Impacts of trade liberalization on countries' sectoral structure of production and trade: a structural decomposition analysis

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Abstract

This study extends structural decomposition analysis (SDA) to consider the substitution between domestic and imported inputs. The approach provides a detailed investigation of the consequences on economic growth following changes in countries' supply chains. We apply the method to data from Brazil and other countries. The results suggest that the substitution of imported for national inputs is a key factor in SDA, assuming that the impact of technological change is underestimated if this substitution is not taken into account.

The findings also show that the substitution of imported inputs is essential to understanding the Brazilian growth path in the 2000s. The positive impact of export growth on total output was offset by the increase in imported inputs, especially in highly technological sectors. The results in Brazil stand in contrast with those in Korea, China, and Germany, where high-tech sectors benefited the most from the substitution.

Keywords: Structural Decomposition Analysis; Structural Change; Open Economies Growth; Deindustrialization

1. Introduction

The process of trade liberalization, which took place in developing countries during the 1990s and 2000s, had significant impacts on world production chains. From a global perspective, these countries were integrated into global supply chains, which permitted an increase in exports that had not been witnessed in decades. On the other hand, these changes may have resulted in the substitution of imported inputs for domestic suppliers. As a result, the potential for growth in demand to precipitate economic growth may have declined, provided that domestic absorption of demand has fallen.

To analyze the consequences of this complex process, a relevant aspect that should be taken into account is identifying which sectors have changed more substantially and what implications this has on economic growth. On the one hand, in Asian economies, the growth in the last two decades was led by the increase of high-tech exports. On the other hand, in Brazil and other natural resource exporters, the wealth effect of primary product exports was one of the most important variables in the recent economic growth. An economic growth led by primary sectors, however, may result in a relevant constraint for economic growth in the long run. Although one can argue that expansion based on the production and export of primary goods did not have a negative effect on the economy, there is a large (and growing) literature that is attempting to show the limitations of promoting growth based on these sectors.

Export growth is crucial to promoting sustainable growth rates in the long run; however, the export composition matters. Berg, Ostry, and Zettelmeyer (2012) showed empirically that "manufacturing share in exports, and more generally, export product sophistication tend to predict prolonged growth." It has been argued that product export shares of the more complex products is positively related with countries' income (Felipe *et al.*, 2012), as sophisticated goods hold a vast amount of productive knowledge (Hausmann, Hidalgo *et al.*, 2011), and thus they are fundamental to the convergence of productivity levels among countries (Rodrik, 2013).

Szirmai (2012) presents strong evidences that manufacturing is the engine of growth in developing countries. According to the author, there is no important examples of countries which has success in economic development without a strong industrial base. Specialization in primary sectors, on the other hand, may increase the technological gap in a country. Chief (2013), for example, showed that, especially in developing economies, the Dutch disease[1] promotes a self-reinforcing mechanism that leads to a productivity divergence pattern.

Moreover, Kaldorian and structuralist approaches present significant contributions in favor of specialization in technologically advanced sectors. They show that manufacturing presents higher degree of increasing returns to scale than primary sectors (McCombie, Pugno, & Soro, 2002[2]; Angeriz, McCombie, & Roberts, 2008) and also higher income elasticities of demand for imports and exports (Gouvea & Lima, 2010). Consequently, specialization in primary goods may negatively affect total productivity growth and lead to a balance-of-payment crisis, which constrains countries' growth rates in the long run.

Structural decomposition analysis (SDA) considers that shifts in total output essentially depend on changes in final demand and intermediate consumption. Changes in final demand affect the total output directly, and because intermediate consumption depends on input-output coefficients, total output is also affected by shifts in them. In this study, we develop a method for decomposing the changes in intermediate consumption into two parts: technological change and substitution of imported inputs. The aim of this decomposition is to identify to what extent substitution between domestic and imported inputs affects output growth across sectors. This analytical tool is relevant to providing a detailed investigation of the consequences of changes in countries' supply chains on their structure of production and trade.

Furthermore, analyzing the decomposition of changes in industrial chains is also important to determine those sectors in which the substitution of imported inputs for domestic inputs is more intense and those in which export growth has compensated for the negative impacts on output. By using the analytical tool developed in this work, it is possible to compare the negative effects of the substitution between domestic and imported inputs and its positive effects on export growth across sectors and countries.

In addition to this introduction, this paper has four other sections. In section 2, we discuss the evolution and limitations of SDA, as well as its applications in Brazil. In section 3, we extend the method to incorporate the substitution between national inputs and imports. Section 4 applies this analytical tool to the Brazilian data and compares the results with the contribution of exports to evaluate the net impacts on output of the

[1] Revenues from exports of natural resources may cause exchange rate overvaluation and could constrain industrial development.

