Challenges and strategic opportunities for Brazil's participation in global value chains

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Abstract

The objective of this study is to measure the effects of global value chain participation on the total factor productivity of the Brazilian economy, using heterogeneous dynamic panel models and methods suitable for diagnosing short-run and long-run effects. The study has two innovative features: it estimates the impact of global value chains on Brazil's sectoral total factor productivity by disaggregating the indicators of simple and complex value chain participation developed by Wang and others (2017), and it uses a novel methodology to analyse the relationship between participation in global value chains and sectoral total factor productivity in Brazil. In the long run, this participation appears to generate productivity gains whatever indicator is considered, with the largest long-run effects arising when activities are carried out in complex chains. Positive effects are found in 15 of the 31 sectors analysed.

Keywords

Economic development, economic integration, international trade, productivity, competitiveness, value, economic models, Brazil

JEL classification

O40, F00, F14

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I. Introduction

Integration into global value chains can be a way to achieve higher productivity gains that, in turn, influence the way a country participates in these chains, generating a dynamic process of long-term growth. A report by OECD/WTO/UNCTAD (2013) points out that, in the long run, global value chains can create opportunities for industrial upgrading through the diffusion of technology and increased domestic value added in trade. According to recent studies, participation in global value chains can lead to productivity gains and indirect technological diffusion in participating countries, allowing them to increase their economic growth (Baldwin and Yan, 2014; OECD/WTO/UNCTAD, 2013; IMF, 2015).

There have been instances of South and South-East Asian countries initially integrating into global production in low-technology sectors with strong demand for low-skilled labour and then successfully consolidating in advanced-technology sectors as they moved up global value chains (Callegari, Melo and Carvalho, 2018). However, these benefits are not automatic. Developing countries can become trapped in low value added activities, as seems to be the case with Brazil. Integration into global value chains is not an automatic process, as factors such as geography, market size, institutional quality, workforce skills and economic policies influence participation in these chains.

Callegari, Melo and Carvalho (2018) observe that Brazil presents a unique form of participation in global value chains, characterized by: (i) an industrial sector that is strongly focused on the domestic market and driven by high levels of foreign direct investment and imported medium-high technology goods and (ii) rising commodity exports. According to the authors, this form of participation in global value chains is a trap that compromises competitive development, since it does nothing to increase momentum in industry and the service sector.

The challenge, then, is to work out how to capitalize on any benefits from integration into global value chains and to develop strategies for migrating to more complex stages of the production process organized in these chains. Pathikonda and Farole (2017) stress the importance of setting realistic goals for increased participation in global value chains. There is a sectoral "ladder" that is not identical in all countries and that has specific requirements. The challenge for policymaking in countries like Brazil is to identify the most viable strategies and sectors for increasing participation in these chains.

Accordingly, it is crucial to investigate the potential productivity gains from integration into global value chains and to identify key sectors in which these gains could be increased, prioritizing strategic investments for integration into chains. The purpose of this study is thus to analyse the effects of Brazil's global value chain participation on its productivity and to determine which sectors have the greatest potential to increase this productivity. In Brazil's case, there is a dearth of empirical studies investigating the impact of global value chain participation on total factor productivity, especially in relation to sectoral participation.

This analysis aims to measure the effects of participation in global value chains using the participation indicators developed by Wang and others (2017), who disaggregate them into simple and complex chains. A sectoral analysis is conducted to identify key sectors for Brazil to increase its participation in globally segmented production chains. Brazil is involved in less complex activities in global value chains, and the hypothesis is that moving towards complex global chains can be a way to boost its productivity and thence its long-term economic growth.

We use heterogeneous dynamic panel models for this study, applying methods that allow short-run and long-run effects to be diagnosed. One advantage of these methods is that they do not require an assumption that variables need to be integrated in the same order to demonstrate the existence of a long-term relationship between two or more variables. This study is the first to use such an empirical approach to analyse the impact of global value chains on total factor productivity, at least in the case of the Brazilian economy, to the authors' knowledge. It is therefore innovative in at least three areas: (i) estimation of the impact of global value chains on total factor productivity, in aggregate and sectoral terms, for the Brazilian economy; (ii) empirical analysis using indicators of participation in simple global value chains and complex global value chains; and (iii) use of heterogeneous dynamic panel models to identify key sectors that would yield higher productivity gains.

The main results suggest that participation in simple global value chains has no effect on long-run total factor productivity and that the coefficients, if statistically significant, have a negative sign. Therefore, the results indicate that participation in simple global value chains is not an attractive strategy for stimulating the productivity of the Brazilian economy. Meanwhile, most sectors participating in complex global value chains do contribute to higher total factor productivity in the long run. The sectors with the largest productivity gains are: food, beverages and tobacco; water, air and inland transport; sale, maintenance and repair of motor vehicles and motorcycles and retail sale of fuel; and the rubber and plastics industry. The results also indicate that there is no clear relationship between the complexity and technological sophistication of the sectors involved in global value chains and productivity gains in the Brazilian case, since a number of the sectors with the largest gains are of low technological sophistication and complexity.

The sectors achieving particularly high productivity gains by virtue of inclusion in global value chains and also accounting for a substantial sectoral share of value added in the Brazilian economy (2% or over) are: mining; food, beverages and tobacco; sale, maintenance and repair of motor vehicles and motorcycles and retail sale of fuel; and inland transport. These segments are thus strategic for public policies aimed at increasing Brazil's participation in global value chains to stimulate productivity growth. With the exception of mining, however, these sectors' share of total value added declined between 2000 and 2014, which may be one of the reasons for the low productivity growth in the Brazilian economy.

The present article is divided into five sections, apart from this introduction and final considerations. The next section presents an analysis of participation in global value chains, describing Brazil's involvement in these chains and explaining the methodological aspects entailed in the indicators used to measure this. The third section presents an analysis of the relationship between participation in global value chains and productivity. The fourth section describes the methodology and database used in the study. The fifth section presents and discusses the results. The sixth and final section concludes.

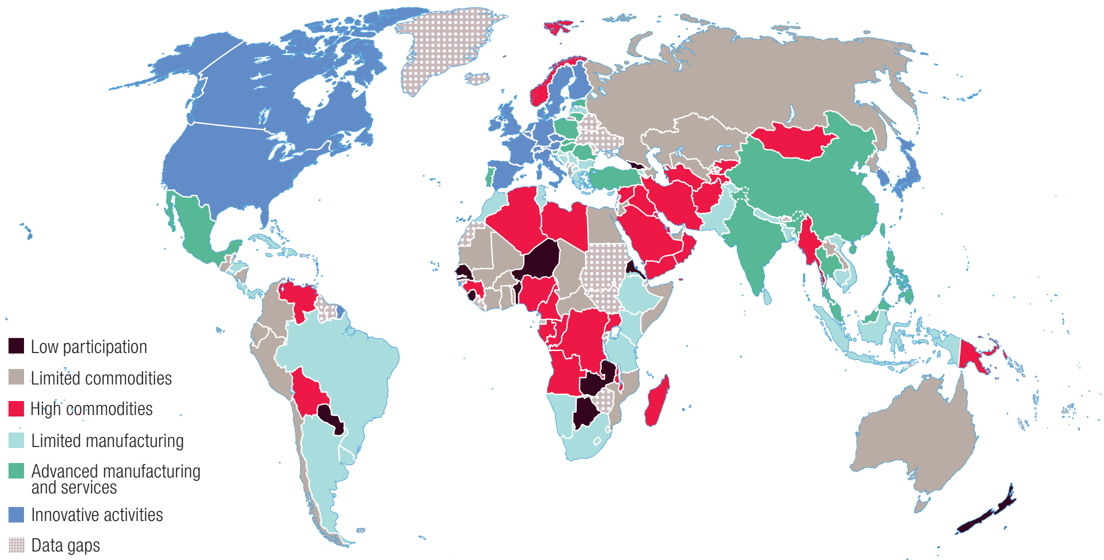
II. Participation in global value chains

1. Brazilian participation

According to a survey for *World Development Report 2020* (World Bank, 2019), and as shown in map 1, many countries in North America, Western Europe and East Asia participate in complex global value chains, producing manufactured goods and services, as well as innovative activities. Meanwhile, many countries in Africa, Latin America and Central Asia, among them Brazil, still supply commodities for processing elsewhere.

