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ARTIGO

Econometric Estimation of Labor Productivity in the Brazilian Manufacturing Sector in the 2000s: a Kaldorian Approach*

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ABSTRACT

In the 2000-2008 period, which covers the analysis of this paper, while the average real GDP growth in Brazil was 3.7 percent per year, labor productivity in the manufacturing industry had a negative variation of 1.0 percent per year. In Brazil, there has been a "cliché" evaluation ofthe relatively low economic growth rates in the period as being the result of low labor productivity growth in the last few decades. However, according to the so-called Kaldor-Verdoorn law, the reverse could also be true: low growth rates of labor productivity in Brazil could be an effect of low growth rates of the real GDP. Based on Kaldorian assumptions, we regressed the change in labor productivity of 21 Brazilian manufacturing industries, covering the 2000-2008 period, on three main variables: the real GDP (which captures the Kaldor-Verdoorn law), gross investment to value added ratio, and technological innovation. Our

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results confirmed the validity of the Kaldor-Verdoorn law, as the real GDP growth was the most significant variable to explain the behavior of labor productivity in the manufacturing industries in Brazil in the 2000s, followed by the gross investment rate.

KEYWORDS | Labor Productivity; Manufacturing; Brazil

JEL CODES | E23; L16; L23; O12; O14

Estimativa econométrica da produtividade do trabalho na indústria manufatureira brasileira nos anos 2000: uma abordagem kaldoriana

RESUMO

No período 2000-2008, que cobre a análise deste trabalho, enquanto o crescimento médio do PIB real no Brasil foi de 3,7% ao ano, a produtividade do trabalho na indústria de transformação apresentou variação negativa de 1,0% ao ano. No Brasil, tem sido um "clichê" avaliar as relativamente baixas taxas de crescimento econômico no período como resultado do baixo crescimento da produtividade do trabalho nas últimas décadas. No entanto, de acordo com a lei Kaldor-Verdoorn, o recíproco também poderia ser verdade: as baixas taxas de crescimento da produtividade do trabalho no Brasil poderiam ser o resultado das baixas taxas de crescimento do PIB real. Com base nos pressupostos de Kaldor, regredimos a taxa de crescimento da produtividade do trabalho de 21 indústrias manufatureiras contra três variáveis principais: o PIB real (que captura a lei Kaldor-Verdoorn), a taxa de investimento e uma proxy para inovação tecnológica. Nossos resultados confirmaram a validade da lei de Kaldor-Verdoorn, pois o crescimento do PIB real foi a variável mais significativa para explicar o comportamento da produtividade do trabalho na indústria manufatureira no Brasil na década de 2000, seguido da taxa de investimento bruto.

PALAVRAS-CHAVE | Produtividade do Trabalho, Manufatura, Brasil

CÓDIGOS-JEL | E23; L16; L23; O12; O14

1. Introduction

Since Adam Smith (1776), productivity growth has been understood as one of the main drivers of economic development. Krugman (1994) expressed this idea well in the quotation below:

> Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker.

Industrialization, in turn, has always been associated with a quick increase in aggregate productivity. Since the manufacturing sector has strong backward and forward linkages and is subject to static and dynamic economies of scale, this allows productivity gains to be easily transmitted throughout the productive structure.[1] Therefore, the industrialization process is linked to a structural change in the economy. If it moves toward a more advanced stage of maturity, more technologically sophisticated sectors should gain weight, increasing the value added embodied in the supplied final products, which, in turn, contributes to the aggregate increase in productivity. Accordingly, higher levels and rates of productivity growth are expected to be observed in economies that have already reached a mature industrial structure.

The performance of the Brazilian economy is one successful example of a late industrialized country in Latin America until, at least, the end of the 1970s. Its industrialization process was shaped after the Second World War and gained momentum during the 1970s, when GDP grew at above 8 percent per annum on average.

Structuralist tradition has always stressed a close positive correlation between the behavior of real GDP and labor productivity in the manufacturing sector.[2] The Brazilian experience between 1970 and the mid-1990s seems to confirm such a relationship. In fact, in the 1970s, despite the oil crisis, the behavior of labor productivity in the manufacturing sector was positively correlated with real GDP

1 Hirschman (1981) was pioneering in exploring the role of the several industries of the manufacturing sector to generate backward and forward linkages carried out by their own investments. Yet Kaldor (1966, 1970), by recognizing that, as "a macrophenomenon", the manufacturing sector operates under static and dynamic economies of scale, remarked its special role in changing and modernizing the productive structure of the economy over time.

2 See especially Kaldor (1966, 1970) and McCombie and Thirlwall (1994, ch. 2). For an excellent survey and empirical evidence for Latin American countries, see Ros (2014).

growth. After 1976, productivity growth decreased for two years, but showed a strong recovery in 1979. However, during the 1980s, after the Brazilian economy had been severely hit by the external debt crisis, it suddenly reversed its long-lasting growth trend and labor productivity in the manufacturing sector decelerated. In the beginning of the 1990s, both indicators renewed their upward trend, but labor productivity growth in the manufacturing sector showed further signs of deceleration in the second half of the 1990s. This trend has not reversed from the 2000s onwards, although real GDP growth has exhibited positive rates.[3] This could suggest, at least at first sight, that the positive correlation between the behavior of the manufacturing labor productivity and real GDP was broken throughout the 2000s. Or was it?