[2] See McCombie, Pugno, and Soro (2002) for a review of the empirical evidence on this topic.

substitution between national inputs and imports. We also apply this analytical tool to other economies, with the aim of comparing Brazil with other countries. Finally, section 5 discusses the relevance and limitations of the proposed approach and provides the concluding remarks.

2. Theoretical and empirical background

Leontief (1936, 1941) was the first to conduct an economic structural analysis by using input-output (I-O) methods. Following his work, this method has been widely used in such analyses and to study the effects of economic conditions on political outcomes, e.g., through the use of backward and forward linkages (Hirschman, 1958; 1968). Nevertheless, the use of decomposition methods to analyze the sources of structural changes was only introduced in the 1970s by Skolka's inaugural paper (Skolka, 1977).

Many studies have applied this methodology in different countries, such as Feldman, McClain, and Palmer (1987) in the United States, and Skolka (1989) in Austria. Feldman, McClain, and Palmer (1987) decomposed industry output changes in the United States in 1963 and 1978 into changes in final demand (level and mix of products) and in input-output coefficients. Alternatively, Skolka (1989) analyzed the composition of net output in terms of the contributions of technological shifts, domestic final demand, foreign trade, and labor productivity.

In the 1980s and 1990s, SDA methods became an important analytical tool in structural studies, and different methods were developed. As a result, Rose and Casler (1996) and Dietzenbacher and Los (1998) developed critiques of the methodology. Rose and Casler (1996) described the fundamental principles behind alternative SDA methods, whereas Dietzenbacher and Los (1998) discussed the problems caused by the application of different SDA methods.

Despite being used widely to understand structural changes in different economies, the SDA method was not applied to analyzing the effects on output growth following changes in coefficients due to substitution between imports and domestic suppliers. Recently, Pei et al. (2011) analyzed the effects of Chinese import growth in terms of vertical specialization. The authors, however, did not use the SDA method to evaluate the demand that was not absorbed domestically as a consequence of substitution between domestic suppliers and imports in different sectors. From a structuralist perspective, it is crucial to understand why countries' growth rates may decline in the long run.

In the case of the Brazilian economy, Guilhoto et al. (2001) decomposed the changes in economic structure between 1959 and 1980 and compared them with those in the United States. The authors confirmed prior findings regarding the role of changes in final demand in determining the growth rate of sectoral output in Brazil during the 1960s and 1970s.

More recently, Messa (2012) and Moreira and Ribeiro (2012) applied SDA methods to Brazilian data to decompose structural changes in the 2000s. Although Messa (2012) showed that a decline in the intermediate consumption of domestic industrial output is the most important determinant of the growth differential between services and industry, the author did not decompose the changes in input coefficients into technical change and domestic supply substitution. Moreover, Moreira and Ribeiro (2012) did a similar analysis and concluded that output growth was primarily explained by changes in final demand, whereas technical progress (measured by input coefficients) had less of an impact.

Thus far, however, studies have failed to account for the effect of substitution between domestic suppliers and imports. Therefore, an analytical decomposition of recent Brazilian growth is necessary to verify the extent to which this country has been achieving low growth rates as a result of substitution between imported and domestic inputs in sectors that have the potential to increase the country's growth rate.

3. Incorporating the substitution between domestic inputs and imports into SDA

Initially, the changes in gross output by sector are decomposed into impacts of final demand growth and changes in Leontief coefficients (the coefficients of direct and indirect inputs). The SDA method is applied following Miller and Blair's (2009) approach. Considering the basic Leontief model for two distinct years (0 and 1), the vector of gross output x in year t = 0, 1 is given by:

$$x^1 = L^1 f^1 \text{ and } x^0 = L^0 f^0 \quad (1)$$

where L is the Leontief matrix of direct and indirect production coefficients, and f is the vector of final demand. Thus, the observed change in gross output is:

$$\Delta x = x^1 - x^0 = L^1 f^1 - L^0 f^0 \quad (2)$$

Some possible rearrangements may be applied to decompose the changes in L and f, and their effects on Δx. Two alternative methods are presented:

$$\Delta x = L^1(f^0 + \Delta f) - (L^1 - \Delta L)f^0 = (\Delta L)f^0 + L^1(\Delta f) \quad (3)$$

$$\Delta x = (L^0 + \Delta L)f^1 - L^1(f^1 - \Delta f) = (\Delta L)f^1 + L^0(\Delta f) \quad (4)$$

Here, the focus will be on the average approach of these two methods. According to Dietzenbacher and Los (1998), this approach is often an acceptable method for SDA. Summing equations (3) and (4)

$$2\Delta x = (\Delta L)f^0 + L^1(\Delta f) + (\Delta L)f^1 + L^0(\Delta f) \quad (5)$$

and averaging gives:

$$\Delta x = \frac{1}{2}(\Delta L)(f^0 + f^1) + \frac{1}{2}(L^0 + L^1)(\Delta f) \quad (6)$$

where the first term refers to the effects of the change in the Leontief coefficients over the change in gross output, and the second term refers to the effects of the change in final demand.