Callegari, Melo and Carvalho (2018) note that Brazil's participation in global value chains is characterized by low use of imported inputs to produce exported goods (backward linkages). Its imports of technological goods are mainly for domestic consumption, whereas in countries with high backward participation in global value chains, imports are mainly used to add value to exports. Considering forward participation criteria, i.e. the participation of domestic inputs in other countries' exports, Brazil's performance is similar to that of other developing countries, but with a heavy concentration in the production and export of low value added commodities.

Map 1
Countries' participation in global value chains, 2015



Source: World Bank, *World Development Report 2020. Trading for Development in the Age of Global Value Chains*, Washington, D.C., 2019.

Brazil's integration into global value chains centres on supplying inputs and raw materials to firms in other countries so that they can add value to their products, with a modest performance when it comes to exporting products with higher value added. Even in sectors where it has comparative advantages, such as agribusiness, the country has struggled to migrate to more advanced stages of the value chain (Sturgeon and others, 2014). Hollweg and Rocha (2018) show that Brazil's performance in global value chains differs substantially across sectors. The authors stress that Brazil is most competitive in agribusiness (excluding primary agriculture), wood and paper, basic metals and the automotive industry, while also performing relatively well in the chemical sector.

Likewise as part of a sectoral analysis, Ferraz, Gutierre and Cabral (2015) highlight a substantial increase between 1995 and 2011 in imported intermediate goods as a share of final goods produced in the country, especially in high-technology sectors. However, they stress that the use of imported intermediate goods in domestic production is still low compared to other countries and that the Brazilian economy exhibits an increase in the production and export of low-technology intermediate goods. In addition, Brazil has been losing competitiveness in the production of more sophisticated goods, such as transport equipment, chemicals and electrical and optical equipment (Ferraz, Gutierre and Cabral, 2015).

Araújo, Perobelli and Faria (2021), considering the period between 1990 and 2015, show that Brazilian production fragmented internationally, consequently increasing its participation in global value chains, especially at the regional level. The results of this study indicate that Brazil's share in the total value added of world exports increased from 0.98% in 1990 to 1.38% in 2015. The authors note that, although the Brazilian economy occupies a prominent position in South America, its participation in global production chains remains modest.

According to the newsletter of the Institute for Industrial Development Studies (IEDI, 2022), an analysis of more recent indicators based on Organisation for Economic Co-operation and Development (OECD) data shows that Brazil's integration into world trade was greater in 2018 than in 2011 or 2015.

Information in the OECD Trade in Value Added (TiVA) database indicates an increase in re-exports of imported intermediate goods as a share of total imported intermediate goods. The indicator increased from 16.0% in 2011 to 19.5% in 2015 and 23.1% in 2018. Imported value added increased from 10.1% to 12.9% of total gross exports in the same years, holding steady at 12.9% in 2018. Imported value added increased from 14.5% of gross manufacturing exports to 17.2% and then to 17.9%, respectively.

Domestic value added in other countries' exports relative to Brazil's total gross exports fell from 25.2% in 2011 to 20.5% in 2015, before rising back slightly to 22% in 2018. Lastly, domestic value added in other countries' exports relative to Brazil's gross exports of manufactured goods also declined between 2011 and 2015, from 19.9% to 15.4%, before increasing to 17.1%, in 2018.

Despite the progress on some indicators, Brazil's profile is still that of a country which is relatively unintegrated into global value chains. This is partly due to problems of external competitiveness and the lack of a sound international trade integration policy, as well as to the large size of its domestic market and an export basket heavily weighted towards commodities. In addition, the higher share of imported value added in Brazilian exports may be related to technological dependence and loss of competitiveness, or indeed to a greater inflow of imported inputs and components not matched by increased production in domestic supply chains (IEDI, 2022).

2. Methodological aspects

Global value chains led to the emergence of borderless production systems in which goods and services began to accrue value added in different countries and sectors. Some studies have attempted to capture these relationships by developing indicators. In a pioneering paper, Hummels, Ishii and Yi (2001) introduced a measure of vertical specialization by calculating the share of imports contained in exports where backward linkages in global value chains were concerned. However, this measure has problems of double counting. Thus, Koopman and others (2010) proposed measures to calculate participation in global value chains based on the share of foreign value added in domestic gross exports (backward) and the share of domestic value added in foreign gross exports (forward). However, these also present problems of double counting, especially where sectoral indicators are concerned (Yanikkaya and Altun, 2020).

To correct the problem, Wang and others (2017) proposed a structure for disaggregating production activities consistent with the System of National Accounts standard. The authors suggest two ways of disaggregating production activities, one from the producer's perspective (based on forward industrial linkages) and the other from the buyer's (based on backward industrial linkages). They set out from this breakdown to present indices of participation in global value chains that are more appropriate than the measures previously available in the literature, disaggregating the value added of each relationship by sector or country with reference to its destination, as depicted in equation (1):

$$Va' = \hat{V}BY = \underbrace{\hat{V}LY^D}_{(1)V\_D} + \underbrace{\hat{V}LY^F}_{(2)V\_RT} + \underbrace{\hat{V}LA^F LY^D}_{(3a)V\_GVC\_S} + \underbrace{\hat{V}LA^F\left(BY{-}LY^D\right)}_{(3b)V\_GVC\_C} \tag{1}$$

The first term in equation (1), V_D, represents value added produced domestically without the involvement of international trade. The second term, V_RT, is the sum of a country or sector's value added used in all downstream sectors and is related to traditional trade, i.e. products are manufactured in a given country and cross its border just once for final consumption.

Term (3a) indicates the measure of activity in simple global value chains. Taking two countries (A and B), V_GVC_S is the domestic value added embodied in the intermediate goods exports of a sector in country A used by country B in domestic production for domestic consumption. Exports cross borders for production just once. Thus, there are no indirect exports via third countries and no re-exports or re-imports of the origin countries' value added. This activity is considered to take place in simple global value chains. As an example, we can take exports from Brazil (country A) to China (country B) of steel that is then used to fabricate houses on Chinese soil.

Term (3b) denotes value added that crosses borders more than once, i.e. when intermediate goods produced in country A are exported to country B and used in turn to produce intermediate or final goods in country B for export to other countries. This is considered to be complex global value chain activity.

Wang and others (2017) break down final goods production in each sector or country by the origin of the value added, as shown in equation (2):

$$Y' = VB\hat{Y} = \underbrace{VL\hat{Y}^D}_{(1)Y\_D} + \underbrace{VL\hat{Y}^F}_{(2)Y\_RT} + \underbrace{VLA^F L\hat{Y}^D}_{(3a)Y\_GVC\_S} + \underbrace{VLA^F \left(B\hat{Y} - L\hat{Y}^D\right)}_{(3b)Y\_GVC\_C} \quad (2)$$

The first term in equation (2), Y_D, represents the value absorbed by domestic final demand without the intervention of international trade. The second term, Y_RT, represents a given country's imports for final consumption, i.e. is related to traditional trade.

Term (3a), Y_GVC_S, is the foreign value added in a sector in country B that is imported by country A to be used in the production of domestically consumed goods and services, these being considered simple global value chain activities. As an example, we can take exports of manure and fertilizer from China (country B) to Brazil (country A), where they are then used in the production of soybeans consumed on Brazilian soil. In this hypothetical example, the entire production chain for manure and fertilizer exported to Brazil is located in China.

Term (3b) in equation (2), Y_GVC_C, represents products exported by country B for the production of final goods for export in country A. This would be the case with exports from Brazil (country A) to China of soybeans grown using manure and fertilizer from China itself (country B) or from other countries (country C, for example). This sector would then form part of a complex global value chain in all the countries involved.

