Problemas del Desarrollo. Revista Latinoamericana de Economía, vol. 53, núm. 211, octubre-diciembre 2022.

The medium-high and high technological intensity sectors in Mexico and Brazil: a structural decomposition analysis between 2000-2014

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Fecha de recepción: 4 de octubre de 2021. Fecha de aceptación: 6 de mayo de 2022.

https://doi.org/10.22201/iiec.20078951e.2022.211.69845

Abstract. We develop a structural decomposition analysis (SDA) to identify the importance of mid-high and high technological intensity (MH&HT) manufacturing and services to the changes in gross output for Brazil and Mexico between 2000 and 2014. We break down the output changes in the composition and level of final demand, the production technique (technical coefficients), and the trade pattern (share of imports in the total supply of inputs and final goods). The results show that the MH&HT importance tends to be pro-cyclical in the two economies, increasing during periods of more remarkable economic growth (2000-2008 for Brazil and 2010-2014 for Mexico). This relation tends to be perceived for manufacturing and less so for services.

Key Words: Brazil; Mexico; structural decomposition analysis; input-output models.

Los sectores de intensidad tecnológica media y alta en México y Brasil: una descomposición estructural entre 2000-2014

Resumen. Se desarrolló un análisis de descomposición estructural (ADE) para identificar la importancia de la manufactura y los servicios de intensidad tecnológica media-alta y alta (MA&AT) a los cambios en el producto bruto de Brasil y de México entre 2000 y 2014. Se desglosan los cambios de producción en la composición y el nivel de la demanda final, la técnica de producción (coeficientes técnicos) y el patrón comercial (participación de las importaciones en la oferta total de insumos y bienes finales). Los resultados muestran que la importancia de MA&AT tiende a ser procíclica en las dos economías, aumentando durante los periodos de crecimiento económico más notable (2000-2008 para Brasil y 2010-2014 para México). Esta relación tiende a ser mayor para la manufactura y menor para los servicios.

Palabras clave: Brasil; México; análisis de descomposición estructural; modelos input-output.

Clasificación JEL: C67; O54; O14.

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1. Introduction

In the literature on economic development, accelerated production and growth trajectories are related to sectors with a greater capacity for technological diffusion. The focus has been exclusively on manufacturing; however, several studies have recently shown that business services have also contributed to stimulating productive activity in countries. In this paper, we develop a structural decomposition analysis (SDA) to identify the importance of the mid-high and high technological intensity (MH&HT) industries to the changes in gross output for Brazil and Mexico between 2000 and 2014.

We compare Mexico and Brazil because they are the biggest economies in Latin America. Together, they correspond to two-thirds of Latin America's gross domestic product (GDP) and are the two most populated countries in the region with significant domestic markets. Historically, from the point of view of economic development, the two countries share common issues. Between 1960 and 1980, they implemented import substitution processes, reaching similar levels of industrialization, as shown by Aroche-Reyes (2013). Since the 1990s, economic liberalization has changed their economic structure and led the two economies along different paths considering their growth and external insertion strategies. Mexico is included in North American Free Trade Agreement (NAFTA), and Brazil is part of the Southern Common Market (MERCOSUR).

To identify the differences between the MH&HT industries for the countries' gross output, we decompose the changes in the sectoral gross output according to three structural factors: level and type of final demand, the production technique, and the trade pattern. To do so, we use the World Input-Output Tables (WIOT, release 2016) and classify the sectors using the OECD technological intensity industry classification (Galindo-Rueda and Verger, 2016).

The general hypothesis is that there is a positive relationship between the importance of MH&HT and economic growth, which means that the higher the economic growth, the better the performance of the MH&HT industries. Also, we consider that other factors such as the reduction in the economy's complexity related to the technical coefficients and an increase in the proportion of imported inputs/final goods and services contribute to reducing the relevance of the MH&HT group.

Recent studies have compared Brazil and Mexico, such as Costa *et al.* (2018 and 2021). However, they analyze the complexity and integration in the Global Value Chains (GVCs) using qualitative input-output through networks. The results show a loss of complexity between 1995 and 2011 and that Brazil has a more complex structure than Mexico. However, they do not analyze the structural changes concerning the activity level and the sectors with greater technological intensity, neither the importance of these sectors to gross output growth.

This study's novelty is comparing the performance of MH&HT manufacturing and service industries in Brazil and Mexico based on a quantitative input-output model for 2000 and 2014. Although some studies have applied this method to Brazil[1] and Mexico[2] individually, none of them have compared these two countries. Furthermore, we propose a different way to deflate the Input-Output Tables (IOT). With this, we may find similarities and differences between countries that can be useful for economic policymaking.

Besides this introduction, this paper has four more sections. We discuss the importance of MH&HT sectors to economic growth in the second section. The third section presents the SDA and the data used. Then, we discuss the results of the SDA in the fourth section, followed by some final remarks.

2. MH&HT INDUSTRIES AND ECONOMIC GROWTH

Historically, one of the main subjects of study on economic development is industrialization because changes in the sectoral composition of the most productive sectors influence growth, the rate of capital accumulation, and economic development, as argued by Rowthorn and Ramaswamy (1999), Chenery and Taylor (1968), and Rostow (1960). According to Kaldorian tradition (Kaldor, 1966), manufacturing is the driver of economic growth and technical progress due to the potential for static and dynamic economies of scale in manufacturing production, higher income elasticity of demand for manufactured goods, and the potential for a catch-up. From Kaldor's second law (also known as the Kaldor-Verdoorn law), manufacturing output growth is positively related to labor productivity growth, and it has a spillover effect on labor productivity from the manufacturing industry to other sectors of the economy.

Recent studies by Haraguchi *et al.* (2017) as well as Felipe *et al.* (2019) have questioned whether manufacturing retains its importance in explaining countries' development levels. They conclude that having a more significant

1 For example, Magacho *et al.* (2018), Alves-Passoni (2019) and Sousa Filho *et al.* (2020).

2 See Murillo *et al.* (2018), Pérez and Peters (2019) and Pérez (2021).

share in employment and production in the manufacturing sector remains important for economic development. Su and Yao (2017) show that the manufacturing sector's role is even more critical for medium-income economies (in countries such as Brazil and Mexico) because it positively influences the rate of technological accumulation and stimulates other sectors, including services.