Indeed, there is an interesting puzzle to be solved in terms of a feasible explanation for the labor productivity performance in the Brazilian manufacturing industries in the recent period. The quandary can be expressed by the following question: what is the relationship between labor productivity in the manufacturing sector and economic growth in the Brazilian economy in the 2000s?

The puzzle of the low productivity growth in the manufacturing sector in the 2000s leads us to a larger debate about the causal relationship between productivity and long-term growth in the economic growth literature. Mainstream economists, following the Solow tradition, argue that productivity is a phenomenon mostly explained by forces from the supply side; Kaldorian economists, on the other hand, consider forces from both supply and demand sides. Since, in the Solow tradition, economic growth performance is explained by productivity growth, physical and human capital accumulation might boost productivity and, therefore, long-term economic growth. Yet, in the Kaldorian tradition, this relationship is not so straightforward and it runs in both directions, but the causality comes from the aggregate demand increase to productivity growth. In short, the Kaldorian approach assures that aggregate demand boosts productivity growth, which, in turn, through the improvement of economic competitiveness, tends to push the economic growth potential up. In this interactive process, structural change plays a decisive role in ensuring a virtuous growth cycle.

When we assume that productive structure matters in explaining productivity and growth performances, we should take into account that the deepening of the premature deindustrialization of the Brazilian economy since the early 2000s might

3 See, for instance, Nassif, Feijó and Araújo (2015b) and Galeano and Feijó (2013) for a discussion about the behavior of labor productivity in the Brazilian manufacturing industry in recent years.

explain the productivity puzzle.[4] Therefore, based on the Kaldorian approach, the aim of this paper is to capture the main forces explaining the behavior of labor productivity in the Brazilian manufacturing industries over the 2000s. Particularly, by regressing changes in labor productivity of 21 Brazilian manufacturing industries to the real GDP (which captures the so-called Kaldor-Verdoorn law), the gross investment to value added ratio and technological innovation, we intend to capture the main forces behind the low growth rates of labor productivity in Brazil in the 2000s. Due to the unavailability of data for the gross investment rate at sectoral level for other years, this study covers only the 2000-2008 period.

Our empirical study closely follows that proposed by León-Ledesma (2002), who estimated a structural model for a set of OECD countries over the 1965-1994 period. In his article, he regresses the changes in labor productivity to a set of structural explanatory variables, such as aggregate demand, investment-output ratio, innovation, and a variable capturing the catching up effect of innovation. Then, in addition to the impacts of investment and the traditional Kaldor-Verdoorn law, he seeks to capture the direct and indirect effects of innovation and technical progress on the behavior of labor productivity. In the author's words, "innovation not only leads to a higher degree of product differentiation and quality but also to process innovation leading to increased productivity" (LEÓN-LEDESMA, 2002, p. 204). The main contribution of our study is to present a model in which labor productivity is basically explained by structural forces.

Besides this Introduction, the paper is organized as follows. Section 2 starts with a critical discussion on the total factor productivity (TFP) approach and introduces the concept, determinants, and a theoretical model for explaining the behavior of labor productivity over time. Section 3 presents the empirical model to explain labor productivity in the Brazilian manufacturing industries in the 2000-2008 period.[5] Section 4 draws the main conclusions and some economic policy implications.

4 Deindustrialization is nothing but an economic phenomenon in which, after a developed country having reached a very high level of per capita income, it begins to face a significant loss of share of the manufacturing sector (measure in real value added) in total real GDP (see CLARK, 1957). More recently, Rowthorn and Wells (1987) argued that such a phenomenon can also occur through a fall in the share of industrial employment in total employment of the economy. However, the deindustrialization is considered "premature" when the importance of the manufacturing sector is reduced before a developing country has reached a relatively high level of per capita income (see PALMA, 2005). For empirical evidence for Brazil, see Nassif (2008), Bresser-Pereira (2010), Oreiro and Feijó (2010), Bacha (2013) and Nassif, Feijó and Araújo (2015b). Rodrik (2016, p. 1) provides sound empirical evidence that "Asian countries and manufactures exporters have been largely insulated from those trends [from premature deindustrialization], while Latin American countries have been especially hard hit".

5 Due to the lack of compatible statistical data, we cannot extend our model neither for the period before 2000, not for the post-2008 period.

2. Labor productivity: concept, determinants, and a theoretical model

Productivity is the measure of the efficiency of the combination of all inputs in the production process. Mainstream economists, based on the concept of a production function, measure the level and variation of productivity through the so-called total factor productivity (TFP). For them, TFP is a superior measure for productivity because this approach takes into account the contribution of all factors and is invariant to the intensity of use of observable inputs (SYVERSON, 2010).