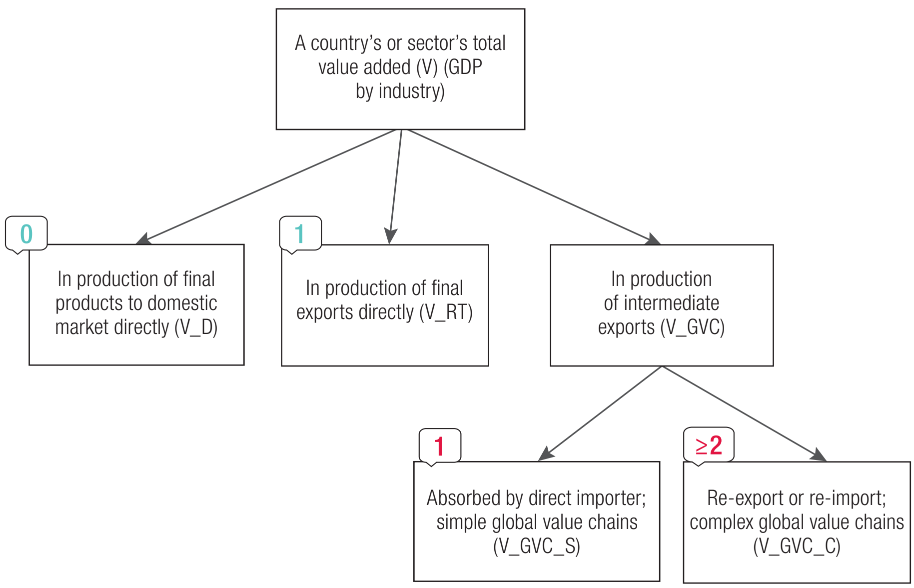
The breakdown described above is summarized in diagrams 1.A and 1.B: diagram 1.A illustrates the decomposition of GDP by industry on the basis of forward linkages, and diagram 1.B illustrates the decomposition of final goods production on the basis of backward linkages.

Diagram 1

Decomposition of production and value added by sector

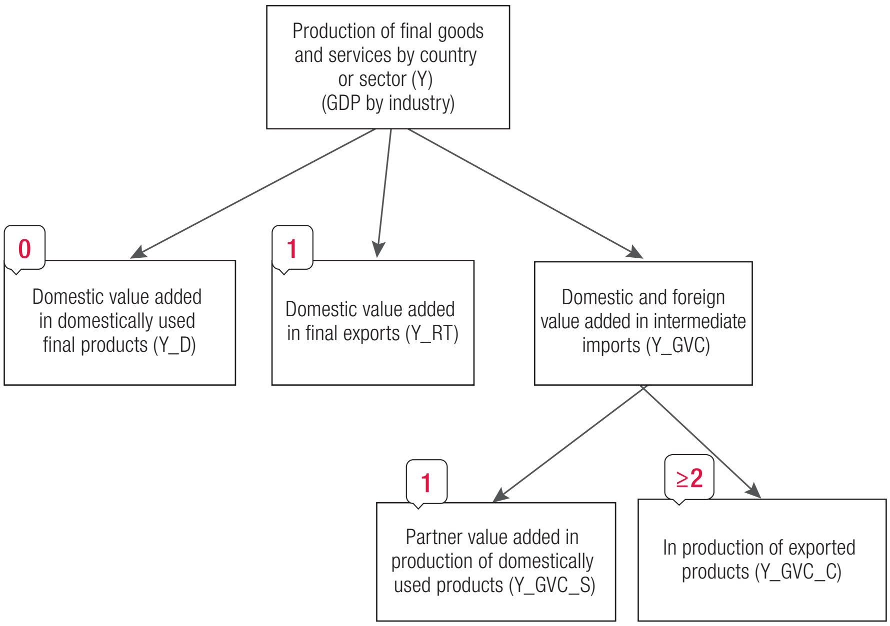
A. Breakdown of GDP by industry

Which types of production and trade are global value chain activities?



B. Decomposition of final goods production by country or sector

Which part of final goods production and trade belongs to global value chains?



Source: Z. Wang and others, *Measures of Participation in Global Value Chains and Global Business Cycles*, No. w23222, National Bureau of Economic Research (NBER), 2017.

The decomposition presented by the authors thus includes the four ways in which it is possible for a country to participate in global production networks:

(i) By exporting intermediate goods to country B to produce goods or services for final consumption (in country B), crossing borders between countries only once.

(ii) By exporting intermediate goods to country B for production that will be exported to other countries, crossing borders between countries more than once.

(iii) By importing intermediate goods from other countries for domestic production of goods that will be exported, crossing borders between countries at least twice.

(iv) By importing intermediate goods from other countries for domestic production of goods that will be consumed domestically, crossing borders between countries only once.

According to Wang and others (2017), the measures of participation in global value chains proposed by Hummels, Ishii and Yi (2001), called VS and VS1 and expressed as percentages of the value of gross exports, only consider the channels of participation represented by (ii) and (iii). Hummels, Ishii and Yi originally called the measure for imports directly and indirectly embodied in a country's exports the VS index. The VS1 measure is for the domestic content of a given country present in the exports of third countries. By excluding items (i) and (iv), these measures omit many of the activities involved in internationally fragmented production.

Another limitation of conventional VS1 measures is that, because they use gross exports as the denominator, the shares calculated from them may be overestimates in the case of sectors with few direct exports. Lastly, conventional measures cannot distinguish between participation in simple global value chain activities and complex global value chain activities.

Accordingly, the authors construct and define two indices of participation in global value chains at the sectoral level:

$$GVCPt\_forward = \frac{V\_GVC}{Va'} = \frac{V\_GVC\_S}{Va'} + \frac{V\_GVC\_C}{Va'} \tag{3}$$

$$GVCPt\_backward = \frac{Y\_GVC}{Y'} = \frac{Y\_GVC\_S}{Y'} + \frac{Y\_GVC\_C}{Y'} \tag{4}$$

These measures differ from the conventional VS measure (as a percentage of gross exports) in two respects: first, they are based on a net concept and, second, they go by production rather than trade. Consequently, the indices presented by the authors take into account both forward and backward industrial linkages, allowing a country's participation in global value chains to be described more accurately.

III. Participation in global value chains and productivity: empirical aspects

According to different theoretical studies, countries can benefit from participation in global value chains through various channels, such as productivity effects generated by trade in intermediate inputs, learning by interaction, access to new markets and movement up the value chain so that they position themselves in higher value added production activities (Yanikkaya and Altun, 2020).

Empirical studies are still in their infancy when it comes to analysis of the impact of country and sector participation in global value chains on output and productivity growth (using indicators of participation in these chains). The available empirical literature focuses mainly on cross-country analysis and generally finds that participation in global value chains has positive effects on output and productivity growth. Sectorally, studies are limited (Yanikkaya and Altun, 2020).

These empirical studies include, for example, Kummritz (2015), who concludes from a sample of 20 industries in 50 countries for the years 1995, 2000, 2005 and 2008 that participation in global value chains has a positive impact on domestic value added only for middle- and high-income countries. Kordalska, Wolszczak-Derlacz and Parteka (2016) provide estimates on 20 sectors (13 classified as manufacturing and 7 as service sectors) in 40 countries and find positive effects from backward participation, especially in the case of manufacturing industries. Constantinescu, Mattoo and Ruta (2019) analyse the relationship between participation in global value chains and labour productivity in a sample of 13 sectors in 40 countries over 15 years. They conclude that participation in global value chains, especially backward linkages, has a positive impact on labour productivity.

However, as highlighted by Wang and others (2017), none of the existing studies disaggregates trade into simple and complex global value chain activities. Applying the methodology they developed, as described in the previous section, the authors assess the impact of participation in global value chains, employing their new participation rates for simple and complex value chain activities. They use data from the World Input-Output Database (WIOD) for 44 countries and 56 industries over the period from 2000 to 2014, dividing this into four subperiods: rapid growth (2002–2008), global financial crisis (2009), post-crisis recovery (2010 and 2011) and growth slowdown (2012–2014).

For both the full sample and the manufacturing subsample, they find a positive association between participation in global value chains and economic growth, with complex chains having a larger and more significant impact than simple chains. Wang and others (2017) find no clear link between the share of value added in traditional trade and economic growth, and the results indicate that most purely domestic production activities have a negative association with economic growth. The authors divide the sample into two subsamples by countries' income level and find a stronger association between participation in global value chains and economic performance in advanced economies.

Yanikkaya and Altun (2020) investigate the impact of participation in global value chains on value added and total factor productivity growth, in sectoral terms, over two periods: 1995–2011 and 2005–2015. In addition to traditional participation indices, the authors use sectoral indices of participation in OECD global value chains that are based on final demand. Using the generalized method of moments (GMM) for their estimates, the authors find that, for the full sample, sectors with greater participation in global value chains experienced considerably higher output and total factor productivity growth, especially over the period 1995–2011. In separate estimates for manufacturing and services, both sectors benefited in output and productivity terms from higher participation in global value chains between 1995 and 2011. However, only manufacturing experienced higher productivity growth in the period 2005–2015.

