



**A critical perspective on global value chains:
an analysis of the Brazilian automotive and aeronautical sectors**

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Área 2. Comércio internacional, cadeias de valor e internacionalização

2.2 Comércio internacional e cadeias de valor

Abstract: Conventional literature on global value chains stresses the benefits of a higher economic integration into world markets. This paper examines the Brazilian automotive and aeronautical sectors in a period of strong international integration to evaluate potential effects and limitations of the different patterns followed by each sector. Production, trade and technological dynamics are emphasized. The analysis points out that a virtuous integration requires investments and technological dynamism, which in turn are linked to companies' capital control. While both industries have benefited from an expansionary cycle over the 2000s, the aeronautical sector has been able through Embraer to sustain a higher level of technological dynamism than the automotive sector, whose dynamics is largely associated to headquarters' decisions abroad. In this context, challenges for a successful integration regarding the new industrial revolution become even bigger.

Keywords: Global Value Chains; Brazil; Automotive Sector; Aeronautical Sector.

Resumo: A literatura convencional sobre cadeias globais de valor destaca os benefícios de uma maior integração econômica nos mercados mundiais. Este artigo examina os setores brasileiros automotivo e aeronáutico durante um período de forte integração internacional a fim de avaliar efeitos e limitações potenciais dos diferentes padrões de inserção conduzidos por cada setor. As dinâmicas produtiva, comercial e tecnológica são enfatizadas. A análise aponta que uma integração mais virtuosa requer investimentos e dinamismo tecnológico, o que, por sua vez, está condicionado ao controle de capital das empresas. Enquanto ambos os setores se beneficiaram do ciclo expansionista dos anos 2000, o setor aeronáutico foi capaz, por meio da Embraer, de sustentar um nível mais elevado de dinamismo tecnológico do que o setor automotivo, cuja dinâmica é fortemente associada às decisões das matrizes no exterior. Neste contexto, os desafios de uma integração bem-sucedida frente à nova revolução industrial se tornam ainda maiores.

Palavras-chaves: Cadeias Globais de Valor; Brasil; Setor Automotivo; Setor Aeronáutico.

JEL: F15; F23; F60; L23; L62; O33; O54

Introduction

The analysis of global value chains (GVCs) has been critical to the studies of economic development under globalization. Mainstream literature has established links between economic integration into the world economy through higher participation into GVCs and domestic development. That, however, requires qualifications, some of which this paper tries to address.

The aim of this paper is to discuss critically global value chains literature considering the analysis of two different industries in Brazil, namely the automotive and the aeronautical sectors. Both industries are strongly engaged into global chains in comparison with the average of Brazilian manufacturing. Contrary to the conventional literature, that identifies higher integration into global production networks as a source of economic efficiency, our analysis tries to show that a successful integration requires investments and technological dynamism, which in turn are linked to companies' capital control.

In this regard, we compare two Brazilian sectors that, despite very different, can provide useful insights. On the one hand, the automotive sector is dominated by large subsidiaries of both foreign carmakers and Tier 1 companies. On the other, the aeronautical sector is concentrated around Embraer. Both sectors are selected because of their importance in terms of investment, research and development (R&D), and external trade. The automotive sector focuses mostly on domestic and regional markets while Embraer is a big global player, given the characteristics of the sector itself.

The period of analysis covers the 2000s onwards, especially because there was a significant increase in production for both sectors, followed by the international financial crisis and, more recently, the economic crisis in Brazil. That allows for assessment of the dynamics of both sectors over time regarding possible economic upgrading. Some historical remarks are also made for better understanding of the dynamics of each sector in Brazil.

The pattern of global integration of these industries is even more illustrative when considered the upcoming technological change that may radically transform project, production and, in the auto sector, consumption. In face of the disruptive innovations comprised by the so-called "Industry 4.0"¹, challenges seem bigger in order to assure not only technological development but also production domestically. The recent economic downturn in Brazil added considerable difficulties to the automotive sector, while for Embraer the potential takeover of its commercial business by Boeing may represent a deterioration of the integration achieved thus far.

The paper details the issues above in three sections. The first section introduces the topic, reviewing the GVC literature. It also discusses critical approaches that challenges the mainstream view of higher global integration as necessarily promoting economic upgrading. The second section deals with the integration pattern of both sectors in terms of production and trade over the 2000s. The third section discusses the performance of these sectors regarding the technological efforts made by them and considering their respective capital control as well as some of the potential impacts of the technological revolution underway. Concluding remarks follow.

1. Economic and technological upgrading: a review on global value chains

The globalization process that has been taking place since the end of the last century has witnessed profound changes in the organization of productive activities at global level. From the 1980s onwards, large corporations from developed countries have implemented deep restructuring processes through which they sought to maintain their profitability and ability to accumulate capital as well as to combine

¹ The term *Industrie 4.0*, coined in 2011 by Henning Kagermann, head of the German Academy of Science and Engineering (*Deutsche Akademie der Technikwissenschaften – Acatech*), is one of the most widely used in the world when referring to a set of advanced and integrated technologies that is being incorporated into the production process. Other notable terms are *Industrial Internet* (USA), *Industrie du Futur* (France) and *Smart Industry* (Sweden) (Pfeiffer, 2017).

the accumulation of assets, especially intangible assets, with higher rationalization and flexibility of production. These changes have emerged as responses to the greater competitive pressure, higher instability of macroeconomic variables as well as higher and faster return requirements arising from growing financial market pressures based on new models of corporate governance aimed at maximizing the shareholder value (Aglietta and Rebérioux, 2005; Lazonick and O'Sullivan, 2000; Lazonick, 2013).

As a result, the productive structure and organization of economic activities have experienced an intense de-verticalization. In other words, there have been increasing fragmentation and separation of activities previously carried out together, both from geographical and ownership perspectives. New organization model has been marked by a reduction of vertical integration, followed by an intense international outsourcing of productive stages. This movement has benefited from possibilities of cost reduction through the management of geographically dispersed productive activities. The production process has increasingly assumed the form of an international network integrating different stages of production in several countries and by different companies, under the coordination of large international corporations.

Such trends have been discussed by the literature on industrial organization, economic geography, international economy and, in particular, the literature associated with Global Commodity Chains (GCC) (Gereffi and Korzeniewicz, 1994). This literature stems from Hopkins and Wallerstein (1977) discussion, which emphasized commodity chains as part of a world-system that created a marked stratification in capitalism development, with unequal returns among the geographical territories participating in the system. However, as pointed out by Bair and Mahutga (2016), GCC approach shifts the focus onto studies of more contemporary industrial systems and onto the units of the system, such as countries and regions, rather than the system as a whole.

Within this approach, the issue of economic development has been addressed by linking it to the mix of activities carried out in a given country or region – and its evolution over time. The idea of economic upgrading has largely become an expression of this concern. To a great extent, the literature on GCC, later renamed as Global Value Chain (GVC), has tried to understand governance arrangements within the chain, especially directed to value creation and coordination of production, distribution and commercialization processes in different network stages. The debate has also drawn attention to development conditions for developing countries within this new context.

The greater internationalization, combined with outsourcing of a growing part of productive stages on a global scale, has resulted in higher decentralization of productive activities. That, in turn, has contributed to redefine the articulation between production, export of manufactures and industrial and economic development. According to Gereffi (2005, p.171), the challenge of economic development in GVCs is “to identify the conditions under which developing as well as developed countries and firms can ‘climb the value chain’ from basic assembly activities using low-cost and unskilled labor to more advanced forms of ‘full package’ supply and integrated manufacturing”. In this regard, Humphrey and Schmitz (2002) identify four ways of economic upgrading: (i) process upgrading, which is related to changes in the production process aiming at making it more efficient; (ii) product upgrading, which comprises the introduction of more advanced product types or new products; (iii) functional upgrading, which refers to a change in the mix of activities performed by firms toward higher value-added tasks; and (iv) chain upgrading, which means a shift to newer industries or markets.

