Unraveling the Trade Potential of BRIC: A Comprehensive Analysis of Global Value Chains and Intra-BRIC Trade in Value-Added

José Firmino de Sousa Filho[1]
Gervásio Ferreira dos Santos[2]
Luiz Carlos de Santana Ribeiro[3]
Rodrigo Barbosa de Cerqueira[4]
Larissa Lopes Lima[5]

ABSTRACT

We analyze the BRIC countries' role in Global Value Chains (GVCs) and their trade patterns in value-added and vertical specialization. Using the World Input-Output Database (WIOD) and a decomposition model of intermediate goods and trade flows, we measure the degree of vertical specialization for each BRIC member. Our findings reveal increased connectivity within global value chains, particularly for China and India. China shows significant advancement in GVCs and intra-BRIC trade, focusing on high and medium-high technology industries. Brazil and Russia, however, have limited participation in GVCs, mainly engaging in value-added trade for medium-low and low-technology industries. Our network analysis reveals an increasing number of connections between countries in global value chains, particularly for China and India. India excels in medium-technology goods and has increased its share in GVCs relative to Brazil and Russia. While India and China demonstrate strong vertical specialization, Brazil and Russia concentrate major component exports on domestic value-added. Our study emphasizes the importance of expanding cooperation among the BRIC countries to foster gains in value-added trade, technological absorption, and overall economic growth.

KEYWORDS: BRIC; Trade in Value-added; Vertical Specialization; Networking Analysis.
JEL: F01. F10. F13.
Área 06: Globalização e competitividade regional

INTRODUCTION

Since the year 1985, international trade relations have undergone significant transformations as global production chains shifted. This shift was driven by the movement of production activities from the capital and technology-rich countries of the global North to the labor-abundant countries of the global South, characterized by lower wages and production costs (Baldwin & Lopez-Gonzalez, 2013). The growth of trade transactions and capital movements in goods and services has outpaced the growth of the world economy's Gross Domestic Product (GDP) (Amador & Cabral, 2008). Globalization has played a pivotal role in redirecting foreign direct investments towards emerging economies, facilitated by economic liberalization and increased capital flows (Diao et al., 2017). Thus, the paradigm of international production organization has witnessed intensified fragmentation of large corporations and entire economic sectors across different countries (Amador & Cabral, 2017).

[1] Research at Center of Data and Knowledge Integration for Health (CIDACS -Fiocruz, BA).
[2] Professor at Federal University of Bahia (PPGE/UFBA)
[3] Professor at Federal University of Sergipe (LEADER/UFS)
[4] Researcher and Head of Innovation and Data Science Department at Superintendence of Economic and Social Studies of Bahia
[5] Research Fellow, Queen's University Belfast, Belfast, United Kingdom

These changes have contributed to the growth of international trade in both final goods and services and intermediate goods used in production. Several factors have been identified as drivers of this growth, including reductions in transportation and communication costs, technological progress, productivity gains, and the removal of trade barriers (Antràs & Yeaple, 2014; Bardi & Hfaiedh, 2021; Costinot & Rodríguez-Clare, 2013; Melitz & Redding, 2012). International trade has evolved beyond the exchange of physical goods, with services gaining momentum and bringing significant implications for transnational corporations and labor markets (Ciriaci & Palma, 2016; Kox & Rubalcaba, 2007; Savona & Lorentz, 2006).

Within this changing landscape, emerging economies such as Brazil, Russia, India, and China (BRIC) have emerged as significant players in the global economy (Stuenkel, 2020). Each BRIC country has experienced structural changes that have shaped their role in global trade. China has become the world's leading supplier of labor-intensive manufactured goods, while India has excelled in communication services and pharmaceuticals. Brazil plays a crucial role as a global supplier in agribusiness and resource-intensive manufacturing, and Russia's strategic location and geopolitical power have positioned it as a key player, particularly in the energy sector (Mishra et al., 2015; Nayyar, 2016; Rosstat, 2020).

The concept of BRIC was coined in 2001 by Jim O'Neill, highlighting the economic growth potential of these emerging economies compared to the G7 countries (United States, Germany, France, Canada, Italy, Japan, and the UK). By the end of 2000, the collective GDP of the BRIC economies accounted for over 23% of the global GDP (weighted by purchasing power parity), surpassing the combined GDP of the Eurozone countries and Japan (O'Neill, 2001). O'Neill also emphasized the transformative impact of China's accession to the World Trade Organization (WTO) on Chinese trade gains. Additionally, increased cooperation among emerging economies has contributed to expanded trade gains and opened new avenues for financing investments and collaborations (Nayyar, 2016).

In the context of trade relations, the concept of value-added has gained relevance. To assess trade in value-added, it is necessary to track commodity flows throughout global supply chains, capturing the contribution of each stage in the production process. Value-added trade accounts for a substantial share of manufacturing and services, reducing market frictions associated with non-tariff barriers and transportation costs. Consequently, geographical distance becomes less critical, as value-added is traded through third countries. The participation of emerging economies, particularly China, India, and Brazil, in value-added trade has witnessed significant growth (Conceição, 2015; UNCTAD, 2023).

Against this backdrop, the research problem examines the progress in BRIC trade in value-added and the role of BRIC[6] countries in global value chains. It also explores the extent to which intra-BRIC trade has contributed to the development of industrial linkages between countries. This study employs network analysis to investigate the BRIC countries' position in global value chains and considers various components of value-added, such as domestic value-added (DVA), domestic value-added returning home (RDV), external value-added in national exports (FVA), and double counting terms (PDC). The analysis of intra-BRIC trade focuses on sectoral aggregation based on technological intensity, accounting for indirect technological incorporations in the flows of intermediate inputs and capital goods (OCDE, 2005; Hauknes & Knell, 2009; Morceiro, 2018).

The research relies on the Input-Output tables from the World Input-Output Database (WIOD) spanning the years 2000 to 2014. With a comprehensive coverage of 56 sectors and 44 countries (including 43 countries plus the "rest of the world"), the study contributes to the discussion of the political and economic aspects surrounding the formation of the BRIC. The

[6] Given the limitations imposed by the database employed in this study, South Africa was not included. Furthermore, the focus of our investigation centers on the early years of the BRIC formation; since South Africa joined the partnership in 2011, its exclusion does not compromise the validity or integrity of our study.

selected investigation period enables the evaluation of BRIC's engagement in global value chains under various scenarios and changes in trade and industrial policies. This assessment aims to determine whether BRIC's onboarding into internationally fragmented production chains aligns with global trends or exhibits distinctive patterns compared to other economies. It sheds light on the challenges associated with closer integration and expanded trade between these countries. Specifically, the research provides a detailed overview of BRIC trade on GVCs and examines specific components of domestic value-added for intermediate and final goods, aggregate industry-level and country-level indicators of vertical specialization, and trade intensity indicators. It contributes to the identification of trade gains and inter-industrial supply and demand relations between countries.

Our findings indicate that trade in value-added between the BRIC countries has not progressed as expected. China stands out with significant advancements in exports and vertical specialization in high and medium-high technology industries. Brazil and Russia have expanded their presence in medium-low and low-technology industries, while India has made notable progress in medium-technology industries. In terms of trade intensity, India and China demonstrate notable vertical specialization in high, medium-high, and medium technology industries, whereas Brazil and Russia focus on domestic value-added components. In summary, the research highlights the need for enhanced international integration among emerging economies to mitigate challenges and weaknesses in international trade and reduce dependency on the global North.

This research contributes to the ongoing discussions surrounding the political and economic dimensions of the BRIC formation. It emphasizes the importance of studying the challenges and opportunities related to closer cooperation and expanded trade among these countries. It provides a comprehensive analysis of BRIC countries in GVCs and value-added trade content, offering insights into intra-BRIC trade, specific components of domestic value-added, vertical specialization at different levels, and trade intensity indicators. This paper distinguishes itself from existing literature by examining the role of BRIC in trade relations within GVCs from two perspectives: the global trade context and the specific intra-BRIC trade dynamics. Collectively, these findings aid in identifying trade gains and inter-industrial supply and demand relations between the BRIC countries.

DATA AND METHODOLOGY

Data

The World Input-Output Database (WIOD) was specifically designed to track the evolution of international trade over time, providing comprehensive time series data on production, trade in value-added, and the consumption of final and intermediate goods that align with national accounts statistics. To ensure the robustness of the WIOTs, Timmer et al. (2016) emphasize the reliability of the methods used and the incorporation of data feedback, particularly pertaining to the inter-industry use of goods and services. This robustness is directly reflected in the matrix of intermediate **Z** coefficients. Typically, each country has at least two benchmark years available, with the most recent being 2012 and the oldest being 2008, enabling the capturing of changes in production during the 2008 economic crisis and its subsequent effects until 2012. For updates beyond 2012, detailed annual data on international trade, gross product, and intermediate inputs by industries and countries are employed.

The credibility and consistency of the WIOD tables are justified by their construction based on a conceptual framework derived from the System of National Accounts developed by the *Intersecretariat Working Group on National Accounts* (ISWGNA, 1993; 2010). These tables are constructed by merging officially published input-output tables, national accounts, and international bilateral trade statistics. Consequently, a WIOT represents a compilation of national input-output tables that disaggregate the utilization of outputs according to their origin. Within each country, the production flows for intermediate and final use are segregated between domestically produced and imported products, thereby revealing the industries responsible for the manufacturing of imported goods (Timmer et al., 2014; Johnson, 2018).

Therefore, to accurately analyze and comprehend the configuration of global value chains, it is essential to identify input flows in international trade and trace them to their ultimate destinations of use. The recommended approach for achieving this objective is the utilization of the Broad Economic Categories (BEC), which disaggregates intermediate inputs and final goods within the context of bilateral trade. The WIOTs employ this methodology, while alternative approaches rely on proportionality assumptions or mathematical optimization algorithms to estimate bilateral flows of inputs (Johnson, 2018).