Regarding Brazil and Mexico, several studies show that the manufacturing industry has lost importance (deindustrialized). Many authors attribute this loss of significance to external events, such as globalization, verticalization, and fragmentation of production, but also due to domestic factors. For Brazil, Marcato and Ultremare (2018), Costa *et al.* (2021), and Alves-Passoni (2019) suggest that deindustrialization is related to the increase in the supply of imported goods in countries as a historical process of technological dependence, plus a result of the chronic appreciation of the local currency. For Mexico, it is related to the trade integration in the Mexican economy, in which NAFTA led to an increase in imported goods and specialization in activities with the low value-added generation, such as the "maquilas" (Calderón and Hernández (2016), Ramírez Sánchez *et al.* (2018), Palma (2019), and Fujii-Gambero and Cervantes-Martínez (2017)).

Nevertheless, in an era in which services are more connected with manufacturing industries, especially those related to business and innovation, these can also generate the beneficial effects reported in Kaldor's laws, traditionally only attributed to the manufacturing industry. In particular, Ciarli *et al.* (2012), Meliciani and Savona (2015), and López-González *et al.* (2019) show the importance of business and knowledge-intensive services associated with the backward/forward inter-industry linkages that these sectors have with manufacturing. These services can incorporate, process, accumulate and disseminate codified and implicit information and knowledge to other companies and sectors. Some studies have questioned whether services industries have this capacity in developing countries. Timmer and De Vries (2009) analyzed 19 countries in Asia and Latin America from 1950 to 2005 and found that increased market services productivity in the service sectors accelerates economic growth. Di Meglio *et al.* (2018) found that the productivity of the services was also important to positively explain aggregate productivity in countries in Latin America, sub-Saharan Africa, and Asia. Therefore, according to these authors, manufacturing and certain services can generate development opportunities for these countries.

However, not all manufacturing and service industries have the desirable qualities to generate the positive effects pointed out by Kaldor's law. For example, traditional manufacturing, natural resource processing industries, and domestic/household services have low technological intensity and income elasticities. Kaldor (1966) and Cornwall (1982) called the "technological sector" those industries with the most significant capacity to develop links and create technological diffusion through investment in research and development and product and process innovations.

3. METHODOLOGY

We base this study on an input-output quantitative model, analyzing the existing sectoral linkages related to all inputs needed for production (direct and indirect use in the production process) and the origin of final goods and services required by the economy. This section discusses the gross output structural decomposition methodology and the data used.

Structural decomposition analysis

From a general point of view, the structural decomposition method analyzes the change of an economic variable using a set of comparative static changes in the parameters in an IOT (Rose and Chen, 1991; Rose and Miernyk, 1989). This method decomposes the changes of several economic variables, but the most common are gross output, value-added, employment, and trade (imports and exports).

We start our decomposition from the definition of gross output in the input-output model (1), which is calculated as the multiplication of the inverse of Leontief $(\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A_d})^{-1})$ by the final domestic demand:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A_d})^{-1} \times \boldsymbol{f_d} \tag{1}$$

$$\boldsymbol{x} = \boldsymbol{L} \times \boldsymbol{f_d} \tag{2}$$

To see the impact of imports on the production structure, we will define domestic (intermediate and final) demand as a fraction of total demand, according to Oosterhaven and Van Der Linden (1997). In this way,

$$\boldsymbol{\Omega} = \boldsymbol{A_d} \times \boldsymbol{A^{-1}} \tag{3}$$

$$\boldsymbol{\mu} = \boldsymbol{f_d} \times \boldsymbol{f^{-1}} \tag{4}$$

where $\boldsymbol{\Omega}$ represents the share of imported technical coefficient concerning the technical coefficients for total (domestic plus imported) inputs ($\boldsymbol{A}$); and μ represents the share of imported final demand in the total final demand ($\boldsymbol{f}$). So, the domestic technical coefficients and the final domestic demand can be expressed as:

$$\boldsymbol{A_d} = \boldsymbol{\Omega} \otimes \boldsymbol{A_d} \tag{5}$$

$$\boldsymbol{f_d} = \boldsymbol{\widehat{\mu}f} \tag{6}$$

where $\otimes$ represents the element-wise Hadamard product.

Using the previous equations, we can express (1) as:

$$\boldsymbol{x} = [\boldsymbol{I} - \boldsymbol{\Omega} \otimes \boldsymbol{A_d}]^{-1} \times \boldsymbol{\widehat{\mu}f} \tag{7}$$

In the SDA, we analyze the changes ($\boldsymbol{\Delta x}$) of two periods in time, '0' ($\boldsymbol{x^0}$) the initial and '1' ($\boldsymbol{x^0}$) the final period, as follows:

$$\Delta \boldsymbol{x} = \boldsymbol{x^1} - \boldsymbol{x^0} \tag{8}$$

Putting together (2) and (8), we can express the changes of ($\boldsymbol{\Delta x}$) in terms of the changes in the Leontief matrix and final demand. So, we have:

$$\Delta \boldsymbol{x} = \boldsymbol{L^1 f_d^1} - \boldsymbol{L^0 f_d^0} \tag{9}$$

Due to the diversity of forms, each decomposition may assume we use the mean of the polar decomposition to calculate the changes, following Dietzenbacher and Los (1998). So the decomposition equation for two variables is (Miller and Blair, 2009):

$$\Delta \boldsymbol{x} = \left(\tfrac{1}{2}\right) \boldsymbol{\Delta L} \times \left(\boldsymbol{f_d^1} + \boldsymbol{f_d^0}\right) + \left(\tfrac{1}{2}\right) (\boldsymbol{L^1} + \boldsymbol{L^0}) \times \boldsymbol{\Delta f_d} \tag{10}$$

If we want the sectoral total, we must multiply each change by a summary vector $\boldsymbol{i'}$ (transposed column vector of ones):

$$\boldsymbol{i'}.\Delta \boldsymbol{x} = \boldsymbol{i'} \left[\left(\tfrac{1}{2}\right) \boldsymbol{\Delta L} \times \left(\boldsymbol{f_d^1} + \boldsymbol{f_d^0}\right) + \left(\tfrac{1}{2}\right) (\boldsymbol{L^1} + \boldsymbol{L^0}) \times \boldsymbol{\Delta f_d}\right] \tag{11}$$