In recent years, the term “Global Value Chains” has been often used by multilateral agencies, which highlight the integration into value chains as a way to promote economic development². The incorporation of concepts associated with value chains in mainstream discourse, also supported by the availability of new databases capable of more effectively measuring trade in value chains, has been used as an element to reinforce the adoption of liberal reforms. The political conclusion in several reports is that promoting free trade and removing trade barriers related to sectoral industrial policies would be the

² GVC literature has also pointed out a more integrated view that includes a social dimension, calling attention to the impacts of GVC participation on rights, skills, social protection and well-being of workers. For more details, see Barrientos et al. (2011) and ILO (2016).

most effective way to ensure that developing countries achieve better levels of development through higher and faster integration into GVCs.

From a critical perspective, it is possible to highlight that GVC literature usually underestimates the difficulties associated with economic upgrading by failing to address properly, at least, three key points. These points are detailed below.

First, there is still large capital and technology concentration through big international corporations. Despite the emergence of new competitors and the opening of selective spaces for some integration of developing countries into GVCs, globalization has not meant a change in global oligopolies toward a generalized reduction of barriers to entry in such markets. It also has not meant an easier implementation of catching-up or upgrading strategies by companies and industries in developing countries, especially in chains involving complex activities in terms of technology and knowledge. Serfati (2008), Serfati and Sauviat (2019) and Durand and Milberg (2018) emphasize, in particular, the strategy of large companies to protect effectively their intangible assets, which are capable of generating income and maintaining the control over the value created in different parts of the value chain.

Although productive decentralization has opened spaces at specific stages of manufacturing activities in several productive chains for companies from developing countries, especially in low value-added activities, this has not necessarily meant a reduction of competitive asymmetries. By contrast, large firms, while focusing on core business activities and outsourcing part of manufacturing stages, have sought to strengthen their intangible assets, by increasing the control over technological standards, and acquire strategic assets from competitors through a fierce process of mergers and acquisitions. Higher command power of large corporations from developed countries over the value generated in different regions around the world has been observed. The increase in scale at global level has become a fundamental factor in the competitive struggle, resulting from the advantages associated with the capacity to diversify risks, operate in several markets and explore cost differentials and locational advantages in different regions. On the one hand, increasing internationalization, measured by trade, investment, and manufacturing data, shows signs of increasing participation of developing countries, albeit from a relatively narrow set of countries (Andreoni and Tregenna, 2018). On the other hand, information about the ability to command and capture value through networks led by large global corporations' points to a process of greater concentration and centralization of capital.

Second, capital origin influences the degree of depth and the ability to advance in terms of upgrading. Several authors highlight the leading role played by large firms in restructuring global chains but do not necessarily tackle the limitations to upgrading in GVCs in the absence of national capital. In some way, this second aspect is related to the first one, considering the difficulties to constitute the elements that give leading firms the power to lead the chain and capture most of the value created. While it is possible to have different degrees of positioning within the value chain through the operation of subsidiaries of multinational corporations in a given country, reaching the highest and commanding levels becomes unfeasible without national companies at the forefront of this process (Chesnais, 1994). In general, although this aspect has been one of the most outstanding elements in the work of François Chesnais, it has received little attention in recent literature. Complementary, Cherif and Hasanov (2019) emphasize the importance of not only producing and exporting sophisticated products but also creating domestic innovators as a way to catching-up with developed economies.

Finally, little attention is given to the fact that developing countries may have their positions in GVCs challenged, especially in times of marked technological, organizational and patrimonial changes. The set of strategies taken by global leading corporations, often supported by their national states, has resulted in a new wave of technological, organizational, patrimonial and business model transformations, including the adoption and diffusion of a set of transversal technologies in the midst of the fourth industrial revolution (OECD, 2017; Hallward-Driemeier and Nayyar, 2018; UNCTAD, 2018). The intense use of information and communication technologies, new materials and new sources of energy in an increasingly integrated way have resulted in a process where technological and economic leadership can only be conquered by actors with ability to master technologies, set standards and organize business

models in order to continue to dominate the value chain. In this movement, mastering and controlling skills and assets required to play a leading role in the chain become critical. This may be even more centralized in some large corporations that are able to compete for leadership. Although one can think of new entrants in a time of destabilization of established trajectories or paradigm shift, the degree of depth of economic, financial and technological capabilities required to become a relevant actor seems to increase even further.

Faced with these changes, consolidated positions of developing countries can be quickly overlapped. It is also possible to consider that changes can bring opportunities to capture new spaces of value creation. However, advances toward economic upgrading in developing economies under such radical changes can become even more difficult in a context of consolidated foreign companies in the leading positions of GVCs. From this critical perspective, a comparative analysis between two important Brazilian industrial chains that are integrated into global value chains is proposed in the following sections.

2. GVC integration patterns of Brazilian automotive and aeronautical sectors

Brazilian automotive and aeronautical industries are both integrated into global value chains but in different ways. Following subsections analyze production and trade dynamics for the automotive and aeronautical sectors, especially over the 2000s.

2.1. The automotive sector

The automotive sector in Brazil is dominated by subsidiaries of global carmakers and Tier 1 companies. The industry, which had been established in the country in the late 1950s through investments of foreign automakers and national suppliers in a protected market, has been reshaped after the economic liberalization of the 1990s. Lower import tariffs, higher competition through the entrance of new players in the domestic market, acquisition of national suppliers by big foreign suppliers, and regional automotive agreements, particularly within Mercosur, have marked a higher integration of the Brazilian automotive sector into global value chains (Laplane and Sarti, 2004; Baer and Cintra, 2004). According to Sindipeças (2016), foreign auto parts companies, which accounted for 47.6% of sales and 48% of investments in 1994, represented 70.6% of sales and 69.9% of investments in 2015.

During the 2000s, the automotive sector has experienced a high growth dynamic, following the Brazilian economic expansion. Higher formal employment levels, interest rate reduction and credit expansion, as well as increasing real income gains, have been some of the characteristics supporting a higher domestic demand over that period (Sarti and Borghi, 2017). The introduction and diffusion of flexfuel vehicles, whose engine can combine ethanol and gasoline, have been fundamental to the sector recovery, especially in the early 2000s. The development of flexfuel technology has demanded R&D investments from both automakers and suppliers, in addition to investments in complementary assets and infrastructure.

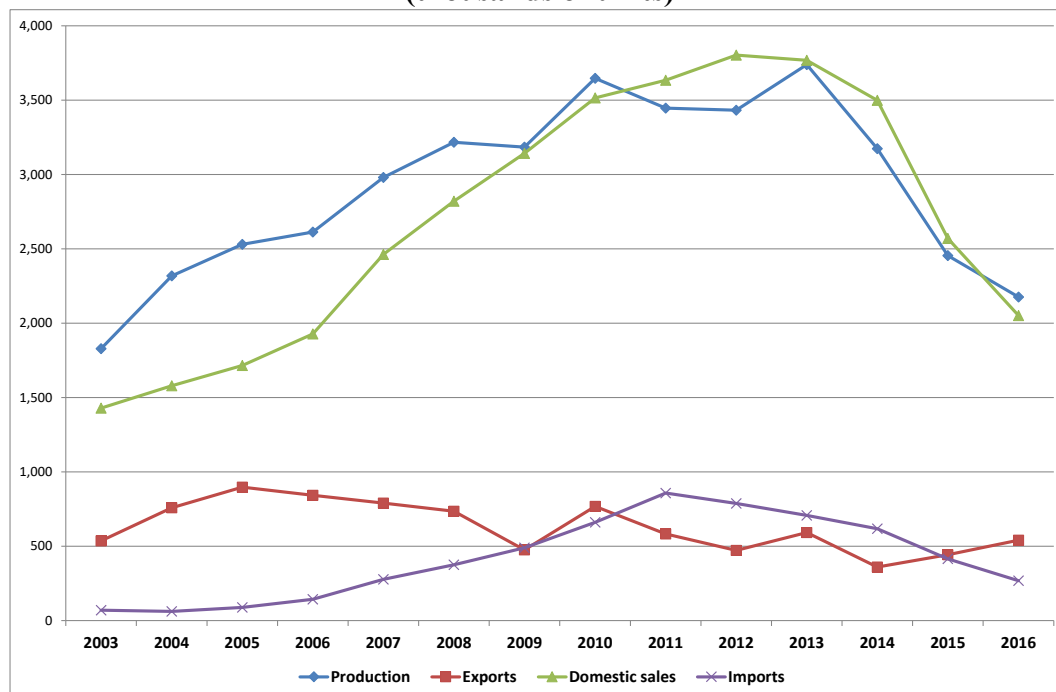
Vehicle production in Brazil has sharply risen over the 2000s. It moved from approximately 1.7 million units in 2000 to almost 3.8 million units in 2013. According to OICA data³, the Brazilian share in the world vehicle production increased from 2.9% in 2000 to 4.2% in 2013. In 2013, Brazil was the seventh largest world vehicle producer and the fourth largest consumer market, only behind China, United States and Japan. However, due to the domestic economic crisis thereafter, vehicle production has been showing a much poorer performance. Vehicle production in Brazil dropped to 2.4 million units and its proportion in the world production reduced to 2.7% in 2015.