Given that the indicators developed by Wang and others (2017) are more appropriate than traditional measures and also permit division into simple and complex chains, the goal of the present study is to estimate the effects of these indicators on total factor productivity in the different sectors of the Brazilian economy.

IV. Methodology and database

1. Heterogeneous dynamic panel models

Let us begin by assuming a simple specification of an autoregressive distributed lag (ARDL) model ($p, q_1, \ldots, q_k$) for certain periods, $t = 1, 2, \ldots, T$, and for the cross-sectional units (sectors), $i = 1, 2, \ldots, N$:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{5}$$

where X_i is a $(k \times 1)$ vector of explanatory variables for the group i; μ_i represents fixed effects; λ_{ij} are scalars for the lags of the dependent variables; and δ_{ij} are $(k \times 1)$ vectors of coefficients. For simplicity of presentation, equal T and p are used across sectors and equal q between sectors and regressors.

If the variables in (5) are, e.g. I (1) and are cointegrated, then the error term is a process I (0) for all i. A major feature of cointegrated variables is their responsiveness to any deviation from the long-run equilibrium, implying an error correction model (ECM) in which the short-run dynamics of the variables in the system are influenced by deviation from the long-run equilibrium.

Using equation (5), the long-run and short-run coefficients can be obtained by estimating the model in error-corrected form (ARDL-ECM):

$$\Delta y_{it} = \phi_i \left(y_{i,t-1} - \theta'_i X_{it} \right) + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \delta^{*\prime}_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \tag{6}$$

where $\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$ is an error correction term for group i. It is to be expected that ϕ_i will be different from zero. Otherwise, there would be nothing to indicate the existence of the long-run relationship. This parameter is expected to be negative on the assumption that the variables return to the long-run equilibrium. Of particular importance is the vector θ'_i, which contains parameters of the long-run relationship between the variables, namely

$$\theta_i = \sum_{j=0}^{q} \frac{\delta_{ij}}{\left(1 - \Sigma_k \lambda_{ik}\right)};\ \lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}, \quad j = 1, 2, \ldots, p-1$$

$$\delta^*_{ij} = -\sum_{m=j+1}^{q} \delta_{im}, \quad j = 1, 2, \ldots, q-1$$

In studies using the heterogeneous dynamic panel method, different approaches may be followed to estimate equation (6). At one extreme is fixed effects (FE) estimation, where only the intercepts can differ between the cross-sectional units. If the slope coefficients are not identical, however, the FE approach produces biased and inconsistent results.

Alternatively, the specifications could be estimated separately for each cross-sectional unit. In this case, a simple arithmetic mean of the coefficients could be calculated. This is the mean group (MG) estimator in heterogeneous dynamic panels proposed by Pesaran and Smith (1995), where the intercepts, the short- and long-run coefficients and the error variance may differ between sample units. Pesaran and Smith (1995) show that the MG method produces consistent estimates of the average long-run coefficients. If the coefficients are homogeneous, however, these estimates will be inefficient.

Since the parameters of (6) are non-linear, Pesaran, Shin and Smith (1999) developed a maximum likelihood method to estimate them. To use the authors' term, the estimators of the long-run and error correction parameters, estimated by maximum likelihood, are pooled mean group (PMG) estimators in heterogeneous dynamic panels. This method allows the coefficients, intercepts and error variance to vary between cross-sectional units in the short run, like the MG estimator, but requires their coefficients to be identical in the long run. With the PMG method, the long-run equilibrium relationships between variables tend to be similar across the cross-sectional units. This method is particularly appropriate for sectoral analyses, considering that different sectors of a given economy are subject to the same exchange-rate policies, inflation movements and business cycles.

Moreover, this method does not require the variables to be integrated in the same order to test for the existence of a long-run relationship (Pesaran, Shin and Smith, 2001). The model is therefore applicable even if the variables are only I(0) (stationary), only I(1) (non-stationary) or a combination of the two.

What is proposed is to estimate equations using measures of participation in global value chains as explanatory variables for Brazil's sectoral total factor productivity. Accordingly, different specifications are estimated considering the general indicator of participation in global value chains presented above and its breakdown into simple and complex chain activities, as presented in the equations below:

$$\text{Model 1: } \ln TFP_{it} = \ln(GVCPt_{it}) \tag{7}$$

$$\text{Model 2: } \ln TFP_{it} = \ln(GVC\_S_{it}) \tag{8}$$

$$\text{Model 3: } \ln TFP_{it} = \ln(GVC\_C_{it}) \tag{9}$$

where $i = 1, \ldots, 31$ represents the sectors of the Brazilian economy[2] and $t = 2000, \ldots, 2014.$ Each indicator of participation in global value chains in each of the three equations above is the sum of the backward and forward participations presented by Wang and others (2017).

Setting out from the methodology described and using disaggregated indicators, it is possible to determine the short- and long-term effects of participation in global value chains, indicating which sectors contribute most to productivity growth in Brazil, depending on the type of global chain in which they are embedded.

[2] The 2013 and 2016 versions of the sectors in the WIOD database are presented in table A1.2 of the annex.

2. Data source

For the econometric estimations, we used the data for the global value chain sectoral participation indicators proposed by Wang and others (2017) available in the UIBE GGVC Database of global value chain indicators developed by the team at the Global Value Chains Research Centre of the University of International Business and Economics (UIBE). This database provides information on the decomposition of value added and final goods production by country and sector, and on gross trade at the bilateral sectoral level. Indicators of global value chain participation based on Wang and others (2017) were generated from these decompositions.

To calculate total factor productivity, data from the socioeconomic accounts of the World Input-Output Database (WIOD) were used (GGDC, 2013 and 2016).[3] This database contains information on capital stock and employment variables and is available in two versions, 2013 and 2016. Given the unavailability of ready-calculated sectoral productivity data, sectoral total factor productivity in Brazil was calculated using the following equation,[4] with data measured in monetary values deflated by the 2014 harmonized consumer price index (IPCA).

$$TFP_{it} = \frac{VA_{it}}{\left(K_{it}^{\frac{CAP_{it}}{VA_{it}}}\right) * \left(EMP_{it}^{\frac{LAB_{it}}{VA_{it}}}\right)} \quad (10)$$

where $i = 1, ..., 31$ sectors, $t = 2000, ..., 2014$, VA is gross value added at 2014 prices, CAP is capital compensation at 2014 prices, LAB is total labour compensation at 2014 prices, K is the real capital stock and EMP is the number of people employed, measured in thousands.

V. Results

1. Cointegration and unit root panel tests

Table 1 presents the results of the unit root tests for panel data. For the series corresponding to the indicators of participation in global value chains ($\ln GVCPt$), participation in complex chains ($\ln GVC\_C$) and participation in simple chains ($\ln GVC\_S$), the results of all tests indicate that the series are stationary. The series $\ln(TFP)$ was found by most tests to be non-stationary.

Since there are different results for the stationarity of the series and for the order of integration, the intention is to investigate the existence of a long-run relationship between the variables. Table 2 presents the results of the Pedroni panel cointegration tests. The combinations of variables are investigated as specified in equations (7), (8) and (9).

In most cases, the null hypothesis of no cointegration can be rejected at a statistical significance level of 1%. The tests therefore indicate the existence of a long-run equilibrium relationship between the different indicators of participation in global value chains and total factor productivity. Once the conditions of differences in the order of integration of the variables and the existence of cointegration have been verified, in addition to the heterogeneity of the sample containing different sectors, it is observed that the application of the FE, MG and PMG methods is viable.

[3] The variables available in the WIOD databases (GGDC, 2013 and 2016) can be found in table A1.1 of the annex.

[4] The variables are represented using the notation of the WIOD database (GGDC, 2016) (see table A1.1 of the annex).

