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# From modern manufacture to large industry: empirical delimitation of technical change in the automotive sector in Brazil (1996-2017)

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*Abstract*

This article aims to empirically delimit the inflection of the principle on the technical basis for the Brazilian automobile sector, marking the period with the greatest probability of the transition between modern manufacturing and machine system. The research tested the hypothesis that this transition took place late in Brazil, not before the 2000s, analyzing the economic factors related to capital inversions and the change in the workforce in the period between 1996 and 2017. The research confirmed the hypothesis and also delimited the occurrence of the transition between 2000 and 2004.

**Keywords:** Technical change. Automobile. Brazil.

## *Da manufatura moderna à grande indústria: delimitação empírica da mudança técnica no setor de autoveículos no Brasil (1996-2017)*

*Resumo*

O objetivo do presente artigo é delimitar empiricamente a inflexão do princípio na base técnica para o setor de autoveículos brasileiro, demarcando o período com maior probabilidade de ocorrência da transição entre manufatura moderna e grande indústria. Realizou-se a pesquisa com a hipótese de que essa transição ocorreu tardiamente no Brasil, não antes dos anos 2000. Para verificá-la, trabalhou-se com análise de fatores econômicos ligados às inversões de capital e à modificação da força de trabalho no período entre 1996 e 2017. A pesquisa não apenas confirmou a hipótese, como também delimitou a ocorrência da transição entre 2000 e 2004.

**Palavras-chave:** Mudança técnica. Autoveículos. Brasil.

## *De la manufactura moderna a la gran industria: delimitación empírica del cambio técnico en el sector automotor en Brasil (1996-2017)*

*Resumen*

El propósito de este artículo es delimitar empíricamente la inflexión del principio en la base técnica para el sector automotor brasileño, demarcando el período con mayor probabilidad de ocurrencia de transición entre la manufactura moderna y la gran industria. La investigación se llevó a cabo con la hipótesis de que esa transición ocurrió tardíamente en Brasil, no antes de la década de 2000. Para verificar esta hipótesis, se trabajó con el análisis de factores económicos relacionados con las inversiones de capital y la modificación de la fuerza laboral en el período entre 1996 y 2017. La investigación no solo confirmó la hipótesis, sino que también delimitó la ocurrencia de la transición entre 2000 y 2004.

**Palabras clave:** Cambio técnico. Vehículos automotores. Brasil.

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## INTRODUCTION

One of the central elements to the study of economic dynamics and the transformation of companies is technical change (Acemoglu & Restrepo, 2019; Dosi, Teece & Chytry, 2005; Frey, 2019), as sanctioned by different schools among Marxists, Neoclassical, Veblenians, Schumpterians etc. (Pelaez & Szmrecsányi, 2006).

The classic distinction between the period of mass production, particularly represented by the assembly of automobiles after 1908, and the period following the 1970s, with the so-called information revolution, is common in literature. While mass production would have been based on mechanization, the period after 1970 would see microelectronics as such a foundation (Perez, 1985). These periods would be distinguished by the change in the current technical-economic paradigm, as mentioned by Perez (2011). Other theoretical traditions employ different terminology ("third technological revolution", "new pattern of accumulation", "post-fordism" etc.), but with the similar purpose of distinguishing historical patterns.

This form of analysis, however, generalizes these patterns in which the difference of development among sectors is obscured, although it is relevant to highlight it (Dosi & Orsenigo, 1988). Instead of paradigms, it becomes necessary to distinguish the principles that underlie certain technical bases in specific sectors, enabling the identification of technical change with greater precision. The point of this article is that the categories developed below – modern manufacture and large industry – better capture this transition between principles of the technical base, especially for the highlighted case of the auto sector in Brazil.

Research on the transformations that have occurred in the auto sector – car, truck and bus assembly – in the country has accumulated many pages since the early 1980s. Regarding the fact of the changes, some investigations created obstacles to the advance of scientific knowledge on the subject (Tumolo, 2001). Many approaches since that decade, including those made in management studies (e.g., Faria, 1992), have considered such transformations with varied achievements. The concern of the late 1980s, from a "Regulationist" nature, about the effects of microelectronics on the labor process as an expression of the transition between Fordism and Neo Fordism, remained inconclusive. In the following two decades, interest in "productive restructuring" – consummated in the 1990s or early 2000s – developed, in particular with regard to the connections between the Toyotist-type of organization of labor and the extensive union labor modifications following the so-called "flexible accumulation". As a whole, both the gradual weakening of interest in technical change itself and its displacement towards organization of labor are observed.

These investigative approximations have left at least two related lacunar aspects: the *stricto sensu* technical change in the productive base and the precise temporal delimitation of this change. As the former was subordinated to concerns about the organization of labor, its identification in historical temporality was also impaired. Therefore, in spite of their contributions, Fordism, Neo Fordism and productive restructuring are limited forms of conceptual approach to the problem of technical change. The scientific necessity to return to the angle of the introduction of elements is evident, as was the case of microelectronics and robotics, which acted on the technical principles that form the productive base of that particular industry. It becomes more relevant to adjust the analysis of these events taking into account the new wave of technical changes that are already on the immediate horizon.

The problematic of this article, therefore, is limited to investigating the change in the principle of the technical basis in the assembly of vehicles in Brazil. From this unfolds the objective of empirically delimiting in time the inflection of this principle in the technical basis. The approach of this change requires the essential differential traces in place of conceptualization – Fordism, Restructuring – which, as said, tends to shift to the dimension of organization of labor. As will be explained below, the reproduction of the objective movement of change in the principle of technical base in the sector and in the country in question reveals the difference and the transition between modern manufacture and large industry as the most decisive characterizing categories, because they adequately express the difference, the transition and the eventual objective inflection of the principles on which different technical bases are modeled.

The initial working hypothesis of the research, gathered from evidences in literature, was that the transition from modern manufacture to large industry in the auto sector has occurred late in Brazil in relation to the central economies, after the year 2000. To verify it, was carried out an investigation that falls within the scope of the interface between technology management and technology economics, considering the temporal variation between 1996 and 2017 of factors that describe the quantitative and qualitative modification of the applied capitals and the workforce. As explained later in the methodological section, it is an indirect research of technical change based on observable disturbances in certain factors. The main sources of data were the

National Association of Motor Vehicle Producers (Anfavea), the Brazilian Institute of Geography and Statistics (IBGE) and the Annual List of Social Information (Rais).

