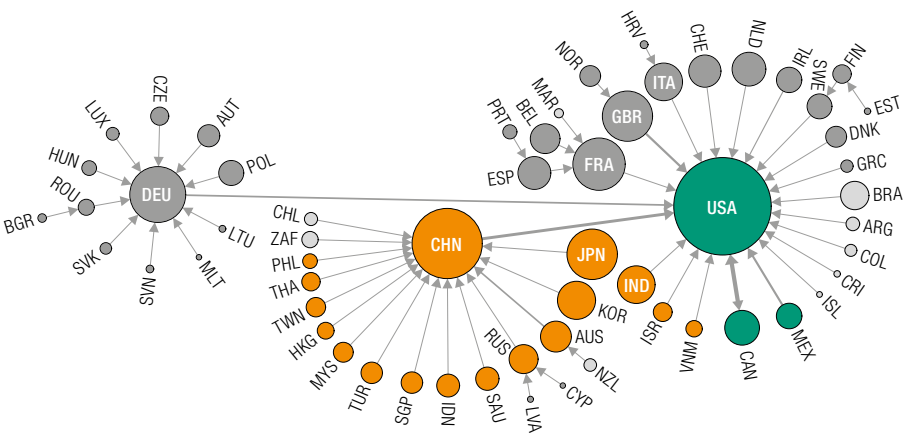
2005

2016

Figure 5. Demand centres of TiVA in various networks for the services sector, 2005 and 2016 (Continued)