Network analysis

We built the networks of the exports countries to analyse the changes in the market from 2000 to 2014. The networks are direct, and countries are represented by nodes. There is an edge from country *i* to country *j* if country *i* exports to country *j*. To compare the networks, we use the following centralities measures: out-degree (since it is a direct network), betweenness, closeness centrality, and page rank (Sayma, 2015). As in Xu and Liang (2019), we use commonly accepted symbols to describe our methods, where the global economy has n countries, x_{ij} measures the input from country i to country j, X_j represents the output exported from county j. The in-degree of a node k^{in}kin is the number of incoming links it has, while the out-degree k^{out} is the number of its outgoing links. Nodes can be weighted according to country exports, while links can be weighted using the value of input–output transactions they represent.

Degree centrality

Degree centrality measures the position of a node within the entire network. In a directed graph, the row sums of the adjacency matrix represent the node's in-degree. The in-degree centrality is a normalized node degree, the actual degree divided by the maximal degree possible $(n-1)$.

$$c_D(i) = \frac{\deg(i)}{n-1} \tag{1}$$

Betweenness and closeness

Betweenness is a measure that quantifies the number of shortest paths that traverse a specific node or link. It is given by:

$$c_B(i) = \frac{1}{(n-1)(n-2)} \sum_{j\neq i, k\neq i, j\neq k} \frac{N_{sp}(j \to^{i} k)}{N_{sp}(j \to k)} \tag{2}$$

where $N_{sp}(j \to k)$ is the number of shortest paths from node j to node *k*, and $N_{sp}(j \to^{i} k)$ is the number of the shortest paths from node j to node *k* that go through node *i*. The normalization is given by dividing the value by $(n-1)(n-2)$.

In network analysis, closeness is a metric that evaluates the proximity of a given node to all other nodes based on their shortest paths and it can be calculated as follow:

$$c_C(i) = \left(\frac{\sum_j d(i \to j)}{n-1}\right)^{-1} \tag{3}$$

Where $d(i \to j)$ is the distance between node *i* and node *j*.

Page rank centrality

PageRank centrality considers the importance of a country based on its connections with other significant countries. However, this centrality incorporates a damping factor that penalizes distant connections. It considers a country to be important not only if it is connected to other important countries but also if those important countries, in turn, do not have significant connections with others. This additional criterion ensures that the centrality measure reflects the importance of countries with more concentrated and influential connections within the network. It is calculated as follow:

$$c_p(i) = v_i \tag{4}$$

This is the *i-th* element of the dominant eigenvector v of the following transition probability matrix.

$$T = \alpha A D^{-1} + (1 - \alpha)\frac{J}{n} \tag{5}$$

where A is the adjacency matrix of the network, D^{-1} is a diagonal matrix whose *i-th* diagonal component is $1/\deg(i)$, J is an $n\ x\ n$ all-one matrix, and α is the damping parameter. Here, we adopted the most common factor ($\alpha = 0.85$).

The decomposition of intermediate goods and trade flows

This section is based on Wang, Wei, and Zhu (2018), in which gross exports from the country s to r, E^{sr}, can be decomposed into exports of final and intermediate goods, according to the accounting identity:

$$E^{sr} = Y^{sr} + A^{sr}X^{r} \tag{6}$$

Exports of final goods can be divided into domestic and foreign value-added by applying the standard Leontief decomposition. However, the decomposition of exports of intermediate goods is more complex; consequently, it is not achieved by multiplying the Inverse Leontief matrix, which would lead to double counting. To overcome that, all trade in intermediate goods must be expressed as the final demand of different countries, according to the country where it is absorbed.

Thus, extending the traditional Leontief model to country G and inserting the last term of equation 6, we can decompose exports of intermediate goods from country s to country r according to where they will be absorbed:

$$\begin{aligned} A^{sr}X^{r} &= A^{sr}B^{rr}Y^{rr} + A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tt} + A^{sr}B^{rr}\sum_{t\neq s,r}^{G} Y^{rt} \\ &+ A^{sr}\sum_{t\neq s,r}^{G} B^{rt}\sum_{u\neq s,t}^{G} Y^{tu} + A^{sr}B^{rr}Y^{rs} + A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{ts} \\ &+ A^{sr}B^{rs}Y^{ss} + A^{sr}B^{rs}\sum_{t\neq s}^{G} Y^{st} \end{aligned} \tag{7}$$

These eight terms on the right side of equation 7 collectively decompose intermediate exports from country s to country r completely according to where they are absorbed. Later, it will decompose the domestic value from gross bilateral trade exports into different value-added and double-counting components. From equation 7, the gross production and balance use condition, we have:

$$X^r = A^{rr}X^r + \sum_{t\neq r}^{G} A^{rt}X^t + Y^{rr} + \sum_{t\neq r}^{G} Y^{rt} = A^{rr}X^r + Y^{rr} + \sum_{t\neq r}^{G} E^{rt}$$
$$= A^{rr}X^r + Y^{rr} + E^{r*} \quad (8)$$

Rearranging the terms, we have:

$$X^r = (I - A^{rr})^{-1}Y^{rr} + (I - A^{rr})^{-1}E^{r*} = L^{rr}Y^{rr} + L^{rr}E^{r*} \quad (9)$$

Where $L^{rr} = (I - A^{rr})^{-1}$ is the local Leontief Inverse matrix.

By combining equation 9 with the last term of equation 6, exports of intermediate goods from country s to country r can also be decomposed into two components according to where they are used (domestic sales or exports), like the input-output model for a single country, i.e.:

$$A^{sr}X^r = A^{sr}L^{rr}Y^{rr} + A^{sr}L^{rr}E^{r*} \quad (10)$$

Equation 10 will break down the external value of bilateral gross exports into value-added and double-counting components. Equations 7 and 10 decompose exports of intermediate goods from country s to country r according to where they are absorbed. Extending equation 10 for a country G, one can obtain the domestic and foreign value-added multipliers of country s, represented by partners from country r and a third country t, as follows:

$$V^sB^{ss} + V^rB^{rs} + \sum_{t\neq s,r}^{G} V^tB^{ts} = u \quad (11)$$

By defining "#" as an elementary matrix multiplication operation export of goods finals of country r can be decomposed into domestic and external value added at the sectoral level by applying the standard Leontief decomposition directly, as shown in equation 6:

$$Y^{sr} = (V^sB^{ss})^T\# Y^{sr} + (V^rB^{rs})^T\# Y^{sr} + \left(\sum_{t\neq s,r}^{G} V^tB^{ts}\right)^T \#Y^{sr} \quad (12)$$

Similarly, the value of gross exports of intermediate goods from country s to country r at the sectoral level can be expressed as:

$$A^{sr}X^r = (V^sB^{ss})^T\#(A^{sr}X^r) + (V^rB^{rs})^T\#(A^{sr}X^r) + \left(\sum_{t\neq s,r}^{G} V^tB^{ts}\right)\#(A^{sr}X^r)$$
$$= (V^sL^{ss})^T\#(A^{sr}X^r) + (V^sB^{ss} - V^sL^{ss})^T\#(A^{sr}X^r) + (V^rB^{rs})^T\#(A^{sr}X^r)$$
$$+ \left(\sum_{t\neq s,r}^{G} V^tB^{ts}\right)\#(A^{sr}X^r) \quad (13)$$

Where V^sL^{ss} is the domestic value-added multiplier like an input-output model for a single country. Finally, combining the equations 7, 10, 12 and 13, we obtain the decomposition for gross exports from country s to country r:

$$E^{sr} = \underbrace{(V^sB^{ss})^T\#Y^{sr}}_{(1)DVA\_FIN} + \underbrace{(V^sL^{ss})^T\#(A^{sr}B^{rr}Y^{rr})}_{(2)DVA\_INT}$$

$$+ \underbrace{(V^sL^{ss})^T\#\left[A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{tt} + A^{sr}B^{rr}\sum_{t\neq s,r}^{G} Y^{rt} + A^{sr}\sum_{t\neq s,r}^{G} B^{rt}\sum_{u\neq s,t}^{G} Y^{tu}\right]}_{(3)DVA\_INTrex}$$

$$+ \underbrace{(V^sL^{ss})^T\#\left[A^{sr}B^{rr}Y^{rs} + A^{sr}\sum_{t\neq s,r}^{G} B^{rt}Y^{ts} + A^{sr}B^{rs}Y^{ss}\right]}_{(4)RDV\_G}$$

$$+\underbrace{\left[(V^sL^{ss})^T\#\left(A^{sr}B^{rs}\sum_{t\neq s}^{G}Y^{st}\right)+\left(V^sL^{ss}\sum_{t\neq s}^{G}A^{st}B^{ts}\right)^T\#(A^{sr}X^r)\right]}_{(5)DDC}$$

$$+\underbrace{\left[(V^rB^{rs})^T\#Y^{sr}+\left(\sum_{t\neq s,r}^{G}V^tB^{ts}\right)^T\#Y^{sr}\right]}_{(6)FVA\_FIN} \qquad (14)$$

$$+\underbrace{\left[(V^rB^{rs})^T\#(A^{sr}L^{rr}Y^{rr})+\left(\sum_{t\neq s,r}^{G}V^tB^{ts}\right)^T\#(A^{sr}L^{rr}Y^{rr})\right]}_{(7)FVA\_INT}$$

$$+\underbrace{\left[(V^rB^{rs})^T\#(A^{sr}L^{rr}E^{r*})+\left(\sum_{t\neq s,r}^{G}V^tB^{ts}\right)^T\#(A^{sr}L^{rr}E^{r*})\right]}_{(8)FDC}$$

Where $V^sL^{ss}\sum_{t\neq s}^{G}A^{st}B^{ts}=V^sB^{ss}-V^sL^{ss}$. Equation 14 indicates that gross exports from country s to country r at the sectoral level can be completely decomposed into 16 terms broken down into eight major categories.