TFP is largely used in empirical literature for estimates of productivity growth that compare different performances of countries and regions over time. However, because it is based on Solow's seminal theoretical and empirical growth models (1956, 1957), this indicator suffers from severe shortcomings. We will mention three of them. First, as the estimation of productivity by TFP is based on either a microeconomic production function (at the firm or sectoral level) or a macroeconomic production function (at the aggregate level), it is hard to conceive of a production function which truly reflects an adopted technology, since technology is not a homogeneous good. Even at the firm level, it is possible to match different "vintages" of embodied knowledge at the same place and time.[6] Second, assuming that a great part of technical progress is embodied in capital goods, it is difficult to find a realistic measure for the contribution of the capital stock in the total productivity growth. Third, and perhaps more importantly, as technical progress is exogenous in Solow's model, the estimation of the contribution of this factor is always done as a residual.[7]

In an influential critique to Solow's model (and the TFP estimation), Nelson (1981, p. 12) pointed out that "technological advance, while acknowledged as a central feature of growth, is treated in a very simple way, and the Schumpeterian proposition that technological advance (via entrepreneurial innovation) and competitive equilibrium cannot coexist is ignored". The author concluded that "the sources of growth (subjacent to Solow's model and TFP estimations) are viewed as

6 Even if the use of a production function to estimate productivity growth were problematic at a firm level, aggregating production functions to represent and estimate the productivity behavior of the economy as a whole would be much more so. Since the late 1950s [see, for instance, Phelps-Brown's (1957) and Simon and Levy's (1963) classical papers], there have been several important studies showing the statistical difficulty to estimate production functions at the aggregate level. Recently, in a clarifying book, Felipe and McCombie (2013) showed why, despite serious statistical problems involving them, by using constant-price value data (and not the correct physical data) as well as ad hoc accounting identities, aggregate production functions tend to show, paradoxically, plausible statistical results. In other worlds, since the variables that enter the aggregate production function are not correctly measured, these "plausible statistical results" do not necessarily mean that they are true.

7 Since the estimation of the residual is subject to all sorts of issues, Abramovitz (1993) referred to the residual as "some sort of measure of ignorance".

operating independently and additively".[8] Abramovitz (1986, 1993) also takes issue with the estimation of the contribution of technical progress as a residual, arguing that it misses important elements for productivity variation such as education, on-the-job training, and research and development (R&D). According to the author (ABRAMOVITZ, 1993, p. 218), "all these missing elements were unmeasured and difficult to measure but still embedded in the residual". Not by chance, Messa (2014, p. 89) reminds us that Domar (1961) warned against any relationship between Solow's residual and actual technical progress.[9]

Given the flaws in the theoretical construction of an aggregate production function as well as in TFP estimates, the relevant productivity concept for long-term growth is labor productivity, which we chose as a more appropriate measure to estimate the economic efficiency change in the Brazilian manufacturing industries in the 2000s. At least three additional reasons can be highlighted to reinforce this choice: by capturing the intensity of use of the other production factors, labor productivity indirectly incorporates the contribution of all of them;[10] once it is translated by the ratio of the value added in a sector or even in the total economy to the respective number of workers (or alternatively to the hours worked), labor productivity is a reliable measure for evaluating the efficiency at both the microeconomic and macroeconomic levels;[11] and along with per capita income growth over time, labor productivity has traditionally been used for evaluating economic and social convergence or divergence among countries (see, for instance, Baumol, 1986; León-Ledesma, 2002; and McMillan and Rodrik, 2016).

In addition, most conventional studies consider that labor productivity is better estimated by supply-side variables. However, as many theoretical and empirical studies have emphasized, the behavior of labor efficiency is affected by both supply and demand forces (see, for instance, DIXON; THIRLWALL, 1975; DELONG SUMMERS, 1991; LEÓN-LEDESMA, 2002; SYVERSON, 2010). As Syverson (2010, p. 43) recognized, although "productivity is typically thought of as a supply-side concept, a new strand of research has begun to extend the productivity literature

8 For more details on the critique of the theoretical and empirical estimations of productivity based on Solow's model, see Nelson (1981).

9 For more details on the theoretical and empirical issues related to the TFP, see Messa (2014).

10 Note that, differently from the above-mentioned Syverson's (2010) conclusion, this characteristic of labor productivity can provide an advantage in choosing it as an appropriate indicator for measuring economic efficiency.

11 Many economists usually construct measures on labor productivity as the ratio between the gross physical production (used as proxy for value added) and number of workers. However, as Bonelli and Fonseca (1998) remind us, if the technical coefficients change over time, this measure can generate biased results and, therefore, cannot be reliable.

to explicitly account for such idiosyncratic demand effects as well". In his survey on the subject, Syverson (2010) argued that the behavior of labor productivity could jointly be affected not only by an efficient combination of capital, labor, and other inputs, but also by other elements such as information technology (IT), R&D, the level of internal and external competition, and even by government policies.

Structuralist literature, based on Myrdal's (1957) and Kaldor's (1966, 1970) principle of cumulative causation, develops theoretical and empirical studies in which the growth of labor productivity is highly dependent on the initial conditions of the economy. This means that, all else being equal, the higher the level of industrialization of an economy, the greater its capacity of sustaining higher rates of growth and, therefore, also of labor productivity. That is because the manufacturing industry presents increasing static and dynamic returns to scale, a crucial assumption to explain productivity growth.[12] Therefore, the relation between growth and productivity change is given by the so-called Kaldor-Verdoorn law, which postulates that labor productivity growth rates are positively influenced by output growth rates.