Domestic sales also went up very quickly and continued growing despite the international crisis in the late 2000s, due to the countercyclical tax break policy on vehicles that, among other measures, contributed to

³ International Organization of Motor Vehicle Manufacturers (OICA). Data available at: <<http://www.oica.net/>>. Accessed in: 2019.

maintain domestic demand high until 2013⁴. The booming economy made exports to decrease and imports to rise over the period (Figure 1). Production and sales, however, would suffer a dramatic reversal because of Brazil's economic recession. The Brazilian economy shrank by 3.8% and 3.6% in 2015 and 2016, respectively, after a little GDP growth rate of 0.5% in 2014. A sluggish recovery is observed in recent years, following the domestic low growth rates (around 1% GDP growth in 2017 and 2018) and regional economic turmoil, for instance, in Argentina, given the sector's concentration on domestic and regional markets.

Figure 1. Total vehicle production, sales, exports and imports, Brazil, 2003-2016 (thousands of units)



Source: Prepared by the authors based on data from Anfavea (2017).

The integration of the Brazilian automotive sector into global value chains has been asymmetrical. That is reflected in the dynamics of both automakers and auto suppliers, especially if looked at trade coefficients related not only to final goods but also to inputs for domestic production.

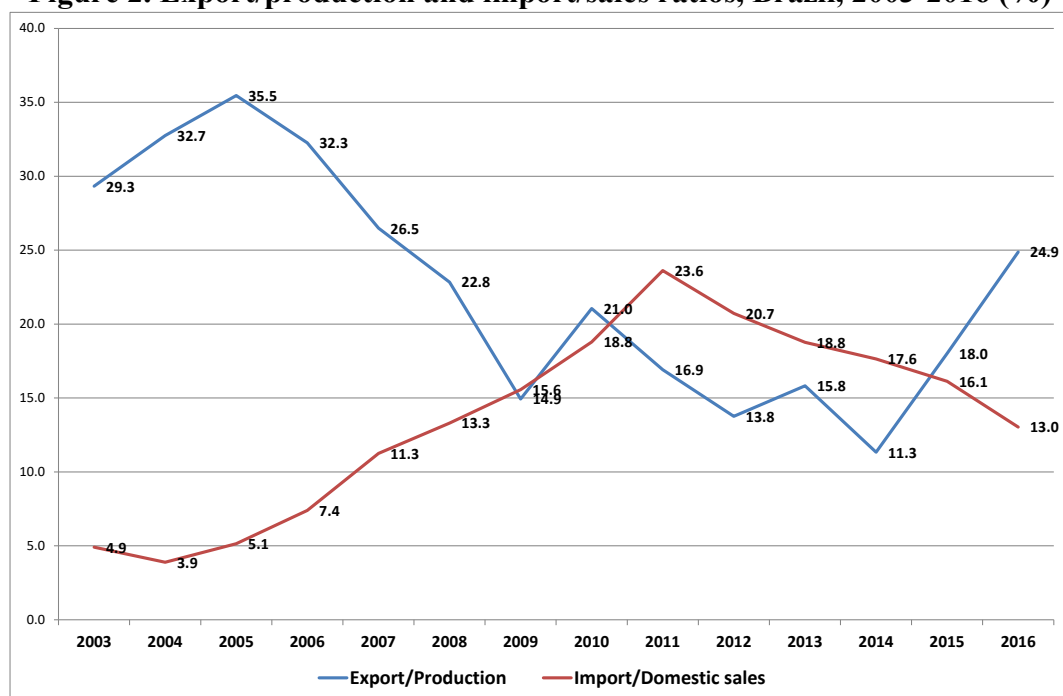
In the early 2000s, due to low domestic demand, exports largely accounted for increases in vehicle production. As a result, the export-production coefficient rose to 35.5% in 2005. In the following years, however, stronger domestic demand picked up and drove production, making the export-production coefficient to decline. Given the overheated domestic market and a heavily appreciated exchange rate from 2003 to 2012, import-sales coefficient, which was only 3.9% in 2004, rose consistently thereafter (Figure 2). For most of the period when the Brazilian economy was growing, there were a reduction of exported production and an expansion in imported vehicles coefficient, as well as increasing import content of domestic production.

Even during the 2008-2009 international economic crisis and the following years, both vehicle production and sales expanded. However, because of the higher demand in comparison with national output, the domestic production/sales gap fell, while a rising portion of domestic sales was met by imports. Global automakers used the growing Brazilian domestic market to adjust their idle capacity in other markets, particularly in face of economic slowdown in developed economies, where headquarters are located. The import-sales coefficient would rise up to 23.6% until 2011, falling thereafter, first due to the adoption of

⁴ The Brazilian government adopted a series of countercyclical policies to stimulate the economy and the sector, in particular. See Sarti and Borghi (2017) and Borghi (2017) for details.

public policy tools supporting national content (e.g. Inovar-Auto program), and, then, due to the economic recession in Brazil after 2014.

Figure 2. Export/production and import/sales ratios, Brazil, 2003-2016 (%)



Source: Prepared by the authors based on data from Anfavea (2017).

Although vehicle imports have significantly affected domestic production of auto parts, the strong increase in imports of auto parts and, then, a rising imported content in domestic production have been key to understanding the asymmetrical performance of automakers and auto parts companies. The import penetration coefficient, which is the ratio between the value of imports of both inputs and final goods as a percentage of total domestic demand, has been increasing over time: 13.1%, 16.9% and 22.1% in 2003-2008, 2009-2013 and 2014-2016, respectively. In addition, there has been a substantial increase in the imported industrial inputs coefficient, which expresses the relationship between imported and domestic inputs used in domestic production of both vehicles and auto parts. This coefficient has risen from 18.5% to 23.4% and, later, to 28.1% during the aforementioned periods (Figure 3).

Figure 3. Export and import coefficients for the Brazilian automotive industry (%)

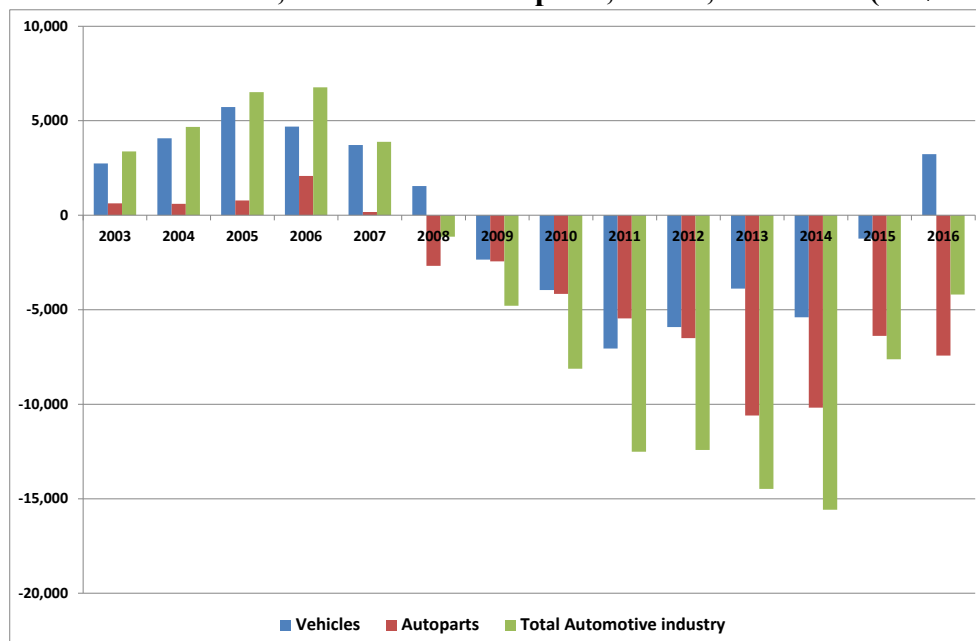
Indicators	2003-2008 (%)	2009-2013 (%)	2014-2016 (%)
Import penetration coefficient	13.1	16.9	22.1
Imported industrial inputs coefficient	18.5	23.4	28.1
Export coefficient	22.5	12.4	18.0

Source: Prepared by the authors based on data from the National Confederation of Industry (CNI).