The first category is $(V^sB^{ss})^T\#Y^{sr}$. The domestic value added (*DVA* or *DVA_FIN*) is embedded in final goods exports. The second category 〚$(V^sL^{ss})^T\#(A^{sr}B^{rr}Y^{rr})$, or *DVA_INT*, is the domestic value added in exports of intermediate goods used by the direct importer (r) to produce final goods consumed in r locally. The third category is the *DVA* for exports of intermediate goods used by direct importers r to produce and export to other countries, except back to s, which will be called *DVA_INTrex*. These first three categories represent all domestic value-added embedded in exports from country s to country r that are absorbed abroad and are associated with export flows based on *backward linkages*. Johnson and Nogueira (2012) call it *VAX*. Since we follow the specifications of Wang, Wei, and Zhu (2018) it will be called *VAX_G*.

The fourth category of *DVA* is exports of intermediate goods that return to country s and are also consumed in s, called *RDV_G*. This term includes three detailed terms $(V^sL^{ss})^T\#(A^{sr}B^{rr}Y^{rs})$ is the *DVA* that returns home via final imports from direct importer r; $(V^sL^{ss})^T\#(A^{sr}\sum_{t\neq s,r}^{G}B^{rt}Y^{ts})$ is the *DVA* that returns home via imports of third countries; $(V^sL^{ss})^T\#(A^{sr}B^{rs}Y^{ss})$ is the *DVA* that returns home via imports of intermediate goods and is used to produce final goods.

These first four categories of *DVA* embedded in country s at the sectoral level of gross exports to country r are included in the value-added created by all sectors in country s. It can be called *DVA_G*. These *DVA* terms represent the different types of production between countries that share bilateral or multilateral agreements and can be used to assign a role and a relevant position in the various stages of the GVCs.

The fifth category has two terms. The first term, $(V^sL^{ss})^T\#(A^{sr}B^{rs}\sum_{t\neq s}^{G}Y^{st})$, is the *DVA* embedded in exports of intermediate goods to the country r, but return home as intermediate imports and are used for the production of final goods for export. The second term, $(V^sL^{ss}\sum_{t\neq s}^{G}A^{st}B^{ts})^T\#(A^{sr}X^r)$, is the *DVA* in exports of intermediate goods to country r, which returns home as imports of intermediate goods and are used in the production of intermediate goods again for export. This term also represents domestic double counting caused by the back and forth of production in trade in intermediate goods, a repeated count in the country s exports of intermediate goods. Thus, the fifth category was named DDC.

The sixth category includes two terms, the first being $(V^r B^{rs})^T \# Y^{sr}$ is the importer's foreign value added (*FVA*) r embedded in final exports; the second term $(\sum_{t\neq s,r}^{G} V^t B^{ts})^T \# Y^{sr}$ is the foreign value added from other countries (t) embedded in final exports. We can name this category *FVA_FIN*. Adding the first and sixth categories (*DVA* of country s and *FVA* of country r and country t) gives us 100% of the sectoral value of gross exports from country s to country r.

The seventh category also includes two terms, where $(V^r B^{rs})^T \# (A^{sr} L^{rr} Y^{rr})$ is importer r's FVA embedded in exports of intermediate goods, which are used by r to produce final domestic goods. The second term, $(\sum_{t\neq s,r}^{G} V^t B^{ts})^T \# (A^{sr} L^{rr} Y^{rr})$ is the *FVA* of the third country t embedded in exports of intermediate goods that are used by country r to produce final local goods. We can call them *FVA_INT*. Adding categories 6 and 7, we have the total external value-added embedded in country s at the gross sectoral exports to country r.

Finally, the eighth category includes double counting terms for the country's exports originating in foreign countries. Similar to categories 6 and 7, it also includes two terms, $(V^r B^{rs})^T \# (A^{sr} L^{rr} E^{r*})$ is the FVA of importer r embedded in intermediate exports to produce its exports, which are pure double-counting terms of country r's value-added in country s's exports. The second term, $(\sum_{t\neq s,r}^{G} V^t \, B^{ts})^T \# (A^{sr} L^{rr} E^{r*})$, is the *FVA* of the third country t embedded in exports of intermediate goods to produce their exports. Therefore, the category can be called *FDC*.

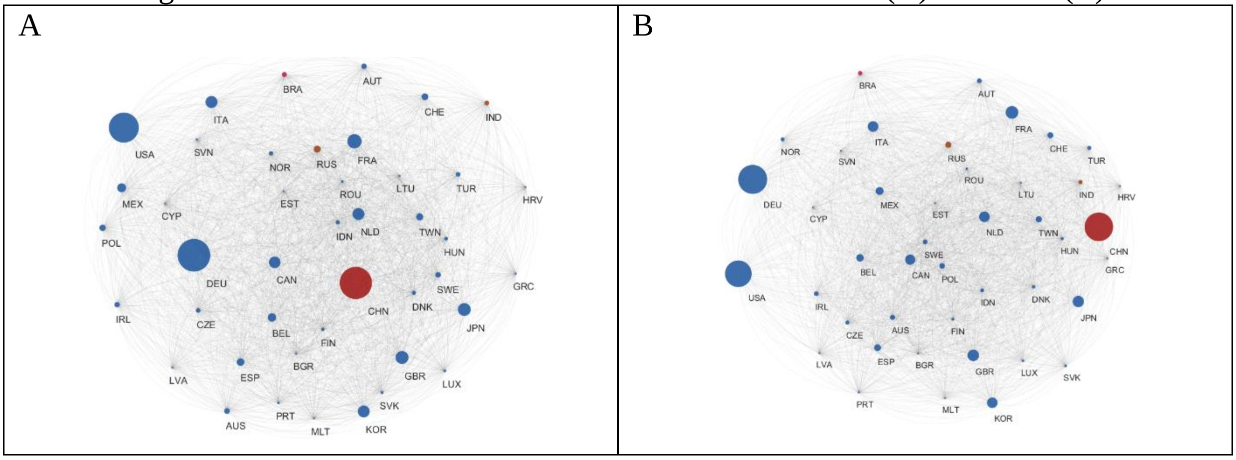
RESULTS

Networking analysis

The application of complex networks offers valuable insights into diverse systems where multiple agents (nodes) interact through relationships. In the field of economics and finance, this approach has shed light on complex phenomena (Pammolli & Riccaboni, 2002; Chessa et al., 2013; Cerina et al., 2015). Adopting a network perspective, we conceptualize the global multiregional input-output system as a world input-output network (WION). In this network, countries serve as nodes, and the value-added flows between countries constitute the edges. Notably, the flow direction follows the path from the exporting country to the importing country. The networks are presented in Figure 1. Although the network structure is similar, the 2014 network is more connected than the 2000 network, showing that the connection between these countries grew in this time interval. The degree centrality, betweenness, closeness, and page rank distributions also differ for both networks.

The intercountry matrix exhibits a high level of sparsity. However, on a global scale, only a limited number of bilateral flows are deemed significant. Throughout the analysis period, the United States consistently served as the primary developed regional core for regional bilateral flows and maintained a significant position in global bilateral flows. Notably, China, alongside Germany, were a significant regional core for regional bilateral flows. While the USA and Western countries maintained dominant roles, China, and other emerging economies, as Brazil, India, South Korea, Mexico, and Russia experienced slow development on GVCs. China emerged as the major driving force behind the expansion of global trade flows and secured its position as the leading exporter of both final and total products, as pointed by Xu and Liang (2019). A significant observation is the remarkable shift in China's position within the world trade network, as evidenced by the substantial increase in trade linkages involving China throughout the research period.

Figure 1. Global networks of trade in value-added in 2000 (A) and 2014 (B).



We present specific networks measures on Table 1. The betweenness centrality exhibited overall stability across most countries throughout the analysis period, with a gradual reduction observed over time. There was an increase in out-degree, closeness centrality and page rank for all countries. These methods provide different rankings for countries as they capture distinct aspects of their connections. However, we argue that network-based measures offer valuable insights into identifying the key countries within the WION. In the case of centrality degree, there are countries with a higher degree in 2014 than in 2000, showing an increase in trade between these countries. On the other hand, there was a reduction in betweenness centrality values from 2000 to 2014, indicating more direct connections in the network and reducing the number of times a node appears on shorter paths. The closeness centrality value increased from 2000 to 2014, which may indicate a reduction in the distance between the network nodes. PageRank centrality incorporates a damping factor that penalizes distant connections. It considers both the importance of a country being connected to other important countries and the absence of significant connections among those important countries themselves. It was the only measure that decreased for a considerable group of countries. Overall, by leveraging network-based methods, we gain valuable insights into identifying the key countries within the WION, complementing the traditional input-output analysis approaches.

Table 1. Out-degree, betweenness and closeness centrality for networks for the BRIC countries.