Strictly speaking, following Kaldor (1966), the Verdoorn law establishes that growth rates of labor productivity depend largely on growth rates of the manufacturing output. However, as Kaldor (1966, p. 106) also argued, "productivity tends to grow faster, the faster output expands; it also means that the level of productivity is a function of cumulative output (from the beginning) rather than of the rate of production per unit of time". In fact, by interpreting Kaldor's assertion, McCombie and Thirlwall (1994, p. 165) pointed out that "a fast rate of growth of exports and output will tend to set up a cumulative process, or virtuous circle of growth, through the link between output growth and productivity growth".

Thus, far from representing a tautology (high labor productivity growth causes high economic growth rates, which, in turn, imply high labor productivity growth), according to the cumulative causation principle, the operation of the Kaldor-Verdoorn law means that as long as an economy builds a large and diversified manufacturing industrial base, it augments its potential of exploiting static and dynamic economies of scale insofar as it is capable of sustaining high economic growth.[13] Since this latter

12 See Young (1928), Kaldor (1966) and McCombie and Thirlwall (1994), among others.

13 The debate on the role of static and dynamic economies of scale (directly associated with the manufacturing sector, and, today, with some tradable segments of the service sector) is relatively old in economics. Graham (1923) had shown that, the more an economy reallocates resources from industries subject to increasing returns to scale to industries subject to constant returns to scale, the lesser it would be its capacity for sustaining economic growth in the long run. Young (1928) also showed that, by incorporating activities subject to increasing returns to scale, the enlargement of the market tends to boost international competitiveness and accelerate long-term growth. In his classic study, Kaldor (1966) emphasized the importance of static and dynamic economies of scale inherent to the manufacturing sector for boosting long-term growth.

phenomenon is closely associated with high investment rates and rapid technical progress, an economy which shows high rates of GDP growth also tends to sustain high labor productivity growth. Not by chance, authors who seek to test the validity of the Kaldor-Verdoorn law (represented by the relationship between the labor productivity growth and the manufacturing output growth) choose either the change in the manufacturing output or the GDP growth as the explanatory variable.[14]

As McCombie and Thirlwall (1994, p. xxi) argued, "a faster growth of output leads to a faster growth of productivity through the "Verdoorn effect" which is caused by, *inter alia*, a higher rate of induced investment and of induced technical progress". Based on this assumption, we consider a theoretical equation in which changes in labor productivity are jointly explained by the effect of investment, innovation, and the aggregate demand growth (the Kaldor-Verdoorn law). Thus, we aim to explain productivity as a result of the short and long-term effects induced by physical investment, innovation, and technical progress. This general model closely follows León-Ledesma's (2002) and can be expressed as:

$$r = a + \alpha Y + \beta \left(\frac{I}{VA} \right) + \varphi Innov \qquad (1)$$

where r is the labor productivity growth (labor productivity defined as the value added in real terms per worker); a is the constant term; y is the real GDP growth; I/VA is the investment ratio, that is, the ratio of the gross investment to the value added; and $Innov$ is a variable associated with innovation. $\propto$, β and φ are positive coefficients. In the next section, we will translate the theoretical model represented by equation (1) into an econometric estimation in order to show empirical evidence for the labor productivity growth of the Brazilian manufacturing industries in the 2000s.

3. Labor productivity: empirical evidence for the Brazilian manufacturing industries in the 2000s

The aim of this section is to show our econometric estimates of the labor productivity of the Brazilian industries in the 2000-2008 period, based on the theoretical equation presented in the previous section.

14 For an excellent theoretical and empirical review of the Kaldor-Verdoorn law, see Ros (2013).

3.1. The econometric model and the data issues

As mentioned earlier, the theoretical model of labor productivity growth of the manufacturing sector associates its dynamic to the growth of aggregate demand, investment in fixed assets and technological innovation. To perform our estimate for the 2000-2008 period, equation (1) can be translated into the following standard econometric specification:

$$r_{it} = a + \alpha y_t + \beta\left(\frac{I}{VA}\right)_{it} + \varphi Innov_{i(t-n)} + \varepsilon_{it} \qquad (2)$$

where subscript *i* represents an industry of the manufacturing sector, *t* refers to the period of observation of the variable (in our case, one year), a is the constant term, ε is the error variable, and *n* the number of time lags.[15] While *r* (the labor productivity growth rate) and *y* (the real GDP growth rate) were expressed as the difference of the logarithms, *I/VA* (the gross investment to value added ratio) and *Innov* (R&D expenditures to total net revenues ratio) were expressed as logarithms. Since positive effects of innovation on labor productivity occur in the long term, the variable *Innov* is introduced into our empirical model with time lags.

It is worth stressing that the above mentioned explanatory variables are in tune with our theoretical argument, according to which the behavior of labor productivity is associated with both demand (the real GDP and the gross investment ratio) and supply (the variable associated with innovation) variables. These variables are also in tune with the Kaldorian hypothesis, according to which labor productivity tends to be increased and sustained by a faster long-term growth (the so-called Kaldor-Verdoorn law), which is, in turn, induced by both gross investment and technical progress (see KALDOR, 1966; MCCOMBIE; THIRLWALL, 1994, p. xxi). Despite empirical tests of this hypothesis having been subjected to several controversies related to the appropriate methodology for estimation, as reported by McCombie and Thirlwall (1994, ch. 2),[16] recent studies of Latin American countries have confirmed the role of the manufacturing sector as the main driver for their labor productivity growth (LIBANIO, 2006; CARTON, 2009; MONCAYO, 2011; ROS, 2013).