The fundamental contribution of the research is theoretical, methodological and empirical. In theoretical terms, the differentiation developed in the following section, between modern manufacture and large industry, corrects conceptual difficulties and establishes a more adjusted theory to the differences between modalities of technical basis. In a methodological way, the isolation of the technical basis for analysis makes it possible to define more rigorously the change in the principle that underlies it. In empirical terms, the gap in the temporal identification of the change in this principle is filled.

The paper is divided into 4 sections, in addition to this Introduction. The first one presents the theoretical basis for delimiting the technical basis and the differences between manufacture and large industry as more adjusted categories. The second one contains details of methodological aspects and procedures. The third one presents the analysis of the data, seeking to delimit the inflection in an effort to verify the hypothesis. The fourth and final section contains the final considerations of the paper.

## THEORETICAL-HISTORICAL BACKGROUND

It is necessary to delimit the fundamental theoretical categories of analysis derived from historical dynamics (Kabat, 2005; Marx, 2011, 2013; Moraes, 1991, 2003; Paço Cunha, 2019; K. Williams, Cutler, J. Williams & Haslam, 1987): differentiation, unity and relationship between technical basis and organization of labor, having as a guide the methodological necessity to isolate the technical basis; and differentiation and transition between manufacture and large industry.

The technical basis is understood as the "specificity of the means employed in terms of fixed capital: instruments, tools, machinery. This technical basis can be changed in an incremental or radical way. While the first one improves existing means, the second one changes the very fundamental principle on which a given production process is based on" (Paço Cunha, 2019, p. 89). Isolating the second modality of alteration, it is a matter of considering, in the first place, the modification of the general pattern, and not ignoring the accumulated incremental modifications – which eventually affect the changes of that pattern. As we will resume ahead, here there is an important difference between, in one hand, mechanization as the introduction of elements such as a new driving force, conveyor, pulled lines, etc., and automation, in the other hand, with the introduction of a single machinery that operates all production functions or the articulation of a system of different partial machines.

In its turn, the organization of labor is a "given combination of different individuals in relation to the operation of the means [...] varying the form and degree of division of labor and specialization" so that certain organizational innovations "can also assume an incremental or more substantive form" (Paço Cunha, 2019, p. 89). From a simple new division of labor to Taylorism, we can see the spectrum of these changes. Fordism, in addition, continues to be a modification in the organization of labor despite a higher degree of mechanization which, however, regards to advances in the technical basis, especially concerning the transport of parts and components among assembly stages. Toyotism equals itself as a way of organizing labor on a technical basis that is also mechanized. Taylorism, Fordism and Toyotism, therefore, are possible under the same technical basis, despite the degree of mechanization.

It is necessary to underline the essential aspects of this triad – Taylorism, Fordism and Toyotism – as a characterization of forms of organization of labor and, as a result, of its predominant connections to the workforce (living labor). In this sense, "Taylorism is characterized as an advanced form of capital control (with the aim at raising labor productivity) over the work processes in which capital depends on the skill of the laborer", operating mainly through "*control of all the rhythms and movements of the worker, that is, the control (...) of all the steps of living labor*" (Moraes, 1991, p. 34, emphasis added). In its turn, "Fordism, as a labor process organized from an *assembly line*, must be understood as the *development of the Taylorist proposal*", considering the sense that one seeks "*assistance from the objective elements of the process* (dead labor), in this case the conveyor, to *objectify the subjective element* (living labor)" (Moraes, 1991, p. 35, emphasis added). In its comparative specificity, Toyotism or "Ohnoism is understood as a particular way of supporting mass production on living labor, which, in turn, arose from the fact that it meant an organizational change, and not a technological one" (Moraes, 2003, p. 108). Thus, it is possible to characterize "Ohnoism as flexible mass production equally based on living labor" (Moraes, 2003, p. 109).

It is possible to construct a theory to the nexus between technical basis and work organization considering the historical movement. Such nexus is not expressed by a simple function relation, as was more common in some traditions (e.g., Woodward, 1980). For this paper, the purpose of that theory is to decant, by an abstract procedure, the technical basis for analysis.

In fact, the technical basis forms the plan of objective conditions of possibility for forms of organization of labor. The conditioning of possibilities is expressed in the variation of forms of organization of labor on the same basis, knowing that determining the possibilities is also limiting them. The organization of labor has heterogeneity and relative autonomy in the face of its technical basis, which is also expressed as a power of managerial decisions, that is, changes in the organization of labor are fully possible, to a certain extent, without causing changes in the technical base, and vice versa. Thus, technical basis and organization of labor are different and form a unity of reciprocity. The changes in the technical basis and in the organization of labor, and, eventually, in the unit as a whole, are problems of empirical-concrete investigation. However, it is possible to trace the dominant trends, considering that the technical basis is the preponderant factor in the relationship with the organization of labor, that is, the one that engenders the conditions of possibility, which exists as an objective condition. On the one hand, as the technical basis objectively forms the possibilities that are inscribed in the organization of labor, an incremental and radical change in the first one must be felt in the second one, to a lesser or greater degree. Being radical, it makes the second one unmatched, if not impossible. On the other hand, changes in the organization of labor to varying degrees also affect the technical basis by strangling the possibilities inscribed in the objectivity of the second one, whose limits can only be surpassed by breaking the principle that grounds the technical basis itself.

This theory corresponds to a classification: (1) manufacture, (1A) modern manufacture and (2) large industry as more or less specific forms of unity between technical basis and organization of labor. We would also have a (2A) large modern industry, but it extrapolates the issues involved in the historical period of the research (cf. Paço Cunha, 2019).

(1) Manufacture is, therefore, a particular unity between technical base and organization of labor. Its fundamental principle is the division of labor, the worker and his instruments. Its technical basis, therefore, is rudimentary. In empirical terms, consider the stage of development of automobile assembly in the early twentieth century to be an example of manufacturing. The assembly line with improved instruments, however, does not change the principle of the technical basis that remains as the division of labor, the worker and his instruments. The highest degree of mechanization has been possible historically on a manufacturing basis. To verify this, it is enough to investigate the development of Toyotism up to the limit of its technical basis.

