State Promotion, Technological Capabilities, and Industrial Competitiveness: Differences Between Brazil and Argentina in The Automotive Value Chain

Federico Dulcich[1*], *Mauro Misiano*[2]

Abstract
The automotive value chain has traditionally been significant in Brazil and Argentina, and encouraged by specific incentives. The aim of this research is to analyse the differences regarding promotion policies of this value chain in these two countries, focusing on those oriented towards technological capabilities and, hereafter, to see their effects in terms of production, technology, and foreign trade. The methodology will be focused on the analysis of variables relevant to the scope of study. The results show that, unlike Argentina, Brazil has incorporated incentives for the development of technological capabilities in policies aimed at the automotive value chain. This resulted in Brazil's greater innovation efforts and results in the sector, a favourable gap in terms of productivity, and greater international competitiveness of the automotive value chain. In addition, it plays a leading role in the technological development of ethanol-fuelled engines and has a greater diffusion of electric vehicles than Argentina. These divergent trajectories demonstrate the relevance of public policy to promote the development of technological capabilities.

Keywords: automotive value chain; innovation; international competitiveness; technological policy; Brazil; Argentina.

Submitted: June 2, 2025/ Approved: October 24, 2025

1. Introduction

The automotive value chain has traditionally been significant in Brazil and Argentina, and encouraged by specific incentives (Marx *et al.*, 2020; Morero, 2013). In the mid-20th century, it was promoted in both countries through import substitution industrialisation (ISI), with policies focused on trade protection and the promotion of foreign direct investment (FDI). However, from the 1970s onwards, the incentives implemented in both countries began to differ, which would have had consequences on their productive, technological, and foreign trade trajectories.

In this context, the aim of this research is to analyse the differences regarding promotion policies of the automotive value chain in these two countries, focusing on those oriented towards technological capabilities and, hereafter, to see their effects in terms of innovation efforts and results, labour productivity, international competitiveness, and the diffusion of alternative motorisation technologies. The main hypothesis focuses on the fact that, unlike Argentina, Brazil began to incorporate incentives for technological capabilities in its policies to promote the automotive value chain, especially from the 1970s onwards, which resulted, together with other factors, in the divergence of productive, technological and foreign trade trajectories.

This article is structured as follows. Section 2 presents the literature review, and section 3 describes the research methodology. Section 4 studies the divergence in the trajectory of the automotive value chain in Brazil and Argentina. The article closes with a discussion (section 5) and the conclusions (section 6).

2. Literature Review

2.1. Theoretical framework: The process of technological change

Technological change is considered a determining factor of economic development by different doctrines, such as the evolutionist school (Dosi and Nelson, 1994) or the National Innovation Systems (NIS) literature (Freeman, 1995). Besides, the neo-structuralism school combines the tradition of structuralism focused on international specialisation, but from a perspective centred on the processes of technological change (Ramos and Sunkel, 1993).

At the microeconomic level, theory shows that there is a high level of uncertainty about the results of research and development (R&D) activities, and the ability to transform them into innovations (Arrow, 1962). The experimentation and testing processes that R&D activities tend to require are intensive in skilled human resources, specific machinery, and other similar inputs. Consequently, some of these processes are often financed by the state (Mazzucato, 2011) to avoid potentially high sunk costs. Furthermore, the fact that new knowledge can be partially excluded means that it is not totally privatizable, so its development generates externalities that are the basis for state intervention (Nelson, 1959).

At the empirical level, several studies have shown the positive correlation between innovation performance (mainly estimated through patents) and economic growth (Hasan and Tucci, 2010; Kogan *et al.*, 2017). Innovation capabilities complement and coevolve with technology absorption capabilities (Castellacci and Natera, 2013), which are particularly important at intermediate stages of development (Viotti, 2002).

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ISSN: 0718-2724 - **Journal of Technology Management & Innovation** - **www.jotmi.org**

In terms of the production structure, several studies emphasise the heterogeneity of the technology content of the different production sectors (Hatzichronoglou, 1997; Lall, 2000; Loschky, 2008), and focus especially on the importance of increasing the technology content of developing countries' exports (Alcorta and Peres, 1998; Lall, 2000). In this context, technology gaps are determinants of convergence or divergence in the long run, and productive and technological policies play a significant role in the accumulation of capabilities (Freeman, 1995; Viotti, 2002; Cimoli *et al.*, 2019).

In Latin America, the NIS has structural deficiencies, such as low investment levels in R&D and human resource training, and restricted interactions among the government, the academy, and firms. This has resulted in an export insertion whose technological content has been stagnant for many decades (Alcorta and Peres, 1998).

In the case of the countries examined in this study, a comparative analysis reveals that Brazil undertakes greater innovation efforts than Argentina. At the aggregate level, Brazil exhibits higher expenditure on R&D as a percentage of Gross Domestic Product (GDP) (see Table A.1 in the Annex). Furthermore, these greater innovation efforts in Brazil, as compared with Argentina, are also evident within the industrial enterprises of both countries (Lugones *et al*., 2007). As a result, there are higher resident patent applications (weighted per million inhabitants) in Brazil since the decade of the 2000s (see Table No. A.1 in the Annex).

2.2. Theoretical framework: Global value chains and the specificities of the automotive value chain

The interaction between technological capabilities and international insertion has been studied in the literature on global value chains (GVCs). Gereffi *et al.* (2005) identifies five forms of governance of GVCs by leading firms. Market relationships are low-complexity, highly codifiable transactions with suppliers with good techno-productive capabilities. In modular relationships, the complexity of transactions increases, and standards tend to unify product specifications to achieve modular production. In relational chains, the capacity to codify technical knowledge is low (with a product architecture that tends to be integral), so the need for interaction between supplier and customer increases. Finally, in captive relationships, the complexity of the transactions, and the possibility of codifying the technical knowledge involved are high, but the techno-productive capacity of the suppliers is low, which generates greater control by the leading company.

Unlike GVCs, the automotive value chain tends to generate regional trade structures (Sturgeon *et al.*, 2009). Global automakers that dominate value chains generally locate vehicle production close to end markets to take advantage of tax incentives and adapt design to local consumer preferences, national environmental and safety regulations, and local road infrastructure, among others (Pavlínek, 2012; Cantarella *et al.*, 2017). At the same time, these firms engage in FDI to circumvent trade protectionism, and in the face of regional integration processes they often engage in efficiency seeking FDI to reorganise their productive factors at the intra-regional level, as happened in the case of the European Union (EU) (Dulcich, 2022b).

The relationship between automakers and their auto parts suppliers tends to be relational or captive (Sturgeon *et al.*, 2009), depending on the degree of asymmetry between them. Low modularity in auto parts increases the need for R&D cooperation between automakers and Tier 1 auto parts suppliers, which tend to be those that produce complete systems (Sturgeon *et al.*, 2017), and which even make more intense innovation efforts than automakers (ECLAC, 2017). In these activities, the existence of tacit knowledge and the need for interaction to make components compatible within the integrality of the product encourage the co-location of automakers and their Tier 1 suppliers. This co-location is also implemented to achieve a just-in-time supply of auto parts (Sturgeon *et al.*, 2009; Pavlínek, 2020; Dulcich *et al.*, 2022).

In technological terms, the automotive industry is one of the sectors that invests the most in R&D, as can be seen in the case of the EU (ACEA, 2023). However, these activities have a low degree of internationalisation and are mainly concentrated in the home countries of the global automotive parent companies or in other developed countries (Miller, 1994); especially in the case of global technology development, such as platforms and modules shared by different models (Pavlínek, 2012; Muniz and Belzowski, 2017; Dulcich *et al.*, 2022). Activities internationalised beyond these destinations are often those linked to product development and adaptation to regional and national conditions (Pavlínek, 2012; Dulcich, 2022b); as in the case of Brazil (Zilbovicius *et al.*, 2002).