Country	**2000**				**2014**			
	Out-degree	Betweenness	Closeness	Page Rank	Out-degree	Betweenness	Closeness	Page Rank
Australia	0.77	0.00	0.78	0.02	0.81	0.00	0.93	0.02
Austria	0.95	0.01	0.93	0.03	1.00	0.00	1.00	0.02
Belgium	1.00	0.01	0.93	0.03	1.00	0.00	1.00	0.02
Bulgaria	0.23	0.00	0.70	0.02	0.95	0.00	0.96	0.02
Brazil	**0.86**	**0.00**	**0.78**	**0.02**	**0.98**	**0.00**	**0.90**	**0.02**
Canada	0.84	0.00	0.83	0.02	1.00	0.00	0.98	0.02
Switzerland	0.98	0.01	0.91	0.03	1.00	0.00	1.00	0.02
China	**0.93**	**0.00**	**0.84**	**0.02**	**1.00**	**0.00**	**0.98**	**0.02**
Cyprus	0.23	0.00	0.69	0.02	0.56	0.00	0.83	0.02
Czech Republic	0.93	0.00	0.83	0.02	1.00	0.00	1.00	0.02
Germany	1.00	0.02	1.00	0.03	1.00	0.00	1.00	0.02

Denmark	1.00	0.01	0.90	0.03	1.00	0.00	1.00	0.02
Spain	1.00	0.01	0.90	0.03	1.00	0.00	0.98	0.02
Estonia	0.30	0.00	0.63	0.01	0.84	0.00	0.90	0.02
Finland	0.95	0.01	0.86	0.02	0.98	0.00	0.98	0.02
France	1.00	0.02	1.00	0.03	1.00	0.00	1.00	0.02
United Kingdom	1.00	0.01	0.98	0.03	1.00	0.00	1.00	0.02
Greece	0.72	0.00	0.88	0.03	0.95	0.00	0.98	0.02
Croatia	0.44	0.00	0.75	0.02	0.81	0.00	0.83	0.02
Hungary	0.84	0.00	0.84	0.02	0.98	0.00	0.98	0.02
Indonesia	0.79	0.00	0.72	0.02	0.91	0.00	0.83	0.02
India	**0.77**	**0.00**	**0.77**	**0.02**	**0.98**	**0.00**	**0.90**	**0.02**
Ireland	0.91	0.00	0.84	0.02	1.00	0.00	1.00	0.02
Italy	1.00	0.01	0.96	0.03	1.00	0.00	1.00	0.02
Japan	0.93	0.00	0.84	0.02	0.95	0.00	0.98	0.02
South Korea	0.86	0.00	0.78	0.02	1.00	0.00	0.96	0.02
Lithuania	0.40	0.00	0.66	0.02	0.81	0.00	0.93	0.02
Luxembourg	0.63	0.00	0.68	0.02	0.95	0.00	0.91	0.02
Latvia	0.33	0.00	0.65	0.01	0.72	0.00	0.83	0.02
Mexico	0.72	0.00	0.83	0.02	0.84	0.00	0.91	0.02
Malta	0.28	0.00	0.66	0.02	0.79	0.00	0.78	0.02
Netherlands	1.00	0.01	0.98	0.03	1.00	0.00	1.00	0.02
Norway	0.91	0.01	0.88	0.02	0.95	0.00	0.98	0.02
Poland	0.93	0.01	0.88	0.02	1.00	0.00	1.00	0.02
Portugal	0.65	0.00	0.83	0.02	0.93	0.00	0.91	0.02
Romania	0.70	0.00	0.80	0.02	0.95	0.00	0.96	0.02
Rest of the world	1.00	0.02	1.00	0.03	1.00	0.00	1.00	0.02
Russia	**0.91**	**0.01**	**0.90**	**0.03**	**1.00**	**0.00**	**1.00**	**0.02**
Slovakia	0.51	0.00	0.69	0.02	0.95	0.00	1.00	0.02
Slovenia	0.49	0.00	0.77	0.02	0.91	0.00	0.90	0.02
Sweden	0.98	0.01	0.93	0.03	1.00	0.00	1.00	0.02
Türkiye	0.93	0.01	0.91	0.03	0.98	0.00	0.98	0.02
Taiwan	0.86	0.00	0.81	0.02	0.98	0.00	0.84	0.02
United States	1.00	0.02	1.00	0.03	1.00	0.00	1.00	0.02

In summary, the analysis of the global trade network reveals that while China has emerged as a significant player, the role of other emerging and developing countries in the global economy remains limited. These countries have experienced certain advancements in areas such as export growth; however, they continue to face challenges in achieving substantial influence and reducing their dependence on the global North. Nonetheless, there are opportunities for collaboration and partnerships among countries in the global South to address these challenges and foster economic development. By leveraging their economic strengths and enhancing trade ties within the global South, these countries may enhance their position in the global trade network.

The network analysis showed global trade relations and highlighted the relevance of some countries as important international hubs, that is, it offered a bird's eye view of international trade. To deepen the evaluation of the pattern of trade between the BRIC countries, the next section presents, through a ground-level view, the decomposition techniques' results of the trade flows between BRIC countries. It is to be expected, as revealed by the network analysis, that China stands out compared to the other countries.

Decomposition of trade flows between BRIC

The results of intra-BRIC trade were aggregated based on the level of technological intensity, as per the classification provided by the United Nations (2008). Consequently, the trade relationships among the BRIC countries were examined across low-technology, medium-low, medium, medium-high, and high-technology sectors.

Figure 2 presents the trends in domestic value-added (*DVA*) among the BRIC countries from 2000 to 2014. Starting from 2006, a notable increase in China's DVA trade with the other BRIC countries became evident. China's prominence primarily extended to the trade of high, medium-high, medium, and medium-low technology industries. This shift can be attributed to China's rapid economic growth, which led to increased production capabilities and export competitiveness. Additionally, Brazil witnessed a significant rise in DVA trade for low-technology industries, reflecting its specialization in sectors such as agriculture and natural resources. India experienced a similar trend for low-medium-technology industries starting from 2007, indicating its growing presence in sectors such as information technology and services.

By 2010, China had consolidated its position in DVA exports from high and medium-high technology industries, both in terms of total DVA and DVA for final goods and intermediates. Moreover, in 2010, China exported more intermediate goods in medium technology industries, while in medium-low technology industries, the focus was on the export of final goods. This development signifies China's success in upgrading its industrial structure and transitioning towards higher value-added activities. Brazil also exhibited prominence in the exports of intermediate goods in medium-low and low-technology industries, driven by its manufacturing sector and the export of commodities. In 2011, there was noticeable progress in the trade of DVA for intermediate goods in Russia and India's medium-low technology industries. However, only China continued to dominate the high, medium-high, and medium technology industries. This pattern persisted until 2014, reflecting the sustained competitive advantages of China in these sectors. Brazil's standout contribution remained limited to the trade of intermediate goods from low-technology industries in terms of DVA, indicating the persistence of its traditional industries.

Figure 3 illustrates the domestic value-added that returns home (RDV). The RDV consists of the value-added returning through imports of final goods (RDV_fin), imports of intermediate goods (RDV_int), and the return of DVA via trade relations with third countries (RDV_TC). Starting from 2005, notable emphasis was placed on China's RDV of intermediate goods in medium-high and medium technology industries, as well as India's RDV of intermediate goods in medium-low technology industries. This indicates that China and India were becoming more integrated into global value chains, with a significant portion of their intermediate goods production being used abroad rather than being domestically. The value-added returned home between the BRIC countries could be more substantial; however, it contributes to the indicators of verticalization in the industries' production. The phenomenon of value-added returning home reflects the increasing complexity of global supply chains and the integration of production activities across countries. Notably, China also emerged as a key player in these indicators when comparing the BRIC countries, reaffirming its central role in global manufacturing networks. Russia exhibited more pronounced results in RDV_fin for low-technology industries in certain years such as 2006, 2007, 2008, 2011, and 2012, indicating its reliance on imports of final goods in these sectors. Conversely, Brazil displayed prominence in RDV_int for the years 2010, 2013, and 2014, highlighting its role as an importer of intermediate goods in specific industries.

Figure 4 delves into the components of foreign value-added, considering both the contribution of third countries and the value-added attributed to the direct importers. The value-added components of third countries in exports of final goods and intermediate goods were aggregated and labeled as VA_TC. Similarly, the value-added contributed by the direct importer in exports of final goods and intermediate goods was designated as VA_direct. The figure also presents a comprehensive view of the degree of vertical specialization in production through the combination of these components, referred to as VS. China consistently emerged as the most prominent country in terms of vertical specialization and the value-added derived from third countries in its production. As early as 2004, high, medium-high, and medium-low technology industries in China began to distance themselves from similar industries in other countries, suggesting a growing reliance on foreign value-added inputs. India's medium-low technology industries also witnessed an increase in the degree of vertical specialization starting from 2006, indicating its integration into global value chains. In the case of Brazil, a noticeable upswing in vertical specialization and the value-added attributed to third countries in the production of low-technology industries was observed in 2008, highlighting its integration on foreign inputs in these sectors.

Chinese industries across high, medium-high, medium, and medium-low technology sectors consistently led in terms of the value-added contributed by third countries to their production, as well as the degree of vertical specialization in production. This trend signifies China's role as a major global manufacturing hub, attracting significant foreign value-added inputs and operating within intricate production networks. Brazil and India vied for prominence in terms of third-country value-added and vertical specialization within the medium-low technology industries, reflecting their respective positions as emerging economies and their potential proximity into global supply chains. This pattern persisted throughout the subsequent years until 2014, with low-technology industries in Brazil displaying a greater reliance on foreign value-added in their production and exhibiting a higher degree of vertical specialization compared to other BRIC countries. Russia, on the other hand, did not emerge as a leader in any of the components analyzed across its industries or levels of technology intensity. However, in 2012, 2013, and 2014, it trailed behind China in terms of high-tech industries regarding third-country value-added indicators and the vertical specialization of production.

Figure 5 focuses on the double-counting terms of domestic value-added in exports among the BRIC countries. The PDC term represents the sum of all double-counting terms, encompassing the double-counting of domestic value-added in both final and intermediate goods exports. Additionally, the terms PDC_TC and PDC_direct account for the double-counting of third-country value-added and the value-added attributed to the direct importer in the production and export processes, respectively. Notably, significant trade movements, particularly in medium-high technology industries in China and medium-low technology industries in India, were observed from 2006 onward. These findings suggest the increasing complexity of value chains within these sectors, with multiple rounds of value-added generation and exchange taking place among the BRIC countries. From 2010 to 2011, Brazil stood out in the trade of medium-low and low-technology industries. Russia remained focused on low-tech industries during this period. It is important to note that the PDC in medium-high technology industries were more pronounced in China compared to India. Furthermore, Indian medium-low technology industries were overtaken by their Brazilian counterparts in 2010, highlighting Brazil's increasing competitiveness in these industries.