To express the changes of $\boldsymbol{\Delta L}$ as changes at $\boldsymbol{\Delta A_d}$, we follow Oosterhaven and Van Der Linden (1997) and Miller and Blair (2009) and use hierarchical SDA:

$$\Delta \boldsymbol{L} \;=\; \boldsymbol{L^1} \Delta \boldsymbol{A_d} \boldsymbol{L^0} \tag{12}$$

If we decompose the changes of $\boldsymbol{A_d}$ based on (5), which is made up of the multiplication of two elements, we have:

$$\Delta \boldsymbol{A_d} \;= \left(\tfrac{1}{2}\right) \boldsymbol{\Delta\Omega} \otimes (\boldsymbol{A^1} + \boldsymbol{A^0}) + \left(\tfrac{1}{2}\right) (\boldsymbol{\Omega^1} + \boldsymbol{\Omega^0}) \times \boldsymbol{\Delta A} \tag{13}$$

Putting together (12) and (13), the changes of Leontief ($\boldsymbol{\Delta L}$) related to the changes in gross output ($\boldsymbol{\Delta x}$) can be expressed by the variations in the share of imported intermediate inputs ($\boldsymbol{\Delta\Omega}$) and the total inputs used for the production ($\boldsymbol{\Delta A}$):

$$\Delta \boldsymbol{L} \;=\; \boldsymbol{L^1} \left[= \left(\tfrac{1}{2}\right) \boldsymbol{\Delta\Omega} \otimes \left(\boldsymbol{A_d^1} + \boldsymbol{A_d^0}\right) + \left(\tfrac{1}{2}\right) (\boldsymbol{\Omega^1} + \boldsymbol{\Omega^0}) \times \boldsymbol{\Delta A_d}\right] \boldsymbol{L^0} \tag{14}$$

Now, desegregating $\boldsymbol{\Delta f_d}$ considering (6), we have:

$$\Delta \boldsymbol{f_d} \;= \left(\tfrac{1}{2}\right) \boldsymbol{\Delta\hat{\mu}} \times (\boldsymbol{f^1} + \boldsymbol{f^0}) + \left(\tfrac{1}{2}\right) (\boldsymbol{\hat{\mu}^1} + \boldsymbol{\hat{\mu}^0}) \times \boldsymbol{\Delta f} \tag{15}$$

Inserting (14) and (15) in (10), the decomposition of gross output can be expressed by the changes in four variables: $\boldsymbol{\Omega}$, $\boldsymbol{A}$, $\boldsymbol{\mu}$ and $\boldsymbol{f}$. Rearranging the changes, we can attribute the changes in the gross output to three sources: trade pattern, technology, and demand:

Trade pattern-intermediate

$$\Delta \boldsymbol{x} \;= \left(\frac{1}{2}\right) \left\{ \left(\frac{1}{2}\right) [\boldsymbol{\Delta\Omega} \otimes (\boldsymbol{A^1} + \boldsymbol{A^0})] \right\} (\boldsymbol{f_d^1} + \boldsymbol{f_d^0}) \tag{16}$$

Trade pattern-final demand

$$\left(\frac{1}{2}\right) (\boldsymbol{L^1} + \boldsymbol{L^0}) \left[\left(\frac{1}{2}\right) \boldsymbol{\Delta\hat{\mu}} \times (\boldsymbol{f^1} + \boldsymbol{f^0}) \right] \tag{17}$$

Technology

$$\left(\frac{1}{2}\right)\left\{\left(\frac{1}{2}\right)[(\boldsymbol{\Omega}^{1}+\boldsymbol{\Omega}^{0})\otimes\boldsymbol{\Delta A}]\right\}(\boldsymbol{f}_{d}^{1}+\boldsymbol{f}_{d}^{0}) \tag{18}$$

Final demand

$$\left(\frac{1}{2}\right)(\boldsymbol{L}^{1}+\boldsymbol{L}^{0})\left[\left(\frac{1}{2}\right)(\widehat{\boldsymbol{\mu}}^{1}+\widehat{\boldsymbol{\mu}}^{0})\times\boldsymbol{\Delta f}\right] \tag{19}$$

The changes in the trade pattern are related to the share of domestic inputs ($\boldsymbol{\Delta\Omega}$) or final demand ($\boldsymbol{\Delta\widehat{\mu}}$) in total supply. If its contribution is negative/positive, there was import substitution/penetration, which means the country uses less/more domestic supply to satisfy the total demand in period one compared to period zero. We also present the changes in $\boldsymbol{\mu}$ for each final demand component (consumption ($\boldsymbol{\mu_c}$), gross fixed capital formation ($\boldsymbol{\mu_k}$), government expenditures ($\boldsymbol{\mu_g}$), and exports ($\boldsymbol{\mu_e}$)).

For technology, the changes are related to $\boldsymbol{\Delta A}$. If it is positive/negative, the whole economy (using domestic plus imported goods) uses more/fewer intermediate inputs to produce. We also show the contributions for each final demand component (consumption ($\boldsymbol{c}$), gross fixed capital formation ($\boldsymbol{k}$), government expenditures ($\boldsymbol{g}$), and exports ($\boldsymbol{e}$)). If this contribution of total final demand ($\boldsymbol{\Delta f}$) or its components is positive/negative, the demand increased/decreased in period one compared to period zero. As the inventories in the national accounts have no economic significance, an empirical adjustment is made to calculate a new final demand, considering all demand components, excluding inventories. Thus, we show the changes in inventories separately to keep the consistency in the model.

Data

We use the WIOT (revision 2016) between 2000 and 2014 (Timmer *et al.*, 2016). These data were preferred over the IOTs published by each country's System of National Accounts (SNA) because they have different structures. The Brazilian SNA is published considering chained indices, while Mexico publishes data on a fixed basis. The difference in each SNA makes it impossible to directly compare the two series since different analysis methods are needed, as discussed by UN (2009), Balk and Reich (2008) and Reich (2008). Although there is an effort in the publication of WIOT to make the different databases compatible, it is almost impossible to change the original data structure. So, this must affect the observed results. Therefore, the SDA results for Brazil (with SNA based on chained price indices) have more relative price variations than Mexico (fixed basis).