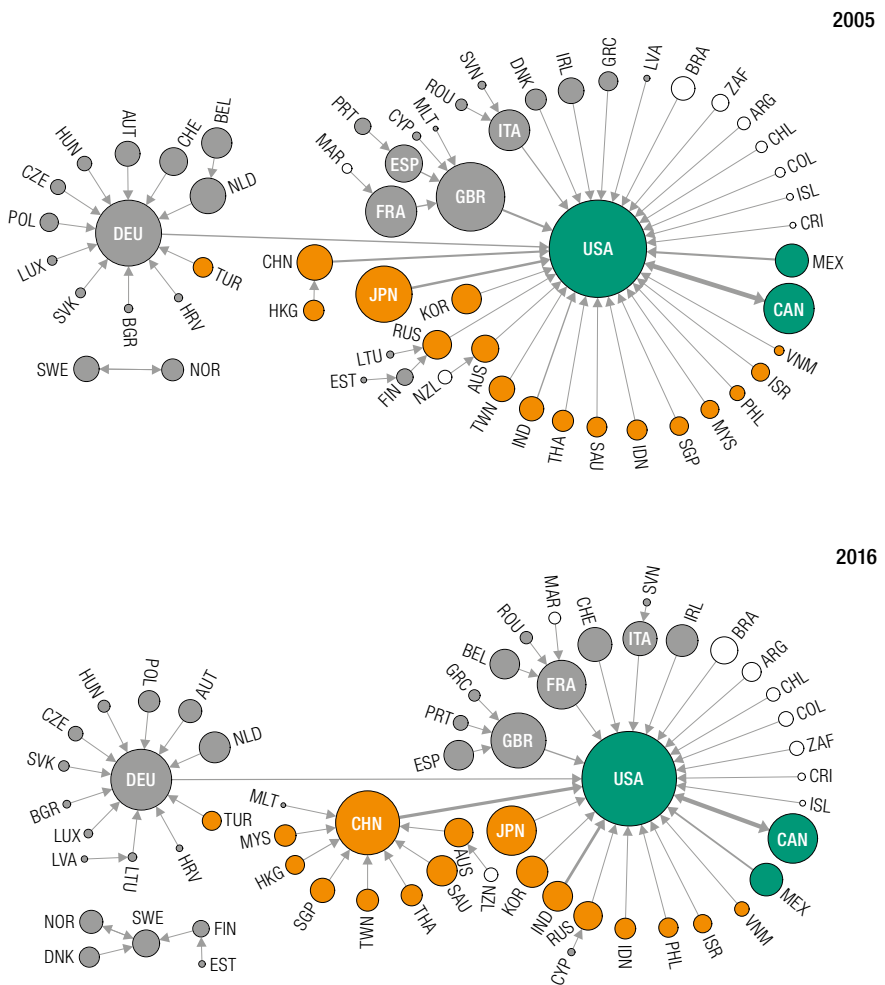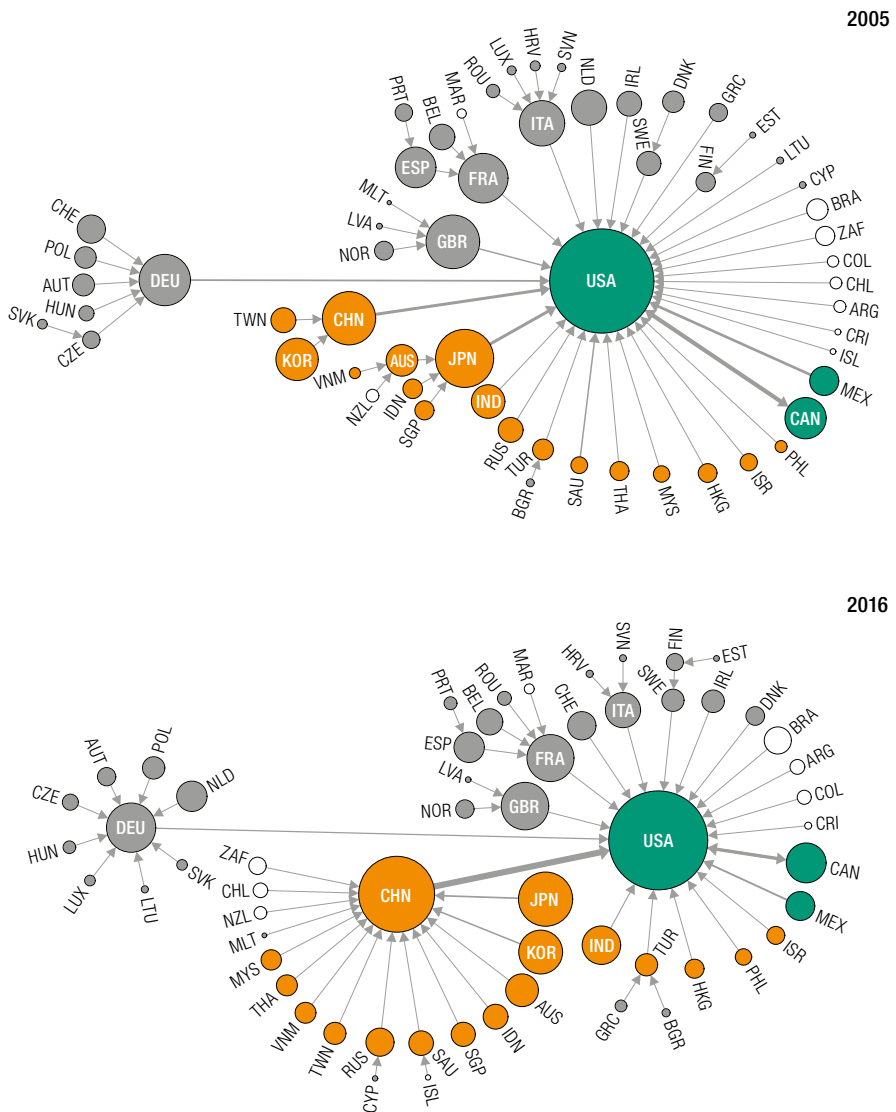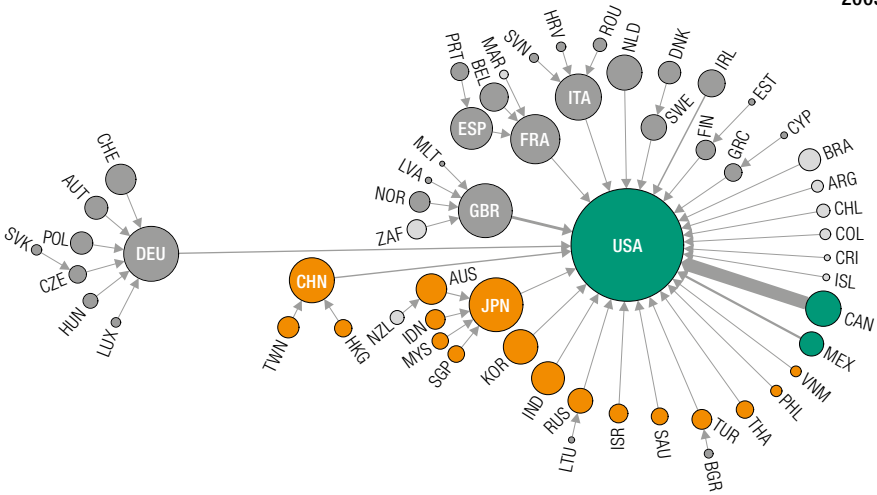