Thereafter, the changes in Leontief coefficients have to be divided into technological changes and substitution between national and imported inputs. Given $L^1 = (I - A_n^1)$ and $L^0 = (I - A_n^0)$, where A_n is the national direct coefficients matrix, post-multiply L^1 through by $(I - A_n^1)$

$$L^1(I - A_n^1) = I = L^1 - L^1 A_n^1 \quad (7)$$

and pre-multiply L^0 through by $(I - A_n^0)$

$$(I - A_n^0)L^0 = I = L^0 - A_n^0 L^0 \quad (8)$$

Rearrange (7) and post-multiply by L^0

$$L^1 - I = L^1 A_n^1 \Rightarrow L^1 L^0 - L^0 = L^1 A_n^1 L^0 \quad (9)$$

Similarly, rearrange (8) and pre-multiply by L^1

$$L^0 - I = A_n^0 L^0 \Rightarrow L^1 L^0 - L^1 = L^1 A_n^0 L^0 \quad (10)$$

Subtract (10) from (9)

$$\Delta L = L^1 A_n^1 L^0 - L^1 A_n^0 L^0 = L^1(\Delta A_n)L^0 = L^1(A_n^1 - A_n^0)L^0 \quad (11)$$

Because A_n^t is the difference between the total direct coefficient matrix (A^t) and the direct coefficient matrix of imported goods (A_m^t), the change in the Leontief matrix can be written alternatively as

$$\Delta L = L^1[(A^1 - A_m^1) - (A^0 - A_m^0)]L^0 \quad (12)$$

Rearranging, the decomposition of changes in the Leontief matrix into technological changes and substitution between national and imported goods is given by

$$\Delta L = L^1(\Delta A)L^0 + L^1(-\Delta A_m)L^0 \quad (13)$$

where the first term is the contribution of the changes in total direct coefficients (technological change[3]) to changes in the Leontief coefficient, and the second term is the contribution of changes in imported direct coefficients (substitution of national inputs).

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[3] In SDA, technological changes mean changes in the input-output coefficients, which do not necessarily impact on total technological growth (in the Solow or growth accounting sense of the term). According to Rose and Castelar (1996:42), “In nearly all SDA formulations, changes in the structural matrix are ascribed to a nebulous 'technological change', which is often broadly interpreted to include any factor that causes a change in a technical (structural) coefficient, such as true technological change, technical substitution (response input price changes) and scale effects.”

Finally, substituting (13) in (6), the total output growth can be divided into the contribution of (i) technological change, (ii) substitution between national inputs and imports, and (iii) final demand growth:

$$\Delta x = \underbrace{\tfrac{1}{2}[L^1(\Delta A)L^0](f^0 + f^1)}_{technological\ change} + \underbrace{\tfrac{1}{2}[L^1(-\Delta A_m)L^0](f^0 + f^1)}_{substitution\ of\ national\ inputs} + \underbrace{\tfrac{1}{2}(L^0 + L^1)(\Delta f)}_{final\ demand\ growth} \quad (14)$$

4. Results

4.1. Application of the analytical tool in Brazil

The method developed in this study was applied to Brazilian data from 1995 to 2008 and to a set of comparison countries[4]. The data are available at the World Input-Output Database (WIOD) (Timmer, 2012). The database covers most of the major world economies (including Brazil) in the period between 1995 and 2008, and the data are available in both current and previous years' prices. Thus, changes in prices and quantities may be analyzed separately, which reduces bias caused by volatility in exchange rates and relative price changes.