Table 1
Unit root tests

Variable	Test	Result	Probability	Stationarity
ln(*TFP*)	Levin, Lin and Chu	-3.130	0.001***	Stationary
	Breitung (t-statistic)	0.616	0.731	Non-stationary
	Im, Pesaran and Shin (W statistic)	-1.047	0.148	Non-stationary
	Fisher based on augmented Dickey-Fuller (ADF) tests ($\chi 2$)	71.743	0.186	Non-stationary
	Fisher based on Phillips-Perron tests ($\chi 2$)	98.744	0.002***	Stationary
ln(*GVCPt*)	Levin, Lin and Chu	-4.484	0.000***	Stationary
	Breitung (t-statistic)	-2.593	0.005***	Stationary
	Im, Pesaran and Shin (W statistic)	-1.666	0.048**	Stationary
	Fisher based on ADF tests ($\chi 2$)	81.260	0.051*	Stationary
	Fisher based on Phillips-Perron tests ($\chi 2$)	140.014	0.000***	Stationary
ln(*GVC_S*)	Levin, Lin y Chu	-4.895	0.000***	Stationary
	Breitung (t-statistic)	-1.599	0.055*	Stationary
	Im, Pesaran and Shin (W statistic)	-1.334	0.091*	Stationary
	Fisher based on ADF tests ($\chi 2$)	78.210	0.080*	Stationary
	Fisher based on Phillips-Perron tests ($\chi 2$)	122.571	0.000***	Stationary
ln(*GVC_C*)	Levin, Lin and Chu	-4.746	0.000***	Stationary
	Breitung (t-statistic)	-4.964	0.000***	Stationary
	Im, Pesaran and Shin (W statistic)	-2.859	0.002***	Stationary
	Fisher based on ADF tests ($\chi 2$)	94.568	0.005***	Stationary
	Fisher based on Phillips-Perron tests ($\chi 2$)	171.106	0.000***	Stationary

Source: Prepared by the authors.
Note: All tests include intercepts (fixed effects) and individual trends. Fisher's test probabilities are calculated using an asymptotic $\chi 2$ distribution. The remaining tests assume asymptotic normality. (***), (**) and (*) reject the null hypothesis at statistical significance levels of 1%, 5% and 10%, respectively.

Table 2
Pedroni cointegration tests

Variables	Within-dimension			Between-dimension		
	Statistic		*p*-value	Statistic		*p*-value
ln(*TFP*) - ln(*GVCPt*)	V	-1.066	0.857	Rho	2.998	0.999
	Rho	0.156	0.562	PP	-3.563	0.000***
	PP	-4.779	0.000***	ADF	-3.871	0.000***
	ADF	-5.440	0.000***			
ln(*TFP*) - ln(*GVC_S*)	V	-0.963	0.832	Rho	2.813	0.998
	Rho	0.052	0.521	PP	-3.174	0.001***
	PP	-4.916	0.000***	ADF	-2.945	0.002***
	ADF	-5.343	0.000***			
ln(*TFP*) - ln(*GVC_C*)	V	-1.475	0.930	Rho	3.249	0.999
	Rho	0.425	0.665	PP	-2.436	0.007***
	PP	-4.368	0.000***	ADF	-1.378	0.084**
	ADF	-2.724	0.003***			

Source: Prepared by the authors.
Note: PP: Phillips-Perron; ADF: augmented Dickey-Fuller (*) and (***) reject the null hypothesis of no cointegration at a statistical significance level of 10% and 1%, respectively.

2. The relationship between total factor productivity and global value chains: estimations using heterogeneous dynamic panel models

Table 3 shows the short-run and long-run effects of participation in global value chains on total factor productivity, considering the panel with aggregate variables. To control for the effects of the 2008 crisis and the contraction of world trade, a dummy variable was included for the post-crisis period. The results presented in the first two columns were estimated using the MG and PMG methods. We use the Hausman test to check for the restriction of equality between the long-run coefficients, whereas in the MG method this restriction is not imposed. If long-run relationships are heterogeneous, PMG estimates are inconsistent; if equality is not rejected, the PMG method is more efficient. Table 4 shows that the PMG method is more efficient in all comparisons, as the null hypothesis of the Hausman test for equality of long-run coefficients is not rejected. The specifications were also estimated by the FE method, using the Hausman test to determine whether it was more appropriate than the MG method.

Table 3
Results of heterogeneous dynamic panel models

Short-term coefficients	Equation (1)			Equation (2)			Equation (3)		
	PMG	MG	FE	PMG	MG	FE	PMG	MG	FE
ln*(GVCPt)*	-0.414*** (0.019)	2.688 (3.319)	-0.131 (0.125)	-	-	-	-	-	-
ln*(GVC_S)*	-	-	-	0.494*** (0.021)	84.254 (84.701)	-0.032 (0.129)	-	-	-
ln*(GVC_C)*	-	-	-	-	-	-	0.260*** (0.032)	0.225 (1.281)	-0.165* (0.098)
Long-term coefficients									
ln*(GVCPt)*	0.281* (0.170)	0.425*** (0.164)	0.098 (0.092)	-	-	-	-	-	-
ln*(GVC_S)*	-	-	-	0.344*** (0.116)	0.152 (0.122)	0.024 (0.097)	-	-	-
ln*(GVC_C)*	-	-	-	-	-	-	0.444*** (0.097)	0.351*** (0.095)	0.123* (0.073)
Crisis dummy	0.206*** (0.042)	0.206*** (0.042)	0.102*** (0.024)	0.179*** (0.032)	0.179*** (0.032)	0.104*** (0.022)	0.221*** (0.046)	0.221*** (0.046)	0.105*** (0.027)
Constant	0.136 (0.417)	0.136 (0.417)	0.187 (0.196)	0.759** (0.294)	0.759** (0.294)	0.349** (0.147)	0.710*** (0.247)	0.710*** (0.247)	0.303*** (0.093)
Error correction	0.347*** (0.063)	0.347*** (0.063)	0.752*** (0.043)	0.387*** (0.063)	0.387*** (0.063)	0.759*** (0.044)	0.358*** (0.066)	0.358*** (0.066)	0.744** (0.038)
Number of observations	465	465	465	465	465	465	465	465	465

Source: Prepared by the authors.
Note: PMG: pooled mean group estimator; MG: mean group estimator; FE: fixed effects estimator. *** significant at 1%; ** significant at 5%; * significant at 10%.

Table 4
Hausman test (*p*-value)

Models without human capital			
Model1	PMG-MG	0.350	PMG
	MG_DFE	0.958	DFE
Model2	PMG-MG	0.323	PMG
	MG_DFE	0.948	DFE
Model3	PMG-MG	0.978	PMG
	MG_DFE	0.986	DFE

Source: Prepared by the authors.
Note: PMG: pooled mean group estimator; MG: mean group estimator; DFE: dynamic fixed effects estimator. The null hypothesis of the Hausman test is long-run equality of coefficients.

The results obtained show short-term effects that are statistically significant only in the case of the PMG method, with the indicators exhibiting positive effects in simple and complex chains. When the overall participation indicator is considered, however, the effect is negative. In the long run, participation in global value chains seems to generate an increase in productivity whichever indicator is considered by the PMG method. Furthermore, according to the results of equation (3) estimated by PMG, the greatest long-term effects arise when productive integration occurs through complex global value chains. This result is consistent with those obtained in Wang and others (2017) for participation in global value chains and its effects on economic performance across countries.

As regards the magnitude of the effects, we find from the PMG method that, in the long run, a 1% increase in participation in global value chains increases total factor productivity by 0.28%, while the impact of participation in simple chains is an increase of 0.34%, and participation in complex chains increases total factor productivity by 0.44%.

Positive and significant coefficients for the dummy variable indicate an increase in participation in global value chains during the post-crisis period, with the largest effects observed for participation in complex chains. As for the error correction term,[5] all specifications indicate the existence of a cointegrating relationship.

To complement the analysis, long-run elasticities of participation in global value chains are estimated for each sector of the Brazilian economy in the sample. Since the PMG method proved to be more efficient than the MG method in results with aggregated data and, moreover, is suitable for sectoral studies, the estimates by sector were carried out using this method. The results presented in table 5 indicate varying effects, which may be related to the differing performance of Brazilian sectors in global value chains, as highlighted by Hollweg and Rocha (2018).

