Original article
Economia e Sociedade, Campinas, Unicamp. IE
http://dx.doi.org/10.1590/1982-3533.2025v34n1.266660

Global value chains, technological sophistication and economic complexity: panel data for 58 economies from 2006 to 2015 *

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Abstract

In the 21st century, the intensification of global production networks has made it important to understand the implications for the productive structures of countries important. This study aims to investigate whether participation in global value chains (GVCs) can change the degree of technological sophistication of exports and a country's economic complexity, considering a sample of 58 countries and a subsample consisting only of developing countries, from 2006 to 2015. We estimate dynamic models by difference and system GMM considering two dependent variables: an export sophistication index ('q') and the economic complexity index. We find a positive and significant relationship between participation in GVCs and degree of sophistication of the export basket, measured by the 'q' index. However, considering a broader measure of economic complexity (the ECI index), the effects were negative and not significant for developing countries.

Keywords: Value added; Structural change; Globalization; Exports; Dynamic panel.

Resumo

Cadeias globais de valor, sofisticação tecnológica e complexidade econômica: uma análise de painel com 58 países no período de 2006 a 2015

No século XXI, a expansão das redes globais de produção tornou crucial a compreensão dos seus impactos nas estruturas produtivas dos países. Este estudo busca investigar se a participação em cadeias globais de valor (CGV) influencia o nível de sofisticação tecnológica das exportações e a complexidade econômica de um país. A pesquisa abrange uma amostra de 58 países e uma subamostra de países em desenvolvimento, entre 2006 e 2015. Utilizando modelos dinâmicos estimados por ambos Difference e System GMM, foram avaliadas duas variáveis dependentes: um índice de sofisticação das exportações ("q") e o índice de complexidade econômica (ECI). Os resultados mostram que a participação nas CGV está associada a um aumento significativo na sofisticação da pauta de exportações, medida pelo índice "q". Porém, quando analisada a complexidade econômica em termos mais amplos (ECI), os efeitos foram negativos e não significativos estatisticamente para países em desenvolvimento.

Palavras-chave: Valor adicionado; Mudança estrutural; Globalização; Exportações; Painel dinâmico.
JEL: F02, F14, F43.

1 Introduction

The rise of global value chains (GVCs) in the 21st century has revolutionized the production process around the world by establishing factories capable of crossing borders through the contractualization of the relationships between buyers and sellers internationally (Daria; Wrinkler, 2016). Whether these are characterized by sequential value chains or even more complex networks, they are present everywhere, in such a way that a product can be "made in the world" (Taguchi, 2014; OECD, 2013), reflecting the growth of the global trade flow of intermediate goods (Sturgeon; Memedovic, 2011). In 2008, around 80% of international trade

* Article received on August 5, 2022 and approved on June 9, 2024.

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involved GVCs, and more than 60% were intermediate goods and services incorporated into various stages of the production process through these GVCs (OECD, 2013; Unctad, OECD, WTO, 2013).

This international fragmentation of production tends to lower production costs and increases contact between leading firms, usually multinationals from developed countries, with subsidiary firms located in developing countries. Baldwin (2013) suggests that this allowed the diffusion of know-how related to a myriad of products along these chains, opening a range of opportunities for developing countries to participate in new ways in international trade. The benefits arising from trade liberalization via GVCs are regularly highlighted in reports from international organizations, such as the OECD (2013) and Unctad (2013), among others. These highlight the participation of emerging countries in GVCs as a fundamental way to accelerate their economic development.

However, in the GVCs, different forms of participation exist. Baldwin (2013) highlighted the existence of headquarters and factory economies, wherein the latter would be dependent on the former. The analytical concept of the "smile curve" identifies that the steps before and after manufacturing/assembly generate greater value-added. Hence, firms located in intangible productive activities such as R&D, design, conception, and technological services would tend to benefit more from GVCs than those specialized in standardized assembly activities (Stöllinger, 2019). Additionally, obstacles to the occurrence of technological spillovers and transfer of know-how along the chain, making firms, especially from developing countries, prisoners of a certain low value-added export productive function, that is, preventing or delaying a structural change in these economies. Consequently, it would bring fewer benefits in development for the country in which it is located (Sturgeon; Memedovic, 2011). For example, Kaplinsky and Farooki (2010) demonstrate how buyers, large and diversified firms, can obstruct the processes of upgrading the activities and functions of smaller producers in GVCs.

Given that the debate on the long-term effects of countries' participation in GVCs is controversial and the the international trade literature is insufficient this study aims to empirically test the following question: Does greater participation in GVCs allow countries to migrate for more technological/more complex productive activities? Additionally, this study seeks to understand whether these effects are homogeneous for all countries or differences can be found when considering only developing countries.

Therefore, we aim to understand whether such participation can generate an increase in the technological sophistication of production from 58 countries in the 2006–2015 period (sample provided by the latest version of the global input-output matrix Trade in Value Added (TiVA, 2018)). To capture this increase in complexity, we employed two indirect measures based on the countries' export agenda: 1) the 'q' index and 2) Economic Complexity Index (ECI). The first index is calculated using measures of domestic value-added in exports. The variation of the 'q' index reflects the change in the "quality"/degree of sophistication of the countries' trade agenda. The second index, originally conceived by Hausmann and Hidalgo (2009) and made available by the Atlas of Economic Complexity, measures the productive capacities of each country through the diversity and ubiquity of the products present on their export agendas, revealing variation in the diversity and sophistication of its productive structure. Conversely, the share in the GVCs is calculated through the sum of the shares back and forth between countries, following the export decomposition methodology from Koopman, Wang, and Wei (2014) and applying it to the value-added data from TiVA (2018).

