DETERMINANTS OF BRAZILIAN INDUSTRIAL PRODUCTIVITY: A KALDORIAN ANALYSIS FOR THE PERIOD 2008-2014

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Abstract

The present paper analyzes the determinants of industrial productivity in a Kaldorian perspective, between 2008 and 2014. The analysis uses data from PINTEC-IBGE and PIA-IBGE, comprising more than 38 thousand industrial companies distributed across around 2.300 Brazilian cities. The study considers locational determinants as well as innovative efforts in an attempt to investigate the productive performance of Brazilian industrial firms. Results show that productive specialization positively affected productivity, especially in cities specialized in low technology intensity sectors. It is also found that innovative efforts based on R&D and equipment and machinery acquisition have not produced the results anticipated in theory.

Keywords: Industrial productivity; innovative efforts; multilevel analysis; brazilian companies.

Área temática: 2. TEORIA ECONÔMICA E ECONOMIA APLICADA

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1. Introduction

One of the main aspects of economic development is related to the innovation process which, according to Schumpeter (1934), would be the only phenomenon capable of increasing the wealth of an economy in the long run. In the discussion related to the processes that lead to innovation, the production, adoption and diffusion of technological innovation are essential factors for economic growth and social change. Moreover, technological innovation is a distinctive feature of the products and sectors in which countries compete successfully in the world market. The innovative effort of firms is fundamental to the creation of knowledge that enables the identification, adoption and production of innovation in a constant learning process (MALERBA, 1992; BELL and PAVITT, 1997; LALL, 2005).

Hall (2011) discusses the relationship between innovation and productivity, both theoretically and empirically. Overall, the author argues that the variety of technological knowledge plays an important role in explaining productivity differences among firms. One can say that Griliches (1979) presented the first formulation that attempted to comprehend this relationship. More recently, in discussing the relationship between innovation and productivity, Morris (2018) found results that reinforced the traditional patterns of innovative efforts, in which physical and human capital intensity are key to innovative performance, as well as to determinate productivity levels. Despite the expected patterns[1], Crespi and Zuniga (2012) warn about some controversies related to measurement and empirical analysis, finding a positive relation for six Latin American countries. Besides, developing countries, structurally, tend to have lower investments on research and, therefore, lesser knowledge production (VIOTTI, 2002). As a result, these countries take part in production only passively and are dependent of technology imports.

This Schumpeterian discussion, brought to the Kaldorian debate on industrial productivity and economic growth, allows the establishment of a parallel between the innovative goal of firms seeking profits and market share, and the aggregate result of this process from the perspective of increasing levels of industrial productivity and the importance of this growth for overall economic performance. The strong causality between industrial and economic growth observed by Kaldor (1966) was justified by productivity. This cannot be understood as exogenous to the economic system, since its behavior would also be affected by the growth of the industrial sector. The existence of a cross-causality between productivity and economic growth has become known as "Verdoorn's law" (KALDOR, 1966; ROWTHORN, 1975; McCOMBIE, 1981; McCOMBIE and DE RIDDER, 1983; McCOMBIE and DE RIDDER, 1984; BAIRAM, 1987).

The aim of the present study is to assess the impact of two dimensions of the innovative[2] effort on the levels of productivity of Brazilian industrial firms according to Kaldor's perspective, as well as the influence of the environment on the firms. This article contributes to the literature by extending the analysis at the enterprise level in a dialogue with the territorial restrictions, as done by Britto and McCombie (2015). This includes innovative effort variables as controls to the potential generation of economic dynamism, via productivity, in economically backward countries. The consequences of the 2008 crisis, and the reality of a developing country of large territorial dimension and significant spatial heterogeneity, is emphasized in the period analyzed. The empirical analysis focuses on the Brazilian manufacturing industry using multilevel modeling, adapted from the model of Verdoorn's law, for the productivity of Brazilian industrial firms for the period between 2008 and 2014.

The paper adds to the debate on innovate effort and productivity in a Kaldorian perspective and its contribution is twofold: firstly, it concerns data disaggregation and the correspondence

[1] R&D investment usually increases absorptive capacity, knowledge assimilation and allows differentiating firms.
[2] One with greater focus on R&D and another with greater focus on machinery and equipment acquisition and on training, which will be explained below.

between two important Brazilian databases. Given the country's continental extension and spatial heterogeneity, data of three subsequent innovation surveys have been combined with annual data on industrial performance, all at the firm level. This leads to the second contribution, which is including the features of regional productive structures among the determinants of productivity. Ultimately, the discussion of innovative efforts and firm performance have important local roots that should be accounted for.

In addition to this initial section, the present article contains four other parts. The second part presents the theoretical framework that supports the discussion; the third part presents the data used in the empirical analysis, with the variables created and the empirical strategy adopted; the fourth part presents and discusses the results of econometric exercises; and, the last part presents the findings obtained from this study.

2. Bibliography

2.1. Innovative activity and Kaldorian productivity

Many scholars who deal with the processes that lead to innovation acknowledge production, adoption and diffusion of technological innovation as key factors of economic development and social change. They also acknowledge that technological innovation is a distinctive feature of the products and sectors in which countries with high wages compete successfully in the world market.