Table 5

Brazil: sectoral elasticities of participation in global value chains (GVCs), long-run coefficients calculated by the pooled mean group method

Sector	Variable and error correction term	Long-run coefficients	Variable and error correction term	Long-run coefficients	Variable and error correction term	Long-run coefficients
Agriculture, hunting, forestry and fishing	*Error correction*	0.918***	*Error correction*	0.925***	*Error correction*	0.892***
	ln(part GVCs)	-0.415	ln(part simple GVCs)	-1.842*	ln(part complex GVCs)	0.315
Mining and quarrying	*Error correction*	0.814***	*Error correction*	0.850***	*Error correction*	0.777***
	ln(part GVCs)	0.213	ln(part simple GVCs)	-0.495	ln(part complex GVCs)	0.484**
Food, beverages and tobacco	*Error correction*	0.952***	*Error correction*	0.943***	*Error correction*	1.009***
	ln(part GVCs)	0.974**	ln(part simple GVCs)	-0.520	ln(part complex GVCs)	1.750***
Textiles and textile products	*Error correction*	0.808***	*Error correction*	0.627***	*Error correction*	0.768***
	ln(part GVCs)	1.409	ln(part simple GVCs)	0.674	ln(part complex GVCs)	0.403
Wood and products of wood and cork	*Error correction*	0.565***	*Error correction*	0.527***	*Error correction*	0.628***
	ln(part GVCs)	-1.315	ln(part simple GVCs)	-2.187**	ln(part complex GVCs)	-0.023
Pulp, paper, printing and publishing	*Error correction*	-0.077	*Error correction*	-0.053	*Error correction*	-0.143
	ln(part GVCs)	-0.588	ln(part simple GVCs)	-0.318	ln(part complex GVCs)	-0.784
Chemicals and chemical products	*Error correction*	0.290	*Error correction*	0.250	*Error correction*	0.297
	ln(part GVCs)	0.598	ln(part simple GVCs)	0.557	ln(part complex GVCs)	0.288
Rubber and plastics	*Error correction*	0.524**	*Error correction*	0.576**	*Error correction*	0.545***
	ln(part GVCs)	0.908*	ln(part simple GVCs)	0.033	ln(part complex GVCs)	1.203***
Other non-metallic minerals	*Error correction*	0.961***	*Error correction*	0.910***	*Error correction*	1.005***
	ln(part GVCs)	0.881**	ln(part simple GVCs)	-0.077	ln(part complex GVCs)	0.797**
Basic metals and fabricated metal products	*Error correction*	0.562**	*Error correction*	0.568**	*Error correction*	0.550**
	ln(part GVCs)	-0.012	ln(part simple GVCs)	-0.678	ln(part complex GVCs)	0.188
Electrical and optical equipment	*Error correction*	0.294	*Error correction*	0.275	*Error correction*	0.195
	ln(part GVCs)	0.093	ln(part simple GVCs)	-0.094	ln(part complex GVCs)	0.044

5 These terms allow analysis of the stability of the long-term relationship and the speed of adjustment of short-term deviations.

Sector	Variable and error correction term	Long-run coefficients	Variable and error correction term	Long-run coefficients	Variable and error correction term	Long-run coefficients
Machinery not elsewhere classified	*Error correction*	1.067***	*Error correction*	1.147***	*Error correction*	1.014***
	ln(part GVCs)	-0.078	ln(part simple GVCs)	-1.522***	ln(part complex GVCs)	0.706*
Transport equipment	*Error correction*	0.782***	*Error correction*	0.779***	*Error correction*	0.839***
	ln(part GVCs)	1.435***	ln(part simple GVCs)	0.315	ln(part complex GVCs)	0.925*
Manufacturing not elsewhere classified; recycling	*Error correction*	0.874***	*Error correction*	0.680***	*Error correction*	0.787***
	ln(part GVCs)	0.054	ln(part simple GVCs)	0.374	ln(part complex GVCs)	0.145
Electricity, gas and water supply	*Error correction*	0.585***	*Error correction*	0.574***	*Error correction*	0.606***
	ln(part GVCs)	0.618*	ln(part simple GVCs)	-0.049	ln(part complex GVCs)	0.702*
Construction	*Error correction*	1.035***	*Error correction*	0.994***	*Error correction*	0.962***
	ln(part GVCs)	-0.725	ln(part simple GVCs)	-1.937**	ln(part complex GVCs)	0.414
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	*Error correction*	0.784***	*Error correction*	0.808***	*Error correction*	0.714***
	ln(part GVCs)	1.079**	ln(part simple GVCs)	0.080	ln(part complex GVCs)	1.258***
Wholesale trade and commission trade, except of motor vehicles and motorcycles	*Error correction*	0.614***	*Error correction*	0.636***	*Error correction*	0.614***
	ln(part GVCs)	0.838***	ln(part simple GVCs)	0.044	ln(part complex GVCs)	0.977***
Retail trade, except of motor vehicles and motorcycles; repair of household goods	*Error correction*	0.357	*Error correction*	0.357	*Error correction*	0.410*
	ln(part GVCs)	1.034**	ln(part simple GVCs)	0.641	ln(part complex GVCs)	0.943***
Inland transport	*Error correction*	0.743***	*Error correction*	0.759***	*Error correction*	0.748***
	ln(part GVCs)	1.101***	ln(part simple GVCs)	0.063	ln(part complex GVCs)	1.280***
Water transport	*Error correction*	0.671***	*Error correction*	0.974***	*Error correction*	0.797***
	ln(part GVCs)	2.722**	ln(part simple GVCs)	-1.681	ln(part complex GVCs)	1.388***
Air transport	*Error correction*	0.937***	*Error correction*	1.046***	*Error correction*	0.735***
	ln(part GVCs)	-0.046	ln(part simple GVCs)	-2.676*	ln(part complex GVCs)	1.385*
Other supporting and auxiliary transport activities; activities of travel agencies	*Error correction*	0.710***	*Error correction*	0.678***	*Error correction*	0.784***
	ln(part GVCs)	0.936***	ln(part simple GVCs)	0.180	ln(part complex GVCs)	1.036***
Hotels and restaurants	*Error correction*	0.977***	*Error correction*	0.979***	*Error correction*	0.963***
	ln(part GVCs)	0.510	ln(part simple GVCs)	-0.700	ln(part complex GVCs)	0.889**
Financial intermediation	*Error correction*	0.503**	*Error correction*	0.513**	*Error correction*	0.494**
	ln(part GVCs)	0.309*	ln(part simple GVCs)	-0.324	ln(part complex GVCs)	0.517**
Real estate activities	*Error correction*	0.155	*Error correction*	0.142	*Error correction*	0.216
	ln(part GVCs)	0.241**	ln(part simple GVCs)	0.067	ln(part complex GVCs)	0.317*
Renting of machinery and equipment and other business activities	*Error correction*	1.010***	*Error correction*	0.905***	*Error correction*	0.965***
	ln(part GVCs)	-0.072	ln(part simple GVCs)	-1.129	ln(part complex GVCs)	0.609**
Public administration and defence; compulsory social security	*Error correction*	0.613***	*Error correction*	0.609***	*Error correction*	0.714***
	ln(part GVCs)	1.052**	ln(part simple GVCs)	0.338	ln(part complex GVCs)	1.007***
Education	*Error correction*	1.011***	*Error correction*	0.991***	*Error correction*	1.078***
	ln(part GVCs)	0.821***	ln(part simple GVCs)	-0.329	ln(part complex GVCs)	0.994***
Health and social work	*Error correction*	0.072	*Error correction*	0.074	*Error correction*	0.093
	ln(part GVCs)	0.530	ln(part simple GVCs)	0.183	ln(part complex GVCs)	0.799
Other community, social and personal services	*Error correction*	0.340	*Error correction*	0.369	*Error correction*	0.348
	ln(part GVCs)	-0.435	ln(part simple GVCs)	-0.855***	ln(part complex GVCs)	-0.230

Source: Prepared by the authors, on the basis of global input-output matrices.
Note: Sectoral data are based on global input-output matrices and underlying data covering 43 countries, plus a model for the rest of the world spanning the period 2000–2014. Sectors are classified according to the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 4). The matrices follow the 2008 version of the System of National Accounts. *** significant at 1%; ** significant at 5%; * significant at 10%.