Equation (14) was applied year by year from 1995-1996 to 2007-2008 with the aim of comparing tables valued at same-year prices, and then the growth rates were accumulated to obtain changes in quantities. Therefore, the percentage changes (*Δ%*) obtained are chain Laspeyres *quantum* indices. For example, to obtain the changes between 1995 and 1997, the changes from 1995 to 1996 (at 1995 prices) were accumulated with the changes from 1996 to 1997 (at 1996 prices), as follows:

$$\Delta\% x^{1995-1997} = \left[\left(1 + \frac{\Delta x^{1995-1996}}{x^{1995}}\right)\left(1 + \frac{\Delta x^{1996-1997}}{x^{1996}}\right) - 1\right] \cdot 100 \quad (15a)$$

$$\Delta\% A^{1995-1997} = \left[\frac{\Delta A^{1995-1996}}{x^{1995}} + \left(1 + \frac{\Delta x^{1995-1996}}{x^{1995}}\right)\frac{\Delta A^{1996-1997}}{x^{1996}}\right] \cdot 100 \quad (15b)$$

$$-\Delta\% {A_m}^{1995-1997} = \left[\frac{-\Delta {A_m}^{1995-1996}}{x^{1995}} + \left(1 + \frac{\Delta x^{1995-1996}}{x^{1995}}\right)\frac{-\Delta {A_m}^{1996-1997}}{x^{1996}}\right] \cdot 100 \quad (15c)$$

[4] The World International Input-Output Database (WIOD) presents data from 1995 to 2009. However, data for the last year were not obtained from the Brazilian National Accounts System (SCN in Portuguese) and were thus excluded from the analysis to avoid bias in the final results.

$$\Delta\%f^{1995-1997} = \left[\frac{\Delta f^{1995-1996}}{x^{1995}} + \left(1 + \frac{\Delta x^{1995-1996}}{x^{1995}}\right)\frac{\Delta f^{1996-1997}}{x^{1996}}\right] \cdot 100 \qquad (15d)$$

The same method was applied to obtain the changes from 1995 to 2008, which means that 1995 is the base year for all results. Table 1 presents the main findings for Brazil[5]. Essentially, it shows, in real terms, the impact of each factor (technological change, substitution of national inputs and final demand) on sectoral output. The total impact, given by the last column is the sum of the impact of each factor.

Table 1 – Decomposition of the Brazilian output growth (1995-2008)

	$\Delta\% A$	$-\Delta\% Am$	$\Delta\% f$	$\Delta\% X$
Total	***10.0%***	***-9.0%***	***45.1%***	***46.0%***
Agriculture and Mining	**29.2%**	**-22.6%**	**64.9%**	**71.4%**
Manufacturing	**4.7%**	**-13.5%**	**41.8%**	**32.9%**
Low/Med-Low Tech Manufacturing	-0.9%	-8.5%	34.7%	25.4%
High/Med-High Tech Manufacturing	15.1%	-23.2%	55.0%	46..9%
Chemicals and Chemical Products	22.3%	-28.8%	33.2%	26.7%
Machinery, Nec	2.7%	-12.4%	80.8%	71.2%
Electrical and Optical Equipment	24.4%	-34.3%	31.8%	22.0%
Transport Equipment	7.7%	-13.5%	90.8%	85.0%
Services	**10.6%**	**-4.7%**	**44.7%**	**50.6%**

Authors' elaboration based on WIOD

The data in Table 1 allow assessing the relevance of the decomposition of changes in the Leontief coefficient into changes in technology ($\Delta\% A$) and substitution of imported inputs for domestic inputs ($-\Delta\% Am$). For the economy as a whole, nearly all of the positive effects of changes in technology on total output were compensated for by the increase in imported inputs. Although the final demand growth had an impact of 45.1% on total output (98% of the total 46.0% output growth in the period 1995-2008), the inclusion of substitution between imported and domestic inputs permitted by the SDA method allowed us to conclude that technological change also had a relevant impact on output (10.0%). However, this impact was compensated for by the increase in import coefficients (-9.0%), and thus changes in input coefficients (which is given by the sum of the impact of substitution for imported inputs and technological change) had limited effects on total output.

Moreover, the analysis of total output was significantly influenced by the results in the service sector. Because the inputs of this sector were predominately domestic, the

[5] The results for all sectors and years are shown in the appendix.

substitution impact on output was limited to 4.7%. If the substitution effect in the other sectors were considered, the results would be more relevant. In the primary sectors (agriculture and mining), the impact of the substitution of imported inputs on output was 22.6%, which means that the impact of technological change in these sectors was significantly compensated for by the increase of imports.

The most important results, however, were observed in the high- and medium-high-technology manufacturing sectors, in which the effects of technological change had an impact of 15.1% on output growth. Nevertheless, the substitution of imported inputs compensated for these effects: it reduced the overall output growth by 23.2%, and the effects were particularly pronounced in the chemicals and electrical/optical equipment sectors, in which the negative impact was 28.8% and 34.3%, respectively.