The automotive industry is currently in a transition to electric mobility. Although electric vehicles (EV) still account for a smaller fraction of global automotive production, they have a higher production and technological dynamic than internal combustion engine vehicles (Dulcich 2022b). The development and production of EV at the international level are strongly influenced by the incentives implemented in various countries (demand subsidies, R&D funding, emissions regulations, etc.), which encourage the transition to electric mobility for environmental reasons and to achieve industrial and technological repositioning (Baruj *et al.*, 2021; IEA, 2024; Lee and Mah, 2020).

2.3. Policies for the productive and technological promotion of the automotive value chain in Brazil and Argentina

2.3.1. Brazil

Brazil has a long tradition of promoting the automotive industry, starting in the 1950s with the *Grupo Executivo da Indústria Automobilística*, a state entity that promoted the ISI through measures such as import restrictions and auto parts nationalisation programmes with a focus on attracting global automotive investment. Already in the 1960s, preferential credits were introduced for the acquisition of automobiles, which strongly boosted the production of this segment in Brazil (Marx *et al.*, 2020).

In the 1970s, in the face of the oil crisis, Brazil sought to reduce its dependence on imported oil by using ethanol, which it could produce from its abundant sugar cane (Saravanan *et al.*, 2020). The National Alcohol Programme *(Programa Nacional do* Álcool -Proalcohol-), initiated in 1975, encouraged this transition through tax cuts for vehicles using ethanol as fuel. National and subnational governments played an important role in driving R&D to develop these technologies. Examples include the R&D of ethanol engines undertaken at the Aeronautical Centre of Technology, as well as studies on new materials and alloys conducted at the Institute for Technological Research (IPT) in São Paulo. In addition, global automakers became involved in ethanol engine R&D to take advantage of the tax benefits for these vehicles, and made use of government fleets to test different prototypes (Martines-Filho *et al*., 2006; Hira and De Oliveira, 2009; Gordinhio, 2010).

In the 1980s, in the midst of regional economic restrictions, Brazil experienced a slowdown in the automotive market and in investment by global automakers, which generated technological backwardness. In the 1990s, the government implemented openness and deregulation measures (Marx *et al*., 2020); at the same time, tax incentives were introduced for small-engine cars (up to 1000 cm3) through the *'Carro Popular'* programme. This boosted the production of vehicles in less expensive segments of the market with less equipment and quality (Cepeda *et al.*, 2017; Marx *et al.*, 2020).

In 1995, Brazil implemented the 'Automotive Regime' to encourage importing automakers to establish production plants in the country. This regime offered a 50% reduction in vehicle import tariffs and other tax benefits in exchange for a commitment to export a value equivalent to the value of imports made under the regime. Numerous global automakers joined the regime (Fiuza, 2002; Marx *et al*., 2020).

In 1997, a law was enacted granting tax rebates on the Industrialised Products Tax (IPI) for vehicles produced in the northeast, north and centre-west regions to boost automotive investment in these relatively less developed areas (Fiuza, 2002; Sierra and Katz, 2002). Simultaneously, Brazilian subnational states began to offer incentives to attract these investments, including infrastructure development, personnel training, and tax reductions (Sierra and Katz, 2002).

In the 2000s, the growth of automotive production in Brazil was mainly based on its domestic market, driven by macroeconomic growth (Barros and Pedro, 2012; Marx *et al*., 2020). In this decade, the Brazilian Development Bank (BNDES), which traditionally incentivised the sector's production, began to incorporate the development of technological capabilities to a greater extent within its incentive activities, which also happened with the automotive promotion plans. An example of this is the Automotive Engineering Support Programme created by the BNDES in 2007, as well as other cross-cutting programmes of the bank from which the automotive industry benefited (Barros and Pedro, 2012).

The Lei do Bem of 2005 is a policy that encourages innovation efforts by companies based in Brazil. The main incentives are the deduction of up to 60% of R&D expenditures from the Corporate Income Tax (IRPJ) and the Social Contribution on Net Income (CSLL); and the 50% reduction in IPI on the purchase of goods for R&D. Although this programme is not specific to the automotive industry, it has been one of its main beneficiaries (MCTI, 2013).

Subsequently, in a specific programme for the automotive industry, the 2013 Inovar Auto Programme sought to improve the sector's productivity, increase the domestic content of auto parts and comply with environmental standards in exchange for IPI tax benefits. To qualify, automakers had to make investments in R&D and engineering (Cepeda *et al*., 2017; Tsukada *et al*., 2017). Despite these initiatives, vehicle production started to decline from 2014 onwards, in a context of macroeconomic retraction in Brazil (Marx *et al*., 2020; Dulcich *et al*., 2020).

In 2018, Brazil launched the Rota 2030 Programme to address the low competitiveness and technological lag of the automotive industry. This programme imposed various requirements for the commercialisation of new vehicles produced in the country; and established R&D investment requirements, offering tax deductions proportional to these expenditures. For example, Rota 2030 includes provisions for duty-free imports of auto parts without equivalent domestic production in exchange for R&D investments in automotive technology by the importer; and IPI reductions for flexible-fuel vehicles (MDIC, 2020; Junior and Santos, 2020).

2.3.2. Argentina

In the case of Argentina, incentives for the establishment of global automotive companies were consolidated in the middle of the last century. At the end of the 1950s, FDI was encouraged and an ISI promotion regime was established for the automotive industry, which determined high tariffs on vehicle imports and a growing participation of domestic auto parts integration (Dulcich *et al*., 2020).

The 1976 de facto government abandoned the ISI policy and promoted deregulation and openness in the automotive industry (Schvarzer, 1995; Morero, 2013; Vispo, 1999). This policy resulted in a significant increase in imports of vehicles and auto parts; which provoked a fall in the national integration of production and the exodus from the country of several foreign car manufacturers (Schvarzer, 1995; Morero, 2013; Dulcich *et al*., 2022).

The macroeconomic adjustment of the 1980s had a negative impact on the domestic automotive market, causing a stagnation of the Argentinean automotive industry. Therefore, the democratic government that began in 1983 maintained restrictions on car imports to protect domestic production (Dulcich *et al.*, 2022).

In the 1990s, the Argentinean automotive industry expanded its production, as well as the volume of imports, in a context of trade openness and an appreciated real exchange rate, and the recovery of the local automotive market because of macroeconomic stability (Dulcich *et al*., 2020). In the face of regulatory changes that stimulated FDI (Kosacoff and Porta, 1997), several global automakers installed or expanded production capacity in Argentina (Schvarzer, 1995; Dulcich *et al.*, 2022).

In 1991, the Economic Complementation Agreement (ECA) No. 14 between Brazil and Argentina boosted bilateral automotive integration through tariff-free bilateral trade for a quota of vehicles and auto parts (Gárriz and Panigo, 2015; Dulcich *et al*., 2020). Simultaneously, the automotive regime in Argentina was modified in 1991 together with tariff reductions for vehicles and auto parts destined for production that had to be 'compensated' by an equivalent value of automotive exports, among others (Cantarella *et al*., 2017; Dulcich *et al*., 2022). These incentives had an impact on an increase in motor vehicle exports, mainly oriented towards the Brazilian market (Dulcich *et al.*, 2020).

In the 2000s, a new stage began marked by strong growth in automotive production in a context of a depreciated real exchange rate (Neffa, 2017), which encouraged export orientation and generated certain protection against imports of vehicles and auto parts (Dulcich *et al*., 2022). In addition, the Customs Regime in Factory implemented during such decade allowed automotive industry inputs to be imported tariff-free temporarily with the aim of being transformed and exported, to prevent tariffs from discouraging exports (Dulcich, 2022a).