15 This time lag will be justified ahead

16 As McCombie and Thirlwall (1994) point out, one of the main problems of using time-series data is that Okun's law becomes entangled with the Kaldor-Verdoorn law because employment does not fluctuate as much as small changes in output over the business cycle. In McCombie and Thirlwall's (1994, p. 198) words, "this means that as output growth falls in the downswing of the cycle so, pari passu, will productivity growth and vice-versa".

To implement the empirical model, we use data from different sources. Therefore, a compatibilization exercise had to be performed in order to harmonize the sectoral classifications.[17] Additionally, we had to deal with a lack of comprehensive data for demand of investment, and few observations in relation to data on innovation.

Productivity growth estimates were obtained from the ECLAC-PADI[18] database, which presents structural statistics for the manufacturing industries by individual countries. Therefore, it is an internationally harmonized database which collects statistical information from national statistical offices. All information provided by ECLAC-PADI is at constant 1985 US dollar prices.[19] We accessed this database for the 1970-2008 period. The estimates for aggregate demand growth came from IBGE's National Accounts estimates for Brazil's real GDP.

Statistical data for sectoral demand of investment and value added in the manufacturing industries were obtained from Miguez et al. (2014). The authors estimated a matrix of investment absorption for the 2000-2009 period and, as far as we know, that is the most comprehensive statistics available for demand of investment for the manufacturing industries for the 2000s. From this source, we calculated the investment rate for each group of industry.

The proxy for the innovative activity in the manufacturing industry was obtained from the Industrial Technological Survey (PINTEC, according to the Portuguese acronym), carried out by the Brazilian Institute of Geography and Statistics (IBGE). This survey is available for the years 2000, 2003, 2005 and 2008, and it covers all manufacturing industries with ten or more employees that performed any innovative activity – either in the productive process or in improving a product or even introducing a new one into the market. From this dataset we calculated the ratio of total expenditure in innovative projects (research and development – R&D) in relation to the total net revenue of sales of products and services by firms in each industry of the manufacturing sector. Therefore, the innovation variable of equation (1) is expressed as the ratio of R&D expenditures of an industry to the total net revenue of sales of products and services from that industry.

17 We aggregate the industrial sectors into three industrial groups according to factor intensity as well as technological sophistication, as follows: science-engineering-and-knowledge-based industries, natural resources-based industries and labor-intensive industries. This classification was the authors' own adaptation of the classic taxonomy proposed by Pavitt (1984). Summing up, we made an effort to harmonize all sectoral classifications whose databases were used in this study. A detailed description of the industries included in each group mentioned above is presented in the Appendix. All other original data can be obtained from the authors upon request.

18 ECLAC is the United Nations Economic Commission for Latin America and the Caribbean. PADI is the acronym in Spanish for Analysis Program of Industrial Dynamics.

19 In the Brazilian case, the main source of information comes from the Industrial Censuses and the Annual Industrial Surveys carried out by the Brazilian Institute of Geography and Statistics (IBGE).

The main problem we had to deal with for the variable representing innovation is that we do not have observations provided by PINTEC for all the years of our study. As Greene (1997) points out, dealing with the missing data issue is problematic because most alternative solutions can generate biased results. The author shows that even the two apparently best solutions, either filling the missing data with means of the available data or running a non-balanced panel data, can produce biased and unreliable results.

Our best solution for dealing with the missing data in the time series consisted in repeating the PINTEC data of our variable proxied for innovation for the years that they were not available (2001, 2002, 2004, 2006 and 2007).[20] This procedure does not generate unbiased results for two main reasons. Firstly, because we assume that the impact of innovative efforts by firms (especially R&D) is spread to labor productivity over time. This assumption is supported by the evidence shown in Grazzi and Pietrobelli (2016), who discuss innovation and productivity in Latin America. One of the conclusions of their study is that the impact of innovation on productivity can be seen as a cumulative causation process. In our interpretation, this means that the innovation effort is introduced by the firm year by year, and it is reinforced by many other factors that also influence the consolidation of this process.[21] The second reason is that we can also argue that this procedure assumes that the firms' decisions about whether to spend or not and the amount to spend on R&D are strongly pro-cyclical, as empirical evidence has shown (see BARLEVY, 2007). Hence, the solution of replicating PINTEC data in the years for which information is not available does not violate the expected trend. In fact, by analyzing the behavior of the real GDP and firms' spending on R&D (as a proportion of their total net revenues) in Brazil in the 2000-2008 period, we realized that R&D expenditures followed, in general, the Brazilian business cycle.

We will also consider the variable proxy for innovation with lags. In this case, we assumed that the impact of innovative efforts (especially in process, which is the most important sort of innovation observed in the PINTEC survey) on gains from labor productivity occurs only after a time span.

20 That is, we replicated the information obtained from the 2000, 2003, 2005, and 2008 surveys.

21 Among the factors influencing the relationship between innovation and productivity, the authors mention, for instance, firm age, access to credit markets, and openness to international relations (GRAZZI; PIETROBELLI, 2016, p. 319).