More relevant insights may be extracted from the results through an analysis of the effects from a historical perspective. Table 2 presents the results according to three distinct periods in Brazilian macroeconomic policies: 1995 to 1999, 1999 to 2003, and 2003 to 2008.

Table 2 – Impact of the substitution between imported and domestic inputs on output

	1995-99	1999-2003	2003-08	1995-2008
Total	***-0.4%***	***-0.1%***	***-8.6%***	***-9.0%***
Agriculture and Mining	**2.0%**	**-1.6%**	**-23.0%**	**-22.6%**
Manufacturing	**-1.5%**	**0.1%**	**-12.2%**	**-13.5%**
Low/Med-Low Tech Manufacturing	0.0%	0.7%	-9.2%	-8.5%
High/Med-High Tech Manufacturing	-4.4%	-1.1%	-17.7%	-23.2%
Chemicals and Chemical Products	-3.7%	-0.4%	-24.8%	-28.8%
Machinery, Nec	-1.5%	-0.9%	-10.0%	-12.4%
Electrical and Optical Equipment	-8.1%	-4.6%	-21.6%	-34.3%
Transport Equipment	-3.6%	0.8%	-10.7%	-13.5%
Services	**-0.4%**	**-0.1%**	**-8.6%**	**-9.0%**

Authors' elaboration based on WIOD

Between 1995 and 1999, there were relevant substitutions of imported inputs for national inputs in high- and medium-high-technology manufacturing. This substitution had a negative impact of 4.4% on total output. During these years, the *Plano Real* was adopted to reduce inflation. This was based on the reduction of tariffs with the aim of opening the economy to imported goods, as well as on real exchange rate appreciation. As a result, the production chains of the most innovative and technologically advanced sectors were significantly affected.

In contrast with this period, from 1999 to 2003 the Brazilian economy experienced a period of subsequent balance-of-payment crisis and exchange rate depreciation. The inflation target regime was implemented with the aim of controlling inflation; thus, high interest rates were necessary to maintain the capital inflows and control demand growth. As a consequence, although the substitution of imported inputs had not significantly affected the output growth, Brazilian growth rates were very low.

The process of substitution between imported and national inputs picked up between 2003 and 2008. For the economy as a whole, the increase of imported inputs decreased the total output by 8.6% during these five years. Again, high-tech sectors were significantly affected. Their total output was 17.7% lower owing to the increase in imported inputs. In the chemical and electrical sectors, the impact on total output was 24.8% and 21.6%, respectively.

This period, however, was characterized by high real exchange rate appreciation and high growth rates. Thus, the net impact of the substitution was very ambiguous. On the one hand, it reduced the positive impacts of final demand growth on total output by 8.6%. On the other hand, it may have been essential to the increase of the final demand effects, assuming it may be relevant to reduce costs and increase exports.

Therefore, it was important to consider that despite contributing negatively to the total output, the process of substitution was not necessarily negative. The positive results for primary sectors suggested that the increase in exports in these sectors was related to the substitution of imported inputs, as a result of reducing prices. In the following section, we identify those sectors in which the growth of exports compensated for the negative impact of the domestic input substitution, in order to assess the net impact of the substitution.

4.2. The net impact of exports and the substitution of imports for national inputs

To evaluate the impact on economic growth of the substitution between imports and domestic suppliers, we analyze the contribution of exports. As previously mentioned, this substitution may have reduced economic growth because the final demand is not absorbed by domestic suppliers. However, it may have increased exports, assuming it reduced the costs of production. Thereby, we analyze its net impact to evaluate the real consequences of this substitution on output.

Starting from equation (6), final demand is divided into the contribution of exports and its other components:

$$\Delta x = \frac{1}{2}(\Delta L)(f^0 + f^1) + \frac{1}{2}(L^0 + L^1)(\Delta f') + \underbrace{\frac{1}{2}(L^0 + L^1)(\Delta Exp)}_{contrib.\ of\ exports} \qquad (16)$$

where ΔExp is the vector of export growth, and $\Delta f'$ is the vector of final demand growth (excluding exports)[6].

The contribution of exports to output growth (ΔExp_{tot}) can be divided into two parts: the direct contribution of the analyzed sector export growth (ΔExp) and the indirect contribution of other sectors' export growth to the analyzed sector output growth (ΔExp_{ind})[7], which is given by the difference between the total contribution and the direct contribution. Table 3 presents a comparison between the contribution of export growth and the substitution of imported inputs on output.