Investments in innovative activities are essential for the creation of technological capabilities that can identify market trends, allowing greater optimization of investments in the opportunities created. Therefore, Malerba (1992) points out that technological activity in the firms would be responsible for the creation of knowledge essential to the learning process (learning by doing, by using, by searching, by interacting, etc.). From a similar perspective, Bell and Pavitt (1997) highlight the importance of building the capacity to enable the generation and management of technological changes, especially the creation of productive skills and the accumulation of knowledge and experience. The process of accumulating technological progress allows companies or countries at the technological frontier to enjoy advantages over those which are backward technologically. Finally, it is exactly the search for this differential gain that drives technological progress.

Firms accumulate knowledge (learning) in different ways. However, the generation of these knowledge stocks and technological capabilities is what would bring gains in the technological trajectories, and not only in terms of production cost (MALERBA, 1992). Nevertheless, this is a costly process that demands effort and discipline from the firm, but which generates technological advantages. This theoretical framework makes clear the importance of creating conditions conducive to the internalization of knowledge. As this is a process that depends on prior construction/investment, it requires significant and continuous effort.

Understanding industry performance through analyzing the innovative process is on both the Kaldorian and the Schumpeterian research agendas. Whereas the Kaldorian perspective is centered on Verdoorn's Law, Schumpeter's perspective focuses on the importance of learning and the creation of productive capacities which tend to generate technological advances that, in turn, make productivity growth possible.

Kaldor (1966) highlights the importance of net exports as the main component of final demand. Important developments and formalizations of export-led growth models have led to the perception that the growth rate of the economy would be given by the ratio between the growth rate of exports and the income elasticity of demand for imports (DIXON and THIRLWALL, 1975; THIRLWALL, 1979; MCCOMBIE and THIRLWALL, 1994, among others). The basis for the development of export-led growth models is in Verdoorn's Law. The starter mechanism of industrial dynamics, which increases industrial productivity and determines economic growth, is related to the external sector of the economy. In other words, the growth of exports (net) is a key factor in determining the rate of growth of economies. This implies that economic growth comes from demand, and not from supply as neoclassical theory stated.

Kaldor-Verdoorn’s Law presents a relationship between increased production and a consequent generation of economies of scale, which would have a key role in increasing productivity. This productivity increase would have a positive effect on the growth rates of exports which, in turn, would have an effect on the balance of payments, and thereby generate a virtuous cycle of growth. The improvement in competitive international insertion stimulates the growth of the industrial sector (through exports) and creates conditions for the generation of better internal economic dynamics through work remuneration (more productive), stimulating domestic consumption growth and investment.

The relationship between productivity and product would be explained by the division of labor, assuming that specialization would allow the growth of human capital (a process similar to learning by doing, which enables the building of productive capacity). Although Kaldor’s theory gives greater focus to the demand-side in determining economic growth, productivity growth, mainly industrial growth, and the endogenous advancement of technical progress, they all create conditions for the adoption of new productive forms and the development of new products, which also exert important stimulus on the supply-side.

Kaldor (1966) presents the original version of Verdoorn's Law, expressed by:

$$p_i = \alpha + \beta q_i \qquad (1)$$

with: p_i = growth rate of labor productivity, α = autonomous component of productivity, q_i= growth rate of production ($\beta > 0$), representing the idea that product growth drives the growth of labor productivity in the economy.

The possibility of a spurious correlation bias existing between product and productivity has led to the development of a new specification (KALDOR, 1975), in which it would be necessary to assume that $\mathrm{p_i = q_i - e_i}$

$$e_i = \tau + \partial q_i \qquad (2)$$

with: $\mathrm{e_i}$ = growth rate of employment, $\mathrm{q_i}$= growth rate of production, 0< ∂<1. Where $\mathrm{p_i = q_i - e_i}$, therefore: $\alpha = -\tau$ e $\partial = (1-\beta)$[3].

Based on this theoretical development, a number of empirical tests were conducted, with several different approaches (national, regional, firms) and specifications, to test for the existence of this causal relationship between product and productivity. Based on Kaldor’s (1966) empirical analysis, Rowthorn (1975), McCombie (1981), McCombie and de Ridder (1983) McCombie and de Ridder (1984), Bairam, (1987), among others, tested the validity of Verdoorn's Law. At the end of the 90s, there was a methodological breakthrough including geographic determination as an important factor to be considered in the analysis. Under this perspective, Bernat Jr. (1996), Fingleton and McCombie (1998), Fingleton (2000), Angeriz et al. (2008), among others, used spatial econometrics to discuss the influence of proximity, positive or negative, on the levels of productivity and product, as well as the importance of considering the space.

Some studies, highlighted below, discuss the theme and test its validity in Brazil: Marinho et al. (2002), and the analysis of the manufacturing industry between 1985 and 1997; Guimarães (2002), who studied industry and agriculture between the 70s and 90s; Morrone (2006), who also studied agriculture and industry in a period close to that of Guimarães (2002); Oliveira et al. (2006), and the analysis of the Brazilian manufacturing industry from 1976 to 2000; among others. Britto and

[3] A debate between Kaldor and Rowthorn, in search of a better specification for Verdoorn's Law, marked the theoretical breakthrough in the 70s. Later, it relied on the contribution of other authors who, to some extent, participated in the debate suggesting alternative specifications (instrumental variables, inclusion of capital stock in determining employment or as an endogenously determined variable of product growth). Rowthorn’s specification (1975), as an alternative to Kaldor (1975), would be: $p_i = \lambda + \varepsilon e_i$, with p_i = rate of labor productivity growth, e_i = rate of employment growth. His argument is based on Kaldor’s (1966) statement that growth would be constrained by the supply of workers.