This study contributes to empirical literature on the impact of GVC participation when measuring the effects of technological sophistication for the first time. Furthermore, it contributes to estimation of data in a dynamic panel through the generalized moments method (GMM), which incorporates the lagged dependent variables among explanatory variables.

The remainder of the paper is structured as follows. Section 2 highlights theoretical elements of GVCs and systematizes a literature review on the participation of GVCs and its impact on structural changes. Section 3 presents the methodology. Section 4 discusses the results and provides a brief descriptive analysis followed by an econometric analysis. Finally, Section 5 presents the final considerations of the research.

2 Global value chains and productive structure

GVCs are production networks distributed according to business and task functions between firms, globally or regionally, involving international trade flows (Daria; Winkler, 2016). Overall, they are characterized by transfer of knowledge through the management of leading firms in the supply chains, in a more organized and interactive way (Fagerberg; Lundvall; Shrolec, 2018). In these networks, contractual relationships exist between sellers and buyers, establishing factories capable of crossing borders (Daria; Winkler, 2016).

The international division of labor has become increasingly dynamic and complex. Economic interdependence in the world, connected to the international fragmentation of the productive process, boosted the trade of intermediate goods and the market of specialized services, which affects the economic structures of localities participating in productive fragmentation (Sturgeon; Memedovic, 2011). In this sense, quality control systems and business standards of the contemporary reality are the main factors pushing developing economies to achieve new capabilities to meet the specific demands of GVCs, whether through better information, openness to new markets, or creating opportunities to learn new technological and human capital skills. Participating in GVCs could hasten developmental experience through a nonlinear catch-up process (Whittaker et al., 2010).

In this sense, international organizations in favor of economic liberalism suggest GVCs as a way of catching up and, hence, a new model of economic development (OECD, 2013; Unctad, 2013). According to them, GVCs would allow countries to enjoy lower production costs, increase competitiveness of companies, facilitate learning and appropriability of knowledge.

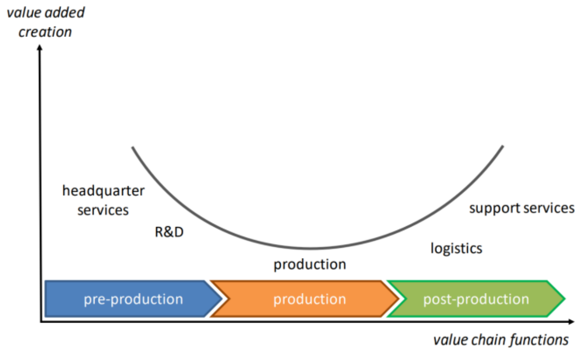
However, these relationships are asymmetrical (Baldwin, 2013). Host economies, which do not usually export intermediate goods, and factory economies, which possess a vast amount of intermediate goods in their export basket unlike the former, both exhibit dependence on the host economies. Kaplinsky and Farooki (2010) highlighted that suppliers in GVCs, when they are not part of large or diversified firms, have difficulty identifying new consumption patterns and adapting to them. Moreover, there may even be obstacles to structural changes in these producers within the GVCs. Evidence in case studies exists indicating the difficulties faced by countries in conducting activities associated with a growth process induced by GVCs (Unctad, 2013; Gereffi; Luo, 2014).

Sturgeon and Memedovic (2011) show that these production chains can create obstacles to learning and stimulate uneven development and restricting firms and industries in certain activities that generate low value-added. Furthermore, if such specialization in these activities remains persistent, GVCs may prevent domestic companies in developing economies from innovating, create industrial activities with high value-added, and involve workers in activities with higher salaries related to technologically sophisticated sectors (Sturgeon, 2016).

Fagerberg, Lundvall, and Shrolec (2018, p. 537) highlight that if a company remains trapped in narrow functions, the implications for the national economy may not be as favorable as public managers would like, at least not in the long term." According to Ye et. al. (2015), gains from participating in GVCs are not automatic, and benefits can vary considerably depending on whether a country operates at the upper or lower end of the value chain.

This problem is easily visualized in the symbolic figure known in the literature as the "smile curve" (Figure 1). This illustrates the intensity of value-added according to the stage of production in GVCs: intangible activities with higher technological content located at the beginning (research and development, design, headquarters services) and at the end (support and after-sales services, logistics) capture greater value-added than assembly activities of the goods object of the GVCs (Stöllinger, 2019).

Figure 1
"Smile curve"



Source: Stöllinger (2019).

Hence, the importance of economic upgrading strategies through GVCs for developing economies emerges, in the sense of seeking to move towards stages that add more value, is associated with more sophisticated activities along the GVC (Cattaneo et al., 2013). In this regard, Kummritz, Taglioni, and Winkler (2017) indicate that the effects of upgrading can vary depending on a country's stage of development, its integration into GVCs, and the underlying transmission channels. Lower-income countries tend to benefit more from backward linkages and technology spillovers, while higher-income countries experience greater gains in forward linkages and skill upgrading. Thus, in much of the literature, success in economic development from the perspective of GVCs is linked to countries' ability to increase their competitiveness in technology and knowledge-intensive activities, that is, to acquire greater technological sophistication through upgrading functions in GVCs.