Table 3 – Impact of exports on output growth (1995-2008)

	$\Delta\%\ Exp$	$\Delta\%\ Exp_{ind}$	$\Delta\%\ Exp_{tot}$	$-\Delta\%\ Am$
Total	***5.6%***	***5.0%***	***10.6%***	***-9.0%***
Agriculture and Mining	**24.9%**	**13.3%**	**38.2%**	**-22.6%**
Manufacturing	**9.7%**	**6.1%**	**15.7%**	**-13.5%**
Low/Med-Low Tech Manufacturing	7.9%	6.0%	13.9%	-8.5%
High/Med-High Tech Manufacturing	13.1%	6.2%	19.3%	-23.2%
Chemicals and Chemical Products	2.7%	7.8%	10.4%	-28.8%
Machinery, Nec	15.3%	4.9%	20.2%	-12.4%
Electrical and Optical Equipment	8.8%	5.1%	13.9%	-34.3%
Transport Equipment	27.4%	6.2%	33.5%	-13.5%
Services	**1.6%**	**3.7%**	**5.2%**	**-4.7%**

Authors' elaboration based on WIOD

The results show that despite being neutral for the economy as a whole, the net impact of the substitution of domestic suppliers had ambiguous effects when considering the sectors separately. The impacts were positive for some sectors, such as agriculture and mining, but they were negative for others, such as chemicals and electrical/optical equipment.

The last two columns of Table 3 show the positive contribution of export growth (direct and indirect) and the negative contribution of the substitution of imported inputs. From these data, we can conclude that high-tech sectors were the most affected by the substitution. Between 1995 and 2008, the substitution of imported inputs for national

[6]

[7] The indirect impact considers, for example, the impact of car exports on tire output growth. Because car production indirectly demands tires, car export growth increases the production of tires.

suppliers contributed negatively to agriculture and mining and to high-tech sectors output growth by around 23%. However, export growth had a 38.2% contribution to agriculture and mining, whereas its contribution to high-tech sectors was only 19.3%. Thus, although the direct impact of the substitution (not considering exports) was negative for agriculture and mining, the net contribution of this substitution process was negative only for high-tech sectors.

Analyzing the high-tech sectors, some other relevant results can be seen from Table 3. The net results were negative for chemical products and electrical/optical equipment (low contribution of exports to growth vis-à-vis high contribution of substitution of imports for domestic suppliers). However, the results were positive for machinery and transport equipment.

Exports contributed 20.2% (15.3% directly and 4.9% indirectly) to the machinery sector output growth, whereas the output decreased by 12.4% due to the substitution of domestic inputs. The transport equipment sector showed even better results. Exports increased the output by 33.5% (27.4% directly and 6.2% indirectly), whereas the negative direct impact of the substitution of national suppliers was only 13.5%.

These results bring an important issue to the debate on industrial policies. The Brazilian National Development Bank (BNDES) provides many benefits for national producers of machinery and transport equipment, such as funding with very low interest rates[8] and certain benefits to stimulate exports (especially for producers that use domestic inputs). Furthermore, the two Brazilian industrial plans launched in the 2000s (PINTEC and PDP) focused on these sectors, providing many tax reductions and other benefits to promote exports[9]. Thus, although high-tech sectors were the most affected by the increase in imported inputs, within this group, those sectors that Brazilian industrial policies have mainly focused on were the ones that took advantage of the substitution process and received a positive net contribution.

4.3. Comparison between Brazil and other economies

The substitution of imported inputs for domestic suppliers has been an important aspect of Brazilian output growth in the last two decades, especially in highly

[8] Because Brazilian financial markets provide funding with high interest rates, BNDES funding with low interest rates is a key factor in the growth of these sectors.

[9] For a brief review of these industrial plans and the BNDES policies for machinery and transport equipment, see Magacho (2012).

technological sectors. However, it is necessary to evaluate this process in comparison with other economies to understand whether Brazil may be characterized as a special case or, alternatively, whether it is merely following a worldwide trend.

We applied the methodology developed in Section 3 to four developing countries (China, India, Mexico, and Korea) and to the three biggest developed countries (Germany, Japan, and United States). The results for the developing countries are presented in Tables 4 and 5, and those for the developed countries in Table 6.