3.2. Econometric estimates and results

The econometric estimate uses panel data models in the static and dynamic versions. Panel data models present important advantages for our empirical exercises for they allow:

- the use of a larger amount of information by combining sectoral data with time series, so that the available labor productivity data for the 21 industries of the Brazilian manufacturing sector, as described in the Appendix (Table A1), could be related to the explanatory variables between 2000 and 2008;[22]
- the use of a larger number of observations, which, in turn, ensures the asymptotic properties of the estimators and increases the degrees of freedom of the estimates;
- the reduction of the risk of multicollinearity, since data from the different sectors of the manufacturing industry have different structures;[23]
- the introduction of dynamic adjustments, which the cross-section analysis would not allow.

Yet dynamic panel data models, by using the lags of the dependent variable as explanatory variables, are powerful at correcting endogeneity problems. The introduction of these lags becomes crucial to control for the dynamics of the process. In such circumstances, the correct specification of the model permits us to discover new or different relationships between the dependent and independent variables. Moreover, by comparing the performance of the dynamic panel data models with static panel data models, Arellano and Bond (1991) concluded that the former exhibit estimators with the smallest bias and variance. In other words, according to the authors, dynamic panel data models are more robust than static panel data models. Table 1 shows our econometric results in both static and dynamic models.

Column 1 presents the explanatory variables of our model. Columns 2 and 3 show the initial estimates considering the static panel models and their respective fixed and random effects. Since our econometric exercise is expressed in growth rates, and not in level, the problems related to the eventual correlation between non-observed variables and the explanatory variables are mitigated. Therefore, such characteristics justify running the model with random effects. Indeed, since the results with fixed (column 2) and random (column 3) effects models are very

22 For more information on the methodology for panel data, see Wooldridge (2010), and for details on these models in the dynamic version, see Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998).

23 More details on the reduction of risk of multicollinearity in our model will be discussed ahead.

similar, as Table 1 shows, it is recommended to use the most efficient model, i.e., the model with random effects.[24]

TABLE 1
Determinants of labor productivity in the Brazilian manufacturing industries
2000-2008

Dependent variable: **Labor productivity growth** $(dlogr_{it})$	**The static model** $r_{it} = a + \alpha y_t + \beta(I/VA)_{it} + \varphi Innov_{i(t-n)} + \varepsilon_{it}$		**The dynamic model** $r_{it} = r_{i(t-1)} + a + \alpha y_t + \beta(I/VA)_{it} + \varphi Innov_{i(t-n)} + \varepsilon_{it}$
(1)	**(2)**	**(3)**	**(4)**
	Fixed effects	**Random effects**	
The constant *a*	-0.18*** (-3.18)	-0.11* (-2.91)	-0.16** -(2.67)
Real GDP growth rate $(dlogy_t)$	2.34*** (3.13)	2.22*** (3.17)	2.12** (2.92)
Growth of the gross investment rate $(dlog(I/VA)_{it})$	0.35 (1.40)	0.30 (1.32)	0.41* (1.72)
R&D expenditures to total net revenues ratio $(logInnov_{i(t-2)})$	0.09** (2.17)	0.03* (1.65)	0.07 (1.50)
Lagged labor productivity $(r_{i(t-1)})$	--	--	-0.55*** (-7.31)
	R-sq: *Within = 0.1233* *Between = 0.0128* *Overall = 0.0772* *F(3,117)= 5.49* *Prob > F= 0.0015*	*R-sq:* *Within = 0.1090* *Between = 0.0197* *Overall = 0.0980* *Wald chi2(3) = 14.78* *Prob > Chi2 = 0.0020*	*Wald Chi2(4)= 82.27* *Prob > Chi2 = 0.0000*
Number of observations = 140 Number of groups = 20 Observations per group: min = 7			

Notes: *t* test in brackets; *** significant at 1 percent; ** significant at 5 percent; and * significant at 10 percent.

24 See Wooldridge (2010).

In addition, the Hausman test (HAUSMAN, 1978), which is based on differences in estimates with fixed and random effects, is appropriate to identify which model best fits the data of the econometric exercise. By applying the Hausman test to both models, we observed that the data were best fitted with random effects. The value of the test was 2.97 and the probability 0.39. Table A2 in the Appendix summarizes these results.

Labor productivity growth in the Brazilian manufacturing industries in the 2000s was largely explained by the real GDP growth (y_t), in the two versions of the model (columns 2 and 3), in accordance with the Kaldor-Verdoorn law.

Investment rate was not statistically significant in explaining the behavior of productivity, although the coefficient is positive and follows the results expected by the economic theory. Even though we used panel data, which mitigates the problem of a linear relationship among variables, we should further investigate the multicollinearity problem between the investment and GDP variables that might explain the non-significance of the investment coefficient in the regression. It is important to stress, however, that we are regressing the growth rate of labor productivity in each industry of the manufacturing sector to the growth rate of the GDP as well as to the ratio of sectoral investment to the value added. This characteristic of our dataset minimizes the risk of multicollinearity because the investment data from different industries of the manufacturing sector have different structures and are not linear combinations of the GDP. We also run the models without the GDP variable to check if the cause of non-significance of the investment variable was due to an eventual multicollinearity with the GDP variable. The results showed that, even without the GDP variable, investment was not statistically significant. The effect of innovation on productivity growth was also not significant in the model with random effects.