Since we are dealing with different points in time, it is necessary to deflate the series to remove the effect of inflation. We follow Reich's (2008) suggestion and deflate all the elements of the WIOT using the gross output deflator, considering 2000 as the base year. This method is the most appropriate when dealing with chained indices since it removes the effect of inflation and preserves the additivity property in the chained IOT (published at current prices and those of the previous year). We prefer this method because it excludes the inflation effect but maintains the relative price's structure and generates fewer distortions if in the presence of imprecise sectoral price indices.

Sectoral classification

We use the most recent OECD industry classification which is based on technological intensity (Galindo-Rueda and Verger, 2016) for two digits of Rev. 4 of the International Standard Industrial Classification (ISIC) of all economic activities. It classifies agricultural, manufacturing, and service industries according to the average sectoral expenditures realized in R&D into five categories: high, medium-high, medium, medium-low, and low technological intensity.[3] As we will focus our analysis on manufacturing and service industries with MH&HT, we present a detailed description in table 1.

Using this classification is an extrapolation for Brazil and Mexico, but it can show the performance of the technological sectors (according to the technological frontier) in these countries. They represent the most sophisticated activities in terms of technology and organization of the production process, including high-tech and durable consumer industries (such as automobiles and electronics). The insertion of medium-high technology intensity industries in this classification is essential because they have a high demand elasticity, a prominent economic scale in production, a segmented market, and few competitors. Therefore, the competition pattern is defined by the capacity to innovate (in process or product). These sectors also have specific government support plans and competition regulations, differentiating them from other industrial groups, supporting technological risk, guaranteeing intellectual property rights, and selective protection.

3 In case of interest, the correspondence table can be requested from the author.

Table 1. WIOT industries of MH&HT according to OECD's classification

OECD groups	*Industry*	*Description WIOD*
Medium-high	Manufacturing (MHT-M)	Manufacture of chemicals and chemical products
		Manufacture of electrical equipment
		Manufacture of machinery and equipment n.e.c.
		Manufacture of other transport equipment
	Service (MHT-S)	Publishing activities
		Motion picture, video, and television program production, sound recording and music publishing activities; programming and broadcasting activities
		Computer programming, consultancy, and related activities; information service activities
High	Manufacturing (HT-M)	Manufacture of basic pharmaceutical products and pharmaceutical preparations
		Manufacture of computer, electronic and optical products
	Services (HT-S)	Scientific research and development

Source: own elaboration based on Galindo-Rueda and Verger (2016) and Timmer *et al.* (2016).

4. Results

Before analyzing the SDA, using the data presented in table 2, we first discuss the structure and evolution of the sectoral composition of gross output. Together, MH&HT industries represented a larger share of gross output in Mexico compared to Brazil. These sectors, in the aggregate, corresponded to around 18.3% of Mexican production in 2000, falling to 16% in 2014. The industries that have a higher share are "Manufacture of motor vehicles, trailers and semi-trailers" (5% on average in total gross output between 2000 and 2014) and "Manufacture of computer, electronic and optical products" (4%). The first mentioned sector is related to the automobile assembly sector, the "maquiladoras", which have greater importance in Mexico due to the production and sales agreements with the United States within NAFTA. This sector is the only one among the MH&HT group that has increased its share of the total

Table 2. Sectoral share of gross output and growth rates: 2000-2014, 2000-2008, and 2010-2014

Years	2000	2008	2010	2014	2000-2014	2000-2008	2010-2014
Mexico							
Variable	Share				Growth		
MHT-M	11.62	10.83	10.59	10.20	-12.22	-6.75	-3.72
MHT-S	0.43	0.48	0.47	0.48	9.62	11.51	0.28
HT-M	5.89	5.37	5.01	4.89	-16.89	-8.79	-2.33
HT-S	0.37	0.40	0.41	0.42	12.46	6.43	3.88
Brazil							
Variable	Share				Growth		
MHT-M	8.94	10.68	9.31	8.27	-7.43	19.54	-11.12
MHT-S	1.91	1.74	1.80	1.77	-7.22	-9.03	-1.57
HT-M	1.98	1.81	1.59	1.47	-26.06	-8.75	-8.05
HT-S	0.88	0.84	0.88	0.91	3.61	-4.73	3.89

Source: own elaboration based on WIOT database.

gross output, especially since 2010.[4] According to Carrillo and Hernández (2020), after the 2008 crisis, the USA's multinational automotive firms changed their strategy, transferring various operations and segments to Mexico, such as the premium categories. This strategy increased the gross fixed capital formation (GFCF), but the exports were the most affected demand component.

Although the MHT-S and the HT-S grew between 2000 and 2014, their share was too small (0.5%) to significantly influence the gross output in Mexico. Nonetheless, Carrillo-Carrillo and Alcalde-Heras (2020) and Ruiz and Demmler (2019) show that they have positively impacted the economy's productivity, especially in the manufacturing sectors that require these services.

In Brazil, the MHT&HT industries (services and manufacturing) share fell from 13.7 to 12.4% between 2000 and 2014. MHT-M and MHT-S shares fall by approximately 7%, mainly in chemical products and electrical equipment. The HT-M share decreased 26% (see table 2), related to the degrowth of

4 Between 2000 and 2009 there is a downward trend (-24%), which is reversed from 2010 when this sector grew 32% until 2014.

"Manufacture of basic pharmaceutical products and pharmaceutical preparations" and "Manufacture of computer, electronic and optical products".