Table 4 – Impact of exports and the substitution between imported and national inputs on output (1995-2008): Brazil, China, and India

	Brazil		China		India	
	–Δ%Am	Δ%*Exp*tot	*–Δ%Am*	Δ%*Exp*tot	*–Δ%Am*	Δ%*Exp*tot
Total	***-9.0%***	***10.6%***	***-46.0%***	***83.3%***	***-12.9%***	***27.4%***
Agriculture and Mining	**-22.6%**	**38.2%**	**-51.1%**	**51.5%**	**-11.0%**	**17.0%**
Manufacturing	**-13.5%**	**15.7%**	**-57.4%**	**112.0%**	**-21.5%**	**39.9%**
Low/Med-Low Tech Manufacturing	-8.5%	13.9%	-29.3%	88.5%	-18.7%	38.0%
High/Med-High Tech Manufacturing	-23.2%	19.3%	-119.0%	147.5%	-29.6%	44.6%
Chemicals and Chemical Products	-28.8%	10.4%	-71.4%	103.8%	-43.1%	45.4%
Machinery, Nec	-12.4%	20.2%	-99.0%	107.4%	-18.2%	41.1%
Electrical and Optical Equipment	-34.3%	13.9%	-208.9%	195.1%	-65.4%	52.8%
Transport Equipment	-13.5%	33.5%	-72.9%	98.1%	-13.8%	45.1%
Services	**-4.7%**	**5.2%**	**-28.8%**	**49.2%**	**-6.0%**	**20.2%**

Authors' elaboration based on WIOD

Table 5 – Impact of exports and the substitution between imported and national inputs on output (1995-2008): Mexico and Korea

	Mexico		Korea	
	–Δ%Am	Δ%*Exp*tot	*–Δ%Am*	Δ%*Exp*tot
Total	***-9.2%***	***22.4%***	***-11.8%***	***55.3%***
Agriculture and Mining	**-12.9%**	**21.8%**	**-121.2%**	**10.2%**
Manufacturing	**-19.2%**	**47.0%**	**-8.2%**	**92.0%**
Low/Med-Low Tech Manufacturing	-11.6%	20.2%	-10.8%	45.3%
High/Med-High Tech Manufacturing	-31.7%	83.9%	-0.6%	136.4%
Chemicals and Chemical Products	-31.7%	13.8%	-4.9%	84.4%
Machinery, Nec	-3.6%	66.1%	-6.0%	92.4%
Electrical and Optical Equipment	-47.2%	134.7%	26.6%	176.2%
Transport Equipment	-17.8%	81.4%	-6.4%	121.1%
Services	**-2.1%**	**6.2%**	**-7.1%**	**20.3%**

Authors' elaboration based on WIOD

Considering these five countries, it is possible to conclude that developing economies have experienced a process of increasing imported inputs, which negatively affected almost every sector. China was the most affected by this process (its output was 46.0% lower due to the substitution for domestic suppliers), corroborating the hypothesis that its industrial chains were strongly integrated into global supply chains during the analyzed period.

High-tech sectors were the most affected in four of the five economies (Brazil, China, India, and Mexico). Korea is an exception; its most affected sectors were agriculture and mining. The impacts of the substitution between domestic and foreign suppliers had limited impacts on high-tech sectors, especially the electrical/optical equipment sector (in which the contribution was positive).

However, as previously suggested, the results were analyzed considering also the positive impacts of export growth. The data on China indicate that the contribution of exports compensated for the decrease caused by the substitution of imports for domestic inputs. Considering the economy as a whole, the net contribution was high. The export growth increased the output by 83.3%, whereas the substitution of imports decreased the output by 46.0%. The net contribution was neutral only for mining and agriculture. In these sectors, exports increased the output by 51.5%, but the substitution for domestic inputs decreased the output by 51.1%.

Similar results were verified for the other developing economies studied, but at a lower scale. The export growth in Mexico and India compensated for the negative contribution of the substitution for domestic suppliers in all analyzed sectors. In Korea it happened in all other sectors than agriculture and mining. Furthermore, although the substitution for domestic suppliers decreased the output of high-tech sectors in Mexico and India by an average of 20%, the net impact was positive, in contrast to the results in these sectors in Brazil.

Thereby, Brazil and Korea were the only analyzed countries in which some sectors were affected positively and others negatively by the substitution. Nevertheless, although in Korea mining and agriculture were the negatively affected sectors, in Brazil the high-tech sectors were the ones that received a negative contribution from the net impact of the substitution of imports for domestic inputs.

To complement this analysis, the contribution of exports and of the substitution between imported inputs and national suppliers to the output growth of developed countries is shown in Table 6.

The results for the three developed countries (United States, Japan, and Germany) show that the negative impact of the substitution of national suppliers was compensated for by the positive impact of export growth. Although the difference between the positive and the negative impacts was not substantial for the United States and Japan, it was very positive for Germany. The substitution of imported inputs impacted negatively on the output of Germany (8.3%). However, exports increased the output by 33.2%, indicating that, similarly to China, Germany strongly benefited from the substitution.