Overall, positive effects on total factor productivity from participation in global value chains were found in 15 of the 31 sectors in the sample. In all of them, elasticities were positive when participation in complex chains was considered, and most had magnitudes very close to or above 1%. The sectors showing the highest long-term productivity gains as a result of participation in complex chains were: food, beverages and tobacco (1.7%); water transport (1.39%); air transport (1.39%); inland transport (1.28%); sale, maintenance and repair of motor vehicles and motorbikes and retail sale of fuel (1.26%); and the rubber and plastics industry (1.2%). In most Brazilian sectors, a total of 20, an increase in participation in complex global value chain activities contributes to a long-term increase in total factor productivity.

Some sectors are notable for showing positive effects with both general and complex measures of participation in global value chains: food, beverages and tobacco; water and inland transport; sale, maintenance and repair of motor vehicles and motorbikes and retail sale of fuel; the rubber and plastics industry; the transport equipment industry; other supporting and auxiliary transport activities and activities of travel agencies; public administration and defence and compulsory social security; retail trade, except of motor vehicles and motorbikes, and repair of household goods; wholesale trade and commission trade, except of motor vehicles and motorbikes; education; mining and quarrying of other non-metallic minerals; and electricity, gas and water supply. Other segments show positive but smaller effects with both measures of participation in global value chains.

The results on productivity from the integration of the above segments into global value chains show that there is no clear relationship between the complexity and technological sophistication of the activities involved and appropriation of the spillovers from participation in chains, since a number of the sectors with the highest elasticities are of low complexity and technological sophistication. Perhaps Brazil's productive specialization process itself generates this type of relationship, an aspect that it will be important to explore in future studies.

Table A1.1 of the annex shows sectoral participation in the value added of the Brazilian economy, the aim being to ascertain whether the sectors with the highest total factor productivity elasticities are those with the largest shares of value added in the Brazilian economy. Mining; food, beverages and tobacco; sale, maintenance and repair of motor vehicles and motorbikes and retail sale of fuel; and inland transport are some examples of segments which have proven to be strategic for participation in global value chains and whose share in the economy's total value added is close to or higher than 2%. However, the total value added share of most of these sectors declined between 2000 and 2014, the exception being mining.

Participation in simple global value chains showed no effect on long-run total factor productivity, and where there was statistical significance, the coefficients were negative. These results indicate a lesser appropriation of knowledge and technology spillovers, as activities in simple chains may be more associated with the supply of basic goods, while little use is made of more sophisticated inputs. The results therefore show that participation in simple global value chains is not an attractive strategy for stimulating the productivity of the Brazilian economy.

For some sectors where Brazil is more competitive, according to Hollweg and Rocha (2018) and Ferraz, Gutierre and Cabral (2015), we also find evidence that its participation in complex global value chains has had positive effects on total factor productivity. These are: mining; rubber and plastics; other non-metallic minerals; machinery not elsewhere classified; and transport equipment. These sectors may also be strategic for Brazil to move forward with its participation in global value chains so as to achieve higher long-run productivity gains. Lastly, as highlighted by Ferraz, Gutierre and Cabral (2015), Brazil is not competitive in global value chains in more sophisticated sectors such as chemicals, electrical equipment and optics. Moreover, table A1.1 of the annex shows that these sectors' share of value added in the economy has been declining, which helps to explain the weak performance of productivity in the Brazilian economy.

The financial intermediation services segment, which exhibits a positive relationship between participation in general and complex global value chains, has a lower elasticity with respect to productivity than a number of other sectors that are less sophisticated and complex. It seems, therefore, that it is not enough for a segment to be more complex and technologically sophisticated for the country to gain by integrating into global value chains. The findings of this paper, together with those presented by Hollweg and Rocha (2018) and Ferraz, Gutierre and Cabral (2015), indicate that the sectors need to be competitive. An important research agenda for a better understanding of the productivity increase attributable to sectoral participation in global value chains may be to conduct studies on the sectoral characteristics other than complexity and technological sophistication that allow this increase to be appropriated, such as, for example, the competitiveness of the segment in relation to the same segment in other countries.

Although the estimated specifications are simple and the robustness of the results has not been tested because of the dearth of sectoral data, the present study helps give an idea of which sectors could deliver higher productivity gains in the long run through greater involvement in global value chains. In addition, it investigates the gains associated with the type of chain that sectors participate in, so as to identify those where an expansion into complex chains would be desirable in order to increase the productivity of the Brazilian economy. These issues are of great importance to the allocation of investments that prioritize strategies aimed at improving Brazil's performance in global trade networks.

VI. Final considerations

This study set out to measure the effects of participation in global value chains using the participation indicators developed by Wang and others (2017), who disaggregate them into simple and complex chains. We have sought to determine which sectors could be critical in enhancing Brazil's participation in globally segmented production chains, an aspect of great importance to the development of strategies for boosting Brazilian economic growth, especially given the current situation in which the country has been performing only modestly in global value chains and its productivity has stagnated. We used heterogeneous dynamic panel models for this research, applying methods that allow short- and long-term effects to be diagnosed. This study adopted a new approach to the relationship between global value chains, productivity and growth and innovated on the existing empirical literature as regards the methodology employed, the global value chain participation indicators used and their sectoral application to the Brazilian economy.

The results pointed to the existence of short-term effects only when the PMG method was used, with the indicators exhibiting positive effects for both simple and complex chains. When the overall participation indicator was considered, however, the effect was negative. In the long run, participation in global value chains seems to generate productivity gains whichever indicator is considered.

In sectoral terms, positive effects on total factor productivity from participation in global value chains were found in 15 of the 31 sectors of the sample. Elasticities were also positive in all of them when participation in complex chains was considered, mostly with magnitudes very close to or above 1%. Meanwhile, participation in simple chains showed no effect on total factor productivity in the long run, and when the coefficients were statistically significant, they were negative, indicating that the strategy of integration via simple global value chains does not seem attractive as a way of increasing sectoral productivity in Brazil.

Some results indicate that it is not enough for a segment to be more complex and technologically sophisticated to achieve gains through the participation of the Brazilian sector in global value chains. The findings of this study, which centre on sectoral participation in global value chains, together with the sectoral competitiveness results of Hollweg and Rocha (2018) and Ferraz, Gutierre and Cabral (2015), indicate that sectors need to be competitive to achieve gains from sectoral participation in global value chains. To better understand the productivity gains accruing from sectoral participation in global value chains, it would be interesting in future research to analyse the sectoral characteristics besides complexity and technological sophistication that allow these gains to be appropriated, such as, for example, the segment's competitiveness relative to the same segment in other countries.

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Annex A1

Table A1.1
Brazil: sectoral value added as a share of total value added
(Percentages)

Sector	Year	Value added (VA)/total VA	Year	VA/total VA	Year	VA/total VA	Year	VA/VA total
Agriculture, hunting, forestry and fishing	2000	5.20	2005	5.35	2010	4.88	2014	5.25
Mining and quarrying	2000	2.58	2005	4.15	2010	3.35	2014	3.79
Food, beverages and tobacco	2000	2.40	2005	2.83	2010	2.40	2014	2.27
Textiles and textile products	2000	2.00	2005	1.53	2010	1.33	2014	1.09
Wood and products of wood and cork	2000	0.41	2005	0.37	2010	0.26	2014	0.21
Pulp, paper, printing and publishing	2000	1.02	2005	0.78	2010	0.70	2014	0.56
Coke, refined petroleum and nuclear fuel	2000	-0.31	2005	-0.34	2010	0.50	2014	-0.59
Chemicals and chemical products	2000	2.35	2005	1.83	2010	1.69	2014	1.38
Rubber and plastics	2000	0.56	2005	0.69	2010	0.65	2014	0.54
Other non-metallic minerals	2000	0.70	2005	0.66	2010	0.68	2014	0.61
Basic metals and fabricated metal	2000	1.96	2005	2.55	2010	2.08	2014	1.83
Electrical and optical equipment	2000	0.49	2005	0.45	2010	0.43	2014	0.38
Machinery not elsewhere classified	2000	0.87	2005	0.93	2010	0.94	2014	0.81
Transport equipment	2000	1.84	2005	2.19	2010	2.18	2014	1.53
Manufacturing not elsewhere classified; recycling	2000	1.51	2005	1.40	2010	1.24	2014	1.11
Electricity, gas and water supply	2000	3.18	2005	3.59	2010	2.83	2014	1.90
Construction	2000	5.68	2005	5.14	2010	6.31	2014	6.68
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	2000	2.60	2005	1.68	2010	2.00	2014	1.80
Wholesale trade and commission trade, except of motor vehicles and motorcycles	2000	3.36	2005	4.14	2010	4.55	2014	4.53
Retail trade, except of motor vehicles and motorcycles; repair of household goods	2000	5.03	2005	5.44	2010	6.14	2014	6.71
Inland transport	2000	2.92	2005	2.91	2010	2.84	2014	2.85
Water transport	2000	0.18	2005	0.16	2010	0.11	2014	0.13
Air transport	2000	0.32	2005	0.19	2010	0.19	2014	0.18
Other supporting and auxiliary transport activities; activities of travel agencies	2000	1.11	2005	1.14	2010	1.18	2014	1.28
Post and telecommunications	2000	1.82	2005	1.95	2010	1.79	2014	1.38
Hotels and restaurants	2000	1.97	2005	1.80	2010	2.14	2014	2.36
Financial intermediation	2000	5.60	2005	6.83	2010	6.85	2014	6.58
Real estate activities	2000	11.51	2005	9.20	2010	8.37	2014	9.55
Renting of machinery and equipment and other business activities	2000	8.79	2005	8.66	2010	8.88	2014	9.74
Public administration and defence and compulsory social security	2000	9.88	2005	10.54	2010	10.47	2014	10.23
Education	2000	5.16	2005	4.42	2010	5.00	2014	5.91
Health and social work	2000	3.87	2005	3.57	2010	3.95	2014	4.32
Other community, social and personal services	2000	2.04	2005	1.97	2010	1.90	2014	1.86
Private households with employed persons	2000	1.37	2005	1.32	2010	1.23	2014	1.22