Figure 2 – Domestic Value-Added in trade between BRIC from 2000 to 2014

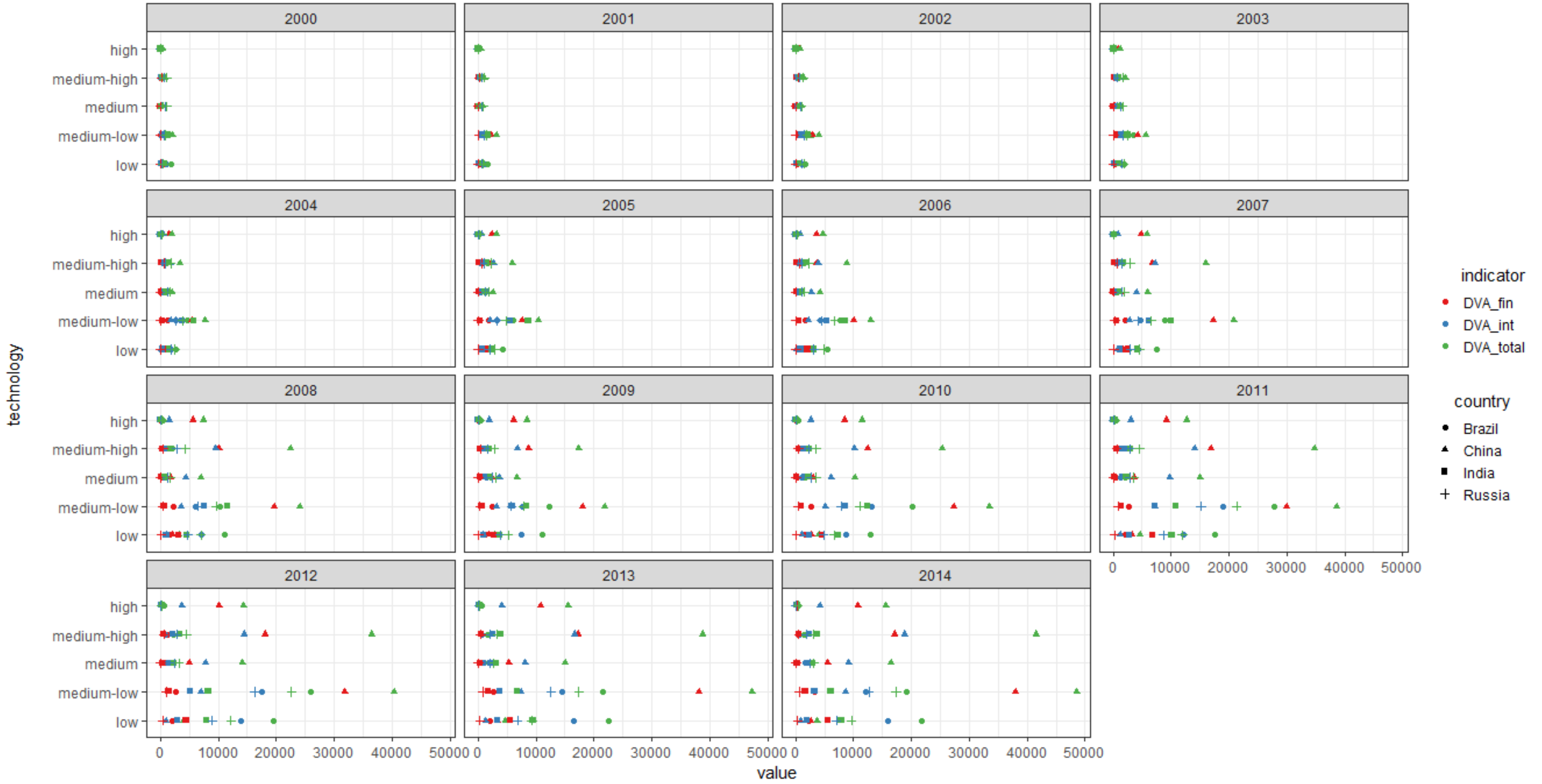


Figure 3 – Domestic Value-Added returning home in BRIC trade from 2000 to 2014

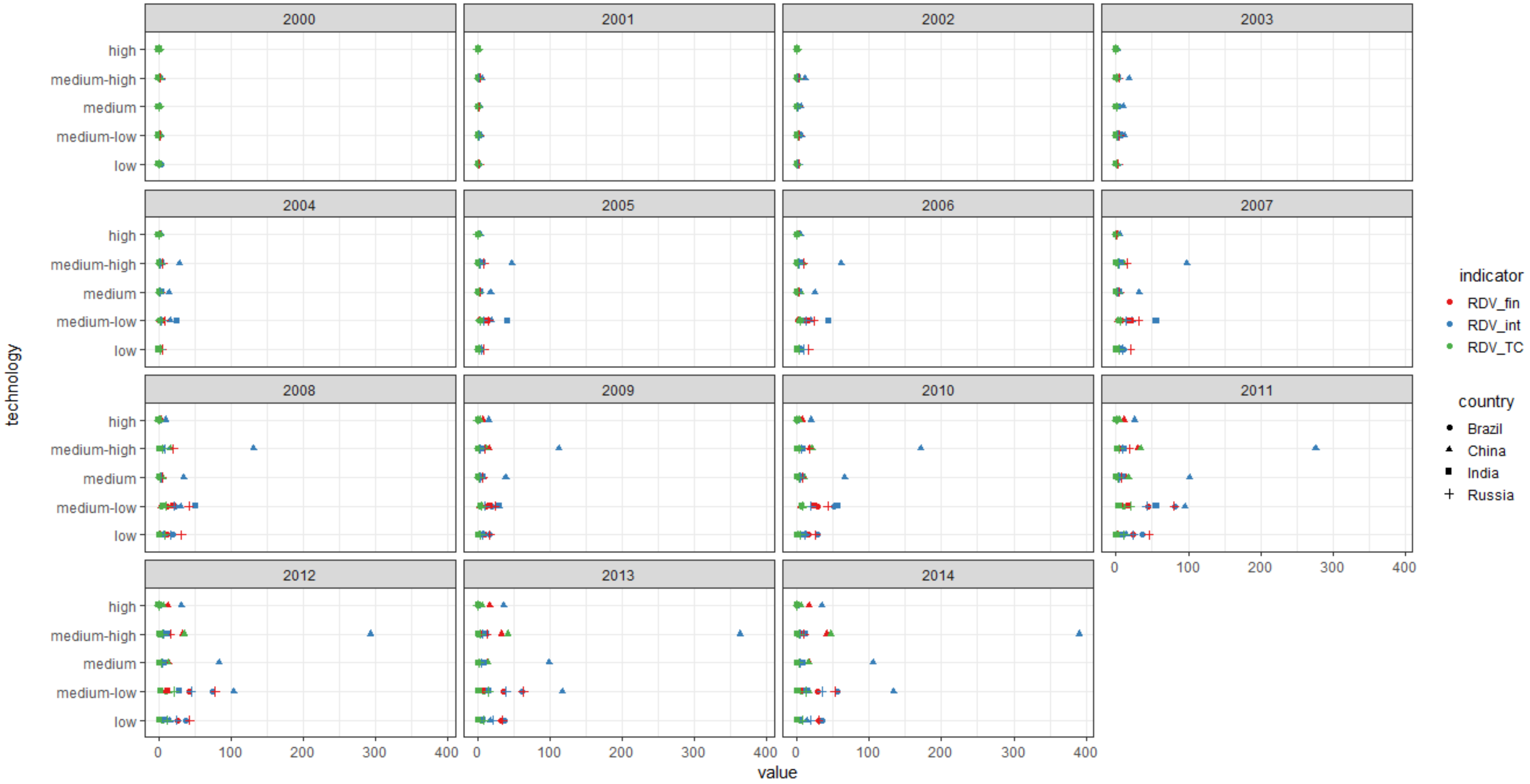


Figure 4 – Foreign value-added based on trade relations between the direct importer and the third countries and vertical specialization among BRIC from 2000 to 2014