Compared to the Mexican economy, services represent a more significant part of the MH&HT group in Brazil, with a share of around 20%. The MHT-S share fell by approximately 7%, and the only sector that saw an increase was HT-S, which grew almost 4% but represented a small share of total gross output (0.9%).[5] Considering the relative importance of these sectors, Santos (2019) and Giovanini and Arend (2019) argue that services intensive in technology had positive effects on the economy from the 2000s onwards. However, Giovanini and Arend (2019) and Lugli *et al.* (2015) mention that the symbiosis between the service and manufacturing sectors depends on the growth of both sectors, which has declined in recent years, especially since 2014, with the slowdown of the Brazilian growth.[6]

The first conclusion is that the MHT&HT share decreased in the total gross output in Mexico and Brazil between 2000 and 2014 and the sub-periods. This result was related mainly to the manufacturing sectors, and growth in service industries was insufficient to offset the fall.[7] However, we must note that the observed change in the gross output of manufacturing industries between sub-periods behaved differently in the two countries. While in Mexico, it is concentrated between 2000 and 2008, in Brazil, this occurs more between 2010-and 2014. In the case of MHT&HT services, there is no generalized decline, and we do not observe a pattern, considering the growth path in the sub-periods.

To understand which factors are associated with changes in gross output, we analyze the SDA. We first show the SDA for the total gross output for Mexico and Brazil from 2000 to 2014 and two sub-periods: 2000-2008 and 2010-2014 (see table 4). The annual rates are also presented in this table because the periods have different numbers of years. Also, we show three more tables to understand the SDA. Table 4 shows the sectoral contribution to the changes in gross output, both in percentage points and shares. Table 5 (Mexico) and table 6 (Brazil) show the sources of change to which this shift in the importance of the MH&HT group is related.

5 HT-S has a positive effect only between 2010-2014.

6 As Alves-Passoni and Blancas (2021) show, the Brazilian economy slowed down from 2014, with growth rates in 2014 of 0.5%, 2015 of 3.5%, and 2016 of 3.3%. Despite resuming positive growth from 2017 until 2020, it has been negligible since then.

7 Corroborating the findings of Lugli *et al.* (2015) in the Brazilian case.

Between 2000 and 2014, Brazil grew at a higher annual rate (3%) than Mexico (2.4%), as shown in table 3. The MH&HT group represents 9 and 10% of gross output in Brazil and Mexico (see table 4). Their contribution is less than the groups' share of the gross output (as shown in table 2), indicating that these sectors grew slower than the average economy. Although most sectors in the group of MH&HT have a positive contribution to growth in both countries (see table 4), the only industry that contributed negatively was HT-M in Mexico[8] (see table 5).

The final demand is the source of change that most contributed to the gross output growth between 2000 and 2014, with 106 and 110% growth for Brazil and Mexico, respectively (equivalent to 65.5 p.p. and 62 p.p, table 5 and 6). In this type of decomposition, it is natural that the final demand corresponds to the most significant share since it has the most considerable magnitude in terms of monetary units. In Mexico, exports and household consumption are the most critical final demand components of gross output growth (see table 5) between 2000 and 2014. For Brazil, household consumption and the GFCF represent the largest share of the demand contribution (see table 6).

Given the contributions of $\boldsymbol{\Omega}$ and $\boldsymbol{\mu}$ for both countries, we observe an import penetration for intermediate and final demand between 2000 and 2014 (see table 3). This result implies that imports grew more than the total supply of goods and services. As shown in table 3, the contributions of intermediate and final trade patterns were -5.9 p.p. and -5.3 p.p. to gross output, representing 14 and 13% of Mexico's accumulated growth of 42.5% between 2000 and 2014. Since household consumption and GFCF represent the largest share of total imports, it contributes the most to the import penetration of Mexico.

In Brazil, the contribution of $\boldsymbol{\Omega}$ and $\boldsymbol{\mu}$ correspond to -3.58 p.p. and -1.1 p.p., equivalent to 6 and 2% of 56.6% growth between 2000 and 2014 (see table 3). This negative contribution is related to consumption, government, and exports. The GFCF contribution is positive, indicating that more domestic goods are being used.[9]

8 Both industries in this group had a negative contribution to the gross output.

9 As mentioned by Aroche-Reyes (2021), this may indicate two phenomena: a reduction in the complexity of the economy and a more efficient use of inputs. Unfortunately, the absence of sectoral capital stock for Brazil makes a deeper analysis difficult to identify whether this process was related to an increase in productivity or why the economy reduced sectoral connections. However, several studies, such as Costa *et al.* (2021), point out that this reduction is related to a reduction in Brazilian economic complexity.

Table 3. Totals of the structural decomposition analysis for Brazil and Mexico, 2000-2014, and sub-periods

Unity of measure							*p.p.*							*%*
Sources	*Trade pattern*						*Technology*	*Total final demand*					*Inventories*	*Gross output*
Variables	$\Delta\Omega$	$\Delta\mu_c$	$\Delta\mu_k$	$\Delta\mu_g$	$\Delta\mu_e$	$\Delta\mu_f$	ΔA	Δc	Δk	Δg	Δe	Δf	Δs	Δx
MEXICO														
Accumulated														
2000-2014	-5.89	-3.09	-1.21	-0.18	-0.83	-5.30	4.03	23.76	6.31	5.86	14.78	50.71	-1.01	42.54
2000-2008	-5.02	-2.86	-1.66	-0.26	-1.03	-5.81	4.33	17.43	5.67	2.93	7.45	33.48	-0.46	26.52
2010-2014	-0.43	-0.71	0.13	-0.03	-0.08	-0.68	0.35	6.05	1.79	1.56	4.07	13.47	-0.23	12.47
Yearly														
2000-2014	-0.31	-0.06	0.01	-0.01	0.00	-0.06	0.21	1.66	0.77	0.56	0.48	3.46	-0.05	3.25
2000-2008	-0.50	-0.04	0.05	-0.01	-0.01	-0.01	0.43	1.11	0.67	0.40	0.87	3.04	-0.05	2.91
2010-2014	-0.08	0.04	0.00	0.04	0.03	0.11	0.07	1.75	0.43	0.54	0.42	3.14	-0.04	3.19
BRAZIL														
Accumulated														
2000-2014	-3.58	-1.13	0.21	-0.10	-0.06	-1.07	-0.65	29.89	13.77	10.00	8.56	62.22	-0.32	56.59
2000-2008	-1.62	-0.39	0.48	-0.11	-0.09	-0.12	1.29	10.63	6.46	3.81	8.33	29.23	1.43	30.22
2010-2014	-1.02	0.18	0.02	0.19	0.15	0.53	-0.10	8.18	2.02	2.50	1.94	14.64	-0.30	13.75
Yearly														
2000-2014	-0.19	-0.06	0.01	-0.01	0.00	-0.06	-0.03	1.60	0.74	0.54	0.46	3.34	-0.02	3.03
2000-2008	-0.16	-0.04	0.05	-0.01	-0.01	-0.01	0.13	1.05	0.64	0.38	0.82	2.88	0.14	2.98
2010-2014	-0.19	0.03	0.00	0.04	0.03	0.10	-0.02	1.55	0.38	0.47	0.37	2.78	-0.06	2.61

Source: own elaboration based on WIOT database.