McCombie (2015) test the validity of Verdoorn's Law for Brazilian industrial firms, drawing attention to the importance of including locational controls in this discussion of industrial productivity and product, which would also have a strong influence on the growth of companies. Among the results obtained by the analysis of Brazilian industrial firms from 1996 to 2002, the increasing returns to scale should be emphasized.

In addition to the importance of the increase in productivity resulting from the increase in production, the importance of the development of productive capacities that allow production in the technological frontiers of products with high income elasticity should also be emphasized. This advancement was essential for creating the conditions necessary to overcome the external imbalances marked mainly by the export of products with low-income elasticity of demand and imports of products with high-income elasticity.

The learning process, due to its cumulative feature, should be stimulated/developed continuously, at the risk of not observing and capturing the spillovers from new technologies or new technological opportunities that maintain the technological distance between leaders and followers and, therefore, the differences in economic growth rates. From this perspective, Abramovitz (1986) talks about the possibility of the increase in productivity levels in follower countries and the consequent catching-up through the development of "social capabilities", allowing the monitoring of countries that are located on the technological frontier, by absorbing knowledge generated by them.

The construction of conditions conducive to competitive international insertion passes through the creation of productive capacities, which demand investment and time. Investments in physical and human capital, such as the purchase of machinery and equipment and training for operations, are necessary for learning and developing skills. At the same time, investments in R&D (internal or external acquisition) create conditions conducive to a better understanding of best practices and opportunities to be developed or followed. In any case, a willingness to invest is essential to enable such gains. Sporadic or occasional investment, as much as it can increase productivity[4], does not create the conditions necessary for the endogenization of progress. Only the continuity of the process would develop conditions and skills so that the advances are determined to be a natural choice of competitive insertion of the firm. The time and the continuity of investments would allow the accumulation of knowledge that would give the firm a greater ability to position itself in response to market changes or to create supply-side stimuli.

Considering the non-innovative nature[5] of Brazilian industry, an alternative would be to invest in capacity building to follow technological advances more closely. This process, carried out continuously, would enable the creation of better conditions for the endogenization of technological progress.

2.2. Industry and Productivity in Brazil

The large identification of the productive process with the territory, and with the possibilities of optimization of its surroundings, leads to the emergence of a new reality that repositions the territorial issue. The decrease of distances, marked by communication technologies and reduction in transportation costs, has allowed a productive reorganization.

In this new scenario, it can be emphasized that technological progress, production automation and the constant search for new products and market niches have promoted a geographical dispersion of production, seeking, in breaking with the productive rigidity of the former system, new ways of providing inputs and services that have required a series of transformations in organizational and commercial standards. At the same time that productive activity was dispersed territorially, new forms of territorial centralization emerged, usually related to high-ranking management of operations and their central control. These new movements present a reorganization, to some extent, strongly driven

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[4] It is difficult to understand the purchase of a machine or equipment that does not aim at production optimization and cost reduction, with consequent productivity growth.

[5] This would be a generalization, recognizing the existence of the innovative feature in a few sectors that, by their dimension (revenues and employment generation), still allow the generalization made.

by disaggregation factors related to the cost of locating in central areas (PUGA and VENABLES,1996; DURANTON and PUGA, 2005; BARBOUR and MARKUSEN, 2007; GLAESER and RESSEGER, 2010, among others).

Bringing this discussion to Brazil, a country with late industrial development and significant spatial heterogeneity[6], it is possible to identify territorial characteristics more or less favorable to the spread of technological knowledge. The lack of a minimum social capacity that allows the absorption of knowledge (ABRAMOVITZ, 1986) determines the exclusion of a large part of the Brazilian territory from production/industrial progress.

It is unquestionable that the country experienced reorganization of its productive structure and spatial distribution after the 1990s. This restructuring, more connected to the external market and more demanding of workforce qualification, began to be more influenced by locational factors. In this scenario, urbanization was clearly an important element of this new productive restructuring dynamic. Furthermore, new studies of agglomeration economies, that relate external economies of scale and regional productive structure with productivity levels, have gained greater prominence recently (GALINARI et al., 2006, FONTES, et al. 2010, FREITAS, 2012).

The economic growth, with income distribution, experienced in Brazil in the 2000s, was strongly influenced by external demand (commodities) that generated an internal dynamic with consequent incorporation of labor and generation of income. The 2008 international crisis seems to have changed the course of this path a bit and the Brazilian economy has lost steam in the process, with economic growth, in the expansion of employment and income, receiving a strong impact. The exhaustion of the Brazilian economic model of the first decade of the 2000s[7] again calls attention to the importance of discussing factors that determine the increase in productivity levels. The industry plays an undeniable role (MESSA, 2015), either through its greater capital volume, being an important source of innovations, or through its capacity to generate better quality jobs (remuneration) with less turnover, favoring the development of specific human capital.

Cavalcante et al. (2015) highlight the importance of the increase in productivity levels of the Brazilian economy for the recovery of the cycle of economic growth. The authors emphasize investments in Research and Development (R&D) and in innovation as drivers of future productivity, suggesting a relationship between innovation and productivity. They test the hypothesis that labor productivity in sectors of less technological intensity would be more sensitive to the acquisition of machinery and equipment than to investment in R&D, and find results that confirm it. Only the sectors of high technological intensity show no positive relationship between productivity and investment in machinery and equipment, with the impact slowing gradually as technological intensity advances (CAVALCANTE et al., 2015). De Negri and Cavalcante (2014) argue that technological innovation must be the main determinant of the increase in productivity (both in terms of process and product), with emphasis on investments in education and workforce qualification as the sources of technological advance.