In regional terms, in accordance with 30th Protocol of the ECA No. 14 of 2000, Argentina and Brazil agreed to establish a Common External Tariff of 35% for vehicles. For auto parts with intra-zone production, tariffs converged at 14%-18% (Gárriz and Panigo, 2015). For intra-zone trade, this Protocol established that free trade was conditional on compliance with the "flex" coefficient, which related bilateral imports and exports of vehicles and auto parts; whose non-compliance implied the loss of 70-75% of the tariff preference (Cantarella *et al.*, 2017; Dulcich *et al*., 2022).

At the auto parts level, the sectoral trade deficit increased substantially; a situation that tried to be corrected with Law No. 26393 of 2008, which offered refunds for auto parts with a maximum imported content of 30% (Cantarella *et al*., 2017; Dulcich *et al*., 2020).

Under Argentina's new administration in 2015, the use of Non-Automatic Licenses for imports decreased. This situation along with Brazil's recession increased imports of vehicles and auto parts, affecting the national integration of automotive production and the volume of vehicles produced (Dulcich *et al*., 2020). In this context, a new attempt to improve the situation of the auto parts industry was Law 27,263 of 2016, which determined a tax credit on the value of purchases of national auto parts with an increasing rate in relation to the national content of auto parts of the manufactured good (Cantarella *et al*., 2017; Dulcich *et al.*, 2022).

Subsequently, the Investment Promotion Law in the automotive and auto parts industries of September 2022 aims to promote investments and production in the chain through incentives such as the elimination of duties on incremental exports of the sector, benefits conditional on the national integration of auto parts, among other measures[1].

3. Methodology

The research design is mainly quantitative, where the descriptive analysis of economic and technological variables is complemented by the study of specialized literature, especially to identify and analyse relevant policies and regulations.

The data analysis is focused on the descriptive analysis of the relevant variables which were constructed from the statistical information sources. The descriptive analysis entails examining the data series compiled for the period under study. This process subsequently involves identifying trends and significant variations in each case, as well as assessing the potential interactions among the variables under analysis.

The variables selected for analysis have a long-standing tradition in studies on technological change, and its impact on productivity and competitiveness, both at the aggregate level for the economy as a whole and at the sectoral level (Dosi *et al*., 1994; Freeman, 1995; Hatzichronoglou, 1997; Lall, 2000; Lugones *et al*., 2007; Loschky, 2008; OECD, 2018; among others). In this regard, it is worth highlighting R&D expenditure relative to sales as a variable that serves as a proxy for sectoral innovation efforts, and patent applications filed by residents as an indicator to estimate sectoral innovation results. These processes of technological change, among others, are reflected in sectoral labour productivity—examined through production per worker—and in international competitiveness, assessed through sectoral trade balances.

The period of analysis will cover from the 1990s to recent years (mainly 2023); because the regional integration of the automotive value chain began in the 1990s, significantly altering its trajectory in both countries (Arza, 2011). Also, data collection was limited by the availability of statistical information (other periods will be included when feasible and relevant). The main sources of information are the associations of automotive companies in Brazil and Argentina, as well as multinational organizations and government sources. In all cases, the sources are identified in the corresponding figure or table.

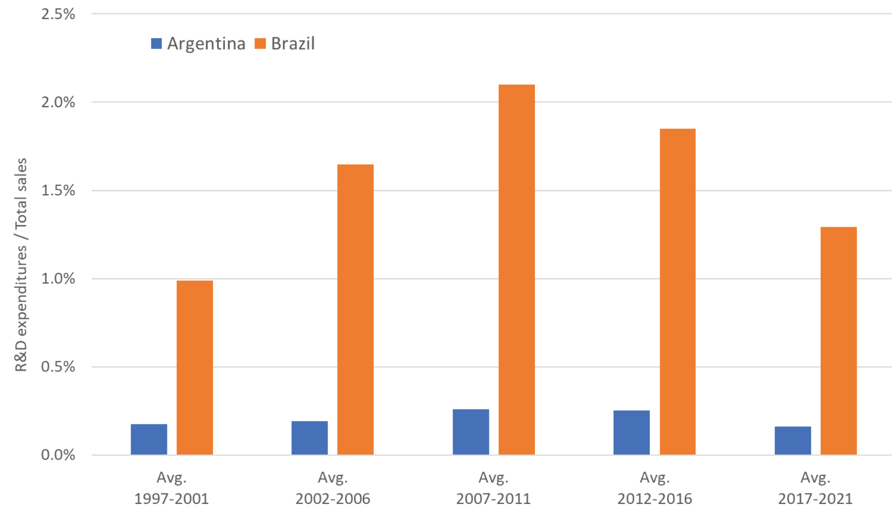
4. Results: Divergence in the technological, productive and foreign trade trajectory of the automotive value chain in Brazil and Argentina

4.1. Innovation efforts

The asymmetries of technological capabilities developed in the automotive value chain in Argentina and Brazil can be seen through different phenomena. To begin, it is important to highlight the significant differences in innovation efforts between both countries. Graph No. 1 shows that US-owned transportation equipment firms invest in R&D (in relation to their local sales) between 5 and 8 times more in Brazil than in Argentina, which became a structural phenomenon since the late nineties. This gap is substantially greater than that existing in aggregate R&D expenditures as a percentage of GDP (see Table No. A.1 of the Annex), so it would be driven by explanatory factors of a sectoral nature, such as differences in promotion mentioned in section 2.3.

[1] For further details, see Law 27686 at https://servicios.infoleg.gob.ar/infolegInternet/anexos/370000-374999/371554/norma.htm (last accessed 09/30/2024).

Graph No. 1: Analysis of the innovation efforts of subsidiaries of majority-US-owned transportation equipment companies in Brazil and Argentina



Source: prepared by the authors on the basis of U.S. Bureau of Economic Analysis.
Note: R&D expenses estimated by the authors for Argentina (years 2011-13 and 2016) and Brazil (year 2003) based on total R&D expenses for the South American region and in Brazil or Argentina (as applicable) in the same source.

This delimitation of the scope of study in US-firms has been carried out due to the lack of sector information available comparable at an international level. However, complementary sources confirm the differences reflected in Graph No. 1. As stated by Marx *et al.* (2020), automotive terminals in Brazil invested 2.08% in R&D (as a percentage of their sales) in 2003, 1.84% in 2005, 2.01% in 2008, and 1.39% in 2011. In contrast, transportation equipment companies in Argentina invested in R&D (as a percentage of their sales) only 0.2% in 2018 (MINCyT, 2019) and only 0.4% in 2019 (MINCyT, 2021).

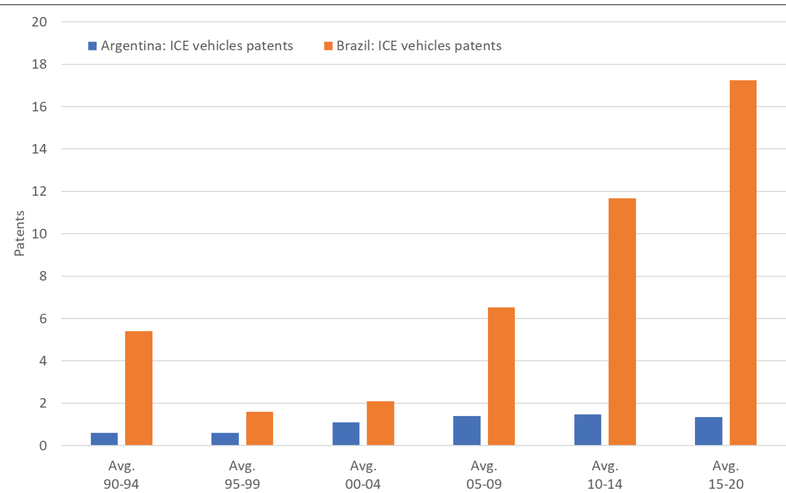
It is important to highlight that in the context of regional integration of automotive production that began in the 1990s, Brazil strengthened its position in the global strategy of automotive companies by hosting projects based on global platforms. This process led to a technological modernisation of the automotive industry in Brazil (Quadros and Consoni, 2009; Marx *et al.*, 2020), from which it ended up monopolizing R&D activities that were previously located in Argentina (Quadros and Queiroz, 2001).