Table 4. Sectoral share of contribution to gross output and growth rates: 2000-2014, 2000-2008, and 2010-2014

Country	*Mexico*						*Brazil*					
Variable	*Contribution (p.p.)*			*Share (%)*			*Contribution (p.p.)*			*Share (%)*		
Period	*2000-2014*	*2000-2008*	*2010-2014*	*2000-2014*	*2000-2008*	*2010-2014*	*2000-2014*	*2000-2008*	*2010-2014*	*2000-2014*	*2000-2008*	*2010-2014*
MHT-M	0.28	0.10	0.55	11.76	3.78	23.31	0.22	0.49	0.02	7.10	16.46	0.75
MHT-S	0.01	0.01	0.01	0.37	0.41	0.21	0.05	0.03	0.04	1.53	1.17	1.57
HT-M	-0.06	-0.02	-0.07	-2.32	-0.76	-2.77	0.02	0.04	0.01	0.55	1.24	0.53
HT-S	0.01	0.01	0.01	0.40	0.33	0.52	0.03	0.02	0.03	0.97	0.70	1.16
Total	2.39	2.65	2.38	10.21	3.76	21.27	3.03	2.98	2.61	10.15	19.57	4.01

Source: own elaboration based on WIOT database.

Table 5. Shares of the sectoral contribution to the gross output according to the source of change: Mexico, 2000-2014 and sub-periods

Changes	*Trade pattern*						*Technology*	*Total final demand*					*Inventories*	*Gross output changes*
Variables	$\Delta\Omega$	$\Delta\mu_c$	$\Delta\mu_k$	$\Delta\mu_g$	$\Delta\mu_e$	$\Delta\mu_f$	ΔA	Δc	Δk	Δg	Δe	Δf	Δs	Δx
2000-2014														
MHT-M	-25.02	-3.73	-5.61	-0.04	-4.79	-14.17	13.27	32.01	7.06	1.06	98.70	138.82	-12.91	100.00
MHT-S	-0.50	3.35	-0.79	-0.02	-0.52	2.02	-27.54	103.13	12.13	15.07	-4.64	125.68	0.34	100.00
HT-M*	84.50	21.65	14.69	0.32	12.55	49.22	21.31	0.50	1.11	-6.99	-77.74	-83.12	28.10	100.00
HT-S	41.81	-6.32	-2.03	43.24	-1.35	33.54	-81.33	61.44	7.17	16.64	22.43	107.68	-1.71	100.00
MH&HT	**-46.37**	**-9.34**	**-9.90**	**1.58**	**-8.44**	**-26.10**	**6.25**	**42.90**	**8.59**	**4.01**	**132.01**	**187.51**	**-21.30**	**100.00**
2000-2008														
MHT-M	-131.02	-26.23	-47.61	-0.27	-27.85	-101.97	31.56	85.17	5.71	2.80	212.51	306.18	-4.75	100.00
MHT-S	-2.55	-3.38	-1.79	-0.42	-1.05	-6.65	-7.82	106.56	10.06	11.75	-10.82	117.55	-0.53	100.00

HT-M*	326.96	63.10	64.19	2.90	87.67	217.86	10.96	-81.05	5.35	-24.20	-380.35	-480.25	24.48	100.00
HT-S	85.50	-12.08	-4.43	76.75	-3.09	57.15	-163.26	89.79	8.08	8.01	17.48	123.36	-2.75	100.00
MH&HT	**-190.58**	**-40.54**	**-61.42**	**5.79**	**-46.09**	**-142.27**	**14.43**	**121.45**	**6.46**	**9.68**	**290.85**	**428.44**	**-10.02**	**100.00**
2010-2014														
MHT-M	3.51	-0.29	3.78	-0.01	-0.73	2.75	10.25	23.16	8.07	0.40	59.65	91.28	-7.79	100.00
MHT-S	-1.36	6.32	0.93	-0.40	-0.19	6.65	-70.43	102.15	27.53	23.33	11.10	164.11	1.03	100.00
HT-M*	-17.41	8.81	-4.85	0.05	2.90	6.93	21.84	17.68	-0.46	-3.14	47.88	61.96	26.68	100.00
HT-S	-8.82	-3.24	0.83	-0.49	-0.31	-3.21	30.77	29.39	8.15	27.92	16.44	81.89	-0.63	100.00
MH&HT	**5.88**	**-1.49**	**4.80**	**-0.03**	**-1.19**	**2.09**	**8.45**	**24.81**	**9.38**	**1.77**	**59.64**	**95.59**	**-12.01**	**100.00**

Note: each column sums up 100% of the changes in the contributions of each sector to the total gross output; *since the contribution of this sector is negative, the effects should be interpreted in the opposite way.

Source: own elaboration based on WIOT database.