Few empirical works on the direct effects of GVC participation on changes in the economies' productive structures have been noted, especially in the way this work is proposed. The effects of GVCs on value-added in countries' exports or on productivity at the firm level have been assessed in studies by Baldwin and Yan (2014), Kummritz (2016), Constantinescu, Mattoo, and Ruta (2019), Urata and Baek (2019), and Hagemejer and Muck (2019). However, although all of them are interesting in the sense of highlighting the importance of GVCs, they have different objectives from the present article. Stöllinger (2016, 2017, 2019, and 2021) found that most resemble the empirical proposal of this work, although they also differ in the method and the response variables.

Stöllinger (2016) assessed the relationship between participation in GVCs and structural changes in the manufacturing sector for a sample of 40 countries in Europe. Using pooled, fixed effects, and random effects estimators, he empirically evaluated this relationship from 1995 to 2011, divided into four-year intervals that do not overlap. As a proxy for participation in GVCs, he used the measure of foreign value added to exports developed by Hummels et al. (2001). The results present the benefits of structural change in the manufacturing sector for the countries of the manufacturing core of the European Center. However, participating members of the GVCs that did not participate in this nucleus accelerated the deindustrialization process.

Stöllinger (2017) extends the previous analysis and investigates a sample of 53 countries on whether participation in GVCs generates structural improvements in economies, evaluating it through a classic measure of structural change: workforce migrations to sectors with higher productivity. By estimating panel static models (pooled, fixed effects, and random effects) for three periods (1995-2000, 2000-2005, and 2005-2010), he found a positive relationship between participation in GVCs and structural improvement for emerging and transition economies, although this was not observed for the global sample.

Stöllinger (2019) uses foreign direct investment (FDI) data for the period 2003 to 2015 and applies the panel data method by fixed effects. He demonstrates that GVCs facilitate the entry of developing countries into the manufacturing industry, while noting that developing countries mainly serve as factory economies, producing inputs with little value-added as suggested by the "smile curve" concept. In the same sense, Stöllinger (2021) performs a variation of the "smile curve" test, addressing functional specialization, which is the attribution of different values to the functions necessary for the production process along the chain of a product for different countries or regions. Based on annual FDI (greenfield FDI) data, we capture the functional specialization of countries in GVCs at the industry level. The author estimates the fractional probit model for 107 countries from 2003 to 2015. The results econometrically confirm the smile curve hypothesis, showing that countries specialized in the center of the curve tend to generate less value-added per unit of production than those specializing in host economies.

3 Methodology

This article proposes to estimate an econometric model whose objective is to determine (and quantify) whether participation in GVCs promotes changes in the productive structures of countries. Using the theoretical discussion established in the previous section as a starting point, we developed two hypotheses: (i) the greater the growth of a country's participation in the GVCs, the more its agenda will shift towards more complex sectors; (ii) of a complementary nature to the first, sophistication gains are greater for developing economies.

To test them, we sought to use two indicators as dependent variables: an export sophistication index, built by the authors themselves and called here the "q Index," and the Economic Complexity Index (ECI).

The "q Index" represents an imperfect proxy for the degree of "quality" of the export agenda in terms of technological sophistication. This was calculated from data on domestic value-added (DVA) present in gross exports from the global input-output matrix TiVA (2018), using the sectorial classification of the OECD to categorize the trade sectors of ISIC Rev. 4 in technological terms. As DVA corresponds to the portion of inputs, parts, and components produced domestically. Hence, values realized by foreign countries that sometimes originate from imports and erroneously accounted for in the traditional statistics of gross exports are excluded, as highlighted by the gross export decomposition literature (Koopman; Wang; Wei, 2014). This can be represented by the following equation:

$$q_{it} = \frac{DV_2 - DV_1}{DV_{total}}, \quad (1)$$

where DV_{total} is the total domestic value-added of the economies in their own exports in year *t*. DV1 corresponds to the value-added in exports by country *i* in year *t* in all primary and low-technology goods sectors, with DV2 being the same measure but only for medium, medium-high, and high technology sectors. The values of this index vary in the interval $-1 \leq q_{it} \leq 1$, where values closer to -1 indicate less technological sophistication of the agenda, and values closer to 1 indicate greater dynamism in technological terms of the content generated domestically. Thus, the percentage variation of this index provides a measure of the variation in the pattern of trade specialization of an economy, making an indirect verification of whether a country is becoming technologically sophisticated possible.

To consider a broader measure for our dependent variable that could more closely measure the economic complexity of a country, we used the ECI index. Originally developed by Hidalgo and Hausmann (2009), the index measures a country's productive capacity expressed in productive diversity and in the capacity to produce non-ubiquitous goods (i.e., goods produced by only a few countries). Positive variations in this indicator may highlight structural changes in countries resulting from two factors: first, from the process in which countries find new products from new combinations that were previously unexplored and, second, from the process in which capacities are accumulated and combined with previous capacities to generate new products (Hausmann et al., 2014). ECI also allows for projecting a country's growth as it assesses whether capacities are being fully used at the time studied. For this reason, recent works in the literature relate economic development to the economic complexity of a country's capabilities (Gala, 2018).