The huge import increase has resulted from a combination of factors, such as the overvalued currency, fiscal and tax incentives from automotive policies as well as strategies of large automakers and Tier 1 suppliers, which manage their production, investment and trade flows within an increasingly integrated global corporate structure. This fact illustrates the asymmetrical integration into GVCs led by subsidiaries

of automakers and large foreign suppliers operating in Brazil. The increase in both import coefficients has not been translated into higher exports of vehicles and auto parts. The export coefficient for the automotive sector, which refers to the ratio between the value of exports and the value of output, has reduced from 22.5% during Brazil's expansionary cycle to 12.4% in the post-financial crisis period. The coefficient has partially recovered during the Brazilian recession period (2014-2016) to 18% but mostly because of the strong decline in production rather than rising exports, as the auto parts sector has continued presenting large trade deficits (Figure 4).

Figure 4. Trade balance, vehicles and auto parts, Brazil, 2003-2016 (US\$ million)



Source: Prepared by the authors based on data from Secex-MDIC.

2.2. The aeronautical sector

The Brazilian aeronautical industry is mostly concentrated in a single large Brazilian company, Embraer. This company is the result of a long-term project that began in 1947 with the establishment of the Technical Aeronautical Center (CTA, from the Portuguese acronym), which aimed at the training of skilled personnel and the development of aeronautical technology in Brazil (Sarti and Ferreira, 2012). In 1969, with the initial target of enabling the serial production of a 12-seater twin turboprop aircraft developed by CTA, the federal government set up the state-owned aircraft maker called Embraer (Drumond, 2004; Silva, 1998).

Embraer's technological capability has improved thanks to the firm's cumulative efforts to develop key technologies, focusing on design, systems integration and final assembly of aircrafts. This strategic option of concentrating on the upper portion of the global value chain was the solution found to face two major challenges. First, the increasing complexity of aeronautical technology, and second, the limitations of the Brazilian industry, particularly in high-tech sectors. As a result, in the 1970s and 1980s Embraer developed and produced ever larger and more complex aircrafts, period when cost and technological complexity were growing significantly, due to advances in information technology (IT) (Ferreira, 2009). Embraer has become a large company at the top of the aeronautical supply chain, leading a broad and diverse set of domestic and, especially, foreign suppliers, which are stratified at different levels. Embraer, particularly after its privatization⁵ in 1994, has developed a remarkable entrepreneurial competence, centered on the market intelligence and the continuous progress of corporate governance (Goldstein,

⁵ In Embraer privatization, a golden share was established, allowing the federal government to veto strategic decisions and block hostile takeovers. In addition, the participation of foreign capital in the company's control was limited to 40% (Ferreira, 2016).

2002; Bernardes, 2000). In addition, in this de-verticalized production model, the ability to coordinate a complex chain of global suppliers became another important competitive advantage for Embraer.

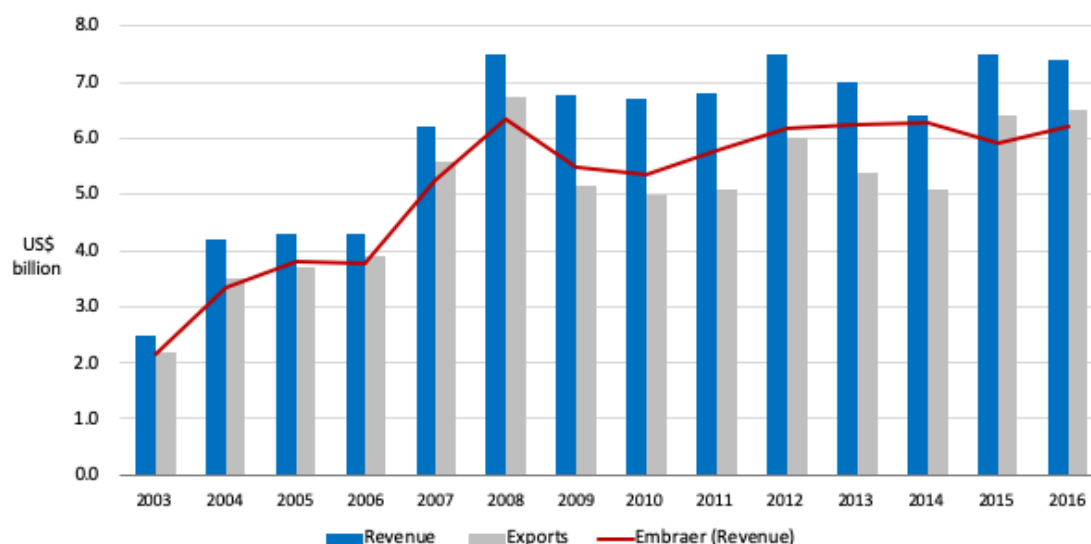
Further to Embraer's own internal competencies, the strong support of the Brazilian state was fundamental to the evolution of Embraer and the whole aeronautical industry in the country (Monte-Cardoso, 2018; Gomes, 2012). The state not only made possible the creation of Embraer, but also concentrated all scientific, technological and financial support in the company. Nevertheless, this strategic choice to direct public policy to Embraer made the market structure of the Brazilian aeronautical industry to focus on a single large company. Most of other companies in the Brazilian aeronautical industry concentrate their activities in the supply of products and services for the leading company. However, this framework should not be considered as a limitation, given the fact that this concentration allowed the technological and commercial progress of Brazil in this sector through its leading company (Ferreira, 2016).

Embraer's extraordinary technological and managerial competence, coupled with the decisive support of public policies, have enabled Embraer to achieve, during five decades, a growing participation in the international market and to become one of the greatest aerospace conglomerates of the 21st century. Embraer is currently the world leader in the commercial jet aircraft segment with up to 150 seats and shows a growing presence in both executive and defense aircraft segments (Embraer, 2019). Embraer has also a prominent position in the Brazilian industry. In 2017, it ranked 28th among the largest Brazilian companies, being the 11th largest private company of national control and the only one among them to act in a high-tech sector (Valor Econômico, 2019). In addition, Embraer also figured as one of the largest Brazilian exporters over the last two decades, ranking every year among the top seven positions (Secex, 2019). Finally, Embraer is the only large Brazilian defense company, reaching the 84th position among the world's 100 largest defense companies in 2017 (Sipri, 2019).

Therefore, it is possible to identify two main features of the Brazilian aeronautical industry. First, it is concentrated in a single large aircraft manufacturer, Embraer. Second, it shows an active integration into GVCs, either through imports of main systems and components or exports of aircraft production. These two central features of the Brazilian aeronautical industry have a common origin: Embraer's continued and growing effort in technologies that determine the plane as an end product. The strategies of the company and the support of public policies over time have led Embraer to the top of the GVC.

During the 2000s, the two main characteristics of the Brazilian aeronautical industry – concentration and international integration – have remained in evidence. Between 2003 and 2016, Embraer's share accounted for approximately 85% of revenues in the Brazilian aeronautical sector (Figure 5). Embraer's supremacy is even clearer when it is found that the revenues of this company and the Brazilian aeronautical industry presented a correlation of 0.98 for the analyzed period. Another point that stands out is the importance of external demand, which represented 83% of the Brazilian aeronautical industry's revenues in that period. Therefore, the performance of the Brazilian aeronautical industry is largely attached to the evolution of its leading company, which, in turn, is oriented to the external market.