Therefore, just as the innovative process as a whole is largely influenced by its local dimension, the productivity of Brazilian industrial firms is more influenced by factors related to proximity.

3. Databases and Methodology

3.1. Databases

Separate databases were combined for the empirical analysis. They are: Innovation Research (PINTEC-IBGE), Annual Industrial Survey (PIA-IBGE) and Annual Survey of Social Information (RAIS-MTE). The database is formed by all companies in the PINTEC studies in 2008, 2011 and

[6] The Brazilian production/industrial structure is heavily concentrated in the State of São Paulo and in the southeast, despite recent policies which fostered regional redistribution of industry, notably toward the northeast.

[7] Rising prices of commodities, capital inflow, expansion of consumption, low rates of savings, among other factors.

2014, and information from the PIA-Local Unit-IBGE, in addition to some municipal indicators constructed largely with data from the RAIS-MTE, was aggregated to them.

PINTEC-IBGE presents a series of sectoral indicators of the innovation activities of Brazilian companies. It aims to evaluate determining factors of the innovative behavior of the companies (strategies, efforts, incentives, obstacles and innovation results). The PIA-Local Unit gathers economic-financial information on the Brazilian industrial sector encompassing, among other aspects, data about employed people, salaries, withdrawals and other remuneration, receipts, costs and expenses, intermediate consumption, production and industrial transformation value, at a level of municipal disaggregation.

Indicators of industrial activity, from the formal labor market profile, at the company level, were aggregated to these data at the municipal level using the RAIS-MTE. RAIS is an annual, administrative record, created to supply the necessities of control, statistics and information to governmental entities from the social area, in order to monitor and characterize the formal labor market. In addition to these data, a municipal distance variable from the city of São Paulo was used[8].

3.2. Multilevel analysis

The analysis of industrial productivity is done by focusing on the importance of the companies' environment, assuming that it is also a conditioning factor of the trajectories, justifying the use of multilevel modeling. This interaction with the firms' environment, with the possible relationship of mutual causality among individuals (in this case, firms) and environment (locale), cannot be disregarded in the analysis (GOLDSTEIN, 1995). The possibility of a relationship among the variability of the individual characteristics, conditioned by the firms' environment, should be considered in the analysis. This is because, even having control of the individual and environmental characteristics there exists the possibility that, in not distinguishing between hierarchical levels and their correlation, the estimates become spurious.

The proposed use of hierarchical modeling is intended for better identification of the behavior of the Brazilian industrial firm (highly concentrated in the space), to avoid attributing to the firms that which is determined by location. For example, understanding that the average behavior of the firm is highly influenced by location and that it is possible to identify that, despite the large industrial concentration in the state of São Paulo, the average behavior of the firms in SP is different from that of the firms in Brazil, overall. Also, that it is important to have this identification in order to avoid inferential errors.

The methodological advance brought by the hierarchical models is related to the possibility of identifying possible intercepts and/or trends for each unit of observation in the 2nd level of the analysis. This option identifies the existence of conditional averages (1st level) that may assume different behaviors within each 2nd level "group" and that, therefore, requires appropriate treatment.

The simplest model brought by the hierarchical analysis is the ANOVA with random effects. This first specification captures significant differences between the general mean of the response variable and the specific means of each 2nd level group. In other words, how the mean variability of the groups is manifested in relation to the general mean of the population, with the variance of the response variable given by:

$$Var(Y_{ij}) = Var(u_{0j} + r_{ij}) = \tau_{00} + \sigma^2 \quad (3)$$

The deconstruction of the variance into two independent components (τ_{00} – between groups and σ^2 – within groups) allows calculation of the intraclass correlation coefficient. This indicates how much of the total variance (of the dependent variable) is explained by the 2nd hierarchical level, which is a measure of how much the environment conditions individual behavior.

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[8] This variable is a 5565 x 1 matrix, which contains the distance of all Brazilian municipalities to the city of São Paulo and was constructed by De Carvalho *et al*. (2016).

This first specification, despite revealing the existence of a correlation among structured variables at different hierarchical levels supporting the use of multilevel modeling, includes no explanatory variable in the model. The construction of more complex models, that incorporate explanatory variables from the 1st and 2nd levels, enables better accommodation of some of the variability of the dependent variable.

Following the methodological developments of multilevel modeling, it is possible to arrive at a generic formulation (RAUDENBUSH and BYRK, 2002). The idea behind this formulation is that the exclusion of elements of this specification (individually, or in a group) allows the representation of any other hierarchical specification. Thus, we have:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(X_{ij}) + r_{ij} \quad (4)$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(W_j) + u_{0j} \quad (5)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(W_j) + u_{1j} \quad (6)$$

Substituting (3) and (4) into (2), we have a hierarchical model with two levels, in its most complete formulation:

$$Y_{ij} = \gamma_{00} + \gamma_{01}(W_j) + \gamma_{10}(X_{ij}) + \gamma_{11}(X_{ij})(W_j) + u_{1j}(X_{ij}) + u_{0j} + r_{ij} \quad (7)$$

W_j represents an explanatory variable of the 2nd level (or a vector of variables), γ_{01} represents the conditional mean of W_j in Y_{ij}, γ_{11} represents the interaction coefficient among variables of the two levels under Y_{ij} and the terms of the random error (u_{1j}, u_{0j} and r_{ij}) with a "0" mean in the two levels of the analysis and in the slope β_{1j}.