5c. Complex GVC trade networks, domestically owned firms
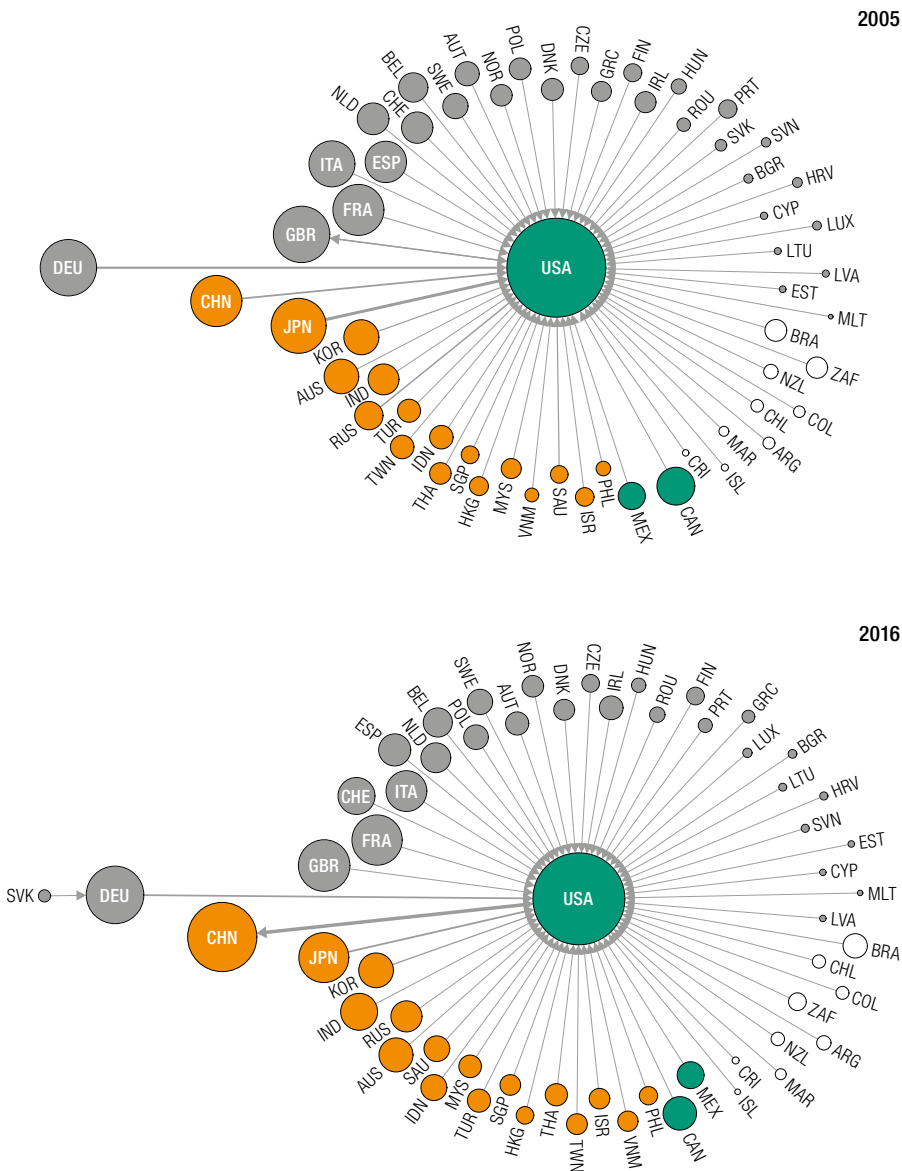
2005