(2) Large industry, on the other hand, establishes itself on another articulating principle between technical basis and organization of labor, which is why one can speak of radical change. It is specifically about the revolution of the means of production and the establishment of a system of machines to which an organization of labor is attached. It is wrong to say that there is no division of labor now. On the contrary, it rests on a systematic organization of automated machinery, transforming the division of labor and labor even into secondary elements in the face of machinery. Once again in empirical terms, the machine system developed late in the assembly of automobiles, which remained very dependent on changes in the organization of labor (Fordism, Toyotism) during most of the twentieth century. Other sectors, such as chemicals and textiles, were, by comparison, early automated in the 19$^{th}$ century and dismissed forms of organization of labor corresponding to the basis of manufacture, such as Fordism (Moraes, 1991, 2003). The same conclusion is reached with the American manufacture of cans, already fully automated at the beginning of the 20$^{th}$ century (Pearson, 2016).

(1A) There is an intermediate stage of transition among the manufacture and automation "riverbeds" (Moraes, 2003). Modern manufacture expresses the gradual mechanization process based on the manufacturing principle, with the adoption of conveyors and other machinery selectively inserted in certain stages of production, without changing the general production pattern, that is, without establishing a complete system of machines. Fordism and Toyotism are empirically emblematic examples of the organization of labor on a progressively mechanized technical basis that, thus, strangle the manufacturing principle that forms its basis. The development of the manufacturing organization of labor that is based on an increasingly mechanized technical base takes the manufacturing principle to a paroxysm, whose overcoming was only possible historically by the establishment of a *predominant* machine system.

In these terms, it is assumed that the assembly of vehicles was constituted as a manufacture and, later, as a modern manufacture, mirroring a progressive process of mechanization throughout the 20$^{th}$ century, before its leap to the "automation riverbed", from the years 1970. It was, therefore, historically possible the coexistence between much technologically advanced sectors, such as those of continuous flow in which automated processes were already used, and apparently sophisticated

sectors whose foundation, however, reflected archaic principles, such as automobile assembly (Fortes, 2019), in which Fordism and Toyotism in the 20th century stood out.

In this regard, it is possible to specify the intransitivity between Fordism/Toyotism and a technical base of *large industry* typically based on the machine system, since the former are based on living labor.

> This crucial fact [of being supported by living labor] provides Fordism /Ohnoism with its specific difference in relation to mass production backed by machinery, a typical case of the textile and continuous process industries. Now, microelectronic based automation will have the consequence of allowing Fordist or Ohnoist industries to start supporting mass production (necessarily flexible) in machinery, and no longer in living labor. This will simply mean the historical end of Fordism, and its "reinvention", Ohnoism, and the emergence of a unified concept of industrial production, which will constitute, in all its segments, a "technological application of science" (Moraes, 2003, p. 109).

With the transition to the machine system, Fordism and Toyotism lost their real basis. This becomes more evident when it is recognized that the backing of Toyotism in living labor has been marked since its constitution, since "Toyota chooses to face this brutal increase in demand without increasing its personnel. Therefore, the only way open was to rationalize labor based on the highest possible income from *living labor*" (Coriat, 1994, p. 55, emphasis added). Even the most objective aspect, so to speak, of Toyotism, in the figure of *Kan-ban* or *just in time*, is associated with circulating capital – stocks, above all – and not necessarily with the technological application in productive machinery. With a view to lean production, it is essentially an "efficient way (as long as it is surrounded by the relevant industrial and cultural conditions) to organize (social) production" (Tauile, 1988, p. 71). It is not by chance that there is so much emphasis on the role of the workforce convincing and joining processes as a condition for the functionality of this organization of labor on a manufacturing basis.

Thus, no matter how important they are as organizational innovations, Fordism and Toyotism, in the auto industry, did not configure by themselves qualitative leaps in the operating principle towards the large industry, although they helped to prepare the ground by strangling more and more the principle of manufacturing throughout the twentieth century, given the reciprocities existing between the technical base and the organization of labor. Finally, the sector's leap, and of significant sectors in economies, to the "automation riverbed" can be considered a "great convergence" of explanatory relevance for the effects observed since the 1970s (Paço Cunha, 2019).

This transition in the assembly of cars, particularly in Brazil, is the primary object that demands apprehension, and it is necessary to specify, given the gaps presented, the period of occurrence of the inflection between modern manufacture and large industry in this important sector of the Brazilian economy.

## METHODOLOGICAL ASPECTS

The empirical investigation of the paper is based on qualitative methodology, using documentary, and quantitative research through basic statistics (Oliveira, 2001). The general approach is anchored in the materialism present in the critique of political economy, for which the nature of the object itself – in this case, the inflection – imposes the appropriate means of its investigation (Chasin, 2009).

In the impossibility of directly observing the inflection and in the interest of overcoming the limits of the case studies accumulated in the literature on the auto sector in Brazil, the analysis must be based on the behavior of variables and their relationships as measures to approach the highlighted problem. Thus, the inflexion of the technical basis is inaccessible to a direct approach, even at the level of the firm. However, the indirect approach, considering the aggregate of the sector in question, is very common in scientific research of "factual nature" (Bunge, 2001, pp. 12-19), that is, one that needs observation and adjustment of the hypothesis to the facts, requiring, for the case, the observation of the *a posteriori* given effects, which were caused by the inflection in a previous moment.

This type of radical modification of the principle of the technical basis, to paraphrase Marx (2010, p. 263), "can be the object of rigorous verification of natural science". In this case, it is subject to observation, collection of evidence and measurement. The challenge now is to indirectly capture and register the change from the principle of modern manufacture to the one of large industry in the Brazilian auto sector, that is, the approximation of the empirical moment of a longer dynamic process.

The process of technical change is not only dynamic, but also total, involving different forces. However, the more scientifically accurate record of the disturbances caused by the change in that principle requires the isolation of the technical basis from its multiple nexuses through a provisional abstract procedure. One must assume the difficulty of analyzing the referred change in the midst of a multiplicity of relationships. Such relations must always be presupposed and reestablished in a subsequent global analysis, demanding researches dedicated to the subject. The progress on other nexuses, however, depends on the analysis of the details.