4. Analysis of results

The estimations presented in this section use productivity growth rate as the dependent variable of the model. The productivity indicator used was "Value of Industrial Transformation / People Employed" – VIT/EP, representing labor productivity. The productivity growth rate was defined, year by year, as the "Ln" of the variation of VIT/PE among the years and the employment indicator used was "People Employed".

Adapting the Kaldor-Verdoorn model to the proposal for analyzing determinants at the firm level, inserting municipal controls and focusing on the innovative efforts of Brazilian firms, the definition of the explanatory variables of the firm is as follows:

- As a *proxy* for the growth rate of the product, the industry net revenue[9] growth rate of the PIA-UL was used, defined as "Ln" of the industry net revenue in "T" minus "Ln" of the industrial net revenue in "T-1", done for the years 2008, 2011 and 2014[10] in order to be compatible with the years from PINTEC;
- Distance Variable of the firm's productivity in relation to the sectoral leader (CNAE 2.0 Division) – the firm's delay in relation to the national frontier of the sector[11];
- Dummy for companies that claimed to have ongoing R&D activities during the triennial PINTEC evaluation;
- Expenditures for innovative activities (two variables, one which synthesizes an innovative effort more related to process innovations and the other to product innovations).

[9] Industrial Revenue was chosen as a proxy for growth rate of the product, to the detriment of the VTI, because the VTI was used as the numerator of the dependent variable of the model and its explanatory use would represent a problem of simultaneity in the estimates.

[10] Ex.: 2008 = 1n (Net Ind. Rev–2008) – 1n (Net Ind. Rev–2007).

[11] This indicator varies negatively from zero, which is the "delta" of the leading company, with the most backward company sectorially representing the smallest value of the variable.

For the second level of analysis (municipal), controls were made for locational characteristics, urbanization and product specialization; also, for the workforce profile by educational level and occupational hierarchy, as follows:

- Characteristics of the local labor market: indicator of spatial concentration for occupations of high technological hierarchy and for high level of education;
- Diversification indicators (Hirschman-Herfindahl index, modified for sectors of the manufacturing industry – CNAE 2.0 Division) and productive specialization (specialization index (QL)). Four specialization indicators were created: low, medium-low, medium-high and high technological intensity);
- Specialization indicator in jobs in the productive services sector (Qls for jobs by class – CNAE 2.0);
- Urban scale indicator (Ln of the municipal population); and,
- Geographic proximity indicator with the municipality of São Paulo.

Thus, the transformation of the generic model of equation (1), according to the specifications that will be tested, is:

$$p_{ij} = \beta_{0j} + \beta_1 q_i + \beta_2(delta\_prod) + \beta_3(R\&D) + \beta_4(\ Inov.Effort\ Proces) + \beta_5(\ Inov.Effort\ \ Prod) + r_{ij} \qquad (7)$$

with p_{ij} equal to labor productivity and r_{ij} equal to the error term, and:

$$\beta_{0j} = \gamma_{00} + \beta_{0k1}Urbanization + \beta_{0k2}Specialization + \ \beta_{0k3}\text{workforce} + \ u_{0j} \qquad (8)$$

e $\beta_1 = \ \gamma_{10}$; $\beta_2 = \ \gamma_{20}$; $\beta_3 = \ \gamma_{30}$; $\beta_4 = \ \gamma_{40}$; $\beta_5 = \ \gamma_{50}$, which, substituted in (7), is:

$$p_{ij} = \gamma_{00} + \beta_{0k1}Urbanization + \beta_{0k2}Specialization + \ \beta_{0k3}\text{workforce} + \gamma_{10}q_i + \gamma_{20}(delta\_prod) + \gamma_{30}(R\&D) + \gamma_{40}(Inov.Effort\ \ Prod) + \gamma_{50}(Inov.Effort\ Proces) + u_{0j} + r_{ij} \qquad (9)$$

The rationale for estimating this adapted form of productivity determinants is the analysis of the impacts of investment in innovative activities on the productivity growth of Brazilian industrial firms, from the perspective that investing in the capacity to absorb knowledge is fundamental to reducing the technological gap in countries with delayed industrial development. Therefore, the proposal is to observe whether, and how, these different innovative efforts help productivity growth.

The variable of interest in determining the industrial productivity growth rate, originating from PINTEC, is innovative effort. This analysis is done taking the territorial conditionalities into account. Since PINTEC has no disaggregation at the municipal level, it was necessary to create a strategy to reconcile this information from PINTEC with the information from Local Units present in the PIA-Business. The strategy adopted was the "simple" division of the PINTEC values (CNPJ) among the different ULs that had the same CNPJ[12].