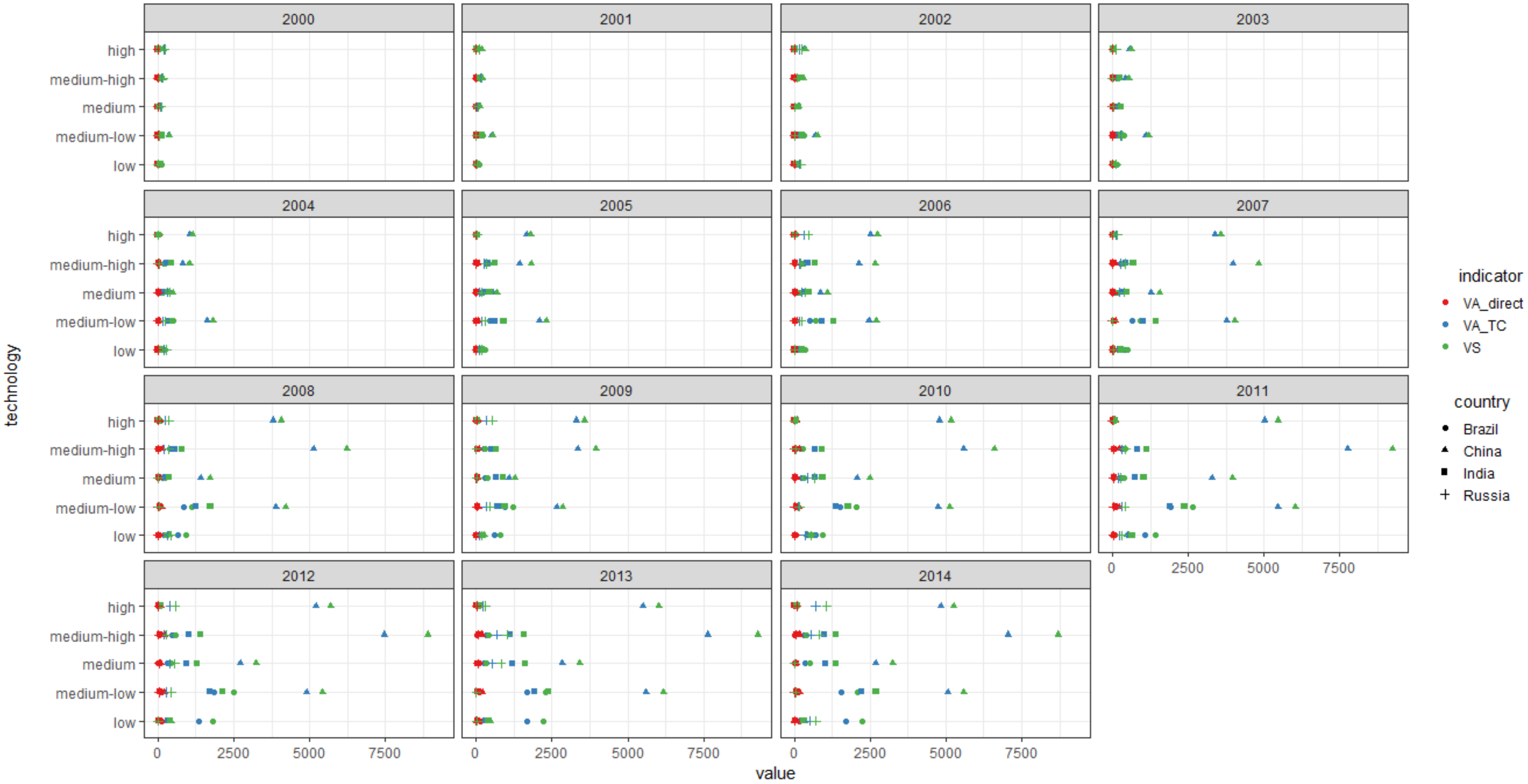
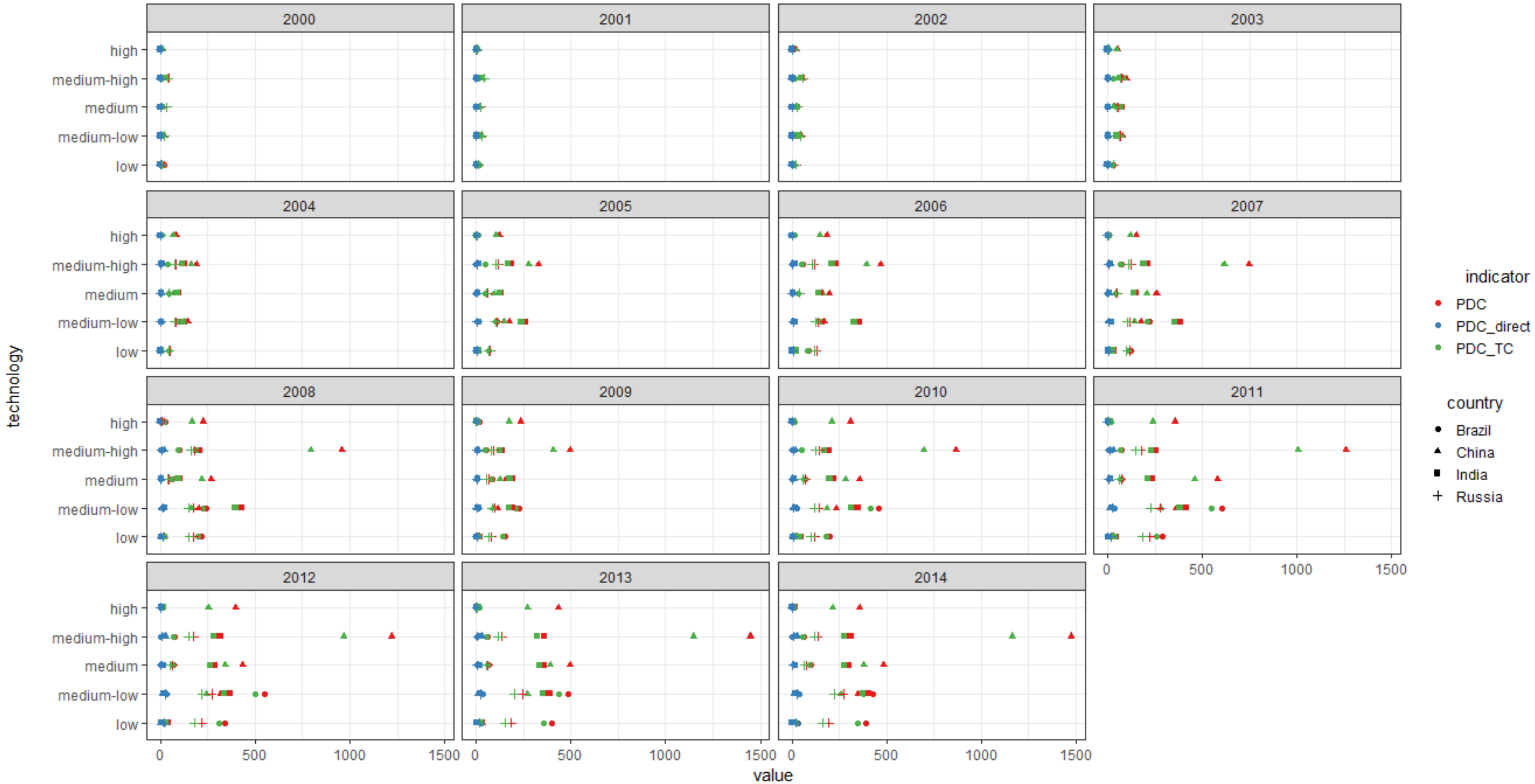


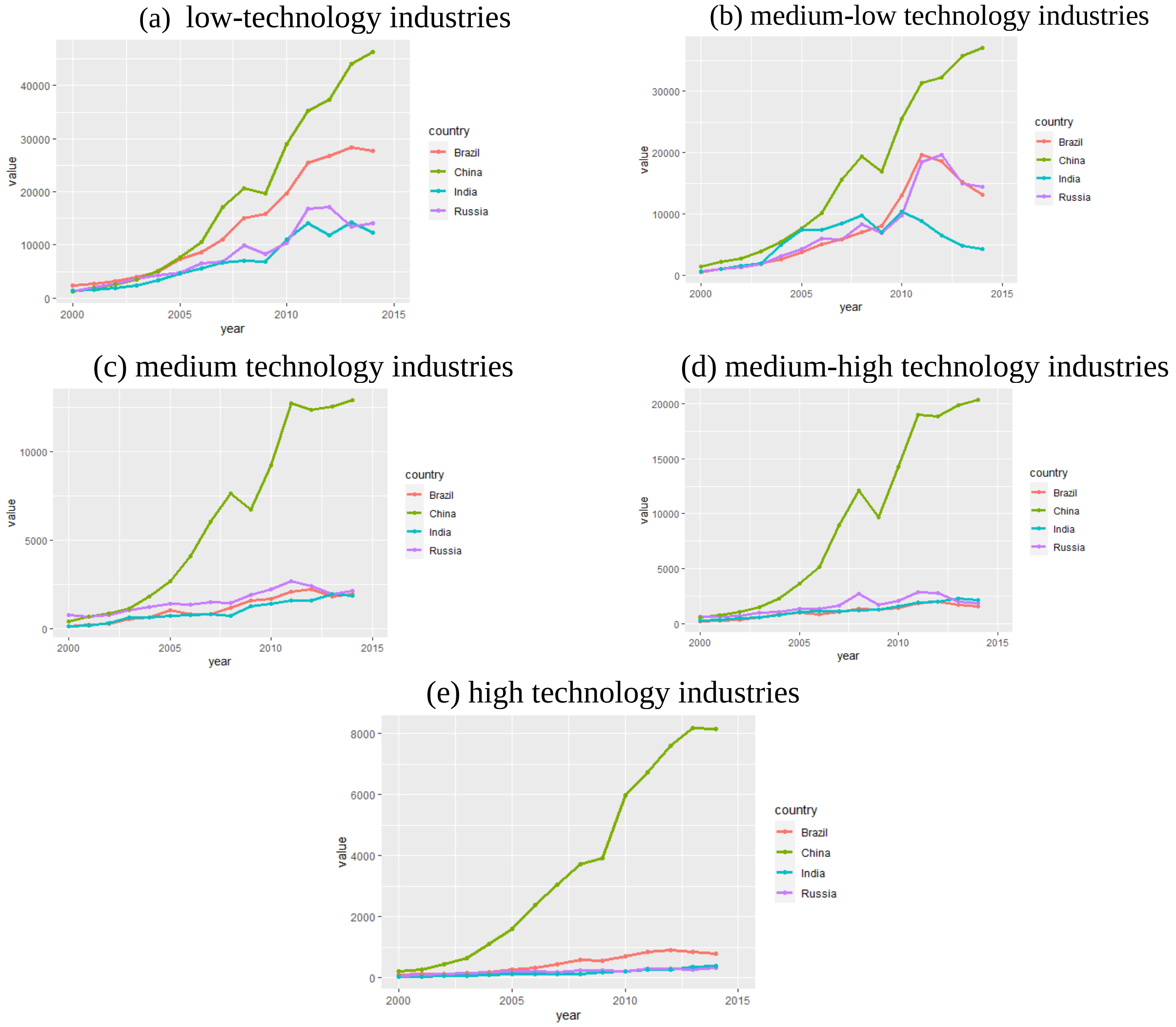
Figure 5 – Domestic value-added in terms of pure double counting between BRIC from 2000 to 2014



The analysis of value-added exports based on forward linkages provides insights into the value-added originating from an industry in all downstream industries from the country of origin. This measure excludes value-added contributions from other domestic industries that would be upstream in the production process. Figure 6 presents the evolution of value-added exports based on forward linkages for the BRIC countries categorized by the level of technological intensity.

In Figure 6(a), which focuses on low-technology industries, China emerges ahead of Brazil. This indicates that China has a stronger presence in downstream sectors and a higher share of value-added contributions in the exports of low-technology industries compared to Brazil. Over the analyzed period, Brazil's exports experienced significant growth, albeit to a lesser extent for Russia and India. However, China consistently maintained higher exports than Brazil and Russia in medium-low technology industries, indicating its dominance in these sectors. For medium technology industries, Brazil, India, and Russia demonstrate a relatively stagnant trend over time, unlike China, as depicted in Figure 6(c). This trend of stagnation persists across the various levels of technological intensity, with only China exhibiting notable growth in the trade of medium, medium-high, and high-technology goods with other BRIC countries.