Once the technical basis has been isolated, the modification to the large industry has presented economic effects that are methodologically significant (Marquetti & Porsse, 2014; Marx, 2013). In other words, the transition that is not directly observable in the beginning must produce *a posteriori* observable disturbance in certain economic factors. It must not be ignored that such observable disturbances may derive from other forces, such as those arising from the expansion of markets. For this reason, the delimitation of aspects associated with production is decisive. Marquetti and Porsse (2014) highlighted, for example, the growth in labor productivity, the fall in capital productivity, the increase in capital intensity, among others. In this direction, although changes in the organization of labor can cause equally relevant effects, the technical change in the transition between modern manufacture and large industry produces, comparatively, deeper effects on productive power as a reflection of the scientific application and technological advancement – that is, application of capital – as well as in the qualities of the workforce. The striking difference, however, is that the technical inflection has an impact on more economic factors associated with capital invested in means of production than the organization of labor could engender. In this way, attention to the effects that reflect the expansion of the technologically oriented productive power is decisive.

In order to conduct the analysis, on the one hand, the sector of auto vehicles in Brazil, considered by Anfavea as assembly of cars, trucks and buses, was delimited. This first delimitation was useful to the documentary analysis for a qualitative approach to the empirical problem under investigation, which included books, newspapers and technical reports that helped to highlight the introduction of robotics as an index of the technical change underway in the analyzed period. On the other hand, the factors that would allow observing the effects resulting from a transition from modern manufacture to large industry in the sector were delimited and data that could express their behavior was sought. The observation of these factors makes it possible to verify the hypothesis, which, for the present case, has a probability character (Bunge, 2001), that is, the research is restricted to a delimitation of the probable period of the inflection at the sector level, and not to a singular moment in time at the level of the firm.

We calculated the productivity of labor, as measured by the units produced monthly due to the number of laborers employed monthly, and also the behavior of the total production and unit sales – this comprising national licenses and exporters –, based on Anfavea's database. This measure of sales abled the exclusion of the hypothesis that the observed disturbances were due to the expansion of the market, as will be evidenced. Additionally, based on the IBGE's Annual Industrial Survey (PIA), available on the IBGE Automatic Recovery System (Sidra), the value of production (VP) was measured in product prices and constant capital (CC) as the sum between fixed and circulating capital, considering fixed capital as depreciation costs – which express how much fixed capital was spent during the year. On the same database, we calculated rents and equipment leasing, plus the balance of fixed asset acquisitions (acquisitions + improvements – write-offs), and considering circulating capital as raw material costs, parts and accessories consumption, maintenance services and other operating costs. Still, the number of employed laborers (T), the mass of annual wages (S) – the sum of paid wages – and the number of companies (E) was extracted.

All the prices-measured data was deflated to 2017 prices through IGP-DI (FGV) index.

The analysis of the indicators based on the variables indicated above covered the period from 1996 to 2017 for two fundamental reasons. Firstly, due to the modification of the methodology for collecting and displaying data from the IBGE's Annual Industrial Survey. As of 1996, the survey became annual and began to present the variables used in the calculation of the indicators at the required disaggregated level – manufacture of cars, vans, trucks and buses (IBGE, 1996). Then the

analysis presented at the beginning of the next section was carried out considering income indicators, labor productivity, introduction of robotics and investment levels, based on Anfavea's database, and on specialized bibliography in newspapers of that time. Such analysis suggested that, until 1996, there was no concretion of the inflection in the technical base present in the production of vehicles in Brazil.

Therefore, it was possible to consider the following measures and the direction of their variations for the inflection between modern manufacture and large industry in the sector: (1) capital productivity (VP/CC), measured by the ratio between the value – measured for all cases in prices – of production (VP) and constant capital (CC), in which negative or stagnant variations signalize the occurrence of the inflection; (2) the intensity of capital (CC/T), measured by the relationship between constant capital (CC) and the number of employed laborers (T), in which positive variations are indicative; (3) the average annual salary (S/T), whose negative variation is indicative; (4) the constant capital per enterprise (CC/E), whose positive variation is indicative; (5) the number of laborers per enterprise (T/E), in which the negative variation is indicative; (6) the organic composition (CC/S) as a ratio between constant capital (CC) and total wages (S), whose positive variation indicates the inflection more vigorously; (7) wage productivity measured by the ratio between the value produced and the mass of wages (VP/S) that deepens the indication by the positive variation when approximately following the organic composition. Finally, it was analyzed (8) the change in the composition of occupations in the sector over the period, as they are directly influenced by the technological inflection. Based on the data from Rais, the variation in occupations with the largest number of laborers in the sector in the years 1996, 2001, 2006, 2011 and 2016 was analyzed. With the transition to large industry, there would be a decrease in specialized occupations in the operation of certain equipment and the appearance of more technology-intensive occupations and a greater presence of maintenance operations.

All of these measures were useful to analyze the period and delimit the transition to the large industry in the sector, taking into account the observed effects. As stated, it was necessary to discard the hypothesis that the observed disturbances were primarily conditioned by the number of sales. This deepens the justification of considering the variable relationships that are more associated with constant capital. By analyzing the variables in this way, it became possible to verify with greater precision the occurrence of the inflection of the technical base, with the most prominent increase in constant capital prior to the expansion of the market.

## DATA ANALYSIS

Bearing in mind the aim of empirically delimiting in time the inflection of the principle in the technical basis, that is, the conversion of the assembly of automobiles from a modern manufacture to a large industry, it is supposed the overcome of the gaps left by the literature regarding the technical change itself and the more accurate indication of such temporality of change in the Brazilian auto sector.

Despite such gaps and the fact that the focus has shifted to the organization of labor, there are important evidences of the process of technological change in the Brazilian auto sector since the 1980s. Research has given great prominence to the effects of the introduction of microelectronics and robotics in that decade. However, the general diagnosis can be characterized as a "selective introduction" in certain stages of production (Carvalho, 1987; Peliano et al., 1987; Schmitz & Carvalho, 1988, 1989; Vieira, 1985), which did not radically altered the established modern manufacture pattern. Not by chance, it was found, already in 1990, that Fordism was still alive in Brazil (Carvalho & Schmitz, 1990). This last finding, contrary to the researchers' intentions, stems from the fact that the technical basis persisted as a modern manufacture, albeit with an increasingly sharpened degree of mechanization. Nevertheless, some data are indicative of technological changes that set the stage for the more fundamental alterations.