After the methodological choices were made, the theoretical foundation of this empirical exercise includes innovative effort as an important alternative to productivity growth, and even to the

[12] There was an option to work with companies that had a single Local Unit (UL), which eliminated the problem of choosing the best strategy for dividing values, but which would lead to the problem of bias in the selection of the base, by excluding companies that probably represent the largest in the country. Another option would be to identify some criterion of division, whether by the portion of "Employed Personnel", by the weight of the "Value of Industrial Transformation" or by any other criterion. The authors have the results of the estimates for the three strategies cited (single ULs, division by "Employed Personnel" and VTI). It can be affirmed that, except for the results for companies that had only one UL, as they represent a distinct group of companies, the other two compatibilization strategies (PINTEC - PIA-UL) presented results very similar to those given below, the simple division of PINTEC values by the ULs without any weighting was chosen. This problem would be fully resolved if PINTEC permitted the identification of the UL in which the expenditure for innovative effort was made.

survival, of the companies. In this sense, the strategy of the firms, in a competitive economy, aimed at innovations that generate revenues and market share, tending to trigger an aggregated result of raising industrial productivity levels, with the consequent impact of this growth on general economic performance.

Dosi (1988) stresses the significant heterogeneity amongst firms, emphasizing the technological asymmetries or technological gaps between them. To Becheikh, Landry and Amara (2006), attempts to close such gaps would lead firms to engage in R&D, to qualify their labor force and to acquire more sophisticated equipment.

Access to international technical knowledge and equipment is relatively homogeneous (LALL, 2005), however, the capacity to benefit from them is substantially different among countries. This emphasizes the need for a deliberate, intentional and growing effort to gather information, test objects and create operational skills and routines. This effort should be understood as vital, and not automatic or passive.

Thus, an extension of Verdoorn's Law, in a hierarchical structure with controls for innovative expenses (firm level) and for municipal characteristics, will be estimated for different specifications. Table 1, below, shows the results of the ANOVA estimation and also of a specification with controls at the firm level.

Table 1: Determinants of Brazilian industrial productivity (Brazil - 2008, 2011 and 2014)

Dependent	Rate of productivity growth (VIT/PE)					
	ANOVA			1st level		
Independent	Coef.		SE	Coef.		SE
Constant	0.0432	***	0.0060	1.1027	***	0.0179
1st Level Variables - Company						
Industrial Revenue				0.5101	***	0.0075
Delta productivity				-0.2241	***	0.0033
Continuous R&D				-0.0356	*	0.0194
Innovative effort - product				-0.0089	***	0.0028
Innovative effort - process				-0.0070	***	0.0017
Dummy - Year						
2011				-0.0553	***	0.0112
2014				-0.0199	*	0.0113
No. of firms	39,905			38,595		
No. of municipalities	2,369			2,301		
	Variance		**CCI**	**Variance**		**CCI**
Municipality	0.0539	***	4.89%	0.1240	***	12.13%
Firm	1.0484	***	95.11%	0.8981	***	87.87%

Source: authors developed, base on PIA-UL (2007, 2008, 2010, 2011, 2013 and 2014) and PINTEC (2008, 2011 and 2014)

Note: *** significant at 1%, ** significant at 5% and * significant at 10%

The ANOVA estimation presents the intraclass correlation coefficient (ICC), significant at 1%, with the municipalities accounting for 4.89% of the variance of the productivity indicator. The β_0 shows that the mean productivity growth rate, in the years analyzed, was 0.043. Including only the 1st level explanatory variables (Table 1), the significance of the ICC (at 1%) is maintained, indicating that the 2nd level of analysis explains the variability of the data. This 2nd specification shows a Verdoorn coefficient of 0.51, significant at 1%, which indicates the existence of economies of scale in industrial activity. This result is close enough to the findings of Britto and McCombie (2015), who also analyzed the Verdoorn coefficients at the firm level.

Also, regarding the 1st level controls, the results suggest there had been a reduction in the technological GAP among the companies, with a significant "productivity delta", suggesting that companies closer to the sectoral leader increased their productivity less than the more delayed companies. This result aligns with the possibility of the productivity of Brazilian industrial firms catching up, presented in Abramovitz (1986). This result was not expected but, maybe explaining the lag in the domestic industry, it is the negative and statistically significant sign of continuous R&D activity. That is, companies that claimed to be conducting continuous R&D had lower productivity variation than the others. Finally, the identification that investments in innovative activities, potential generators of product or process innovation, do not generate a productivity differential for the companies that conduct them also reinforces the situation of the relative delay in Brazilian industrialization. Domestic companies that spend on R&D (internal or external), acquisition of machinery and equipment, training, acquisition of other knowledge and software, cannot transform these investments into an increase in their productivity levels. On the contrary, companies that spent more on this innovative effort, during the period analyzed, had less favorable results than those companies that spent less. It is important to note that the industrial companies, the focus of this analysis, belong to the group of PINTEC companies. That is, they are larger companies with greater innovative bias.

Table 2, below, shows the results of the estimates, including the 2nd level controls. It is organized with the inclusion of the municipal controls separately, and in a general model that contains all the controls together.

Table 2: Determinants of Brazilian industrial productivity – municipal controls (Brazil – 2008, 2011 and 2014)