Its calculation is expressed as follows: Considering that $k_c = f(M_{cp}, k_p)$ is the complexity of a place, given by the function of all activities present in it, and $\tilde{k}_c$ is the average of k_c and $\sigma(k_c)$ is the standard deviation of k_c, one finds the following:

$$ECI = \frac{k_c - \tilde{k}_c}{\sigma(k_c)}. \quad (2)$$

When using the weighted average of the complexity of the products, comparative advantage is found, as the weights are the country's total exports, from which there is information on the amount of capital and labor employed in them, in addition to the country's own capacity to create products ("crystals of imagination"). Therefore, ECI variations are variations in a country's economic complexity, revealing a variation in the sophistication of its productive structure (diversity and complexity of products developed in the country) (Hausmann et al., 2014). ECI is a relatively new index in the international trade literature; however, it has been widely used, and is made available, among other sources, by the Atlas of Economic Complexity of the Harvard Kennedy School of Government.

However, both the "q index" and the ECI are, in variation, indirect measures of structural changes differ in some ways. The "q index" contains information solely on the domestic value-added of exports, being a simpler and relatively limited perspective of changing the productive structure of sectors geared, wholly or partially, to exports. However, it is adequate for the present research when measuring the degree of sophistication of exports, serving as an outcome measure.. We interpret a positive change in the "q index" as gains from a country's trade specialization pattern. This means that the economy would increase the value added in the production of greater technological intensity in its export basket.

Conversely, ECI is not limited to this perspective. Imports and exports are included in the indicator, measuring the technical knowledge or even existing and potential productive capacities of an economy, in addition to the results per se. Transforming countries' trade data into the measurement of capabilities through a bipartite network of exports of the most significant products is called the reflexive method (Torres, 2019). Variation of the ECI demonstrates gains or losses from the complexity of the productive structure of the country analyzed, being an alternative view to the "q Index" but conceptually more comprehensive to study the same object.

Our variable of interest representing participation in GVCs follows the indicator developed by Koopman, Wang, and Wei (2014), from their mathematical decomposition of exports into measures of value-added, which can only be calculated using global input-output matrices. In this study, we calculated it using measures presented in the TiVA matrix (2018). This corresponds to the sum of the share forward *(VS1)* and backward *(VS)* in GVCs as a percentage of gross exports *(E)* of a given country *s* in period *t:*

$$GVCparticipation_{i,t} = VS_s/E + VS1_s{*}/E \tag{3}$$

Forward part (VS1 measure) corresponds to the strictly national content present in exports from third countries in terms of percentage of total gross exports, and the backward part refers to the foreign imported content present in domestic exports as a percentage of exports.

The sampling component was constructed according to the availability of data for our explanatory variable of interest in TiVA (2018), wherein information is available from 64 countries in the annual range from 2005 to 2015. However, towing to the lack of data, we removed six countries from the sample, leaving 58 economies (Table 1). We also eliminated the initial year to calculate the variation.

Table 1
Sample of countries, by degree of development

Developed countries			Developing countries		
Australia	Greece	New Zealand	Argentina	Kazakhstan	Thailand
Austria	Hungary	Norway	Brazil	Malaysia	Tunisia
Belgium	Ireland	Poland	Bulgaria	Mexico	Turkey
Canada	Israel	Slovakia	Cambodia	Morroco	Viet Nam
Chile	Italy	Slovenia	China	Peru	
Czech Republic	Japan	Spain	Colombia	Philippines	
Denmark	Korea	Sweden	Costa Rica	Romania	
Estonia	Latvia	Tunisia	Croatia	Russian Federation	
Finland	Lithuania	United Kingdon	Hong Kong (China)	Saudi Arabia	
France	Lithuania	United States	India	Singapore	
Germany	Netherlands		Indonesia	South Africa	
Total: 32			Total: 26		

Source: Authors (2021).

We opted to estimate dynamic panels using the generalized method of moments (GMM), considering both the difference GMM estimator and the system GMM developed by Arellano and Bond (1991) and Blundell and Bond (1998). Applying dynamic panel estimation allows the evaluation of dynamic relationships between variables, often correlated with their past values, correcting for potential bias. These models are characterized by the inclusion of lagged dependent variables among the explanatory variables and by considering all explanatory variables as endogenous, resulting in unbiased estimators, unlike static panel models. Moreover, it allows for the control of problems arising from the presence of endogeneity and heteroscedasticity. Thus, considering that changes in production structures are cumulative, both response variables must be controlled by themselves with a lag in time. Additionally, the GMM dynamic panel estimators are recommended when periods (T) are shorter than the cross sections (N). In our study, N was greater than T (n = 58; T = 10).