If considered the "net income" variable based on data from the National Association of Automotive Vehicle Manufacturers (Anfavea, 2018), we see that, at the end of the 1980s, US$14.9 billion were registered, and, for the end of 1990, 12.2 billion, slightly different figures. The same occurs with productivity, considering vehicle produced per laborer per year, which reached 0.68 in December 1983 and 0.66 in the same month of 1992. However, the 1990s represented, consistently, a marked change

regarding the acceleration of the introduction of robotics in vehicle production centers in Brazil. Some aspects are noteworthy in the face of the crisis then. As shown by Luedemann (2003), among these factors there is the central participation of the State, such as the facilitation of importing machinery and tax incentives and the decision of the main automakers to produce internationally standardized models on more automated assembly lines.

The overall result was manifested in important changes in the main plants and in the installation of several new plants of incoming multinationals, installed with assembly lines with a high degree of automation and application of robotics. Examples of these robotics diffusion processes, with the exception of incoming ones, can be seen in Box 1.

**Box 1**
**Introduction of robots in the automobile assembly plants in Brazil (1990-2000)**

| Plant | Description of the modification |
|---|---|
| General Motors | In 1996, introduction of 377 robots in 2 assembly lines (Luedemann, 2003). In 2000, a new plant with 120 robots was opened (Carvalho, 2003). |
| Volkswagen | In 1997, there was 167 robots (Carvalho, 2003). In the beggining of the year 2000, it became 400 (Jornal do Commercio, 2001). |
| Ford | A total of 230 robots installed at the Camaçari's factory in 2001 (Firmino, 2003). |
| Fiat | Installation of 38 robots, in 1996, for the assembly of Palio. At the time, another assembly line did not use robots yet. (Jornal do Brasil, 1996). |
| Volvo | Installed plant with 8 robots (Ribeiro, 1997). |
| Scania | In 1994, 15 robots were distributed at the lines of motors, axis, cabins, chassis and final assembly (Luedemann, 2003). |

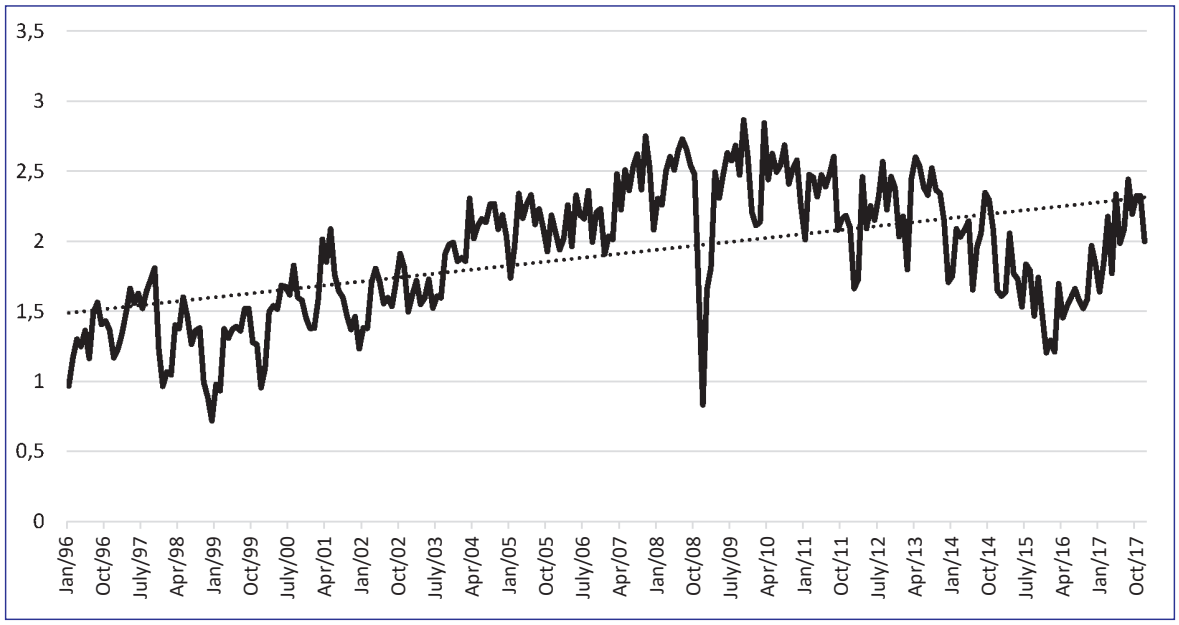
Note: systematization of information found in theses and national newspapers that covered the process of introduction of robotics available in the National Library's Digital Library collection.

Source: Elaborated by the authors.

This global change reflects the outbreak in investments that consisted, on average, of 1.6 billion dollars between 1994 and 2001 (Anfavea, 2010). A brief analysis of investments between 1990 and 2012 shows that the period from 1995 to 2001 represents a phase of very high capital investments. However, the auto sector still ends the 1990s in a similar pattern to the previous one, incorporating microelectronic based technologies in a progressive manner, in which the indicated expansion of robotics is the index of the modifications in progress.

The effects of these investments and, therefore, of the technical changes in progress will be observed indirectly in the following decade. Evidence of this is the number of vehicles produced per laborer: 0.68 in December 1983, 0.66 in the same month in 1992 and 1.86 in 2003 (Anfavea, 2020). The Graph 1 shows, in a more extensive way, this development of labor productivity, with emphasis on the impulse that occurred in the years after the year 2000 as an effect of these investments.