Source: Prepared by the authors, on the basis of information from the World Input-Output Database (WIOD), "World Input-Output Database (WIOD) 2013" [online] http://www.wiod.org/database/seas13.

Table A1.2
Variables in the Groningen Growth and Development Centre (GGDC)
World Input-Output Database (WIOD)

Output	Millions of national currency
GO	Gross output by industry at current basic prices
II	Intermediate inputs at current purchasers' prices
VA	Gross value added at current basic prices
Labour input	Employment units
EMP	Number of persons engaged (thousands)
EMPE	Number of employees (thousands)
H_EMPE	Total hours worked by employees (millions)
Compensation	Millions of national currency
COMP	Compensation of employees
LAB	Total labour compensation
CAP	Capital compensation
Capital input	Millions of national currency
K	Nominal capital stock
Indices	2010=100
GO_PI	Price levels of gross output
II_PI	Price levels of intermediate inputs
VA_PI	Price levels of gross value added
GO_QI	Gross output, volume indices
II_QI	Intermediate inputs, volume indices
VA_QI	Gross value added, volume indices
Additional variables	2013 version
LABHS	High-skilled labour compensation (share in total labour compensation)
LABMS	Medium-skilled labour compensation (share in total labour compensation)
LABLS	Low-skilled labour compensation (share in total labour compensation)
H_HS	Hours worked by high-skilled persons engaged (share in total hours)
H_MS	Hours worked by medium-skilled persons engaged (share in total hours)
H_LS	Hours worked by low-skilled persons engaged (share in total hours)

Source: Prepared by the authors, on the basis of information from the World Input-Output Database (WIOD), "World Input-Output Database (WIOD) 2013" [online] http://www.wiod.org/database/seas13.

Table A1.3
Structure of sectors, versions used in the 2013 and 2016 World Input-Output Database (WIOD)

International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4	Sector description (2016 WIOD)	ISIC, Rev. 3	Agriculture, hunting, forestry and fishing
A01	Crop and animal production; hunting and related service activities	AtB	Agriculture, hunting, forestry and fishing
A02	Forestry and logging	AtB	Agriculture, hunting, forestry and fishing
A03	Fishing and aquaculture	AtB	Agriculture, hunting, forestry and fishing
B	Mining and quarrying	C	Mining and quarrying
C10–C12	Manufacture of food products, beverages and tobacco products	15t16	Food, beverages and tobacco
C13–C15	Manufacture of textiles, wearing apparel and leather products	17t18	Textiles and textile products
		19	Leather and footwear
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20	Wood and products of wood and cork
C17	Manufacture of paper and paper products	21t22	Pulp, paper, printing and publishing
C18	Printing and reproduction of recorded media	21t22	Pulp, paper, printing and publishing
C19	Manufacture of coke and refined petroleum products	23	Coke, refined petroleum and nuclear fuel
C20	Manufacture of chemicals and chemical products	24	Chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	24	Chemicals and chemical products
C22	Manufacture of rubber and plastic products	25	Rubber and plastics
C23	Manufacture of other non-metallic mineral products	26	Other non-metallic minerals
C24	Manufacture of basic metals	27t28	Basic metals and fabricated metal
C25	Manufacture of fabricated metal products, except machinery and equipment	27t28	Basic metals and fabricated metal
C26	Manufacture of computer, electronic and optical products	30t33	Electrical and optical equipment
C27	Manufacture of electrical equipment	27t28	Basic metals and fabricated metal
C28	Manufacture of machinery and equipment not elsewhere classified	29	Machinery not elsewhere classified
C29	Manufacture of motor vehicles, trailers and semi-trailers	34t35	Transport equipment
C30	Manufacture of other transport equipment	34t35	Transport equipment
C31 and C32	Manufacture of furniture; other manufacturing	36t37	Manufacturing not elsewhere classified; recycling
C33	Repair and installation of machinery and equipment	71t74	Renting of machinery and equipment and other business activities
D35	Electricity, gas, steam and air conditioning supply	E	Electricity, gas and water supply
E36	Water collection, treatment and supply	E	Electricity, gas and water supply
E37–E39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	E	Electricity, gas and water supply
F	Construction	F	Construction
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
G46	Wholesale trade, except of motor vehicles and motorcycles	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
G47	Retail trade, except of motor vehicles and motorcycles	52	Retail trade, except of motor vehicles and motorcycles; repair of household goods
H49	Land transport and transport via pipelines	60	Inland transport
H50	Water transport	61	Water Transport
H51	Air transport	62	Air transport
H52	Warehousing and support activities for transportation	63	Other supporting and auxiliary transport activities; activities of travel agencies
H53	Postal and courier activities	64	Post and telecommunications

International Standard Industrial Classification of All Economic Activities (ISIC), Rev. 4	Sector description (2016 WIOD)	ISIC, Rev. 3	Agriculture, hunting, forestry and fishing
I	Accommodation and food service activities	H	Hotels and restaurants
J58	Publishing activities	21t22	
J59 and J60	Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	21t22	
J61	Telecommunications	64	Post and telecommunications
J62 and J63	Computer programming, consultancy and related activities; information service activities	71t74	Renting of machinery and equipment and other business activities
K64	Financial service activities, except insurance and pension funding	J	Financial intermediation
K65	Insurance, reinsurance and pension funding, except compulsory social security	J	Financial intermediation
K66	Activities auxiliary to financial services and insurance activities	J	Financial intermediation
L68	Real estate activities	70	Real estate activities
M69 and M70	Legal and accounting activities; activities of head offices; management consultancy activities	71t74	Renting of machinery and equipment and other business activities
M71	Architectural and engineering activities; technical testing and analysis	71t74	Renting of machinery and equipment and other business activities
M72	Scientific research and development	71t74	Renting of machinery and equipment and other business activities
M73	Advertising and market research	71t74	Renting of machinery and equipment and other business activities
M74 and M75	Other professional, scientific and technical activities; veterinary activities	71t74	Renting of machinery and equipment and other business activities
N	Administrative and support service activities	71t74	Renting of machinery and equipment and other business activities
O84	Public administration and defence; compulsory social security	L	Public administration and defence; compulsory social security
P85	Education	M	Education
Q	Human health and social work activities	N	Health and social work
R_and S	Other service activities	O	Other community, social and personal services
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	P	Private households with employed persons
U	Activities of extraterritorial organizations and bodies		

Source: Prepared by the authors, on the basis of information from World Input-Output Database (WIOD), “World Input-Output Database (WIOD) 2013” [online] http://www.wiod.org/database/seas13 and “World Input-Output Database (WIOD) 2016” [online] https://www.rug.nl/ggdc/valuechain/wiod/wiod-2016-release?lang=en.