4.2. Innovation results

4.2.1. Innovation in internal combustion engine technologies

Graph No. 2 shows the innovation outcomes for internal combustion engine technology, as proxied by patent applications filed by residents. The innovation gap, historically advantageous for Brazil, diminished towards the late 1990s and early 2000s, subsequently increasing thereafter. This trend is attributed to the dynamics of this variable in Brazil, particularly in light of Argentina's stagnation. The technological dynamic in Brazil is linked to the advancement of internal combustion engine technology utilizing ethanol and flexible-fuel, a development in which Brazil has been a significant player, and which will be examined in section 4.6.

Graph 2: Analysis of innovation performance of internal combustion engine vehicles within Brazil and Argentina



Source: prepared by the authors on the basis of OECD.

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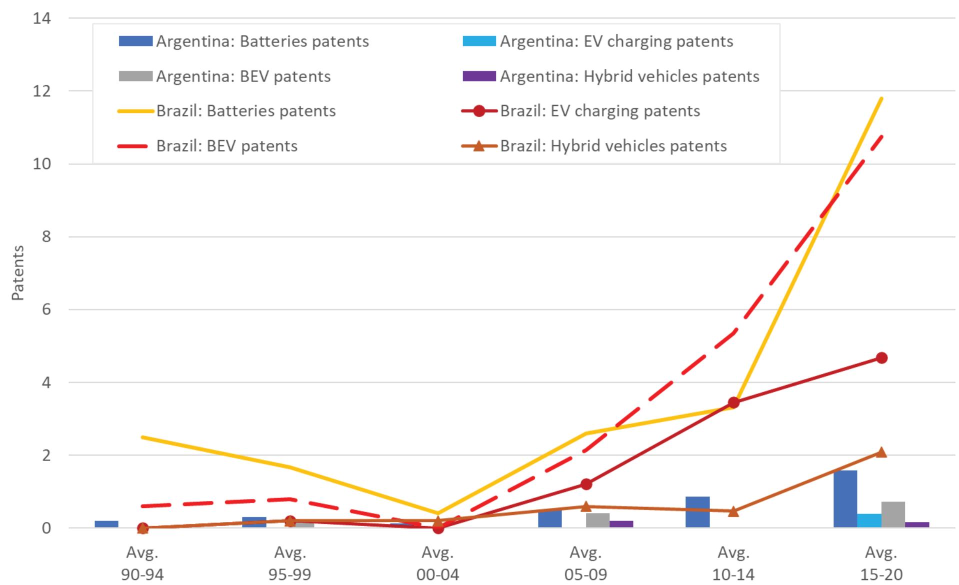
This innovation gap highlights Brazil's position as a regional hub for automotive technology. Conventional worldwide technology is adapted to regional specificities in Brazil, including local content policies, consumer preferences and income levels, transportation infrastructure conditions, safety and environmental requirements, among others (Zilbovicius *et al.*, 2002; Pavlinek, 2012; Dulcich, 2022b).

Going further product adaptation, the automakers that incorporated Brazilian subsidiaries to a greater extent in product development towards the end of the 1990s and the beginning of the 2000s were those with a longer production tradition in the country and therefore had accumulated greater technological capabilities. Fiat and Ford, for example, carried out in Brazil product developments derived from existing models, with a strong link with the technology centres of their parent companies; as in the case of the Fiat Palio platform and the Ford Fiesta. The Brazilian subsidiaries of Volkswagen and General Motors (GM) have gone even further by developing new models based on existing global platforms, as in the case of the GM Meriva (based on a re-engineering of the Corsa platform) and the Volkswagen Fox (developed on the Polo platform, aiming for a more economical version of the model). However, none of these subsidiaries has been involved in innovations of global scope, such as platform development and related R&D activities (Quadros y Consoni, 2009).

4.2.2. Innovation in electric motor technologies and related technologies

The analysis of innovation performance in EV and related technologies yields similar results to those obtained for internal combustion engine technology. Brazil has structurally larger patent applications by residents than Argentina (Graph No. 3), increasing from the 2000s onwards, in contrast to Argentina's, which is much more stagnant.

Graph 3: Analysis of innovation results in EV and related technologies in Brazil and Argentina



Source: prepared by the authors on the basis of OECD.

As regards the progress in battery and battery electric vehicle (BEV) technologies, section 4.6 shows in more detail that Brazil, unlike Argentina, has a significant local production trajectory of BEV buses and trucks. As a hypothesis, these segments would have driven Brazil's differential technological development in batteries and BEV, as well as the charging infrastructure, which is highly sensitive for the optimisation of BEV bus fleets (Eufrásio *et al.*, 2023); as Brazil's differential behaviour in the market share of light-duty EV has not been observed until recent years (see Graph No. 11). In the case of hybrid technologies, it is noteworthy that since 2019 Brazil has been producing the Toyota Corolla Hybrid, which, until recent years, was the only hybrid vehicle manufactured by global automakers in South America. This model even dominated the EV market in Argentina in recent years (Dulcich *et al.*, 2022). In accordance with the Brazilian market, this vehicle presents a flexible-hybrid version that combines an electric motor with flexible-fuel technology (which combusts different proportions of gasoline and ethanol), the first development of its kind globally (Baruj *et al.*, 2021), where Toyota engineers in Brazil participated in the development of this technology (Toyota, 2018).

4.3. Productivity in the automotive industry

Brazil has also a favourable labour productivity gap with Argentina in the automotive industry (Graph 4). Labour productivity grew in both countries in the 1990s, a period of significant technological modernisation of the regional automotive sector (Dulcich *et al.*, 2020; Marx *et al.*, 2020). Later, Brazil achieved an average favourable gap of 5.5 vehicles produced annually per worker between 2003 and 2018. From 2020 onwards, this indicator becomes convergent, but is affected by the dissimilar impact of the COVID-19 crisis on production activity in both countries.

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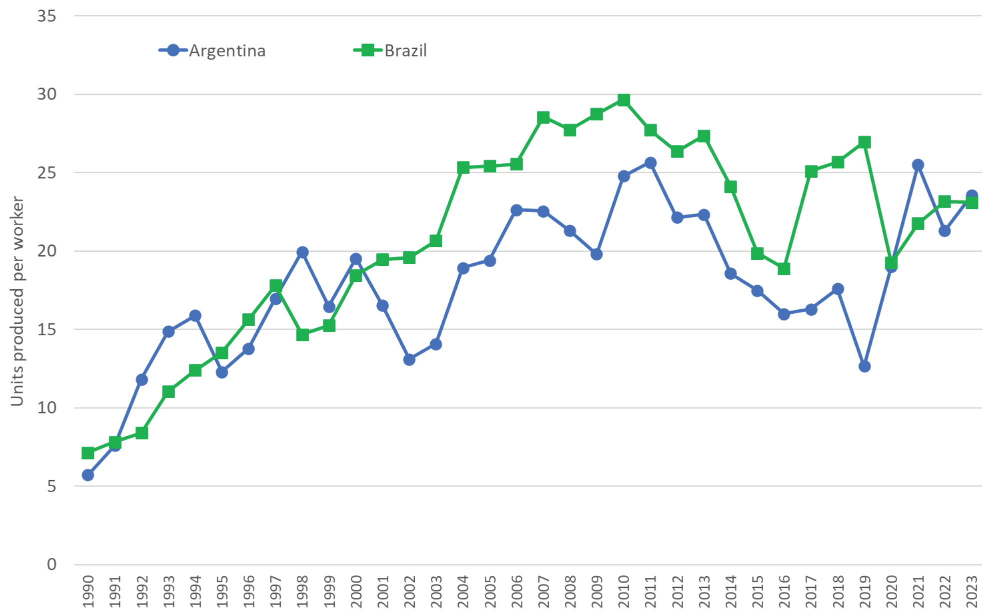
Graph No. 4: Vehicles produced per worker in Brazil and Argentina



Source: prepared by the authors on the basis of ADEFA and ANFAVEA.