Dependent	Productivity growth rate (VIT/PE)							
	Labor Market		Location				General Model	
			Urbanization		Specialization			
Independent	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Constant	1.1680 ***	0.0192	1.1583 ***	0.0249	0.1747	0.4763	-3.6401 ***	1.1632
2nd Level Variables - Municipality								
Mercado de trabalho								
Occupation - High	-44.5379 ***	13.0571					-22.0641 *	13.7662
Occupation Lower Upper	0.4414	3.5633					1.1947	3.3300
Occupation - Middle Upper	-1.5806 ***	0.3568					-1.1240 ***	0.3688
Education - completed undergraduate	-0.6508 ***	0.1333					-0.4656 ***	0.1416
Education - Master's	-4.4880	3.5633					-2.3212	3.5767
Education - Doctoral	-3.9816	7.8116					-3.2311	7.7951
Urbanization								
Industrial Diversification			-0.1299 ***	0.0261			-0.0737 ***	0.0258
Distance to São Paulo			0.0000	0.0000			0.0000	0.0001
Population			0.0000	0.0000			0.0000	0.0000
QL productive services			-0.0521 ***	0.0134			-0.0259 **	0.0137
Specialization								
QL low intensity					0.5165 **	0.2440	2.5014 ***	0.5964
QL medium low intensity					0.2165 *	0.1224	1.2235 ***	0.2988
QL medium high intensity					0.1576 *	0.0933	0.9434 ***	0.2275
QL high intensity					0.0177	0.0171	0.1644 ***	0.0410
Regions								
North			-0.0422	0.0699	0.0375	0.0371	-0.2390	0.0681
Northeast			0.0215	0.0529	0.0699 ***	0.0224	0.0219	0.0510
Southeast			0.0185	0.0206	0.0366 *	0.0194	0.0108	0.0202
MidWest			0.0304	0.0357	0.0445	0.0292	0.0191	0.0346
South			-0.0231	0.0212	-0.0221	0.0171	-0.0491 **	0.0206
1st Level Variables - Firms								
Industrial revenue	0.5092 ***	0.0075	0.5088 ***	0.0075	0.5096 ***	0.0075	0.5087 ***	0.0075
Productivity delta	-0.2262 ***	0.0031	-0.2267 ***	0.0031	-0.2268 ***	0.0031	-0.2290 ***	0.0031
Continuous R&D	-0.0308	0.0194	-0.0300	0.0194	-0.0304	0.0194	-0.0294	0.0194
Innovative Efforts - product	-0.0078 ***	0.0028	-0.0092 ***	0.0028	-0.0084 ***	0.0028	-0.0082 ***	0.0028
Innovative Efforts - process	-0.0069 ***	0.0016	-0.0071 ***	0.0016	-0.0071 ***	0.0016	-0.0071 ***	0.0016
Dummy - Year								
2011	-0.0455 ***	0.0113	-0.0560 ***	0.0112	-0.0554 ***	0.0112	-0.0462 ***	0.0114
2014	0.0292 **	0.0122	-0.0188 *	0.0113	-0.0198 *	0.0113	0.0142	0.0128
No. of firms	38,592		38,595		38,595		38,592	
No. of municipalities	2,299		2,301		2,301		2,299	
	Variance	**CCI**	**Variance**	**CCI**	**Variance**	**CCI**	**Variance**	**CCI**
Municipality	0.0956 ***	8.81%	0.1027 ***	10.26%	0.1016 ***	10.16%	0.0882 ***	8.95%
Firm	0.9895 ***	91.19%	0.8982 ***	89.74%	0.8982 ***	89.84%	0.8980 ***	91.05%

Source: authors, based on the PIA-ul (2007, 2008, 2010, 2011, 2013 AND 2014) and PINTEC (2008, 2011 and 2014)

Note: *** significant at 1%, ** significant at 5% and * significant at 10%

It is important to note that the inclusion of the 2nd level controls practically does not change the results of the 1st level controls. Small changes in the magnitude, signal maintenance and loss of significance, were only observed for the continuous R&D variable, which was significant at 10% and stops being significant. The first specification of Table 2 shows the municipal controls for the labor market. The occupational hierarchy indicators show that the greater the concentration of workers employed in "high" level occupations (significant at 1%), and the greater the concentration of "upper medium" level occupations (significant at 1%), the less were the productivity growth rates of the firms located in these cities. In terms of magnitude, the negative impact associated with "high" level occupations is significantly greater than the negative impact observed in the cities that have a greater concentration in "upper medium" level occupations. As for educational controls, a reduction in productivity is seen in firms located in cities with a greater concentration of industrial workers who completed undergraduate education, significant at 1%, while the concentration of workers with Master's or doctorates is not statistically significant.

The 2nd model, which controls for urbanization characteristics, shows the lack of influence of the urban scale, measured by the indicator of municipal population, also the lack of influence of distance to São Paulo. A measure of the influence exerted by the main city of the country shows that, although expected, the proximity to São Paulo does not facilitate access to the supply of goods and services that it produces (LEMOS, 1988; AMARAL and SIMÕES, 2015). The concentration of productive services, having a strong relation with the urban scale, showed a significant negative sign. This suggests, to some extent, the diseconomies of scale seen in such urban centers. Another determinant, also negative and significant, and which was expected to be a positive sign, is industrial diversification. The possibility of a "cross fertilization of ideas" seen in the diversified space would tend to raise the levels of industrial productivity, which is not seen in this specification (JACOBS, 1969). To some extent, this result aligns with the negative and significant sign of innovative R&D effort (expenditures), since this diversified space would be more propitious to such expenditures, with a significant correlation between these two variables.

The model that controls for the externalities of the specialized space, in the municipal determinants, the indicators of sectorial productive concentration by technological intensity, present an increase of the magnitude of the signal as the technological intensity is reduced. The municipalities with greater concentration of high technological intensity sectors did not show any difference in the determination of productivity (positive sign, but not significant), while the low intensity sectors were those with the greater positive and significant coefficient at 5%. This suggests that, in those spaces, there was greater impact on the growth of industrial productivity. The sectors of medium technological intensity had positive and significant impact. The importance of the externalities produced by this specialized space is broadly discussed and empirically tested, and the results obtained in this specification are supported in the literature (GLAESER *et al.*, 1992; COMBES, 2000; HENDERSON, 2003; among others).