Figure 5. Brazilian aeronautical industry: evolution of the revenues and exports, with emphasis on Embraer's revenue, 2003-2016 (US\$ billion)



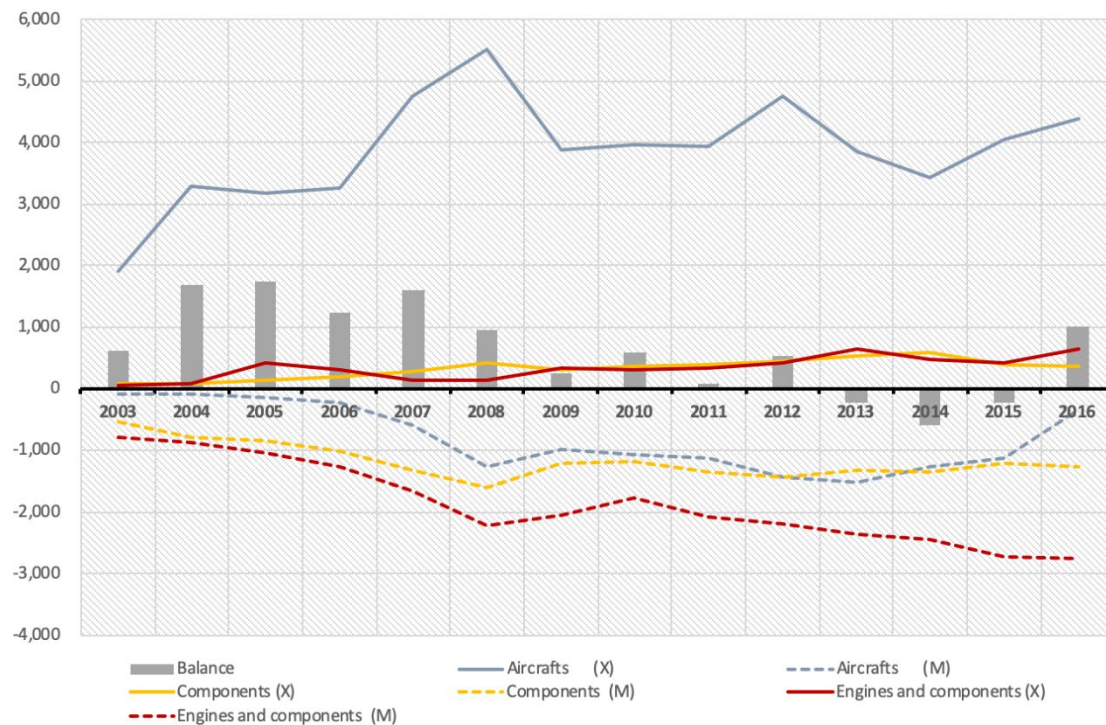
Source: Prepared by the authors based on data from Aerospace Industries Association of Brazil (AIAB) and Embraer.

The Brazilian aeronautical industry presented a significant expansion until the 2008 financial crisis. Between 2003 and 2008, revenues of this sector practically tripled, increasing from about US\$ 2.5 billion to US\$ 7.5 billion. This exceptional growth was mainly determined by the expansion of the global demand for commercial aircrafts, particularly after the start-up of commercial aircraft of E-Jet family in 2004. In the following eight years, revenues remained at a level of US\$ 7.0 billion with slight variations (AIAB, 2019). The expansion of sales of executive jets and the defense segment were particularly important to maintain the level of revenues of the Brazilian aeronautical industry after the 2008 crisis⁶. By 2016, the Brazilian aeronautical industry presented revenues of US\$ 7.4 billion (PIA database) and exports of US\$ 6.5 billion (Secex database), which corresponded to 0.79% of revenues and 3.5% of exports of the Brazilian manufacturing industry, showing the significant importance of this industry, particularly in foreign trade.

The Brazilian aeronautical industry has an active presence in the international market, particularly in aircraft exports. According to Figure 6, aircraft exports showed a large expansion, moving from US\$ 1.9 billion in 2003 to US\$ 5.4 billion in 2008, when suffered a drop due to the international economic crisis. Since then, aircraft exports have shown a reasonable stability around US\$ 4 billion per year. As previously stated, exports of the Brazilian aeronautical industry are concentrated in Embraer's international sales, particularly in the exports of its commercial jet family E-Jets, one of the most successful aircraft in the commercial aviation market, with more than 1,400 units delivered until the end of 2018, among which more than 1,300 units were sold in the international market. In turn, when analyzing the volume of aircraft imports, there was a continuous expansion between 2007 and 2013, which followed the investments of local airlines, given the robust growth of the domestic economy at that time.

Figure 6. Brazilian aeronautical industry: imports, exports and trade balance, according to aircraft, component and engine categories, 2007-2016 (US\$ million)

⁶ The defense and executive jets segments, which accounted for 25% of Embraer's revenues in 2006, increased their share to 49% of total revenues in 2014. In the following years, there was a slight reversal of this trend with the participation of these two segments falling to 42% by 2017 (Embraer, 2019).



Source: Prepared by the authors based on data from Secex-MDIC.

In the segment of aeronautical components, an opposite situation is observed (Figure 6). Brazil is a major importer of components, while exports are marginal. During the 2000s, imports of components have expanded along with the growth of local aircraft production. The Brazilian industry does not produce most of the aeronautical components, particularly onboard high-tech systems. Component exports, therefore, have a low volume. The segment of aircraft engines and their components is a special case because of the presence of GE Celma, one of the largest maintenance services unit of aircraft engines in the world⁷. On the one hand, this company is responsible for importing a high volume of components used in the maintenance of aeronautical engines⁸. On the other hand, the increasing exports of aircraft engine maintenance services are not accounted in the SECEX database, but rather in the balance of services. In 2016, the trade deficit of US\$ 2.2 billion in turbines and their components was balanced by the exports of services made by GE Celma in the amount of US\$ 2.3 billion (Carmo, 2017).

The integration model of the Brazilian aeronautical industry into global value chains focused on higher value-added stages, particularly in the development and production of aircrafts. That allowed the Brazilian aeronautical industry to add to trade balance US\$ 9.3 billion between 2003 and 2016. This demonstrates that the industry registers structurally surpluses.

3. Technological upgrading in Brazilian automotive and aeronautical sectors

In terms of technological development, the Brazilian automotive and aeronautical sectors present different performance. Higher technological efforts have been made in the aeronautical sector than in the automotive sector in Brazil if compared to each sector's world average. Their different patterns of global integration reflect in bigger challenges in face of the upcoming technological changes that may radically transform project, production and, in the auto sector, consumption too. Following subsections address these issues for each sector.

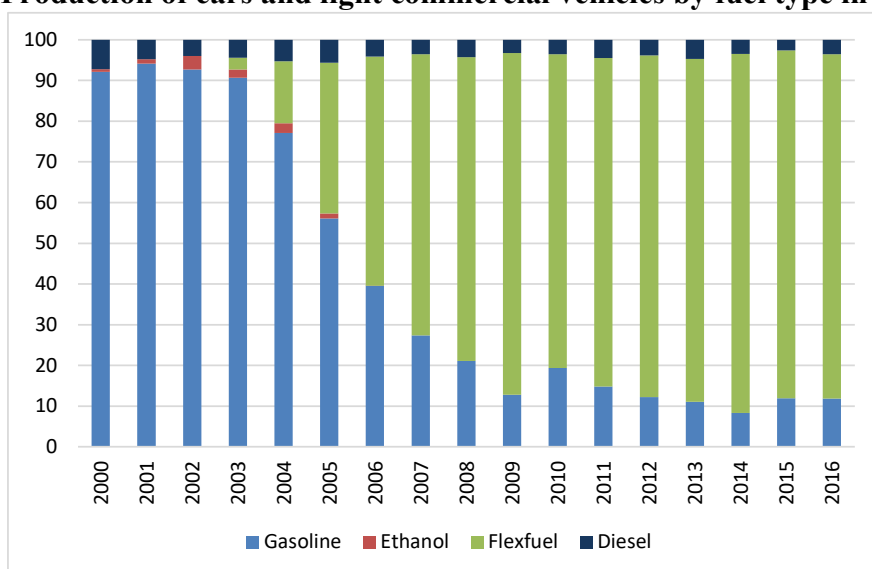
⁷ The Celma company was founded in 1951 and denationalized in 1996, when US-based firm GE Aviation acquired its whole equity. GE Celma is now the second largest GE Aviation's jet engine overhaul unit, employing some 2,000 people and exporting over 90% of its services (GE Brazil, 2019).