Accordingly, we present equations representing estimated functional models:

$$\Delta q_{i,t} = \alpha + \Delta q_{i,t-1}\beta + \Delta GVCparticipation_{i,t-1}\gamma + X'_{i,t}\delta + \varepsilon_{i,t} \quad (4.1)$$

$$\Delta ECI_{i,t} = \alpha + \Delta ECI_{i,t-1}\beta + \Delta GVCparticipation_{i,t-1}\gamma + X'_{i,t}\delta + \varepsilon_{i,t} \quad (4.2)$$

Where $i = \{1, 2, \ldots, 58\}$, refer to countries in the sample set; $t = \{1, 2, \ldots, 10\}$, refer to the years covered by the sample; $\Delta q_{i,t}$ refers to the rate of change in the "q Index" that will define the first model and $\Delta ECI_{i,t}$ is the change in the ECI index; $\Delta GVCparticipation_{i,t-1}$refers to the rate of change of participation in CGVs lagged by one unit of time, as learning and upgrading possibilities would not be immediate, as highlighted in empirical literature; $X'_{i,t}$ corresponds to the vector of control variables; and an error term $\varepsilon_{i,t}$. Furthermore, we also include lagged dependent variables in accordance with the specified econometric methodology.

To test hypothesis ii), these models were estimated for a subsample consisting solely of developing countries (26 economies as listed in Table 1). Table 2 summarizes the models estimated according to dependent variables, estimation method, and sample size.

Table 2
Summary of estimated models

Models	Dependent variable	Method	Sample
Model 1	q index	Diff -GMM	All countries
Model 2	ECI index	Diff -GMM	All countries
Model 3	q index	Diff -GMM	Developing countries
Model 4	ECI index	Diff -GMM	Developing countries
Model 5	q index	System-GMM	All countries
Model 6	ECI index	System-GMM	All countries
Model 7	q index	System-GMM	Developing countries
Model 8	ECI index	System-GMM	Developing countries

Source: The authors (2021).

For the control variables, we included those considered by traditional theoretical models as determinants of changes in the productive structure of economies. For example, domestic investment – represented by gross fixed capital formation as a percentage of GDP – is the source from which great dynamic changes in economic development are expected through autonomous investment (Hirschman, 1958). Alternatively, a lack of investment capacity undermines the catch-up opportunities for developing economies. From a more traditional perspective, investment can also be understood as the accumulation of fixed capital, increasing economic productivity. Similarly, foreign direct investment can play an important role in reducing productivity bottlenecks and enhancing firm competitiveness (Mcmillan; Rodrik, 2011; Baldwin, 2013).

Both initial real GDP and real GDP per capita were also included. The former was controlling the size of the economy to minimize the effects of large economies with high growth rates (e.g., China between 2000 and 2010), and the latter is to control the country's stage of development. Furthermore, we added a human capital index to control for the effects arising from the level and returns to schooling.

We also considered income from natural resources as a percentage of GDP, as extensive literature indicates that greater dependence on exports of such goods correlates with a lower degree of industrialization in the manufacturing sectors. Therefore, a "natural resource curse," in addition to the Dutch disease itself, is interpreted as obstacles to structural change and long-term economic growth (Gollin; Jedwab; Vollrath, 2016). Additionally, we included the real exchange rate, given its potential impact on structural changes due to the negative relationship between higher prices and the movement of capital to tradable sectors (Rodrik, 2009).

Table 3, finally, lists all the variables used in this research, along with their respective descriptions and sources.

Table 3
List of variables and description

Variable	Description	Expected sign	Source
q index	Export quality or sophistication index calculated using domestic value added in exports as described in this section, expressed in logarithms.	Dependent variable	Trade in Value-Added (2018)
ECI	Economic Complexity Index developed by Hidalgo and Hausmann (2009). Expressed in logarithms.	Dependent variable	The Atlas of Economic Complexity (2009)
GVC_participation	Index of participation in GVCs, calculated through the measures of participation forward and participation backward (Indicator and Koopman, Wang and Wei, 2014). Expressed in logarithms.	+	Trade in Value-Added (2018)
GDP initial	Real GDP entered as a log using the beginning of the period (t-1).	+	World Development Indicators (2019)
GDP	Real GDP per capita entered as a log using the beginning of the period (t-1).	-	World Development Indicators (2019)
Domestic Investment	Gross fixed capital formation, expressed as a percentage of GDP. Expressed in logarithms.	+	World Development Indicators (2019)
Foreign Direct Investment (FDI)	Inward foreign direct investment (FDI Inward), expressed as a percentage of GDP. Expressed in logarithms. The average for FDI in the period of 5 years prior to period t was used.	+	UNCTAD FDI Database
Human Capital	Human capital index, based on years of schooling and returns to education.	+	Penn World Tables (Versão 9.1)
Natural resources	Percentage of natural resource returns on GDP, to capture possible effects of Dutch disease or natural resource curse. Expressed in logarithms.	-	World Development Indicators (2019)
Exchange rate	Real exchange rate expressed in US dollar terms.	-	Penn World Tables (Versão 9.1)

Source: The authors (2021).

4 Results

4.1 Descriptive Analysis

Table 4 summarizes the average behavior of the explanatory variables of interest. The ‘q’ and ECI indices of the countries denote the best and worst results. Regarding the ‘q’ Index, developed countries with high technological intensity in their export basket are generally among the 10 best results, with exceptions for Mexico and Singapore. Countries with the lowest ‘q’ indices demonstrate a low degree of domestic technological sophistication. They are also located in various regions of the world: Oceania, Asia, Latin America, and Eastern Europe. On ECI results, similarities arose in comparison to the ‘q’ Index: Japan, Singapore, South Korea, the United Kingdom, Germany, and the Czech Republic appeared among the highest averages. However, in ranking the ECI, countries with the highest rates are all developed, unlike those with the lowest ECI, where only Australia and Chile are developed.