Table 6 – Impact of exports and the substitution between imported and national inputs on output (1995-2008): United States, Japan, and Germany

	USA		Japan		Germany	
	$-\Delta\%Am$	$\Delta\%Exp_{tot}$	$-\Delta\%Am$	$\Delta\%Exp_{tot}$	$-\Delta\%Am$	$\Delta\%Exp_{tot}$
Total	***-5.6%***	***7.9%***	***-5.9%***	***13.8%***	***-8.1%***	***33.2%***
Agriculture and Mining	**-48.0%**	**8.0%**	**-108.8%**	**7.3%**	**-47.7%**	**30.1%**
Manufacturing	**-9.2%**	**17.1%**	**-6.4%**	**30.6%**	**-12.8%**	**58.3%**
Low/Med-Low Tech Manufacturing	-7.8%	9.3%	-5.5%	16.4%	-10.8%	44.7%
High/Med-High Tech Manufacturing	-11.2%	26.6%	-7.2%	45.9%	-14.7%	70.9%
Chemicals and Chemical Products	-16.4%	15.4%	-8.4%	21.4%	-15.8%	71.0%
Machinery, Nec	-9.4%	21.4%	-4.0%	31.7%	-9.6%	61.2%
Electrical and Optical Equipment	-14.1%	43.8%	-10.4%	55.0%	-21.7%	81.2%
Transport Equipment	-6.3%	22.4%	-4.9%	59.4%	-12.6%	70.1%
Services	**-2.5%**	**4.9%**	**-2.3%**	**5.1%**	**-4.5%**	**18.6%**

Authors' elaboration based on WIOD

Analyzing the sectors separately yielded very similar results to those found in Korea. Only mining and agriculture did not present a positive net impact in all the developed countries analyzed. In all other sectors, especially the high-tech ones, exports impacted positively on output and compensated for the negative impact of the growth in imported inputs.

5. Discussion

This study analyzed the sources of Brazilian growth during the 2000s in comparison with other economies. The impacts of changes in countries' production structures and in demand absorption were investigated through structural decomposition analysis (SDA). Although this method has been widely applied to understanding the contribution of particular sources of demand to countries' growth patterns, these applications have not considered the substitution between domestic suppliers and imports. Thus, we extended the SDA method to provide a detailed investigation of the sources of national growth from a sectoral perspective because this substitution may have important consequences for long-term economic growth.

The empirical investigation suggests that the substitution of imported for national inputs is a key factor in SDA, assuming that the impact of technological change is underestimated if this substitution is not taken into account. Therefore, the extension of

SDA in this paper is very relevant to analyzing structural changes in countries' production chains.

From the results presented in this paper, it is possible to verify that global supply chains were significantly more integrated in the late 2000s than in the early 1990s. All the countries analyzed presented the substitution of imported inputs for domestic suppliers, and this fact was verified in almost every sector.

The substitution process, however, had positive impacts in many sectors in most of the countries studied, despite having negative impacts in some cases. The net impact for Brazil (considering also the impact of export growth in the sectoral output) was positive for mining and agriculture but was negative for high-tech sectors, especially for chemicals and electrical equipment. In the other countries analyzed, only the agriculture and mining sectors were negatively affected, whereas positive impacts were seen in all other sectors.

Thus, in Brazil, the potential for growth in demand to precipitate economic growth has declined in the most technologically advanced sectors but has increased in agriculture and mining, whereas the exact opposite is true in the other countries studied. Thereby, an important constraint to Brazil's long-term growth has emerged in the past decades, assuming that high-tech sectors are the ones that present higher increasing returns to scale, higher positive spillovers in production, and higher potential to boost productivity growth.

Finally, our findings show that China, Korea, and Germany were the countries most positively affected by the substitution. Although the substitution of imports for domestic suppliers contributed negatively to economic growth, this effect was significantly compensated for by the increase in exports in all sectors other than mining and agriculture. The results suggest that these countries benefited the most from the integration of global supply chains, whereas Brazil's high-tech production sector was not able to take advantage of the process.

6. Conclusion

The findings in this study have to be analyzed while considering that the sectoral structure of production and exports is relevant to explaining the long-term growth rates of countries. Taking into account that the production of technologically advanced goods is an important determinant of productivity gap reduction (Rodrik, 2013; Angeriz, McCombie, & Roberts, 2008) and that specialization in primary sectors may increase the technological gap in a country (Chief, 2013), we conclude that Brazil's specialization in agriculture and mining contributes negatively to the country's productivity growth. On the other hand, the specialization of China and Korea in high-tech activities is positive for these countries because it is important to reduce the productivity gap with the most advanced economies, such as the United States, Japan, and Germany.

Appendix A. Supplementary data Supplementary material related to this article can be found,in the online version,

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