2016

Figure 5. Demand centres of TiVA in various networks for the services sector, 2005 and 2016 (Concluded)

5c. Complex GVC trade networks, TNCs
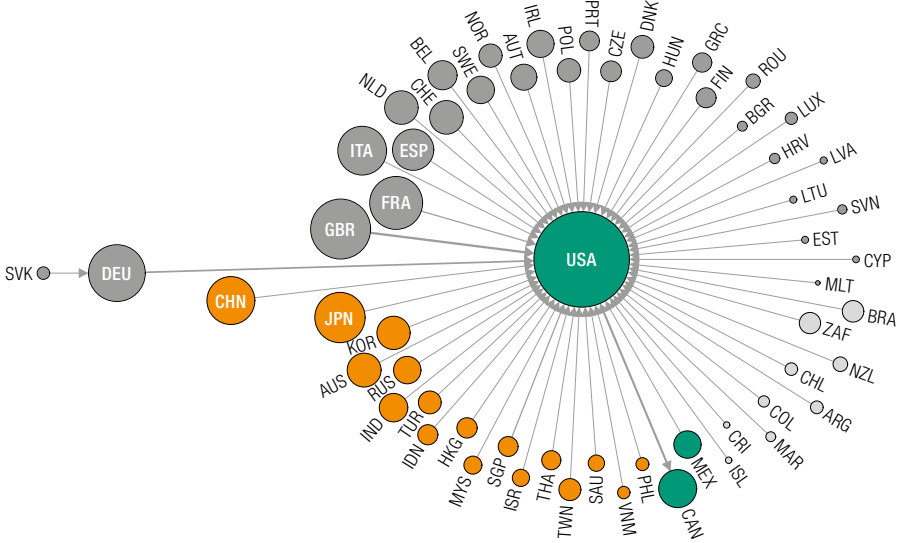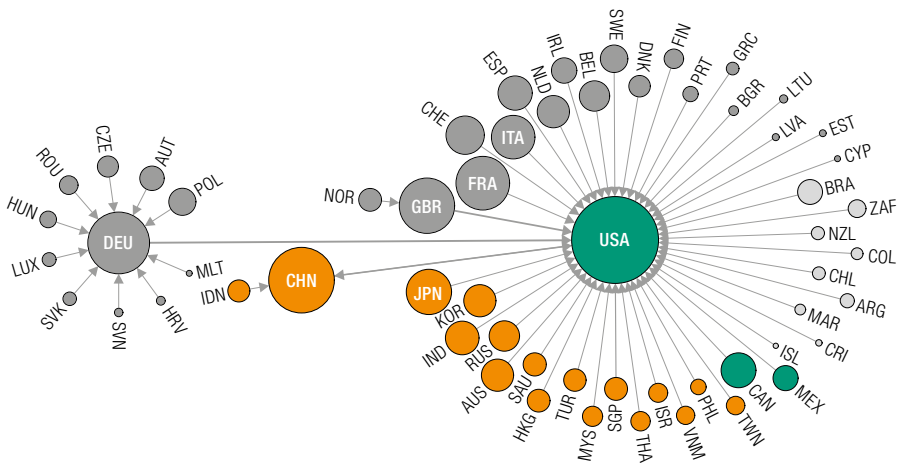
Source: Authors' estimations.

Note: A bubble's size represents the share of a country's value added exports or imports of the world total. The shares of value added flowing between two countries are represented by the thickness of the arrow. The point of the arrow shows the direction of the value added flow. Country and economy codes appear in the appendix.

6. Conclusions and policy considerations

Using intercountry input–output tables that distinguish between domestically owned firms and TNCs, this paper depicts the network centre characteristics and interrelationships of countries in GVCs through traditional trade, simple value chain trade and complex value chain trade. Our empirical results contribute to a better understanding of some important puzzles widely considered in research on both TNC and IB policy, such as what GVCs look like, whether GVCs are more regional or global, which country dominates which type of GVC, and whether or not TNCs organize GVCs with different or similar patterns regarding domestically owned or foreign-owned firms. We provided a more detailed, nuanced and insightful way to consider GVCs, further empowering both businesses and policymakers. Our general conclusion is that GVCs are more likely to be organized regionally and dominated by large countries; more interestingly, different types of firm ownership exhibit different types of presence, which vary by perspective (supply side or demand side), sector (manufacturing or services) and the type of network adopted.

Compared with the literature on GVC topology, we find that the polycentricity of supply through channels and the demand through networks of traditional and simple value chain trade are supported by three regional centres, namely, the United States, Europe (especially Germany) and China – the most important centres during the period studied. Monocentric demand through complex GVC networks is still dominated by the United States. We also found that the characteristics of GVC networks of TNCs and of domestically owned firms are quite different. Several European countries, which were originally overshadowed by aggregate measures, e.g. the United Kingdom, show particular importance in transnational trade in GVCs, especially in complex value chains that cross borders several times. This is also related to the practice of TNCs placing a large number of financial services into centres such as the United Kingdom. A third finding, in terms of distribution of the three value chain networks, is that China has occupied a very important position in manufacturing GVCs. In the simple value chain trade of the services sector, China has also become a core of East Asia's services sector trade, from both the supply and the demand side. This is also related to the high demand for productive services associated with China's role as a manufacturing hub. These findings redefine and extend scholarly understandings of the role of TNCs and their ownership in GVCs, as depicted in both the TNC and IB literature. They also affect policy decisions related to developments in GVC hubs and participation in the future.