Table 4
Countries with highest and lowest ‘q’ Index and ECI, 2006–2015 average

Average *q Index*				Average ECI			
Lowest		Biggest		Lowest		Biggest	
New Zealand	-0,63509	Japan	0,904121	Cambodia	-1,08475	Japan	2,307414
Cambodia	-0,51367	South Korea	0,787606	Peru	-0,70881	Switzerland	2,004165
Chile	-0,41712	Singapore	0,771751	Morocco	-0,56665	Germany	1,964914
Vietnam	-0,31703	Czech Republic	0,740067	Kazakhstan	-0,51494	Sweden	1,838339
Latvia	-0,30451	Mexico	0,71307	Australia	-0,37188	Austria	1,711146
Peru	-0,24766	Germany	0,692287	Vietnam	-0,35825	Finland	1,697431
Argentina	-0,16104	Israel	0,633412	Chile	-0,26086	Singapore	1,620084
Indonesia	-0,12206	Ireland	0,600637	Indonesia	-0,12133	South Korea	1,619961
Estonia	-0,06069	Hungary	0,596866	Saudi Arabia	-0,12104	United Kingdom	1,600405
Lithuania	-0,04899	United Kingdom	0,593127	Argentina	-0,03663	Czech Republic	1,584267

Source: The authors (2021).

Table 5 ranks the six highest and lowest participations in the GVCs, calculated as in equation (3) and subdivided by the averages presented for the periods 2006-2010 and 2011-2015. Although heterogeneous, the results partially reflect the ranking of countries and in accordance with the ‘q’ Index (Table 4). These countries, on average, had the highest shares in GVCs during both subperiods and are from Asia and Europe. Moreover, the same countries are the same at the top and bottom of the rank from one period to the next. This suggests an absence of relative radical changes regarding such participation in the most recent period (2011-2015). Countries with lower rates were not able to intensify their participation in GVCs faster than the world average.

Table 5
Ranking of participation in GVCs, by country

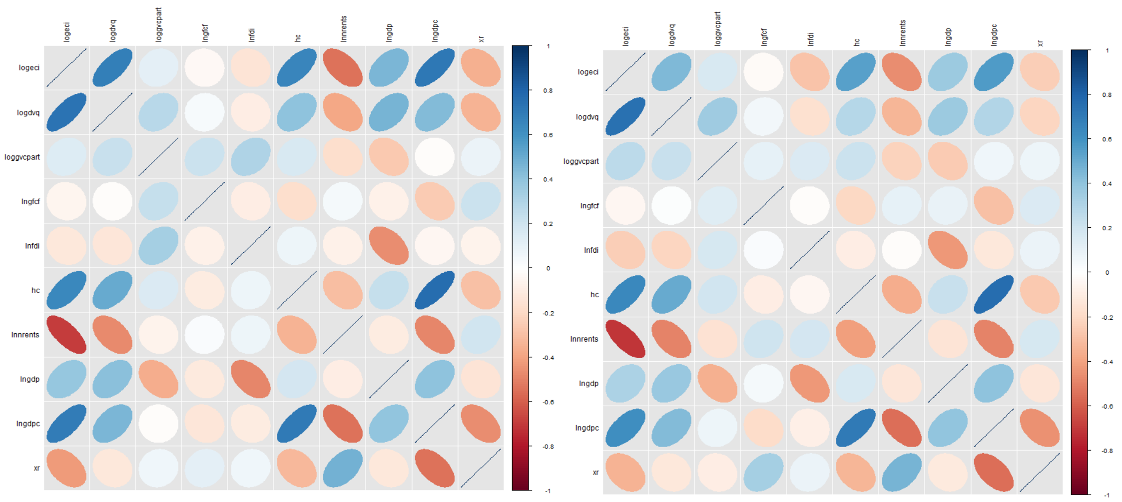
GVCs participation							
2006-2010				2011-2015			
Highest		Lowest		Highest		Lowest	
Singapore	63,9%	New Zealand	28,8%	Slovakia	63,1%	Argentina	27,2%
Slovakia	61,04%	Argentina	28,3%	Singapore	62,7%	New Zealand	28,3%
Malaysia	59,5%	Colombia	30,8%	Hungary	61,3%	Costa Rica	30,8%
Hungary	58,9%	Costa Rica	31,7%	Czech republic	57,1%	Croatia	32,5%
South Korea	55,9%	Turkey	31,9%	South Korea	56,8%	U.S	33,9%
Czech republic	52,8%	Brazil	32,3%	Malaysia	56,8%	Brazil	34,2%

Source: The authors (2021).

Figure 2 presents two graphs with the calculation of Pearson's correlation above the diagonal and Spearman's correlation below the diagonal for all the variables described in Table 3, divided into two periods: 2006–2010 and 2011–2015. Minor variations were found in the correlation values when temporal subdivision was performed. This indicates a consistency in the temporal dimension of the sample. The correlation between the ECI variation and the 'q' Index variation was positively high for all tests (Figure 2, line 2), ranging between 0.681 and 0.732, demonstrating the similarity of our response variables. However, correlation between these two dependent variables and the variation in participation in GVCs was between 0.117 and 0.351 (Figure 2, line 3). Therefore, initially, a positive and high correlation can be seen between the variation in the participation of GVCs and the variation in the sophistication of the productive structure of the economies. Such participation shows greater correlation with the variation in the ECI index.