The available firm-level data supports this labour productivity difference favouring Brazil for the automobile industry. In accordance with Pinazo *et al.* (2017), Toyota's plants in Brazil produced 46.7 vehicles per worker in 2012, compared to 17.5 in 2011 and 28.6 in 2016 at the Zárate plant in Argentina. Similarly, in 2015, Renault's Córdoba plant in Argentina managed to manufacture 44.3 vehicles per worker, compared to 50.5 vehicles per worker at its Curitiba plant in Brazil.

4.4. International competitiveness of the automotive industry

The regulation of ECA No. 14 (see section 2.3), which restricts the imbalances of bilateral trade in the automotive value chain for a given volume of trade, strongly influences bilateral trade, which makes up a significant portion of both countries' automotive foreign trade (Dulcich, 2022a). This is an important methodological limitation when analysing the international competitiveness of the automotive industry in Brazil and Argentina.

In this way, bilateral automotive trade is strongly influenced by the strategies of the automakers to avoid non-compliance with this regulation, including the production of the same vehicle models on both sides of the border to reduce imports into Argentina (Dulcich and Comito, 2024).

Therefore, in order to analyse the competitiveness of the automotive value chain in Argentina and Brazil, and especially in the automotive industry (with administered intra-firm trade that gives greater scope for these strategies), it is considered methodologically relevant to discount bilateral trade from global foreign trade in order to better approximate the genuine competitiveness of the industry; which will be done below.

First, Graph No. 5 shows that, with notable exceptions (see Dulcich *et al.*, 2020), Argentina's foreign car trade is fundamentally in deficit, whereas Brazil's has taken a more volatile course. Nonetheless, Brazil's two periods of significant trade deficits align with macroeconomic circumstances that encouraged imports and inhibited exports, such as an increasing real exchange rate in the mid-1990s and again starting in the late 2000s. This real exchange rate even led to significant overall trade deficits in goods and services in that country (see Table A.1 in the Annex).

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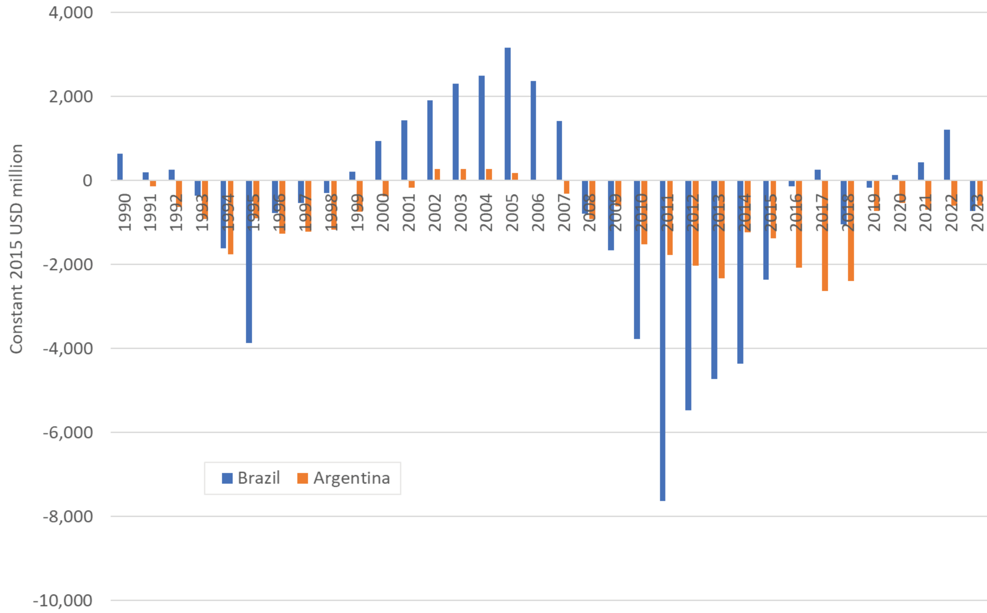
Graph No. 5: Brazil and Argentina's foreign trade balance in automobiles. Global trade flows excluding bilateral trade.

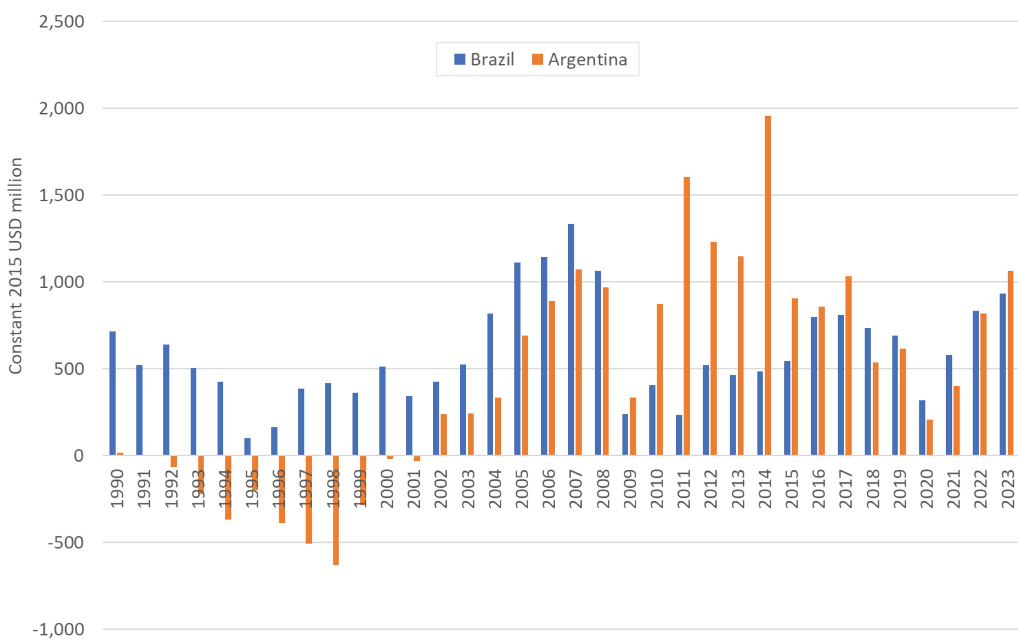


Source: prepared by the authors on the basis of United Nations and World Bank.

Secondly, in the case of heavy trucks and light commercial vehicles, Brazil is traditionally in surplus in its foreign trade (discounting bilateral flows), while Argentina transformed a deficit in the 1990s into a significant surplus from the 2000s onwards (Graph No. 6), especially from pickups exports (Dulcich, 2022a).

It is important to point out that, except in years of strong real appreciation in Brazil in the early 2000s (see Table A.1 in the Annex), there are no significant differences in the volume of trade surpluses in this century, despite the fact that this sector is the most competitive in the Argentine automotive industry (Dulcich, 2022a). This would reflect the existence of a certain productive and foreign trade specialisation by sub-segments within the pickup sector. For example, while Argentina specialises in the production of medium-sized pickups, Brazil specialises regionally in the production of compact pickups (Perez Almansi, 2023).

Graph No. 6: Brazil and Argentina's foreign trade balance in heavy trucks and light commercial vehicles. Global trade flows excluding bilateral trade



Source: prepared by the authors on the basis of United Nations and World Bank.