⁸ GE Celma is also responsible for the assembly of engines used in Embraer's commercial aircraft family of E-Jets.

3.1. The automotive sector

Most production and sales of light vehicles in Brazil are based on flexfuel engine, which combines ethanol and gasoline. Implemented in 2003, this technology was developed by subsidiaries of Tier 1 suppliers in the country, such as Bosch and Magneti Marelli, with governmental support. Production and sales of flexfuel autos have increased substantially since then. In 2009, flexfuel production accounted for 84% of total production of cars and light commercial vehicles and it has been fluctuating around this level thereafter (Figure 7).

Figure 7. Production of cars and light commercial vehicles by fuel type in Brazil (%)



Source: Prepared by the authors based on data from Anfavea (2017).

Although the development of flexfuel engine has allowed the creation of endogenous capabilities in the country, its large diffusion in the Brazilian market limits the adoption of new technologies in the short term, particularly of electric vehicles, which are seen to be the worldwide dominant technological trajectory in the following years. The diffusion of electric motorization has been quite rapid in the world. Sales of electric cars have already reached 1.1% of the world market in 2016 with more than 750,000 units sold. The main producer and consumer market for electric and hybrid cars – both BEV (Battery Electric Vehicle) and PHEV (Plug-in Hybrid Electric Vehicle) technologies – is China. In 2016, 336,000 units were sold, representing 44% of global demand and 1.4% of total vehicle demand in China. In other advanced countries, demand is also increasing: Japan (0.6% of demand for vehicles), Germany (0.7%), the United States (0.9%), the United Kingdom (1.4%) and France (1.5%). Electric motorization technology has been overcoming some economic and technological bottlenecks, such as high price, storage capacity and battery life. Investments in infrastructure of energy distribution and charging have also been substantially increasing worldwide. The global stock of electric cars reached 2 million units in 2016 (IEA, 2017).

To a large extent, Brazil can be considered as “locked in” in flexfuel technology. Imported hybrid and electric vehicles still represent a very low share of Brazilian total sales, accounting for less than 0.1%, according to Anfavea (2017). In 2016, only 1,091 electric vehicles were sold in Brazil, although a much higher amount than few years before. Some electric vehicles, particularly buses, have started to be used for public transportation at municipal levels but in a very recent and still incipient strategy. Brazilian long distances are hardly covered by fuel autonomy of current electric batteries. The country also lacks infrastructure to allow running and charging electric vehicles around the country or even in big cities, not to mention the high prices of such vehicles. These issues represent setbacks for the adoption of the new technological trend in the sector in Brazil.

At the same time, Brazil's dominant flexfuel technology is not widespread in the world market, which makes it difficult to increase exports, generate competitive economies of scale and, therefore, attract new investments for the development and improvement of technology. Moreover, none of the three market leaders in Brazil – Fiat, General Motors and Volkswagen⁹ – has announced a project to produce and/or develop electric vehicle technology in the country. These companies have been installed for decades in the country and able to maintain their leadership position even after the entry of new companies (French and Asian automakers) into the Brazilian market since the mid-1990s. All three companies have research and development (R&D) centers in Brazil, which are responsible for adaptation of platforms developed by their headquarters and development projects of new products more suitable for local and regional markets.

At international landscape, these companies have been registering lower productive and technological dynamism, especially when compared to Asian automakers, such as Toyota (1st in production and sales ranking according to OICA), Hyundai (3rd), Nissan (6th), Honda (7th) and Suzuki (11th). It is important to note that the partnership between the Japanese Nissan and the French Renault (10th), which also includes more recently the Japanese Mitsubishi, has created the largest automotive group in terms of worldwide sales. Although increasing, the market share of Asian subsidiaries operating in Brazil in terms of production and sales are still lower than worldwide, and the relevance of their operations in relation to their global activities are smaller. This lower relative importance is reflected in their low announced and effective investments and in not developing R&D activities in Brazil. Nevertheless, their headquarters have been conducting important technological changes of both products and processes, with advances particularly in electric and hybrid technologies.

According to Barassa and Consoni (2016), automakers and auto parts suppliers in Brazil have not made effective efforts to develop projects associated with electric vehicles yet. Initiatives have come mostly from companies in the electric energy sector together with research institutes and public universities, but without a comprehensive, well-defined national strategy toward the development of electric vehicles¹⁰. Some tax benefits have been included for acquisition of electric vehicles in the "Route 2030" automotive program, however, no specific incentive for production and national technological development of these vehicles is addressed, apart from general goals in terms of R&D expenditures, safety and emissions.

Brazilian innovation data show that companies in the automotive sector have been, on average, more innovative than the overall manufacturing industry, apart from the period 2009-2011, according to the innovation ratio, i.e. the proportion of firms that introduced process or product innovation in relation to all firms. When compared the subsectors of the automotive sector, most automakers have introduced some sort of innovation, although no further detail about the innovation is provided. In the period 2012-2014, 79% of automakers made some (product and/or process) innovation. The average innovation ratio of the manufacturing industry was around 36% and that of auto parts was 46% while of cabins producers was just 29% over the same period (Figure 8).

Figure 8. Innovation ratio of automotive and manufacturing companies in Brazil (%)

	2001-2003	2003-2005	2006-2008	2009-2011	2012-2014
Total Automotive	39.7	37.0	45.1	29.1	39.1
Cars, Trucks and	57.5	71.1	83.2	75.0	78.7

⁹ According to the Automotive Vehicles Distribution National Federation (Fenabrave), GM, Fiat and Volkswagen accounted, respectively, for 17.4%, 15.4% and 11.5% of total sales of cars and light commercial vehicles in Brazil in 2016, followed by Hyundai (10%), Toyota (9.1%), Ford (9.1%), Renault (7.6%) and Honda (6.2%). These eight companies together totaled more than 86% of the market share. In 2016, GM surpassed Fiat in sales after eleven years of leadership of the Italian automaker in Brazil and Ford lost its historical fourth position in the Brazilian market.

¹⁰ Nissan has recently announced a joint study with the University of Campinas (UNICAMP) to investigate the use of bioethanol as an alternative to electric mobility in fuel cell vehicles (Sugimoto, 2019). Although alternative technologies of hybrid vehicles with ethanol and bioethanol fuel cell could represent good opportunities for productive and technological development, initiatives are still incipient in face of the fast movement taking place in advanced economies by company's headquarters.

Buses					
Cabins and Trailers	32.6	25.1	41.6	20.2	28.8
Auto Parts	45.2	45.4	46.7	34.1	45.8
Total Manufacturing	33.5	33.6	38.4	35.9	36.3

Source: Prepared by the authors based on data from Pintec-IBGE.

The innovative performance of the sector can also be explained by R&D expenditures. Automakers have concentrated most of R&D expenditures in the automotive sector but their share have been reducing over time. In turn, auto parts companies have increased their share in the sector's R&D expenditures (Figure 9). This is also reflected in the R&D intensity made by companies, i.e. the ratio between R&D expenditures and net revenues. Automakers have shown higher R&D/net revenue ratio than their suppliers, although decreasing over time, while for auto parts companies, to some degree, it has expanded over the same period (Figure 10).

Figure 9. Distribution of R&D expenditures in the Brazilian automotive sector (%)

	Total R&D					In-house R&D				
	2003	2005	2008	2011	2014	2003	2005	2008	2011	2014
Total Automotive	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cars, Trucks and Buses	77.5	71.5	72.8	71.0	59.0	86.1	83.9	80.3	70.2	65.5
Cabins and Trailers	3.1	2.4	3.6	2.3	3.6	1.7	1.6	2.6	2.5	4.5
Auto Parts	19.4	26.2	23.6	26.7	37.4	12.2	14.6	17.1	27.3	30.0

Source: Prepared by the authors based on data from Pintec-IBGE.