Finally, the General Model presents the set of determinants tested in the three previous specifications. The estimate containing controls of the labor market, the urbanized space and the specialized space, together, have practically the same coefficients and meanings presented previously. This shows consistency of the econometric results and permits inference about the predominance of productivity growth in the specialized locations, and which concentrated industries of less technological intensity. To some extent, this reflects the less innovative character of the domestic industry, which has stood out more in sectors of low aggregate value and has not been able to benefit from expenses in innovative activities or of urban spaces more conducive to the flourishing of innovative activity. Such results reinforce the thesis that the domestic industry has great difficulty in keeping up with the industrial developments dictated by the global players.

Ultimately, innovative domestic investment could not generate productivity differentials for the companies that perform them. Thus, they are unable to create knowledge conducive to learning – *learning by doing, by using, by searching,* among others – as highlighted by Malerba (1992). To some extent, this result resembles that found by Taveira et al. (2019), also using Brazilian firm data from PINTEC, which verified the absence of a relationship between R&D and productivity from 2003 to 2008. Despite the methodological differences and although Taviera et al. (2019) follow Griliches (1979) and analyze this relationship from a Schumpeterian perspective, results draws attention to the lack of correlation, that is maintained for the period immediately after (2008 – 2014), when Brazil starts to face a slowdown of its growth trajectory.

It should be stressed that Brazil is characterized by low R&D investment levels, low human capital in science and technology, as well as low patenting rates (IEDI, 2011). Besides, it has only a few firms that innovate in products or collaborate to innovation. This scenario points to the importance of scale, in order that innovative efforts can produce the expected results.

The analysis of the Brazilian economy, in terms of relative delay in its industrial productivity, associated with the alternative of investing in the absorption of available technological knowledge, suggests that Brazil, in the period analyzed, could not move toward reducing the existing technological gap. This scenario emphasizes the tendency to aggravate this distance which, historically, refers to the alternative of taking advantage of its productive capacities related to the extractive and agricultural sectors. It should be remembered that these sectors have low aggregate value, low labor remuneration and low capacity for leveraging and placing a major portion of the Brazilian population into the labor market.

5. Conclusion

Given the relevance of the industrial sector to stimulate the economic activity of a country, either by its capacity to connect with other sectors or by being a source of high quality jobs, the search for its development should be understood as an alternative for developing countries. It is impossible to think of the industrial development of a country without focusing on raising productivity levels, though. This is further exacerbated in technologically backward countries, by the difficulties imposed by the modern market structure, marked by oligopoly in many sectors, with many barriers to the entry of new actors, especially in high technological content sectors, consequently, higher revenue elasticity.

The strategy adopted by industrialized countries, to remain on the technological frontier, leads them to invest in innovative activities which constantly create new, productive frontiers. These generate new technologies and modes of production that end up changing the existing pattern. This is the nature of economic activity, regarding market competition. In this, the simple process of industrialization is unable to reposition the backward economies. The identification of the technological frontier and the endogenous creation of conditions that permit the advance of the industrial sector, in terms of innovation and constant repositioning, become a condition for the survival of companies.

Thus, it is important to construct conditions conducive to learning. However, its cumulative characteristic does not allow construction in disconnected steps, without continuity and concern for creating capacity to identify and capture the technological overflows common to the development process. The lack of this capacity maintains, or even widens, the technological distance between leaders and followers while also maintaining the differences in the rates of economic growth.

It is in this scenario that Brazil finds itself, with an underdeveloped industry in sectors of greater productive complexity and greater participation in sectors of low technological intensity. The search for alternatives must involve improving productivity levels and increasing the participation of sectors with greater technological intensity. The difficulty of Brazilian products to compete in the international market may be explained, in part, by the existence of a technological gap between internal production and the world leaders. This gap reinforces the thesis that investments in R&D, infrastructure and technology would tend to leverage the productivity levels of the Brazilian economy. This was not seen in the present study, for the period from 2008 to 2014. Although the results suggest increasing returns on an industrial scale, according to the Verdoorn coefficient, they call attention to the fact that investments made in innovative activities (internal R&D, external R&D, acquisition of other knowledge, acquisition of software, acquisition of machinery and equipment and in training) did not affect the growth rate of domestic productivity, as was expected.

The results suggest that the domestic industry is going through a difficult situation, as it cannot transform its expenditures into innovative activities to raise the productivity growth rate. Such result is directly related to the need of higher resource allocation in innovative activities. Without reaching a minimum scale of investments, which is a historical challenge for Brazil, the externalities and capabilities necessary to allow productivity increases are not created. As mentioned above, the construction of conditions conducive to the development of the domestic industry requires the creation of productive capacities, which demand investment and time. Investments in physical and human capital are necessary for the learning and creating of productive skills. Also, investments in R&D (internal or external) expand the ability to understand better the existing practices and opportunities which should be followed. Whether on the one hand or on the other, the trend to invest is taken as a starting point, without which nothing gets started. The results observed for the domestic industry between 2008 and 2014 may, to some extent, reflect the occasional or sporadic nature that the innovative process takes in Brazilian industry. To some extent, it may have been aggravated by the crisis of 2008, with consequent reduction of the expenditures on innovative activities in Brazil for the years 2011 and 2014.

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