Finally, we investigated the endogeneity bias by running a dynamic panel data with the Generalized Method of Moments (GMM) in the form proposed by Arellano and Bond (1991). The endogeneity bias may be present because GDP growth, for instance, tends to affect productivity at the same time as it is affected by it.

The dynamic nature of Arellano and Bond's method (1991) is expressed in the use of the dependent variable lagged with one period as an additional explanatory variable in the model. Thus, equation (2) can be changed to:[25]

$$r_{it} = a + \mu r_{i(t-1)} + \alpha y_t + \beta (I/VA)_{it} + e_{it} \quad (3)$$

25 In equation (3), μ is a parameter term of the lagged labor productivity.

However, to control the correlation between this new variable and the error term, the dynamic estimation model of Arellano and Bond (1991) is performed in first difference. It is important to stress that, due to the possibility of endogeneity of other explanatory variables, instrumental variables were used for all explanatory variables in the model, as was proposed in the methodology of Arellano and Bond (1991). Formally, the first difference equation proposed by Arellano and Bond (1991) may be expressed as:

$$\Delta Y_{it} = \Delta\alpha_i + \delta\Delta Y_{it-1} + \beta' \Delta X_{it} + \Delta\varepsilon_{it} \quad (4)$$

where Y is the dependent variable and X is the vector of explanatory variables. Thus, following Arellano and Bond's (1991) methodology for solving endogeneity problems, our equation can be expressed by:

$$\Delta r_{it} = \Delta\alpha_i + \delta\Delta r_{it-1} + \beta' \Delta X_{it} + \Delta\varepsilon_{it} \quad (5)$$

where r is the dependent variable and X is the vector of explanatory variables.

Therefore, the strategy is to use the GMM method for modeling estimation in first difference, using all possible lags as a tool for the lagged variable. For endogenous variables, their lagged levels are used as instrumental variables, and for predetermined variables, their levels are lagged once. This method seeks to use all the information contained in the sample to construct the set of instrumental variables, eliminating the unobservable specific effect and enabling the estimation.

To check the consistency of the GMM estimator, it is necessary that the instruments used in the model are valid. For this, Arellano and Bond (1991) suggest two tests: the Sargan test, whose null hypothesis is that the instruments are valid; and the serial autocorrelation test. [26] The Sargan test indicated that the restrictions are valid. The serial autocorrelation test examines the hypothesis that the error term is not serially correlated. More specifically, it tests whether the error term differential is serially correlated in second order (by construction, the error term differential is probably of first order serially correlated, even if the original error term is not). The tests indicated that we cannot reject the null hypothesis of no serial correlation of second order in the error term differential.

26 It is noteworthy that, according to Baum (2006, p. 233), Arellano and Bond's (1991) approach tends to build more consistent estimators than an instrumental variable methodology, considering that the latter does not exploit all the information available in the sample. Therefore, Arellano and Bond's methodology, compared with most instrumental variable methodologies, can be considered a superior one, for the latter methodologies may fail to exploit the full potential of the orthogonality condition.

The results of the estimation of the dynamic model are shown in column 4 of Table 1. The difference between the results of equation (3) and the estimates of equation (2) is the inclusion of a lagged labor productivity term (the last line in Table 1) as an explanatory variable. Again, in the dynamic model, like in the static model estimates, GDP growth rate continued to be the main explanatory variable of labor productivity growth of the Brazilian manufacturing sector in the 2000s, reaffirming the importance of the Kaldor-Verdoorn law to explain productivity.

Innovation, in turn, was significant only at 13 percent level. This means that the innovation variable can be considered economically significant but not statistically significant for explaining the labor productivity behavior in the Brazilian manufacturing sector over the 2000s.

Finally, differently from the static model estimates, in the dynamic model estimates (equation 5) the gross investment rate was significant at 10 percent level to explain the labor productivity behavior of the Brazilian manufacturing sector in the 2000-2008 period.

Summing up, among the three methods applied to run our theoretical equation (2), the best results were obtained from the dynamic panel data with GMM in the form proposed by Arellano and Bond (1991). This means that the real GDP growth and the investment rate were the most significant variables to explain the behavior of labor productivity in the Brazilian manufacturing industries over the 2000s. Although the innovation variable did not show statistical significance, the sign of the variable was as expected.

4. Concluding remarks

Evaluating the low economic growth rates in the 2000s as a result of low labor productivity growth rates in the Brazilian economy has been a cliché. In the 2000-2008 period (which covers the analysis of this paper), while the average real GDP growth was 3.7 percent per year, labor productivity had a negative variation of 1 percent per year. However, according to the so-called Kaldor-Verdoorn law, the inverse could also be true: the low growth rates of labor productivity in Brazil could be an effect of the low growth rates of the real GDP. Therefore, the aim of this paper was to identify the main variables associated with labor productivity in the manufacturing industry in order to explain why this indicator was so low in Brazil in the 2000-2008 period.

We developed our econometric panel data model based on a Kaldorian theoretical approach. Because the period of our empirical estimation is relatively short (2000-2008), due to the difficulty in obtaining compatible data, the results, in principle, must be cautiously analyzed. However, by applying the econometric models to 21 industries in the Brazilian manufacturing sector, we were able to significantly increase the size of our database.