Figure 2
Graph of correlation between selected variables

2006-2010 | 2011–2015



Source: The authors (2021).

4.2 Econometric analysis

Table 6 summarizes the results of the Difference GMM and System GMM estimates, both for the complete sample (all countries) and for developing economies, resulting in eight distinct estimates (Table 2) All tests for the dynamic panel were conducted according to the methods proposed by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998).

The Arellano and Bond (1991) AR(2) autocorrelation tests indicated no second-order correlation in any of the estimates performed.. Additionally, Hansen's overidentification tests produced a p-value greater than 0.05, indicating no correlation between the instruments and the error term in the difference equation. Differences in Hansen tests also ensured the exogeneity of the subset of instruments used in the system GMM estimations.

For dynamic panels, difference GMM estimators were closer to the fixed effects estimators[1].

(1) We also used criteria according to Blundel and Bond (1998) to give preference to the estimation of Difference GMM or System GMM. To identify weak instruments, estimates by Difference GMM can become impoverished. Thus, static pooled and fixed effects models were anticipated to follow choice criteria: the pooled method estimator is considered the upper band, while fixed effects estimator is considered the lower band. In this sense, the closer the Difference GMM estimator is to the lower band (EF), the greater the probability that the estimator will be biased downwards, indicating existence of weak instruments in this estimation method. When this occurs, the System GMM estimator is preferred.

Table 6
Estimations from difference GMM and System GMM (2006-2015)

Models	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation	Diff	Diff	Diff	Diff	System	System	System	System
Sample	58 countries	58 countries	26 countries	26 countries	58 countries	58 countries	26 countries	26 countries
Dependent variable	Index: *q*	Index: ECI	Index: *q*	Index: ECI	Index: *q*	Index: ECI	Index: *q*	Index: ECI
L.log*q*	0.376***		0.192***		0.951***		0.708***	
	(0.00)		(0.05)		(0.00)		(0.04)	
L.logECI		-0.627***		-0.742***		0.777***		0.488***
		(0.01)		(0.11)		(0.01)		(0.13)
GVC_participation (log)	0.144***	-0.178***	0.141	-0.805**	0.086***	0.049*	0.193**	-0.047
	(0.03)	(0.05)	(0.11)	(0.24)	(0.01)	(0.02)	(0.06)	(0.12)
Human Capital	0.146**	0.568***	0.013	0.487*	0.011	0.093***	-0.038	0.302***
	(0.04)	(0.06)	(0.09)	(0.19)	(0.01)	(0.02)	(0.05)	(0.06)
Natural resources (log)	-0.001	0.011	0.014	0.035	-0.003***	-0.011***	-0.001	-0.037***
	(0.00)	(0.01)	(0.01)	(0.04)	(0.00)	(0.00)	(0.00)	(0.01)
Real Exchange rate	0.000***	0.000***	0.000	0.000***	-0.000***	-0.000***	-0.000**	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FDI (log)	-0.007*	-0.081***	0.025*	-0.129***	0.000	-0.026***	-0.020	-0.152**
	(0.00)	(0.01)	(0.01)	(0.03)	(0.00)	(0.01)	(0.02)	(0.04)
Investment (log)	0.050***	0.061***	-0.032	0.075	0.008	0.068***	0.115*	0.151
	(0.01)	(0.02)	(0.06)	(0.09)	(0.01)	(0.02)	(0.05)	(0.08)
GDP initial (log)	---	---	---	---	0.232***	0.396***	0.119	0.430
	(.)	(.)	(.)	(.)	(0.03)	(0.09)	(0.31)	(0.60)
GDP *per capita* (log)	---	---	---	---	-0.118***	0.134	0.491*	0.716*
	(.)	(.)	(.)	(.)	(0.02)	(0.07)	(0.18)	(0.31)
N	460	459	208	208	518	517	234	234
Instruments	58	73	46	30	50	50	26	36
AR(2)	0.179	0.210	0.347	0.235	0.208	0.631	0.369	0.278
Hansen	0.188	0.727	0.916	0.651	0.345	0.175	0.515	0.928
Diff-Hansen test	-	-	-	-	0.397	0.337	0.745	0.982

Notes: Robust standard errors are in parentheses. * p<0.05, ** p<0.01 e, and *** p<0.001 indicate statistical significance to 10%, 5%, and 1%. Models include unreported time dummies. Test statistics p-values are reported in AR (2), Hansen test, and Diff. Hansen Test. All estimations were performed using the command “xtabond2” by software Stata, developed by Roodman (2009), and the “two step” option was used in all of them. In all estimations, the laglimits or collapse commands were used to reduce the number of instruments. Estimation by the Difference GMM model purged (dropped) the variable initial GDP and initial GDP per capita, as they are variables fixed in time.Source: The authors (2021).

For this reason, system GMM estimators are slightly preferred (Table 3). This is also corroborated by the results of the difference in the Hansen test. In summary, System GMM proved more appropriate as an estimation method than the difference GMM, either for the complete sample or for the sample of developing countries. Regarding independent variables against dependent variables, we obtained a p-value greater than 0.05 for all estimates. This shows that level instruments are valid; therefore, the system GMM model adds to the difference GMM model. Therefore, the estimation results by system GMM are the main methods used in the present research.