This paper also sets the scene for making various assumptions about how locational decisions of TNCs are affected by these patterns. TNCs typically oversee their value chains directly (direct suppliers and buyers), yet our analysis

makes GVC participation visible across networks and with all indirect participants and their interdependencies. This also paves the way for better analyses of country-level relations, as we focused on the United States–China relationship for illustration. This links to contributions that further the important research on the impact on degrees of openness, participation and position of a country or region in GVCs (Maliszewska et al., 2020; Sforza and Steininger, 2020). This is particularly relevant as the COVID-19 pandemic, a concurrent recurring exogenous shock to GVCs, has triggered certain GVC reconfigurations both during the pandemic and in the post-pandemic world. These effects have been documented in qualitative TNC and IB research since early 2020 and include strategic supply chain diversification (Gereffi, 2020), reshoring and regionalization (Elia et al., 2021), greater localization of production of essential supplies, and the consideration of realignment and reduction in "irreversible" investments abroad as part of GVCs (UNCTAD, 2021; Verbeke, 2020). Furthermore, based on our empirical results on the evolution of GVC topology, we could argue that, in the short run, the rising importance of TNCs in GVC will greatly increase the complexity of the current governance of international economics as the regulatory system has to expand from "on the border" to "beyond the border". In the medium and long run, however, it would be wise for global policymakers to establish a broader system of bilateral and multilateral investment treaties as well as to advance to deeper international regulatory cooperation. This will reduce the cost of TNCs' activities while also encouraging them to take more comprehensive social responsibility throughout GVCs when they receive the dividend. By then, GVC studies that can clearly trace value creation through the international division of labour, such as the research in this paper, will become powerful tools for global policymaking.

We suggest that future research use these new tools for analyses and the findings we present in this paper to complement research related to TNCs, IB and policy on the role of TNCs in GVCs, extending to further developments in the theorization of GVC locational fragmentation and governance. As this study was limited to the most recent data available in the database, i.e., to 2016, we urge future and further research into GVCs to continue testing our findings as new data becomes available. Differentiating domestically owned firms from domestically owned TNCs and those firms that cannot be classified as TNCs will also become relevant to TNC research. Finally, it is also necessary to conduct econometric analyses (using gravity models with consideration for trading route and firm type) of the determinants of GVC topology shown in our empirical results. We believe that more unique reasons might arise concerning TNCs' GVC governance and market strategies (e.g. transfer price, profit transfer, intellectual property protection) adopted in different countries or industries. This should take us well beyond conventional thinking on determinants (e.g. size of economy, distance, tariff and nontariff barriers) of trade and investment facilitation issues.

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Appendix. Country or economy code

Serial number	OECD code	OECD countries	Serial number	Non-OECD code	Non-OECD economies
1	AUS	Australia	37	ARG	Argentina
2	AUT	Austria	38	BRA	Brazil
3	BEL	Belgium	39	BGR	Bulgaria
4	CAN	Canada	40	CHN	China
5	CHL	Chile	41	COL	Colombia
6	CZE	Czechia	42	CRI	Costa Rica
7	DNK	Denmark	43	HRV	Croatia
8	EST	Estonia	44	CYP	Cyprus
9	FIN	Finland	45	IND	India
10	FRA	France	46	IDN	Indonesia
11	DEU	Germany	47	HKG	Hong Kong (China)
12	GRC	Greece	48	MYS	Malaysia
13	HUN	Hungary	49	MLT	Malta
14	ISL	Iceland	50	MAR	Morocco
15	IRL	Ireland	51	PHL	Philippines
16	ISR	Israel	52	ROU	Romania
17	ITA	Italy	53	RUS	Russian Federation
18	JPN	Japan	54	SAU	Saudi Arabia
19	KOR	Korea, Republic of	55	SGP	Singapore
20	LVA	Latvia	56	ZAF	South Africa
21	LTU	Lithuania	57	TWN	Taiwan Province of China
22	LUX	Luxembourg	58	THA	Thailand
23	MEX	Mexico	59	VNM	Viet Nam
24	NLD	Netherlands	60	ROW	Rest of the world
25	NZL	New Zealand			
26	NOR	Norway			
27	POL	Poland			
28	PRT	Portugal			
29	SVK	Slovakia			
30	SVN	Slovenia			
31	ESP	Spain			
32	SWE	Sweden			
33	CHE	Switzerland			
34	TUR	Türkiye			
35	GBR	United Kingdom			
36	USA	United States			

Source: OECD, Analytical AMNE database (www.oecd.org/sti/ind/amne.htm).