Despite these differences among subsectors, the trend in terms of total R&D intensity for the automotive sector as a whole has been of reduction since 2005, reaching 2.4% in 2014, a slightly higher level than the manufacturing industry. For automakers, the ratio was 5.6% in 2005 and dropped to 2.1% in 2014. Considering in-house R&D expenditures, which are more related to the effort to accumulate endogenous technological capabilities and develop new products and processes, the ratio for the automotive industry as a whole was 1.1% in 2014 and no clear trend between 2003 and 2014 could be observed. For automakers, in-house R&D intensity was close to 2% from 2003 to 2008 but reduced to 1.1% in 2014. In turn, for auto parts companies, the ratio was 0.6% in 2003 and rose to 1.2% by 2011 (Figure 10).

Figure 10. R&D intensity in the Brazilian automotive sector: share of R&D expenditures in net revenues (%)

	Total R&D					In-house R&D				
	2003	2005	2008	2011	2014	2003	2005	2008	2011	2014
Total Automotive	3.9	4.4	3.5	2.5	2.4	1.6	1.3	1.5	1.3	1.1
Cars, Trucks and Buses	4.7	5.6	4.2	2.8	2.1	2.1	1.8	2.0	1.4	1.1
Cabins and Trailers	2.3	2.2	2.5	1.1	1.4	0.5	0.4	0.8	0.6	0.8
Auto Parts	2.5	3.0	2.4	2.3	3.1	0.6	0.5	0.7	1.2	1.1
Total Manufacturing	2.5	2.8	2.6	2.5	2.2	0.5	0.6	0.6	0.7	0.7

Source: Prepared by the authors based on data from Pintec-IBGE.

In general, innovation efforts in the Brazilian automotive industry have not increased, although domestic sales more than doubled in the period 2003-2013, as remarked before. Indeed, the total R&D/net revenue ratio decreased sharply between 2005 and 2014. The ratio of 2.1% for assemblers and 3.1% for auto parts companies in 2014 were below the global average of the automotive sector, which was around 3.9% and 4.5% for automakers and auto parts companies, respectively, in that year, according to PWC (2017).

In this context of low investments in innovation and limited innovation centers by automakers and auto parts subsidiaries in the country, the advance and consolidation of the electric motorization in the world

market represents a big challenge for the Brazilian automotive industry. Although the diffusion of the new technology is very slow in Brazil, the perspective of consolidating this technological trajectory in the world scenario could redirect investments to other regions and represent a drastic reduction in investments of automakers and auto parts companies in the productive and technological development of flexfuel motorization. This challenge seems even bigger if considered that the gap between companies leading the technological change worldwide and their operations in Brazil, especially in terms of domestic technological development, is considerable large. These concerns put emphasis on possible limitations that the sector's international integration can result in terms of future economic and social upgrading.

3.2. The aeronautical sector

The Brazilian aeronautical industry produces a wide and diversified portfolio of aeronautical platforms, most of them developed in the last fifteen years by Embraer, as well as assembles some helicopter models by Helibras, a subsidiary of European Airbus Helicopters. Currently, Embraer's three new aircraft models are starting to operate, one for each segment of the company: modern family of commercial E2 jets; KC-390, a military transport with the capacity to carry a payload of 26 tons, being the largest aircraft ever produced in Brazil; and Praetor 500/600 business jets. This shows the high dynamism of the Brazilian aeronautical industry led by Embraer.

Embraer has built a position among global leaders. For more than 10 years, it has been the third largest manufacturer of commercial aircraft in the world, behind only Boeing and Airbus. However, the impact of the wide set of disruptive and incremental innovations on the aeronautical sector may be so high that could challenge Embraer leading position in the global aerospace industry. Commercial jet aircraft, which is Embraer's main market segment, should be one of the most impacted by these innovations. It is expected that new disruptive technologies become a new "dominant project"¹¹ through the first half of the 2030s (Ferreira, 2018).

The major commercial aircraft manufacturers, Boeing and Airbus, supported by their respective government technology development programs – Green Aviation and Clean Sky – are moving toward the definition of a new aircraft project of commercial aviation, probably "hybrid wing-fuselage" standard (Clean Sky, 2019; Nelson and Reddy, 2017). This change will be a rupture in relation to projects developed by the global aeronautical industry so far. New aircrafts will also be produced through a mix of different advanced materials, particularly advanced metal alloys and nanostructured composites. In addition, the production of new aircrafts may be carried out within the most advanced production methods centered on the increasing and integrated use of digitalization, automation and additive manufacturing. Finally, the incorporation of transformative information and communication technologies (ICTs), especially artificial intelligence, will lead to major changes in aircraft operations, with relevant impacts on airlines' business models. Aircraft manufacturers should offer a growing range of services within their aircrafts, allowing airlines to have simpler, more flexible and lower cost structures in the future (Ferreira, 2018; Klotzel, 2015).

In this context, Embraer's biggest challenges lie in the areas where the company has the greatest competencies: design, integration and production of aircrafts. Although Embraer is a company that adopts the strategy of technological follower, the Brazilian company has made intense efforts to incorporate these new technologies, particularly those resulting from disruptive innovations, in order to follow the world leaders in the development of the future generation of commercial aircrafts.

Embraer's investments in these innovative technologies started with product engineering through the design of the "Digital Airplane" used in the development of commercial E-Jets family in the beginning of the 21st century¹². During the 2010s, the digital concept has been expanded to the production process through the implementation of the "Digital Factory", a real-time information system that integrates the

¹¹ For more details about this concept, see Utterback (1994).

¹² Embraer's Virtual Reality Center was created in this context (Embraer, 2019).

entire production process to optimize aircraft manufacturing. The introduction of robots by Embraer began in 2007 and has increased since then, including the use of interactive robots (CNI Digital, 2017). In 2013, Embraer started using 3D printing technology in the production of high complexity parts and components (Ferreira, 2018). According to recent research of the National Industry Confederation (CNI), called “*Indústria 2027*”, Embraer was the company that invested most in advanced manufacturing processes in Brazil in recent years (Bordeaux-Rego, 2017). In the field of product technology, Embraer’s recent investments in onboard software are worth mentioning with emphasis on the inside development of new aircraft fly-by-wire system (Vasconcelos, 2018). The company has also developed a broad diversity of services that optimize the operation of its aircrafts through the intensive use of onboard monitoring sensors. The use of this technology in the aircraft fleet, for example, contributes to optimize maintenance services, the so-called predictive maintenance.

Another evidence of Embraer’s innovative efforts is the recent adoption of a reinternalization strategy of part of its production, changing the model previously focused on outsourcing and risk partners. This strategy aims to offer the company a greater control over the integration of innovative technologies into its new aircraft projects. In addition, only the reinternalization of part of productive activities makes, both technically and economically, the implantation of the advanced manufacturing technologies possible (Ferreira, 2018). For example, in the new family of commercial E2 jets, there was a significant verticalization of production, particularly in two areas: aerostructure and aircraft control software (fly-by-wire system).

Due to this strategy, part of the reinternalized activities is being held at Embraer’s units located abroad. Most of these investments have been directed to two modern aerostructure factories installed in Portugal¹³ (TVI24, 2012), one interior components factory installed in Mexico (SEC, 2016), and two final assembly units (executive jets and military aircraft) and one seat factory in the USA (Costa, 2016). The first initiative focused primarily on public resources for technological development from the European Union, the second focused on Mexico’s low production costs and the third aimed at establishing closer proximity to the consumer market. In addition, internationalization contributes to mitigate risks by avoiding a high concentration of the company’s structure in a single country.