For the full sample, estimates (1, 2, 5, and 6) show that the coefficients obtained from participation in GVCs were statistically significant and mostly positive. The 1% increase in participation in GVCs implied an average increase of 14.4% (difference) or 8.6% (system) in the 'q' Index. However, for ECI, coefficients were different in both methods: an increase of 1% in the participation in GVCs would, lead to a decrease of 17.8% in the ECI via difference and an increase of 4.9% via the system on average. For the most part, control variables showed statistical significance in the full sample and corroborated the hypotheses initially adopted in this work.

However, the results of the estimates conducted for developing countries (3, 4, 7, and 8) were different for ECI compared to the full sample. We found a statistical significance of participation in GVCs only for the variation of the ECI index in the Difference GMM model, showing that, on average, a 1% increase in participation would cause a decline of 8.05%.

The coefficient of this variable in the system GMM, although statistically insignificant, was also negative. However, we did not observe the same for the 'q' Index. The coefficients for the subsample were positive in both methods, and only system GMM obtained statistical significance. A 1% increase in participation in GVCs would, on average, imply a 19.3% increase in the 'q' Index for developing countries. Similar to the complete sample, the coefficients obtained for the control variables generally corroborated the hypotheses taken previously.

When comparing the above results, for both samples, a positive relationship can be seen between growth in the participation of countries in the GVCs and growth of both 'q' and ECI indices, with the exception of the latter when only developing countries are considered. This suggests a reduction in economic complexity owing to the expansion of their insertion into GVCs.

These general results raise some points. First, considering only the 'q' index, we can conclude that the sophistication of the export agenda should occur according to deepening of the GVCs. Even considering only developing countries, results suggest such chains as opportunities to expand the technological content of their agendas, although to a lesser extent.

However, this index only aggregates information on domestic value added. Even if indirectly, this reflects a change in the productive structure. This does not mean that a beneficial spread can be found throughout the rest of the economy; however, it undoubtedly occurs in the export sector. This can be attributable to the need to adapt to new global demands, whether inside or outside the GVCs, through the transfer of productive know-how to achieve the minimum quality required by leading companies (Baldwin, 2013; Daria; Wrinkler, 2016).

Taking the system GMM as slightly preferable to the difference GMM and considering the complete sample, we note a positive and significant relationship with our variable of interest. However, a lack of significance and a negative sign appear when considering only the sample of developing countries. Hence, participation in GVCs by developing countries has negatively affected the productive structure of their economies, reducing their complexity and, therefore, their existing and potential capacities. This result is contrary to that found by Stöllinger (2017), who identified a structural improvement for emerging economies through a traditional measure of structural change.

Therefore, when analyzing the variation of the ECI index, which is more comprehensive than that of the 'q' Index, the dynamism caused by the GVCs for developing countries has a reverse impact. These results adhere to those of Fagerberg, Lundvall, and Srholec (2018) in that there may have been a constraint in certain productive functions in the GVCs, which, together with the hypotheses of Kaplinsky and Farooki (2010), dictate harmful effects on the economic complexity of developing countries in the long term. Results also converge with Baldwin's (2013) study on a possible distinction of effects between developed and developing countries, similar to his division between "headquarters" and "factory" firms. Furthermore, for developing countries, negative effect on economic complexity may also suggest a process of de-industrialization, as Stöllinger (2016) highlighted for Eastern Europe.

Other control variables also prove important for changes in the complexity of economies, such as the human capital ratio and investments. Conversely, rent from natural resources were also significant, with negative impacts on changes in the productive structure. The logic behind this relationship can be seen in the sense that greater productive incentives for specializing in very low-tech goods (commodities) discourage structural improvement for our sample. This can begin a process of deindustrialization owing to short-term benefits of trade in these goods, even if long-term benefit disappears. Furthermore, the real exchange rate achieved mixed results, as did, to some extent, GDP per capita.

5 Conclusions

This study investigates the impact of countries' participation in GVCs on measures of technological export sophistication and economic complexity, considering a panel of 58 countries and a subsample of 26 developing economies. Therefore, a dynamic panel approach was used using difference and system GMM estimators for 2006-2015 period. Our study advances the literature by being the first to propose this methodology for testing the impact of GVCs on two distinct proxies reflecting changes in a country's productive structure.

Our results confirm our first hypothesis as they suggest that an increasing rate of participation in these global production networks tends to increase degree of sophistication of the export agenda and the economic complexity of the countries in the global sample. However, the second hypothesis is rejected, as the gains for developing countries are not higher. Furthermore, given our broadest measure of economic complexity – the ECI index – the effects were negative, though not significant, for developing countries. Our result contradicts that presented by Stöllinger (2017). Conversely, this suggests that such effects on the production structure may be related to the role played by these countries in the production chain, as in Stöllinger (2021).

Thus, as denoted in the theoretical discussion on the subject, countries that want to appropriate long-term benefits from GVCs, above all for developing countries, commercial and industrial policies capable of expanding local productive capacities allow upgrading of skills and appropriations of technological spillovers. Our results show that for these countries, development would occur only in the export sector (Index q), without positive spillovers to the rest of the production structure (ECI). Our results should be of great use to public and, especially, industrial policy makers, to reflect on how to make optimal use of the new configuration of world trade without incurring damage to the productive structure of the economy participating in the GVCs.

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