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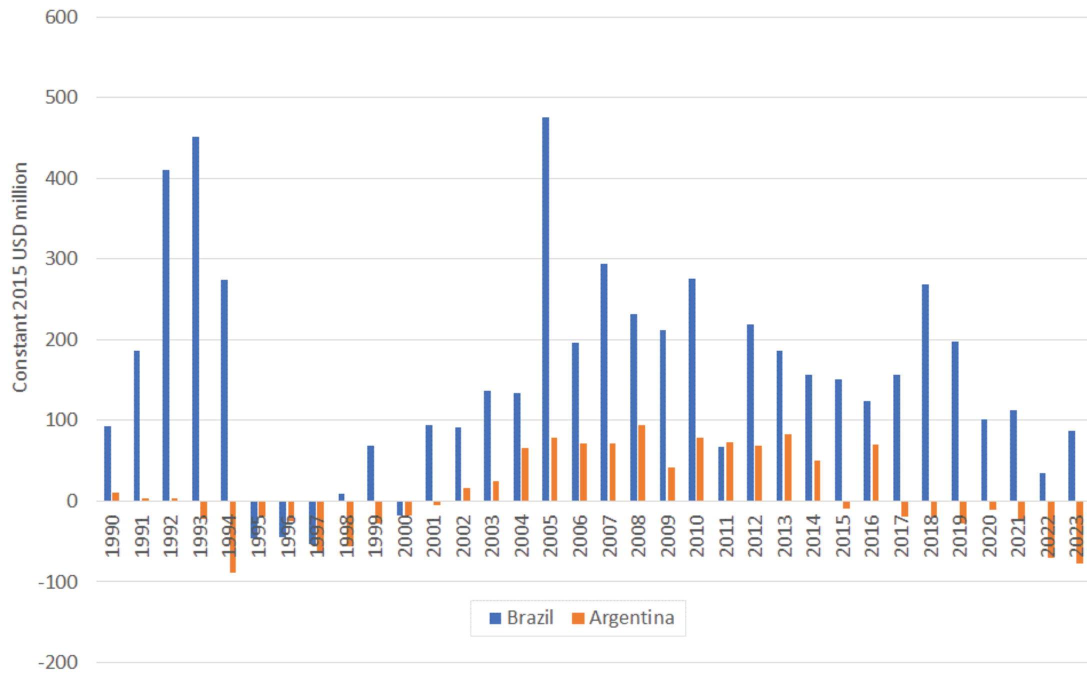
In the case of the heavy truck industry, the difference in favour of Brazil in terms of production is prominent. The latest official statistics for Argentina that allow international comparisons are from 2014, and a comparison of production volumes shows that while Argentina produced an annual average of 20,800 heavy trucks in 2013-2014, production in Brazil was 163,527 heavy trucks in the same period (OICA, 2015), almost eight times the Argentinean production.

In third and last place, Brazil is structurally in surplus in its foreign trade of buses (discounting bilateral flows) while Argentina shows a more erratic behaviour, and in surplus contexts it is far from reaching Brazil's trade balances (Graph No. 7).

Graph No. 7: Brazil and Argentina's foreign trade balance in buses. Global trade flows excluding bilateral trade.



Source: prepared by the authors on the basis of United Nations and World Bank.

In the case of the bus industry, as in the heavy truck segment, the difference in favour of Brazil in terms of production is significant. The latest official statistics for Argentina that allow international comparisons are from 2015. A comparison of the production volumes shows that while Argentina produced an annual average of only 1,261 buses in 2014-2015, the production in Brazil was 27,218 buses in the same period (OICA, 2016), more than twenty times the Argentinean production.

4.5. International competitiveness of the auto parts industry

The international competitiveness of the auto parts industry also shows a performance favourable to Brazil. While Argentina presents a structural trade deficit (excluding bilateral flows), Brazil presented several years of trade surplus, prior to the intense real appreciation of the local currency in the mid-2000s (see Table No. A.1 in the Annex). Later, it was never able to reverse the trade deficit, but maintains a structural trade surplus with Argentina (Graph No. 8).

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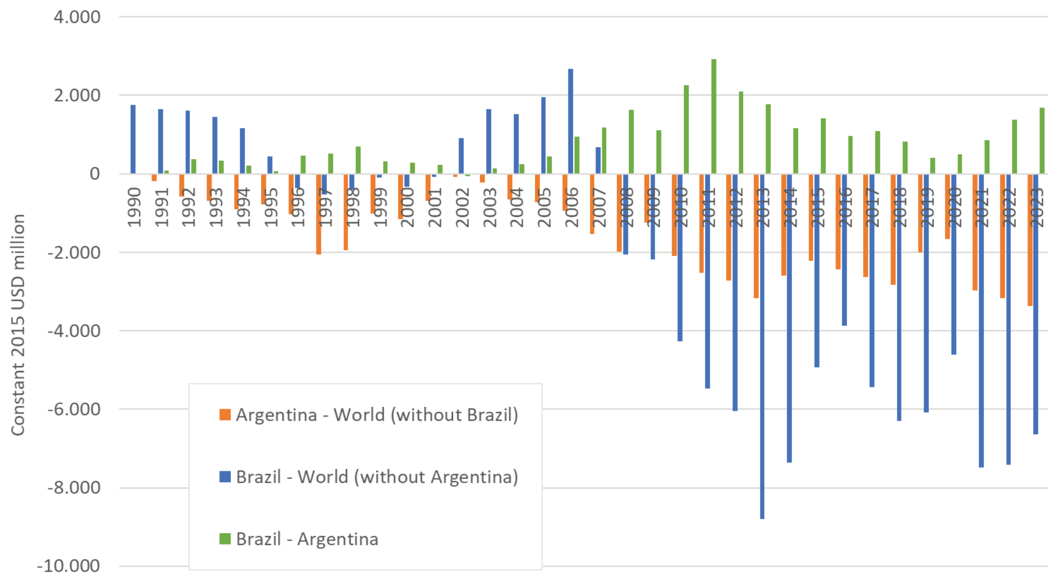
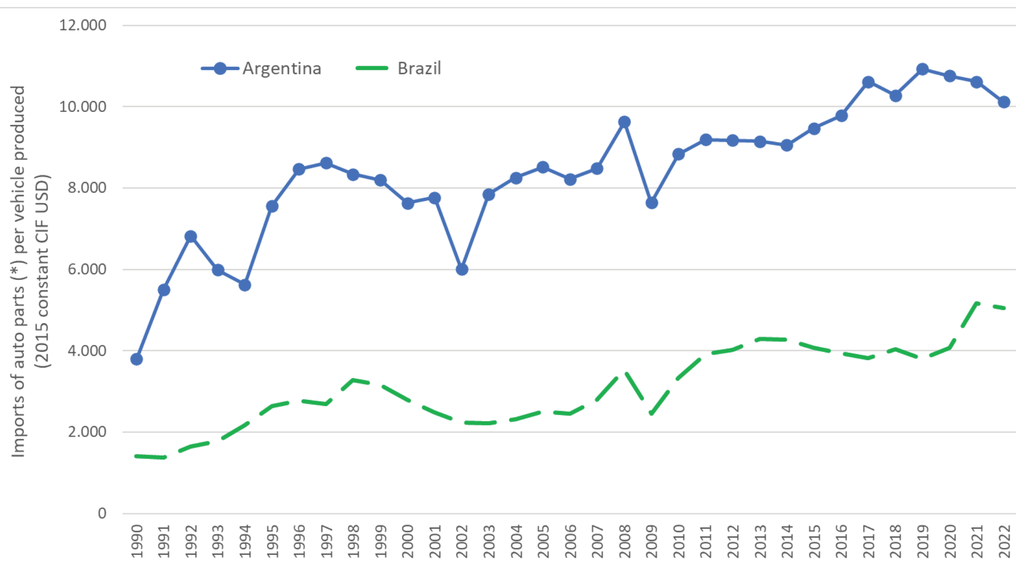
Graph No. 8: Brazil and Argentina's foreign trade balance in auto parts (excluding bilateral trade) and Brazil's bilateral auto parts balance with Argentina



Source: prepared by the authors on the basis of United Nations and World Bank.
Note: Following Dulcich et al. (2020), auto parts include rubber tyres & tubes (SITC rev. 1 code 6291), internal combustion engines (7115), automotive electrical equipment (7294), chassis with engines mounted (7326-27), and other auto parts (7328); and their equivalents in SITC rev. 3 (period 2000-2009) and SITC rev. 4 (period 2010-2023).