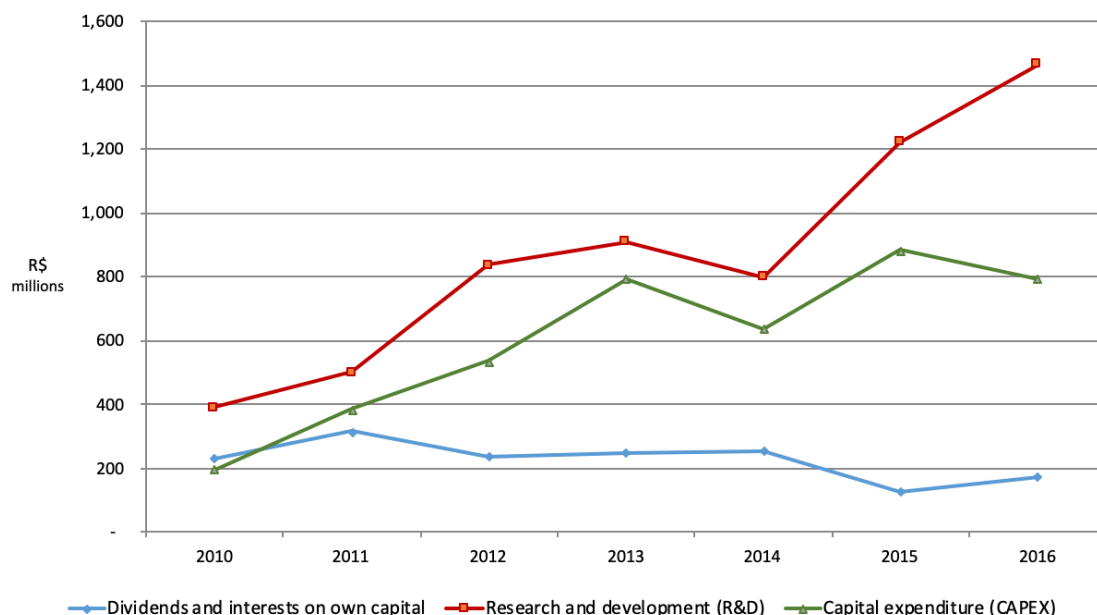
Embraer’s innovative efforts culminated in 2018 with the creation of the Embraer X division in the USA aimed at prospecting disruptive innovations that could affect the aeronautical sector. This new division has two teams to monitor key innovations being developed at US research centers, being one in the Silicon Valley (California) and another in Boston (Massachusetts) (Embraer X, 2019). Embraer X participates in the development of the electrical Vertical Take-Off and Landing (eVTOL) aircraft, within the urban air transport project Uber Elevate (UberElevate, 2016). This program is of great importance for the technological development of Embraer, since it allows the joint participation of the Brazilian company with several high-tech companies¹⁴ in a revolutionary project that involves disruptive technologies, particularly those related to advanced materials, energy storage, networks and artificial intelligence. Moreover, in case the project is successful, Embraer could occupy a prominent position in one of the most revolutionary programs of the aeronautical sector, opening a new segment of activity.

In summary, Embraer has adopted a strategy that prioritized the technological training and competencies necessary to develop competitive advantages in the long term. For this reason, the company makes large investments in R&D and CAPEX, as shown in Figure 11. Both variables showed robust growth over the period, down only in 2014, but recovering the upward trend in the following years. In the seven-year period, these investments nearly tripled in real terms, spending on R&D increased by 274% and CAPEX increased by 303%. Just for comparison, the distribution of profits to shareholders decreased 24% over the same period.

¹³ Part of the funds came from the European Union via its Structural Funds for Innovation Support under the National Strategic Reference Framework (NSRF).

¹⁴ Uber, Bell Helicopter, Aurora Flight Sciences (Boeing), Pipistrel Aircraft, Mooney, in addition to NASA’s partnership (UberElevate, 2016).

Figure 11. Embraer: evolution of R&D, CAPEX and dividends and interests on own capital (R\$ millions*), 2010-2016



* 2016 constant values.

Source: Prepared by the authors based on data from Embraer.

Embraer's annual average R&D investments were about US\$ 400 million in the 2012-2016 period, against US\$ 150 million in the previous 2007-2011 period. The R&D intensity, which shows the share of R&D expenses in net revenues, increased in the case of Embraer from 2.8% in the first five-year period to 7.2% in the second, far exceeding the 4.3% of the aerospace sector (IRIMA, 2019). These figures reinforce Embraer's intense innovative efforts in recent years, relatively greater than those made by the average of its international competitors.

During 2010s, there have been also efforts to incorporate disruptive innovations by Embraer's local supply chain. The main technological advances have been concentrated in a few engineering offices (virtual reality systems) and metalworking companies (digitalization of projects and interconnection of machine tools). In this context, Embraer implemented in 2011 the Aeronautical Supply Chain Development Program (PDCA) to strengthen second-tier local suppliers, which later received support from federal and local governments (Silveira, 2016). As a result, there was a greater qualification of more than 70 local suppliers and, consequently, the increase in sales of these companies to Embraer.

However, in 2018, Embraer and Boeing submitted a memorandum of understanding, which, in 2019, became a Boeing's effective proposal to acquire the commercial aviation of the Brazilian company. If this operation is carried out, Embraer's commercial aviation segment, which accounts for about 60% of the company's revenues and 90% of its profits (Embraer, 2019), will become part of the Boeing's global supply and production chain (Embraer, 2019a). In this scenario of Embraer's subordinate integration, it is likely that activities generating greater value-added and/or allowing higher control over the supply chain, such as innovative activities, will be increasingly concentrated in the acquiring company. In turn, other business areas remaining under Embraer's control (e.g. executive and defense aviation) are also at high risk of productive and technological downgrading due to the loss of intense synergy between them and the commercial aircraft segment. In addition, this operation brings a high risk to local suppliers, as Embraer's main operations will become part of Boeing, which already has a chain of large global suppliers. In short, this operation may bring a high risk for future technological development of Brazil's aeronautical industry.

Concluding remarks

This paper addressed global value chains from the perspective of two key industries of the Brazilian productive structure, namely the automotive and the aeronautical sectors. Both industries have a high degree of international integration. The automotive sector is dominated by large foreign companies. World's largest automakers and auto suppliers have operations in Brazil or sell their products in the Brazilian market. The aeronautical sector, in turn, is led by Embraer, a national company with global presence in the commercial and military aircraft markets. Embraer stands as atypical and unique case in the Brazilian productive structure, since it is the only large national company with global presence in a technology-intensive industry. To a large extent, that enabled the Brazilian aeronautical industry to advance and consolidate internationally.

The different international integration pattern followed by Brazilian automotive and aeronautical industries raises key elements to rethink GVC conventional approach. Our analysis pointed out that both sectors have performed well in terms of production and sales levels over the 2000s. Some differences between sectors were observed in terms of trade. Both registered surpluses, at least until the international financial crisis. The situation, however, rapidly deteriorated in the case of the automotive sector. Part of the high domestic demand was increasingly met by foreign supply of both vehicles and inputs. The dominance of foreign transnational corporations in the automotive sector in relation to the Brazilian Embraer in the aeronautical sector contributes to explain their different dynamics, once considering productive integration into global markets and degree of freedom in decision-making in each case. While Embraer focuses on the global market, but is a Brazilian controlled company, the dynamics of the Brazilian automotive sector depends on the domestic and regional markets with limited autonomy of subsidiaries, as subordinated to global decisions of large transnational companies. Given the high integration of the automotive sector in global value chains, production and employment could be maintained, to some extent, once repositioned to meet demand from external markets after the domestic crisis starting in 2014 in Brazil. However, this was not observed, thus reinforcing the argument the Brazilian automotive integration in GVCs has been largely asymmetrical.

Additionally, the aeronautical sector has been able through Embraer to sustain a higher level of technological dynamism than the automotive sector, especially during the 2010s. Innovative efforts of the automotive sector in Brazil have proved timid in relation to the world average. On the one hand, the sector's dynamics is largely associated to headquarters' decisions abroad. On the other, domestic production and consumption patterns seem "locked in" in flexfuel technology. In turn, Embraer has shown higher innovative efforts if considered its R&D expenditures as proportion of net revenues in comparison with the global average in its sector, increasingly connecting itself to the frontier of technologies that may impact the future of the sector.

Therefore, in face of the disruptive innovations comprised by the so-called "Industry 4.0", challenges seem bigger in order to assure not only technological development but also production domestically. The recent economic downturn in Brazil has added considerable difficulties to the automotive sector, which even during the booming economic period had largely lagged behind, while for Embraer the potential takeover of its commercial business by Boeing may represent a potential deterioration of the integration pattern with decision autonomy achieved thus far.

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