**Graph 1**
**Productivity of labor in the automobile sector in Brazil (1996-2017)**

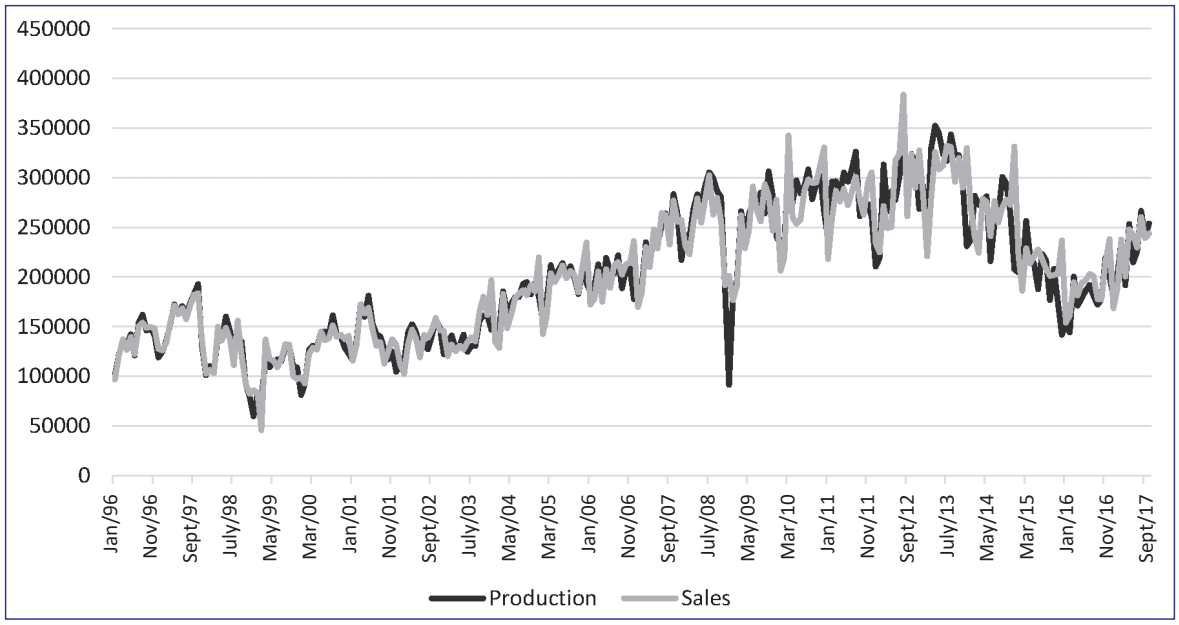



Note: Labor productivity measured by the number of vehicles produced monthly (cars, trucks and buses) divided by the number of laborers employed monthly.

Source: Anfavea (2020a, 2020b).

It is possible to observe that the levels of productivity after the 2000s do not decline to the levels of the 1990s not even with the market retractions after 2013, as shown in Graph 2. The trend of expansion of production and sales between 1999 and 2013 (Graph 2), as well as the growth in labor productivity until 2010 (Graph 1), signals the possibility of the occurrence of the technical inflection from the year 2000, at least.

**Graph 2**
**Production and sales of auto vehicles in Brazil (1996-2017)**




Note: monthly production and sales quantities (national licenses and exports) of auto vehicles.

Source: Anfavea (2020a).

Production indicators per laborer, total production and sales, however, are very much affected by market variations due to fluctuations in economic cycles. As a result, there is the need for a more detailed analysis that allows verifying whether the observed disturbances are due to the change in the technical principle, and not to market fluctuations. Thus, it is worth carefully assessing the variation of the most central aspects over the period under study. This variation can be seen in Table 1.

**Table 1**
**Economic measures calculated for the Brazilian auto sector (1996-2017)**

| Year | CC/T | VP/CC | S/T | CC/E | T/E |
|---|---|---|---|---|---|
| 1999 | 130,6 | 74,3 | 107,9 | 97,1 | 74,3 |
| 2003 | 164,3 | 77,4 | 95,3 | 78,3 | 47,7 |
| 2007 | 161,5 | 92,5 | 91,3 | 123,5 | 76,5 |
| 2011 | 149,2 | 99,7 | 100 | 138,2 | 92,6 |
| 2014 | 139,3 | 91 | 100,1 | 116,7 | 83,8 |
| 2017 | 140,5 | 84 | 93,4 | 108,4 | 77,2 |

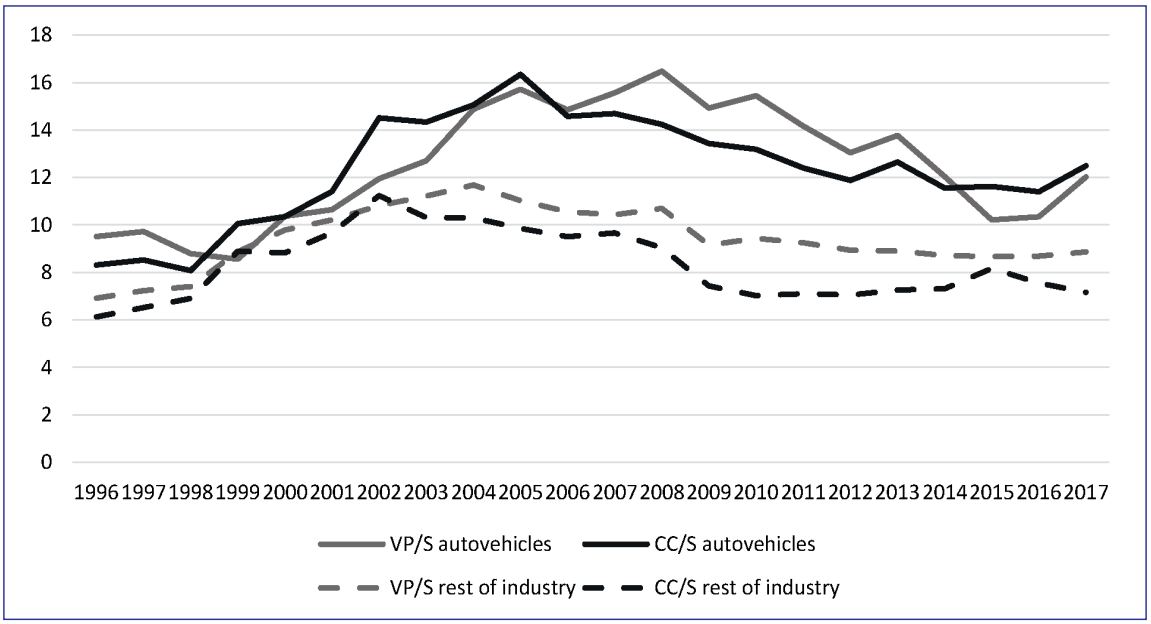
Note: (CC/T) Intensity of Capital, (VP/CC) Capital productivity, (S/T) Medium wage, (CC/E) Constant capital per enterprise, (T/E) Laborer per enterprise. Year 1996=100. Data deflated to 2017 prices by IGP-DI (FGV).

Source: Raw data from IBGE (2020).