Table 6. Shares of the sectoral contribution to the gross output according to the source of change: Brazil, 2000-2014 and sub-periods

Changes	*Trade pattern*						*Technology*	*Total final demand*					*Inventories*	*Gross output changes*
Variables	$\Delta\Omega$	$\Delta\mu_c$	$\Delta\mu_k$	$\Delta\mu_g$	$\Delta\mu_e$	$\Delta\mu_f$	ΔA	Δc	Δk	Δg	Δe	Δf	Δs	Δx
2000-2014														
MHT-M	-18.59	-0.54	0.36	-0.04	-0.21	-0.44	-2.10	52.23	48.02	2.38	17.63	120.26	0.87	100.00
MHT-S	-10.14	-4.82	-2.22	-0.19	-0.07	-7.30	-14.59	35.78	65.97	19.62	10.58	131.95	0.09	100.00
HT-M	-38.78	-39.54	72.53	-2.87	-0.32	29.80	-36.86	119.25	39.15	16.74	-47.81	127.33	18.50	100.00
HT-S	-6.49	-2.81	0.56	-0.17	-0.10	-2.52	10.19	54.50	17.19	13.50	13.85	99.03	-0.21	100.00
MH&HT	**-17.26**	**-3.53**	**3.92**	**-0.23**	**-0.18**	**-0.02**	**-4.70**	**53.62**	**47.29**	**6.82**	**12.64**	**120.37**	**1.61**	**100.00**
2000-2008														
MHT-M	-6.19	1.02	3.96	-0.03	-0.30	4.66	7.37	26.44	35.94	0.84	24.73	87.94	6.21	100.00
MHT-S	-12.57	-5.80	-1.67	-0.54	-0.24	-8.25	-41.89	39.30	79.82	18.87	21.93	159.92	2.79	100.00

HT-M	7.22	-12.63	36.31	-0.84	-0.54	22.30	-6.71	47.26	18.55	5.12	-7.46	63.48	13.71	100.00
HT-S	-8.35	-2.80	2.36	-0.41	-0.36	-1.21	-16.62	53.06	23.49	12.96	31.17	120.68	5.50	100.00
MH&HT	**-5.80**	**-0.38**	**5.61**	**-0.12**	**-0.31**	**4.80**	**2.69**	**29.47**	**37.00**	**2.62**	**22.76**	**91.86**	**6.46**	**100.00**
2010-2014														
MHT-M	-429.03	25.80	-66.53	1.27	18.82	-20.63	48.47	339.07	2.48	21.55	108.94	472.03	29.16	100.00
MHT-S	2.05	0.74	1.01	1.36	0.66	3.77	-0.29	13.20	52.95	18.57	9.51	94.23	0.24	100.00
HT-M	-83.53	-25.34	15.98	-2.60	2.10	-9.86	-20.93	174.35	41.12	13.78	-31.46	197.80	16.52	100.00
HT-S	0.76	0.45	-0.39	0.81	0.81	1.68	23.73	43.50	6.50	11.93	13.19	75.12	-1.29	100.00
MH&HT	**-89.94**	**1.85**	**-9.97**	**0.66**	**4.27**	**-3.19**	**13.01**	**104.08**	**28.50**	**16.56**	**23.63**	**172.77**	**7.34**	**100.00**

Note: each column sums 100% of the changes in the contributions of each sector to the total gross output.

Source: own elaboration based on WIOT database.

What stands out here is the significant role of the trade pattern as a factor that reduced the gross output by 26% in Mexico compared to 6% in Brazil between 2000 and 2014. This result demonstrates the greater importance of imports for the productive structure in the Mexican economy than in the Brazilian one. However, for both countries, penetration represents a more significant negative contribution between 2000 and 2008 compared to 2010 and 2014.

There are different movements for each country if we consider the contribution of $\boldsymbol{A}$ to the gross output (see table 3). For Mexico, changes in technical coefficients positively impacted the growth in the gross production, contributing approximately 7% (4.03 p.p.). It indicates an increase in the total production inputs sectoral relationship. However, the contribution of $\boldsymbol{\Omega}$ is more remarkable than $\boldsymbol{A}$, indicating that the increase in linkages came from imports. In other words, this suggests that domestic producers could not take advantage of the increase in sectorial production relations to offer more domestic inputs.

In Brazil, between 2000 and 2014, there was a reduction in the sectoral ratio of total production inputs, negatively contributing to the gross output by 1% (see table 3). Since the total (direct and indirect) linkages decreased, the economy needed fewer inputs to produce goods.[10] This drop was particularly associated with medium-low technological intensity manufacturing. All industries with MH&HT contributed negatively to the gross output growth (see table 6).

After an overview of the period (2000-2014), we highlight some differences between the two analyzed sub-periods: 2000-2008 and 2010-2014. The reason for comparing the two sub-periods is to see whether the behavior of the sectors has changed over time. Alves-Passoni and Blancas (2021) show that Brazil grew the most between 2003 and 2008, while Mexico had the most remarkable growth between 2011 and 2014. The Brazilian growth in this period is associated with a “developmental” strategy of expanding productive activity based on direct government intervention through fiscal spending and an income transfer policy. On the other hand, the growth in Mexico was related to the export sector, connected with the incentives given by the Mexican government (tax and exchange devaluation) and the increase in the demand for Mexican exports of manufactured products by the USA.

10 However, this result seems to have an effect on relative prices. By making a decomposition for Brazil between 2010-2014 that considers relative prices from a different approach, Alves-Passoni (2019) demonstrates an import penetration for this component of demand.

Even though some sectors, especially MHT-M and HT-M, have lost their share of gross output (see table 2) in both countries, their contributions have not always been negative (see table 4). Only the HT-M sector contributed negatively in the three analyzed periods for Mexico, explained primarily by the increase in the proportion of imported inputs in its intermediate and final demand (see table 5). On the demand side, this is also related to the fall in the GFCF in this sector. Despite the positive contributions of these sectors in Brazil (see table 4), their importance decline is connected with the slowdown in economic growth. On the other hand, the services sector increased its relative importance (see table 5), positively contributing to technology and consuming a smaller proportion of imported inputs, goods, and services (see table 6).

In Mexico, the MH&HT group contributed a larger share to the gross value growth between 2010 and 2014 (21.5%) compared to 2000-2008 (4%), as shown in table 5. The opposite occurred in Brazil, which between 2000 and 2008 contributed 20%, while in the second period corresponded only 4% (see table 6). The MHT-M group had the most significant contribution in both cases and was almost entirely related to the "Manufacture of motor vehicles, trailers, and semi-trailers". Another sector of great importance in Brazil is the "Manufacture of machinery and equipment n.e.c.".

As we see in table 3, exports and consumption mainly explain the changes in the gross output in Mexico and household consumption and GFCF for Brazil for both sub-periods (2000-2008 and 2010-2014). Therefore, the MH&HT group will be more important in explaining gross output changes when exports and consumption grow faster in the Mexican case. Similarly, this will occur when consumption and GFCF grow more in Brazil. This result corroborates the findings of Alves-Passoni and Blancas (2021) that the external sector is more important for the Mexican economy, while the domestic sources of change explain Brazilian growth.