Another indicator of the better relative performance of the Brazilian auto parts industry is the fact that, as shown in Graph No. 9, imports of auto parts per vehicle produced in Argentina are structurally higher than those of Brazil. These differences in favour of Brazil are maintained even when evaluating the weight of these imports of auto parts in the gross value of production of each automotive industry (Dulcich, 2022a). This greater integration of domestic auto parts in Brazilian automotive production reflects the greater relative competitiveness of the Brazilian auto parts industry with respect to that of Argentina.

Graph No. 9: Imports of auto parts by vehicles produced in Argentina and Brazil



Source: prepared by the authors on the basis of United Nations, ADEFA and ANFAVEA.
Note: Given the impossibility of identifying them, imports of auto parts destined for the replacement market were not discounted.
(*) Note: Following Dulcich et al. (2020), auto parts include rubber tyres & tubes (SITC rev. 1 code 6291), internal combustion engines (7115), automotive electrical equipment (7294), chassis with engines mounted (7326-27), and other auto parts (7328); and their equivalents in SITC rev. 3 (period 2000-2009) and SITC rev. 4 (period 2010-2023).

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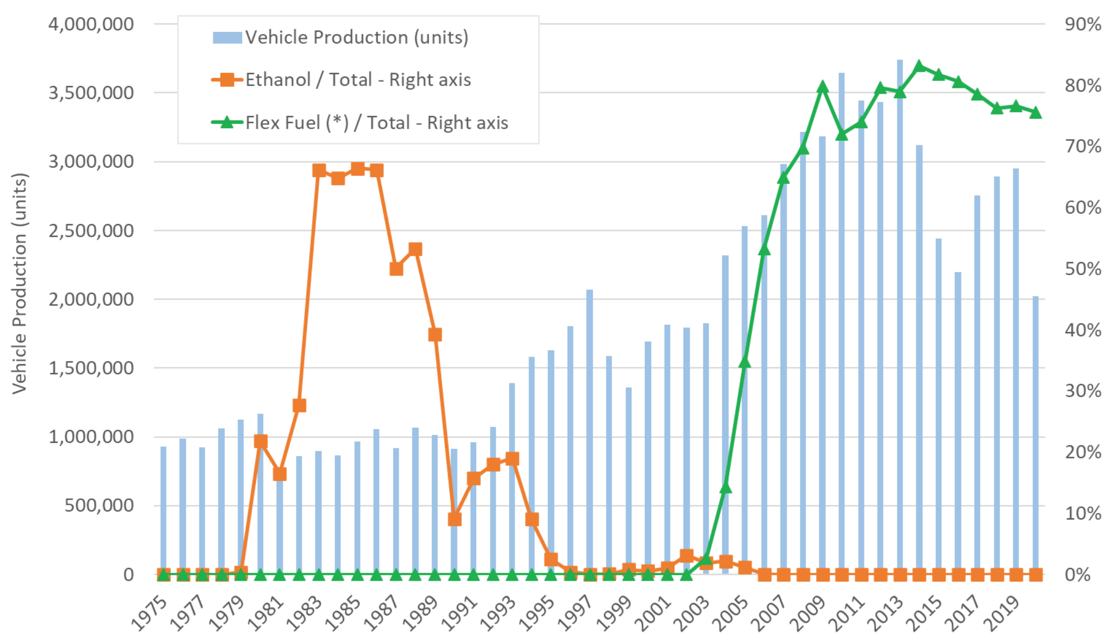
4.6. Production and diffusion of alternative motorisation technologies

As seen in section 2.3, since the mid-1970s Brazil promoted the use of ethanol as a fuel. This generated two waves of technological development. The first stage focused on ethanol-fuelled engines, the predominant engine technology in the 1980s (Graph No. 10). Gordinho (2010) highlights the ethanol-powered Fiat 147 produced in Betim as the first ethanol-powered vehicle marketed in Brazil, starting in 1979. This strategy was later followed by local product developments by Volkswagen, GM, and Ford (Gordinho, 2010). However, in the 1990s, the competitiveness of ethanol vehicles declined due to falling relative prices of gasoline versus ethanol, the reduction of taxes on gasoline vehicles, and ethanol shortages that discouraged consumers (Hira and De Oliveira., 2009; Brito *et al.*, 2019).

Graph No. 10: Evolution of automotive production in Brazil and the incidence of alternative internal combustion engines in this production



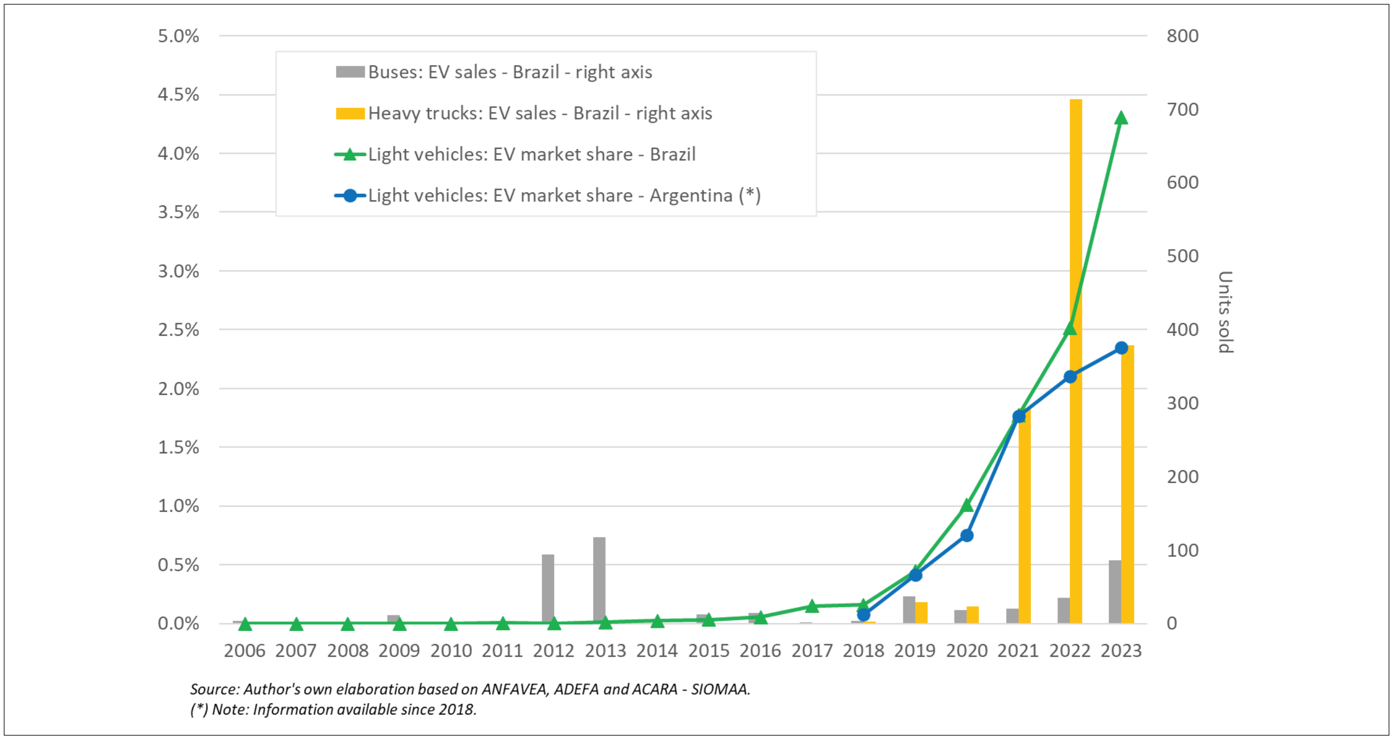
Source: Author's own elaboration based on ANFAVEA.
Note: Information available until 2020 inclusive.
(*) Note: Flex fuel vehicle is a vehicle with an internal combustion engine designed to run on ethanol fuel blended with gasoline.