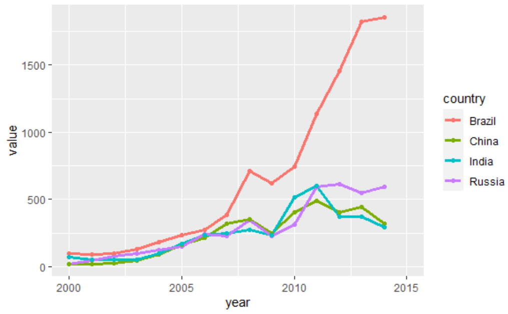
Figure 6 – Level of trade based on forward linkages.



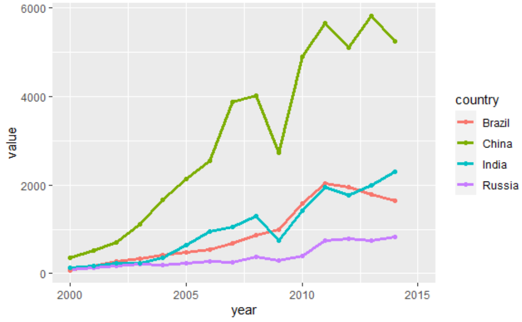
Turning to the analysis of backward linkages, which captures the value-added exports in upstream sectors, Figure 7 reveals that Brazil surpasses other BRIC countries in terms of export values for low-technology industries. However, these amounts are significantly lower compared to the forward linkages ratios, indicating a higher degree of reliance on downstream sectors. In contrast, China takes the lead in exports for other levels of technological intensity, suggesting its ability to absorb and incorporate technologies resulting from imports of intermediate inputs into its exports, as highlighted by Kuroiwa (2014). Notably, China's export basket includes important items in the electronic and electrical sectors, for which it relies heavily on imports. Therefore, the ability to establish agreements and partnerships between the BRIC countries and other Asian nations will be crucial for sustaining China's position as a major exporter of technological goods.

Figure 7 – Level of trade based on backward linkages.

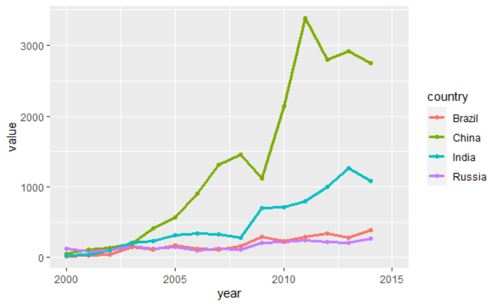
(a) low-technology industries



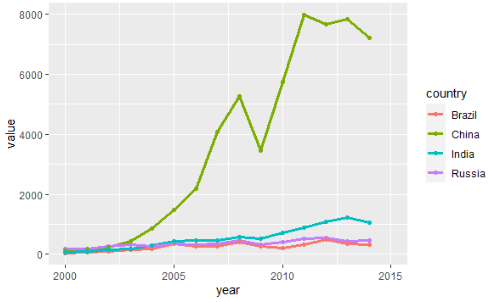
(b) medium-low technology industries



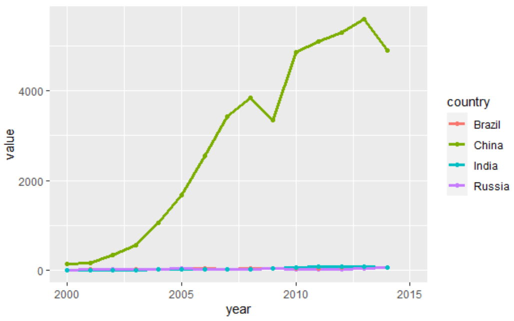
(c) medium technology industries



(d) medium-high technology industries



(e) high technology industries



The enhancement of commercial (and political) relations plays a pivotal role in ensuring stability, fostering economic growth, and promoting investment cooperation among the BRIC countries. As these nations transition from bilateral trade to a multilateral framework of trade and investment transactions, it becomes imperative to strengthen the partnership. By deepening economic relations, the BRIC countries can bolster their competitiveness within the macroeconomic landscape. These relationships are anticipated to generate synergistic effects through the expansion of cooperation and the intergenerational evolution of trade policies among the nations.

Decomposition in terms of trade intensity

When examining trade intensity, only a few indicators demonstrate significant findings concerning domestic value added and vertical specialization. Figure 8 reveals that the terms of domestic value added in exports of intermediate and final goods exhibit notable patterns. Notably, domestic value added constitutes nearly 100% of Brazilian and Russian exports in low and medium-low technological intensity industries. Similarly, it serves as the primary aggregate indicator across all technological levels in intra-BRIC trade. Trade in intermediate goods demonstrates the highest intensity in terms of domestic value added.

Trade intensity indicators related to vertical specialization provide insights into the positioning of countries or industries within global value chains, including intra-BRIC trade. In this regard, China and India emerge as prominent players with a substantial presence in the internationalization of production across high, medium-high, medium, and medium-low technology industries. The significance of vertical specialization in low-technology industries is relatively minor. Nevertheless, China exhibits higher participation rates compared to Brazil. Furthermore, trade intensity with third countries plays a significant role in augmenting the value-added to intra-BRIC exports, as depicted in Figure 9.

It is worth noting that China and India have effectively leveraged their partners' technological endowments. Although India may not match China in nominal absolute terms, as previously illustrated, an analysis of trade intensity reveals a specialization or focus on Indian exports in more advanced technological industries. This underscores the nuanced dynamics of technological specialization and the differential strengths of each BRIC country within the context of intra-BRIC trade.

A possible explanation for the high volatility in intra-BRIC trade intensity is found in Johnson and Moxnes (2019). According to these authors, production costs play a crucial role in GVCs. Given the different endowments and production stages of each industry in each country, upstream and downstream costs weigh in the decision-making process of producing inputs and final goods for the composition of the exports. In addition, as production costs fall, the elasticity of trade in inputs increases, increasing the possibilities of producing new intermediate inputs and final goods in several countries, substantially fragmenting production.

This conception was also previously pointed out by Krugman and Venables (1995), Venables (1996), and Venables (1999). The vertical specialization strategy guarantees the growth and development of productive capacities in industry and other productive sectors. The consumption of intermediate goods tends to create linkages between firms and encourages industrial agglomeration. Therefore, the industrial agglomeration process depends on how strong the local productive linkages are and the commercial costs. If the linkages are weak and there are low transport costs, commercial specialization leads to the dispersion of the productive processes of the entire industry as the firms respond differently to the relations of the productive factors of capital and labor.

Figure 8 – Trade intensity terms based on domestic value added in BRIC trade from 2000 to 2014

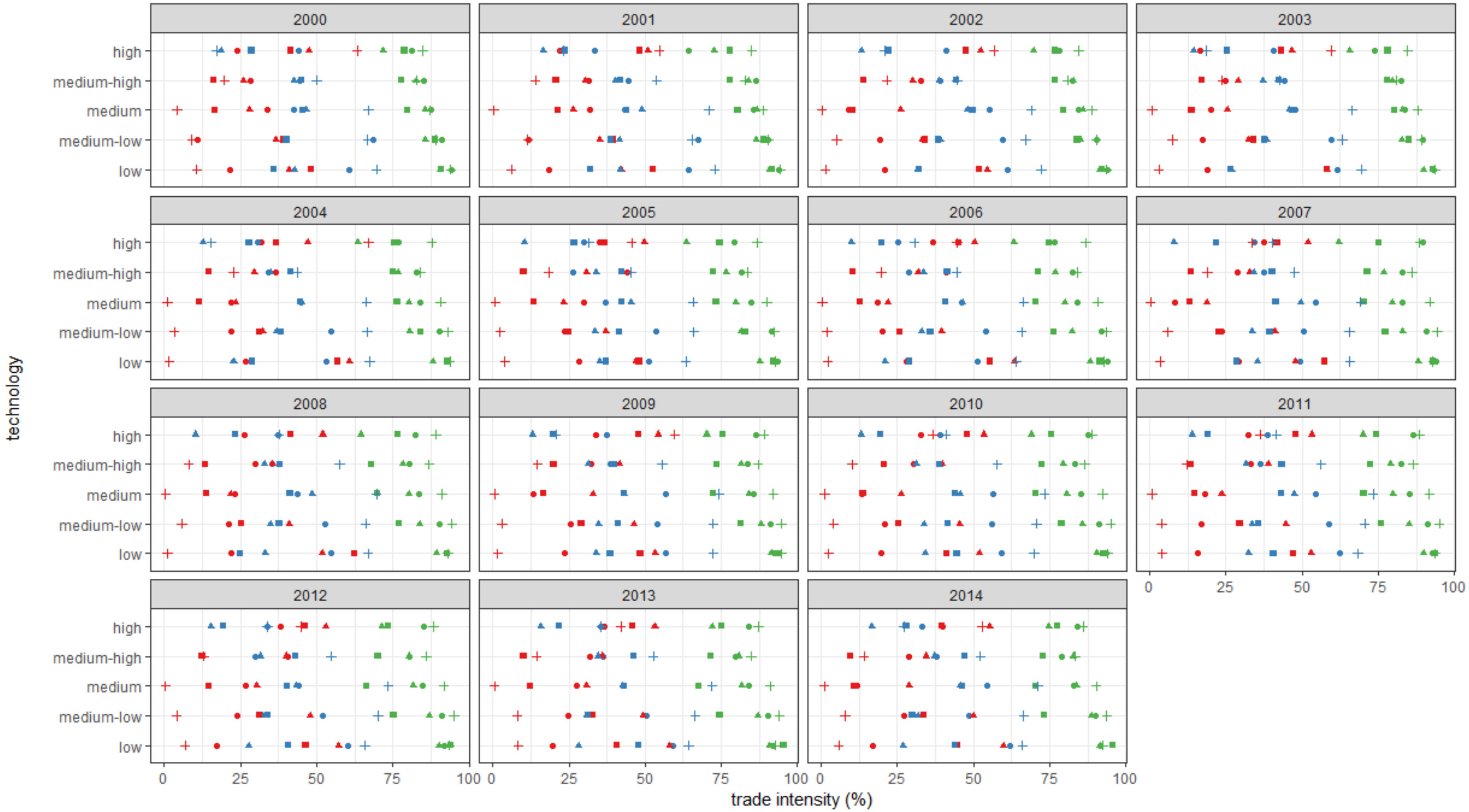


Figure 9 – Terms of trade intensity based on foreign added value of trade relations between direct importer and third country, and vertical specialization of intra-BRIC production from 2000 to 2014

FINAL REMARKS

In this study, we have examined the world input-output network (WION) using the available WIOD database to analyze its characteristics and dynamics. Our analysis encompasses global, regional, and local properties of the network, shedding light on its evolution over time. We find that as production chains become more integrated, the WION becomes sparser. The increasing foreign share of intermediate transactions emphasizes the interdependence among national policies, where industry-specific policies can have unintended consequences on both domestic and foreign markets. However, it is important to note that, apart from China, emerging or developing countries have not gained a significant role in global trade and the economy.