In all the econometric models we ran, the real GDP growth was the most significant variable to explain the behavior of labor productivity in the manufacturing industries. The gross investment rate also proved to be significant in the dynamic panel model. An important finding of our estimates is that the larger and more sustainable the real GDP growth in Brazil is, the greater its labor productivity growth rates in the manufacturing sector will be. This result is consistent with the Kaldor--Verdoorn law, according to which labor productivity growth is highly dependent on the growth rates of the economy as a whole. This result is also in tune with several other empirical studies that have confirmed the role of the manufacturing sector as the main driver for labor productivity growth in Latin American countries (LIBANIO, 2006; CARTON, 2009; MONCAYO, 2011; ROS, 2013).

Our estimated results, based on the Kaldorian theoretical approach, also suggest the answer to the productivity puzzle, as stated in the introduction. The answer is that GDP growth rates in the Brazilian economy in the 2000-2008 period were not high enough to boost industrial productivity. The main reason for it is that the Brazilian economy had been suffering a process of premature deindustrialization since the early 1990s, and this process was accelerated during the commodities boom which comprises the period of our analysis. As several empirical studies have shown (PALMA, 2005; OREIRO; FEIJÓ, 2010; NASSIF; FEIJÓ; ARAÚJO, 2015b; RODRIK, 2016), deindustrialization in the Brazilian case in the period implied that less technologically intensive industries and other industries of low productivity had gained relative weight in the productive structure. Therefore, the negative result for the aggregate productivity growth in the manufacturing industry in the period, in spite of the positive (but relatively low) aggregate growth in GDP, should be seen as the result of the loss of weight of the manufacturing industry in the productive structure of the country.

These observations are also consistent with several recent studies which show empirical evidence that premature deindustrialization in Brazil intensified in the

2000s.[27] Nassif, Feijó and Araújo (2015b) presented empirical evidence that the technological gap (measured as the relative labor productivity in the Brazilian manufacturing industries compared with those of the United States) grew significantly in all manufacturing industries, classified according to their technological intensity, between the mid-1990s and 2008. Bacha (2013) showed that between 2005 and 2011 the Brazilian economy highly benefited from the improvement in the terms of trade and large net capital inflows, which were both responsible for the overvaluation of the Brazilian currency (the real) in real terms. Bacha (2013, p. 97-98) also states that this short period of external "bonanza" explains, on the one hand, the relatively good performance of the Brazilian economy in the 2005-2011 period (a real GDP growth of 4.2 percent per year) and, on the other hand, the strong reallocation of resources from domestic production to imports in the same period.[28]

Finally, in terms of economic policy implications, the empirical evidence suggests that Brazilian policy-makers were not able to - by taking advantage of the short period of favorable external conditions that occurred between 2004 and 2011 - design and implement industrial and macroeconomic policies to boost labor productivity in industries with a major capacity for innovating and disseminating gains from productivity to the economy as a whole. Although suggestions of economic policies go further than the scope of this paper, it has important normative implications. Thus, the main contribution of the paper is to enlighten policy-makers to the fact that labor productivity growth and real GDP growth are closely correlated variables. Specifically, our main conclusion is that any attempt at boosting real GDP growth and labor productivity rates in Brazil should include instruments that could reactivate investment and innovation in industries characterized by a high capacity to spill over their gains from productivity to the economy as a whole. In our view, this will be accomplished when confidence in long-term expectations improves, and the rate of aggregate private investment starts to increase, as it occurred in the period of significant economic growth in Brazil throughout the 1970s.

27 See, for instance, Bresser-Pereira (2008), Oreiro and Feijó (2010) and Bacha (2013), among others.

28 It should be mentioned that Bacha's (2013) analysis suggests that the early deindustrialization in Brazil would have begun in the mid-2000s. However, there is strong evidence that this process began in the mid-1980s, continued in the 1990s and intensified in the 2000s. Most empirical studies conclude that one of the main factors responsible for this phenomenon is the overvaluation trend of the Brazilian currency in real terms, which can be observed since the mid-1980s. Episodes of depreciation of the Brazilian real have suddenly occurred in response to internal or external shocks. For details, see Nassif, Feijó and Araújo (2015a).

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TABLE A1
Manufacturing industry according to technological intensity

Science, engineering and knowledge-based
Metal products
Non electrical machinery
Electrical machinery
Motor vehicles
Scientific instruments
Chemicals
Natural resource-based
Food and beverage
Tobacco
Wood products
Paper and cellulose
Petroleum refining and oil and carbon products
Glass and other non-metallic mineral products
Iron and steel
Non ferrous metals
Labor intensive
Textile
Clothing
Leather manufactures and footwear
Furniture, pottery and other manufactured products
Paper printing
Other chemicals
Rubber products and plastic products

Source: ECLAC-PADI

TABLE A2
The Hausman test

	Coefficients			
	(b)	(B)	(b-B)	Sqrt (diag(V_b-V_B))
	Fixed		Difference	S.E.
D.i_va	0.3564957	0.3041109	0.0523848	0.1068432
D.lny	2.343518	2.226511	0.1170075	0.2586765
L2.lninnov	0.0943601	0.0326415	0.0617185	0.036255

b = consistent under Ho and Ha; obtained from xtregB = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic

chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 2.97
Prob>chi2 = 0.3960