Table 1 shows the percentage variations of the variables in different years, being 1996 the base year. It is interesting to note that, for the entire period considered, there is a positive variation in the proportion of capital invested per laborer (CC/T) while reducing the relation between production and capital (VP/CC) and a certain stagnation of medium wages (S) is observed. This suggests that capital investment has been disproportionately followed by labor and wages, signaling steady capital intensification. This is a characteristic effect of the inflection to the large industry. Based on the period between 1996 and 2003, there is a decrease in capital per enterprise (CC/E) which is explained by the expansion in the number of automakers, which jumped from 5 in 1996 to 13 in 2003 (Frainer, 2010, p. 79). There was also, until 2003, a considerable drop in the number of laborers per enterprise (T/E) and a subsequent resumption, which does not reach the level of 1996 as the base year. This resonates with the findings of Frainer (2010), for whom the expansion of investments was much greater than the one of jobs between 2000 and 2004, which is partially explained by "capital intensive investments and, therefore, savers of labor" (Frainer, 2010, p. 97). This reinforces the hypothesis of the inflection of the technical basis in the period between 2000 and 2004.

It is possible to add to the analysis the behavior of the organic composition (CC/S). As suggested in the methodological section, the larger this composition, the more marked the inflection becomes, as it portrays a more accelerated growth of potential investments in machinery. In the same direction is the relationship between the value of production (VP), measured in product prices, and wages (S), in which the higher the resulting rate (VP/S), the greater the contribution of the quantum of labor earnings for relative prices or higher is the productivity of the wage. In Graph 3, the growth trend is evident between 1999 and 2008 for both measures. There is a reinforcement of the hypothesis under verification, especially when compared to the behavior of the curve of the same indicator for the rest of the national industry. The change in the trend is explained by market factors with the recession that started with the 2008 *subprime* crisis.

**Graph 3**
**Organic composition and wage productivity in the auto sector and in the economy as a whole in Brazil (1996-2017)**



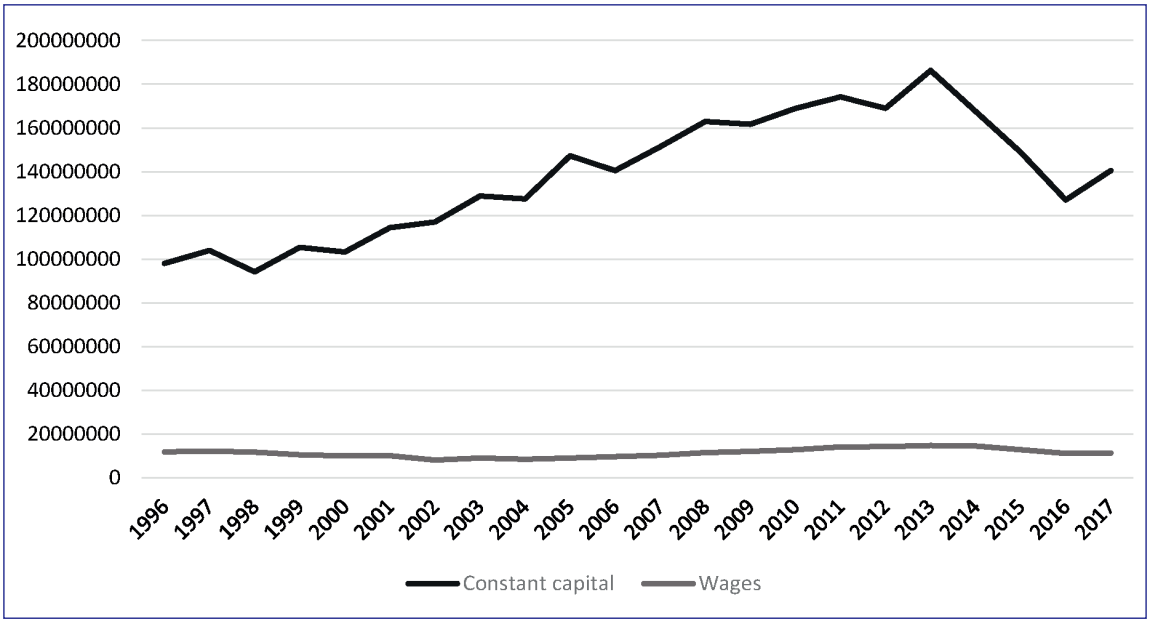

Note: organic composition (CC/S) as a ratio between constant capital (CC) and total wages (S), wage productivity m easured by the ratio between the value produced and the mass of wages (VP/S). The rest of the economy comprises the other sectors of the extractive and manufacturing industries. Data deflated to 2017 prices by IGP-DI (FGV).

Source: IBGE (2020).

It is clear that the organic composition (CC/S) in the auto sector, in addition to reaching a higher level than the rest of the Brazilian economy as a whole, sustains the growth and the level reached throughout the 2000s, even after the 2008 crisis. In the rest of the industry, there is a more erratic movement and growth with little support from the beginning of the 2000s. The same contrasting movement occurs with the relationship between value produced and wages (VP/S). This relationship, by the way, reaches its highest point after the peak of the organic composition, showing an effect of those capital-intensive investments. It should be noted that, as of 2001, despite the declines, the indicators do not fall back to the levels of previous years, even for those of more acute recession after 2014. In other words, the market slowdown makes neither CC/S nor VP/S regress to the moment of transition to the large industry; and that presents itself more and more limited for the period between 2000 and 2004.

The decomposition, in particular of the organic composition (CC/S), in its related terms, allows us to observe the most contributory factor to the observed behavior. There are, in general, results conditioned by differences in trends and speed. The same rate of composition could be obtained with steady capital stagnation and falling wages, for example, or growth with disproportional speed on the part of the relation numerator. However, the data suggest another conclusion. Graph 4 allows the observation of the difference between the trends of the two factors.

**Graph 4**
**Constant capital and mass of wages in the auto sector in Brazil (1996-2017)**




Note: Annual breakdown of investment in Constant Capital (CC) and in wages (S) in the production of vehicles in Brazil. Data deflated to 2017 prices by IGP-DI (FGV).

Source: IBGE (2020).

The growth of the organic composition was sustained by the increase in constant capital, and not by the decrease in wages or by disproportionate speeds of growth of the factors. This growth is symptomatic of the development of the large industry as a distinct pattern from the previous decade, and it is possible to delimit for this period the "great convergence", that is, the leap to the "automation riverbed". This conclusion becomes more evident if added to the previous findings of Marquetti and Porsse (2014), for whom a new technical standard was established in Brazil between 1991 and 2008, with the disadvantage of establishing a broader range than the collected evidence suggests.