The results reveal limited participation of the BRIC countries in global value chains (GVCs) and intra-BRIC trade in terms of value-added relations. While Brazil and Russia exhibit stagnation over time, India's share has only marginally increased. On the other hand, China has demonstrated significant advancements in domestic value-added trade, particularly in high, medium-high, and medium-tech industries. This highlights technological dynamism and distinct production standards compared to other BRIC countries.

Analyzing the trade intensity relations, we observe that China and India exhibit better positioning indicators in high, medium-high, and medium technology industries within intra-BRIC trade. This is primarily driven by vertical specialization indicators and trade based on backward linkages. The human capital endowments of these countries play a crucial role in their consolidation within global supply chains. It is important to recognize that low production costs mitigate the volatility of operationalizing production in these countries.

Furthermore, measures of value-added trade intensity reflect the changing nature of trade, as described by Hummels, Ishii, and Yi (2001). The high volatility observed in intra-BRIC trade intensity lacks a consistent pattern of increase or decrease, even during economic inflection points such as the 2007-2008 financial crisis. However, it is evident that industries in India and China with higher technological concentration have made greater trade gains.

On the other hand, Russia and Brazil have yet to make substantial progress in terms of technological content in their exports, which continue to rely predominantly on natural resources. Diversifying their exports is a crucial point of discussion between these countries, particularly in building cooperation agreements for technology diffusion with China and India.

This study provides a basis for further analysis of trade relations between the BRIC countries, other developing economies, and the global North and South. Future research can explore heterogeneous markets, employment implications, and the effects of emerging technologies facilitated by closer commercial ties. Enhancing trade relations between these countries is anticipated, primarily through the elimination of non-tariff barriers. The BRIC countries' political and trade agreements will play a pivotal role in fostering cooperation and effectively shaping future trade relations among these emerging markets and other developing economies.

It is important to acknowledge certain limitations of this analysis. The availability of WIOD matrices only until 2014 and the limited coverage of countries in the database impose certain restrictions. Moreover, input-output analysis methods have their caveats, as discussed extensively in Miller and Blair (2022). Incorporating new analysis methods will enhance the formulation of a consistent and robust research agenda. Additionally, the significance of political and trade developments on the global stage is increasing. Therefore, deeper studies on trade in the BRIC countries are essential to guide consistent and long-term structural changes and transformations through commercial and political cooperation.

REFERENCES

Amador, J., & Cabral, S. (2008). Especialização vertical no comércio internacional português. *Boletim Económico*, 1(1), 97-114.

Amador, J., & Cabral, S. (2017). Networks of value-added trade. *The World Economy*, 40(7), 1291-1313. https://doi.org/10.1111/twec.12469

Antràs, P., & Yeaple, S. R. (2014). *Multinational firms and the structure of international trade*. In G. Gopinath et al. (Eds.), Handbook of International Economics (Vol. 4, pp. 1-80). Elsevier. http://dx.doi.org/10.1016/B978-0-444-54314-1.00002-1

Baldwin, R., & Lopez-Gonzalez, J. (2013). *Supply-chain trade: a portrait of global patterns and several testable hypotheses*. National Bureau of Economic Research. (Working Paper No. 18957).

Bardi, W., & Hfaiedh, M. A. (2021). International trade and economic growth: evidence from a panel ARDL-PMG approach. *International Economics and Economic Policy*, 18, 847-868. doi: 10.1007/s10368-021-00507-4

Cerina, F., et al. (2015). World Input-Output Network. *PLoS ONE*, 10(7), e0134025. https://doi.org/10.1371/journal.pone.0134025

Chessa, A., et al. (2013). Is Europe Evolving Toward an Integrated Research Area? *Science*, 339(6120), 650–651. https://doi.org/10.48550/arXiv.1302.3126

Ciriaci, D., & Palma, D. (2016). Structural change and blurred sectorial boundaries: assessing the extent to which knowledge-intensive business services satisfy manufacturing final demand in western countries. *Economic Systems Research*, 28(1), 55-77. doi: 10.1080/09535314.2015.1101370

Conceição, C. S. (2015). Desenvolvimento industrial e mudança estrutural: tendências recentes observadas nas indústrias mundial e brasileira. *Indicadores Econômicos FEE*, 43, 43-60.

Costinot, A., & Rodríguez-Clare, A. (2013). *Trade theory numbers: quantifying the consequences of globalization*. National Bureau of Economic Research. (Working Paper No. 18896).

Diao, X., McMillan, M., & Rodrik, D. (2017). *The recent growth boom in developing economies*: a structural change perspective. National Bureau of Economic Research. (Working Paper No. 2332).

Federal State Statistics Service (ROSSTAT). (2020). *BRICS Joint statistical publication 2020*. [Moscou].

Hauknes, J., & Knell, M. (2009). Embodied knowledge and sectoral linkages: an input-output approach to the interaction of high- and low-tech industries. *Research Policy*, 38, 459-469. doi: 10.1016/j.respol.2008.10.012

Hummels, D., Ishii, J., & Yi, K-M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, 57, 75-96. https://doi.org/10.1016/S0022-1996(00)00093-3

Intersecretariat Working Group on National Accounts. (1993). *System of National Accounts 1993*. United Nations.

Intersecretariat Working Group on National Accounts. (2010). *System of National Accounts 2008*. United Nations.

Johnson, R. C. (2018). Measuring global value chains. *Annual Review of Economics*, 10, 207-236. https://doi.org/10.1146/annurev-economics-080217-053600

Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: production sharing and trade in value added. *Journal of International Economics*, 86, 224-236. https://doi.org/10.1016/j.jinteco.2011.10.003

Kox, H., & Rubalcaba, L. (2007). *Analysing the contribution of business services to European economic growth*. Munich Personal Repec Archive (MPRA). (Paper No. 2003).

Kuroiwa, I. (2014). *Value-added trade and structure of high-technology exports in China*. Institute of of Developing Economies (IDE). (Paper, No. 449).
Melitz, M. J., & Redding, S. J. (2012). *Heterogeneous firms and trade*. National Bureau of Economic Research. (Working Paper No. 18652).
Miller, R. E.; Blair, P. D. *Input-output analysis*: foundations and extensions. Cambridge: Cambridge University Press, 2022. 7860 p.
Mishra, A. K., et al. (2015). Trade flows between India and other BRICS countries: an empirical analysis using gravity model. *Global Business Review*, 16(1), 107-122. https://doi.org/10.1177/0972150914553523
Morceiro, P. C. (2018). *A indústria brasileira no limiar do século XXI*: uma análise da sua evolução estrutural, comercial e tecnológica. Tese de Doutorado, Universidade de São Paulo.
Nayyar, D. (2016). BRICS, developing countries and global governance. *Third World Quarterly*, 37(4), 575-591. https://doi.org/10.1080/01436597.2015.1116365
O'Neill, J. (2001). *Building better global economic BRICs*. Global Economics. (Paper No. 66).
Organisation for Economic Co-operation and Development. (2005). *Oslo manual*: guidelines for collecting and interpreting innovation data (3ª ed.).
Pammolli, F., & Riccaboni, M. (2002). Technological regimes and the growth of networks: An empirical analysis. *Small Business Economics*, 19(3), 205–215. https://doi.org/10.1023/A:1019682612073
Savona, M., & Lorentz, A. (2006). *Demand and technology contribution to structural change and tertiaisation*: an input-output structural decomposition analysis. Laboratory of Economics and Management. (Working Paper No. 2006-17).
Sayama, H. (2015). *Introduction to the Modeling and Analysis of Complex Systems*. Open SUNY Textbooks.
Stuenkel, O. (2020). *The BRICS and the future of global order*. The Rowman & Littlefield Publishing Group.
Timmer, M. P., et al. (2014). Slicing up global value chains. *Journal of Economic Perspectives*, 28(2), 99-118. doi: 10.1257/jep.28.2.99
Timmer, M. P., et al. (2016). *An anatomy of the global trade slowdown based on the WIOD 2016 release*. Groningen Growth and Development Centre. (GGDC Research Memorandum No. 162).
United Nations Conference on Trade and Development (UNCTAD). (2023). *Unctadstat*. http://unctadstat.unctad.org/wds/ReportFolders/reportFolders.aspx?sCS_ChosenLang=en
United Nations. (2008). *International standard industrial classification of all economic activities (ISIC), Rev. 4*. The United Nations Statistics Division.
Wang, Z., Shang-Jin, W., & Zhu, K. (2018). *Quantifying international production sharing at the bilateral and sector levels*. National Bureau of Economic Research. (Working Paper No. 19677).