However, something familiar to both countries is a negative contribution to gross output growth associated with HT-M exports (see table 5 for Mexico and table 6 for Brazil). This result demonstrates that exports of more sophisticated goods, generally associated with greater value-added and technological incorporation, decreased in both sub-periods. Based on it, we must question the type of international insertion that countries carry out, especially considering the destination of exports. Torracca (2017) argues that Brazil exports fewer products of high technological intensity due to the loss of market share of Brazilian exports in MERCOSUR.

In Mexico, the import penetration of intermediate and final imports observed in 2000-2014 concentrates its growth between 2000 and 2008 (the negative contribution corresponds to 332% of the changes in the sector, table 3). It focuses on intermediate goods, mainly related to the MHT-M industry, which contains the "maquila" sector (see table 5). In this MHT-M sector, there is also an import penetration for final demand components related to GFCF and exports. As this sector represents the majority of the total MH&HT for Mexico proportionally (see table 2), it is crucial to determine the group's influence on the economy.

For the Brazilian case, the contribution of $\boldsymbol{A}$ indicates that more inputs were required in the two sub-periods. Between 2000 and 2008, an exchange rate appreciation may have led to an increase in intermediate inputs[11] domestically. This result corroborates the findings in Magacho *et al.* (2018)[12] between 1995-2008 and Sousa Filho *et al.* (2020) from 2000-2005 and 2010-2015.[13] However, between 2010 and 2014, the imported penetration was more pronounced. Added to the demand deceleration, this also corroborates the loss of importance of the MH&HT group between 2010 and 2014 (see table 6).

Regarding technological change, there is a positive contribution to gross output in Mexico for the MH&MT group in both sub-periods (see table 5), mainly related to MHT-M. The other sectors had a reduction in linkages.[14] However, in the Brazilian case, it is only possible to observe an increase in relations between 2000 and 2008 (see table 5). Interestingly, only the MHT-M positively affected this sub-period, which predominated against the negative contribution to the MHT-S, HT-M sectors, and HT-S.

5. Final remarks

The main conclusion is that the importance of the MH&HT group, as seen using SDA, tends to be pro-cyclical in both economies, which means that it tends to increase when the economic growth is higher and reduce when there is a slowdown. The result corroborates the hypothesis raised throughout this work. However, the importance of MH&HT is more associated with the growth of the final demand component, whose production is more related to this

11 Due to the changes of relative prices in the period because of the changes of exchange rate and domestic prices, this result should be analyzed carefully. For the changes of the Brazilian relative prices, see Alves-Passoni (2019).

12 They use data from WIOT, version 2013.

13 They use data from the Brazilian SNA, reference 2000 and 2010.

14 Between them, only HT-S had a positive effect between 2010-2014.

group of sectors. The MH&HT group in Brazil showed the most significant importance between 2000 and 2008, when household consumption, GFCF, and the economy had the highest growth. In Mexico, while the production grew more between 2000 and 2008, the MH&HT group represented a more significant portion of the gross production value between 2010 and 2014.[15] The second period's growth is mainly associated with exports, the demand component that requires the most from the MH&HT group.

This pro-cyclical behavior is mainly associated with manufacturing medium-high technology intensity for both countries. In the case of services, they positively affect output growth, but they are small and contribute in a minor way to the entire economy (the MHT-S and HT-S are more important in Brazil compared to Mexico). However, the input-output model cannot measure the indirect effects that services may have on the productivity of the manufacturing sectors and thus on the entire economy.

From a theoretical point of view, this result corroborates what is expected by the Kaldorian tradition, where there is a positive relationship between the growth of the components of capital accumulation (Brazil) and exports (Mexico). Furthermore, it is also possible to relate it to the connection between the growth rate and productivity, as described by the Kaldor-Verdoorn law.

Another significant result is that the MH&HT group trade pattern has been more dependent on imported inputs to supply the production process and final demand to fulfill the total supply. This result is more remarkable for Mexico (mostly related to MHT-M), but it is also valid for Brazil (especially for the HT-M sector). Concerning technology, the technical coefficients show a positive contribution of these factors to gross output growth, especially in the periods of highest growth. However, from the point of view of the domestic technical coefficients, there is a reduction in the linkages in Mexico and Brazil since the negative contribution of the intermediate trade pattern offsets the contribution of the total technical coefficients. This means that the increase in sectoral interrelations originates from imported inputs, demonstrating that the local economy cannot absorb the generation of connections created in the period.

We observed that the manufacturing sectors with high technological intensity (pharmaceutical and electronic products) had lost importance in terms

15 Although exports play the role in increasing the participation of this group of sectors, several studies indicate that the capacity to generate added value/employment for this component of final demand is low. See Fujii-Gambero and Cervantes-Martínez (2017) and Murillo *et al*. (2018).

of exports, indicating a loss of these sectors in the external insertion of these countries. Although medium-high manufacturing has increased its exports, this has happened in activities with lesser capacity to generate added value, such as motor vehicles, trailers, semi-trailers sectors (most important for Mexico), and chemicals.

The results discussed in this work have some limitations. Despite being widely used, the construction of international input-output databases and the technological intensity classification involves simplifying hypotheses that can contribute to biased results. The categorization of industries may not represent the technology flows in developing countries, but still, there are some spillover benefits from these sectors to the economy. In the database case, the problem is related to the changes in relative prices present within the input-output system.

Given the results found in this work, for the MH&HT group to play a more predominant role in the Mexican and Brazilian economies, macroeconomic policies that favor a sustainable growth path over time are needed first. They must be linked to industrial and innovation policies that favor national competitiveness, and these should reduce dependence on imported inputs and final goods and increase domestic producers' intersectoral relationships. These policies should advance and not only defend the current structure of the national industry through traditional industrial policy mechanisms (devaluations, exchange rate devaluations, increase in import tariffs, subsidized interest rates). The industrial policies must be transversal (Andreoni *et al.*, 2019) because they create an overall technological development structure through key technologies per a knowledge base. They can be sector-oriented, but the most significant advantage is exploring the synergy between all economic sectors, manufacturing or services.

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