Finally, important changes also occurred in the composition of the workforce due to a previous inflection of the technical basis. Table 2 shows the development of the representativeness of these occupations with the change in the proportion of each one in relation to the total number of laborers.

**Table 2**
**Variation in the proportional composition of the workforce in the auto sector in Brazil (2001-2016)**

| Ocupations | 2001 (%) | 2006 (%) | 2011 (%) | 2016 (%) |
|---|---|---|---|---|
| Mechanical adjusters, assemblers and mechanics of machines, vehicles and precision instruments | 107,37 | 126,61 | 138,27 | 118,46 |
| Metalworking laborers | 92,55 | 62,40 | 47,57 | 38,48 |
| Plumbers, welders, planers, boilers and assemblers of metal structures | 105,01 | 85,24 | 82,33 | 55,61 |
| Technicians, technical designers and similar laborers | 120,06 | 79,7 | 60,7 | 75,03 |
| Painters | 108,79 | 99,65 | 106,75 | 78,50 |
| Electricians, electronics and similar laborers | 44,53 | 35,33 | 44,06 | 58,16 |
| Masters, foremen, supervisors of production and industrial maintenance and similar laborers | 82,04 | 67,64 | 93,24 | 115,30 |
| Laborers who handle the transport and manipulation of goods and materials | 83,45 | 70,51 | 77,08 | 97,82 |
| Engineers, architects and similar laborers | 124,28 | 168,15 | 183,16 | 207,12 |
| Economists, administrators, accountants, managers and similar workers | 135,76 | 184,47 | 189,51 | 246,63 |
| Production line feeder | - | 100,00 | 150,68 | 442,05 |
| Quality inspector | - | 100,00 | 96,39 | 96,09 |

Note: Variation in the proportion of professions in relation to the total amount of workforce in the assembly of vehicles considering 1996 as the base year (1996 = 100). As of 2002, the method of categorizing professions has been modified by IBGE. Thus, in 2006, new professions with a high number of workers were verified, such as a production line feeder and quality inspector.

Source: Raw data from the Ministry of Labor and Employment (MTE, 2020).

Regarding the qualitative composition, it is possible to say that there was, on the one hand, an important increase in the number of engineers, managers and workers whose occupation is to feed the production line, assemble vehicles and act in the maintenance of machines. On the other hand, this growth, which began in 2001 and increased over time, was accompanied by a relative decrease in more specialized occupations, such as technicians, painters, electricians and welders. Although some central and permanent modifications had already appeared in 2001 – such as the increase in the importance of engineers, the increase in the number of workers located in the assembly and the decrease in electricians –, the modifications were consolidated during the 2000s, with the progressive fall of designers and machining laborers and the appearance of other occupations related to quality control and the performance of the assembly line itself. It is necessary to emphasize, however, that the technological change did not represent the elimination of more specialized occupations, but reduced its weight in the total quantity, thus qualitatively modifying the whole of the workforce. In short, there has been a gradual modification intensified since 2001, when more specialized occupations start to give way to others more linked to the projection of the operation of the factories, to their operational functioning properly (managers and engineers), to the monitoring of the production line and the maintenance of the productive means that make up the process.

In conclusive terms, the study suggests that the inflection from modern manufacture to large industry in the auto sector in Brazil was probably concentrated between the years 2000 and 2004, considering the analyzed factors and its behaviors for the period. Thus, it is considered that the hypothesis could be confirmed.

## FINAL CONSIDERATIONS

The aim of this paper was to empirically delimit the inflection of the principle in the technical basis for the Brazilian auto sector, marking the period with the greatest probability of the transition between modern manufacture and large industry in that sector.

The research was conducted with the hypothesis that this transition occurred late in Brazil, not before the 2000s. In order to verify it, we worked with the analysis of certain observable factors in the period between 1996 and 2017 that provided significant evidence of the occurrence of inflection of the technical basis.

By analyzing these factors, it was possible to confirm the hypothesis and better delimit the period of occurrence. The evidence suggests that the change in the technical basis in the sector took place with greater probability between 2000 and 2004. This period witnesses the moment that proceeds to the capital inversions and that precedes the observable behavior of the highlighted and indicative variables, including the modification of the composition of the workforce for the sector years later.

One of the main limitations of the research is its level of analysis. As it operated at the level of the economic aggregate, the observation of the disturbances caused by the accumulated technical change is relatively independent of the degree of the technical basis' conversion. At the firm level, however, it will make a big difference to consider the inflection stage, to the degree to which production was taken over by machinery. Thus, it is an important issue for the continuity of research and for the study of other sectors to resolve how to fixate the inflection in the plan of a production process in terms of degree. There is also an additional limitation regarding the period covered by the survey in regarding the indicators (from 1996) and the quality of the available data. As suggested in the Introduction, we hypothesized based on the literature that suggested that there was no acute change in the technical basis before the 2000s. Extending the analysis period can be an important task to be considered, taking into account that the available data for the period prior to 1996 are not disaggregated to enable the same analyzes carried out in this paper, as underlined in the section on methodological aspects. The very character of the research, which sought to establish the period of greatest probability of inflection to the large industry in the sector, leaves the way open for further investigations. In this sense, studies comparing sectors that are equally manufacture, or, on the contrary, which have already shown themselves to be entirely focused on large industry, may be contributory to the deepening of the research carried out.

Finally, there is also an interesting direction for the continuity of the research. The more robust literature enshrined the suggestion that the "selective" process of introducing new technologies – in selected stages of the production process – in the sector was a characteristic feature of Brazil, and could be extended to other countries with similar socioeconomic conditions, especially among those that show low wage levels (cf. Carvalho, 1987). There is a hypothesis which verification would be contributory to the body of knowledge on the subject: is the selective process of introducing new technologies that cause a transition between modern manufacture and large industry a peculiarity of low-wage countries? The problem becomes more interesting as there is evidence in the literature that the introduction of new technologies in the production of vehicles is selective even in countries with more advanced economies, differing due to the speed at which the degree of automation reaches a high level (Koshiro, 1987). The same problem arises for the investigation of the transition between *large industry* and *large modern industry*, with the development of *machine learning* and other devices in the context of the so-called 4th Industrial Revolution.

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