Then, a second stage based on flexible-fuel engines began in the 2000s, which predominates in Brazilian automotive production up to the present (Graph No. 10). This engine allows greater flexibility in consumption by combining different proportions of gasoline and ethanol, becoming the predominant engine in the Brazilian automotive market (Brito *et al.*, 2019). Brazil played a leading role in the race to develop this technology, in which global automakers associated with different Tier 1 auto parts manufacturers competed (Yu *et al.*, 2009; Yu *et al.*, 2010; Tromboni de Souza Nascimento *et al.*, 2009).

It is important to note the existence of a certain joint dynamic between patent applications for internal combustion engine technologies (Graph No. 2) and the diffusion of these ethanol-fuelled technologies in Brazilian automotive production (Graph No. 10). The reduction in patent applications in the mid-1990s and early 2000s could be associated with the decline of ethanol-only engines, while the upturn and growth in patent applications from the mid-2000s onwards could be associated with the development and productive diffusion of flexible-fuel engines that took place from those years onwards.

Besides, there aren't any significant differences between Argentina and Brazil in terms of diffusion of EV in the light vehicle market (Graph No. 11). Both nations lacked substantial production incentives, with the primary focus being on the import with tariff preferences of EV from outside the region (Baruj *et al.*, 2021; Dulcich *et al.*, 2022). This might have been spurred in Brazil by the rivalry between electric and flexible-fuel engines, which have gathered a variety of stakeholders (De Mello *et al.*, 2013).

Graph No. 11: Market share of EV in the light vehicle segment in Argentina and Brazil, and sales of EV heavy trucks and buses in Brazil.



However, Brazil's production and domestic market trajectory in the electric heavy-duty vehicle segment is far more relevant than Argentina's, which partially reflects the disparities in conventional technology now present in this segment (see section 4.4).

As seen in Graph No. 11, sales of EV buses in Brazil began almost ten years ago, when there was still minimal progress in electrifying the segment outside of China (IEA, 2024). Besides, Argentina does not have official sales data for EV buses. However, the website https://ebusradar.org (implemented by the International Council on Clean Transportation and others) shows that as of 10 September 2024, Argentina's vehicle fleet included 22 electric buses, compared with 298 in Brazil.

Furthermore, Brazil has a significant production path in the EV bus market. Eletra company has been producing EV buses for over a decade, while China's BYD firm teamed up with local bus body maker Marcopolo to build electric buses in Campinas. Additionally, the Volvo Buses subsidiary in Curitiba was the first Volvo subsidiary outside Europe to be selected to produce hybrid buses in 2011 (Baruj *et al.*, 2021). It is important to note that BYD and Eletra presented in 2018 an installed production capacity of close to 1,000 EV buses per year, while Volvo's was 400 EV buses (PROMOB-e, 2018).

Besides, sales of electric heavy trucks have increased dramatically over the past three years (Graph No. 11). With substantial involvement of local players in the development of electric powertrains, Volkswagen's BEV e-Delivery stands out in this market (Baruj *et al.*, 2021). This truck has been produced at the Resende factory since 2021 and it is the second explanatory factor for the growth in sales of electric heavy trucks, after the sales of electric trucks from the Chinese company JAC Motors (FENABRAVE, 2024).

5. Discussion

After decades of using ISI incentives to promote the automotive value chain, the promotion of these activities in Brazil and Argentina started to split in the 1970s. Brazil started implementing incentives for the development of technological capabilities, whilst Argentina's promotion became more irregular. In the context of the oil crisis, encouraging the development of motorization technologies that use ethanol as fuel was a turning point in this process. However, Brazil later included incentives for technological change in many of its policies targeted at the automotive value chain, especially since the 2000s. This made it possible for Brazil to establish itself as the hub for adapting global technology to the local context and to take part in the creation of goods and technologies primarily targeted at emerging markets, particularly those in the region.

This has resulted in Brazil showing greater innovation efforts and results than Argentina in automotive technologies, obtaining a favourable gap in terms of labour productivity; and, beyond the impact of short-term macroeconomic factors, presenting greater international competitiveness in the automotive value chain.

Additionally, it has a greater diffusion of alternative technologies, not only in the previously mentioned cases of ethanol engines and flexible-fuel engines (where it plays a prominent role in terms of technological development) but also in electric vehicles, where it has also made greater progress in terms of production than Argentina.

These divergent trajectories demonstrate the relevance of public policy to promote the development of technological capabilities, especially considering the existing market failures in these activities. In an international oligopolistic industry, where global technology development is concentrated in developed countries but requires product adaptations to local contexts, this can generate significant advantages at a regional level for peripheral countries that adopt these initiatives and sustain them over time, especially considering the regionalized structure of the automotive value chain.

However, certain aspects of Brazil's experience are not easily extrapolable to other peripheral countries. On the one hand, it has a large domestic market and does not face competition from developed countries with automotive production that belong to the same region. This, combined with its long-standing tradition of incentives for the automotive industry and other factors, has positioned the country as the leading actor within South America's regional automotive value chains. On the other hand, the unique development of ethanol-fuelled engines is closely linked to Brazil's specific endowment of natural resources during the oil crisis of the 1970s, characterised by a shortage of petroleum and an abundance of sugarcane, from which ethanol could be produced.

6. Conclusions

This article is part of the long tradition of research on the automotive industry in Brazil and Argentina, primarily informed by studies of these countries separately. Its main contribution is a comparative analysis focused on technological capabilities and their effects on production and international competitiveness.

The main findings of this research reveal significant differences in the policy approaches of Brazil and Argentina with respect to the automotive value chain. Unlike Argentina, Brazil has implemented targeted policy incentives aimed at enhancing technological capabilities within the sector. This has resulted in markedly greater innovation efforts and results in Brazil, alongside a favourable productivity and international competitiveness gap relative to Argentina. Furthermore, Brazil has taken a leading role in the technological development of ethanol-fuelled engines and exhibits a higher rate of electric vehicle adoption than Argentina.

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STATISTICAL ANNEX

Table Nº A.1: Analysis of different scientific-technological and economic variables at national level in Brazil and Argentina

Variable	País	Avg. 1990-94	Avg. 1995-99	Avg. 2000-04	Avg. 2005-09	Avg. 2010-14	Avg. 2015-19	Avg. 2020-23
Research and development expenditure (% of GDP)	Argentina	n.d.	0.4%	0.4%	0.5%	0.6%	0.5%	0.5%
	Brazil	n.d.	n.d.	1.0%	1.1%	1.2%	1.2%	1.1%
Patent applications by residents (per million people)	Argentina	23	24	21	22	15	12	15
	Brazil	15	16	20	22	23	25	23
Real effective exchange rate index (2005 = 100)	Argentina	n.d.	n.d.	n.d.	n.d.	103.0	118.6	136.2
	Brazil	78.2	81.0	120.8	86.9	73.0	96.2	125.4
Net trade in goods and services (constant 2015 USD million)	Argentina	-1,797	-6,087	11,365	15,401	6,962	-4,403	5,413
	Brazil	12,395	-20,296	7,578	21,736	-38,482	-2,491	13,345

Source: prepared by the authors on the basis of World Bank and ECLAC.

Note: n.d. = no data.

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