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Innovation and productivity: empirical evidence for Brazilian industrial enterprises

Inovação e produtividade: evidências empíricas para empresas industriais brasileiras

Innovación y productividad: evidencias empíricas en empresas industriales en Brasil

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Abstract

The aim of this paper is to carry out an empirical investigation into the relationship between innovation and the productive performance of Brazilian businesses measured by Work Productivity and Total Factor Productivity. Data taken from the Research of Innovation and estimated cross section models and panel data was used. The results suggest that innovation produces an incipient impact on competition in the national industry, reflected in the small magnitude of coefficients associated with the diverse indicators of innovation.

Keywords: Innovation; Productivity; Panel data analysis

Resumo

Neste artigo, tem-se como objetivo realizar uma investigação empírica acerca da relação entre inovação e desempenho produtivo das empresas industriais brasileiras medido por Produtividade do Trabalho e Produtividade Total dos Fatores. Foram utilizados dados provenientes da Pesquisa de Inovação e estimados modelos *cross section* e de dados em painel. Dada a pequena magnitude dos coeficientes associados aos diversos indicadores de inovação, os resultados sugerem que a inovação produz impacto incipiente na produtividade da indústria nacional.

Palavras-chave: Inovação; Produtividade; Painel

Resumen

El objetivo en este trabajo es realizar una investigación empírica sobre la relación entre la innovación y el desempeño productivo de las empresas industriales en Brasil medido por Productividad Laboral y Productividad Total de Factores. Se han utilizado datos de la Encuesta de Innovación y se han estimado modelos de corte transversal y datos de panel. Dada la pequeña magnitud de los coeficientes relacionados con los diversos indicadores de innovación, los resultados sugieren que la innovación produce impacto incipiente en la productividad de la industria nacional.

Palabras clave: Innovación; Productividad; Datos de panel

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Introduction

Several studies have shown the existence of a positive relationship between innovation and productivity. Internationally, many countries are moving to incorporate R&D measures in their national accounting systems and thus directly attribute its impact on growth as well as adding the importance of knowledge for economic development. Furthermore, the theoretical debate has converged to understand that the growth of productivity permeates by the innovative activity of enterprises.

Pioneering studies on productivity growth sources reveal that the capital and labor inputs explain less than half of the variation in productivity. The unexplained part, called "residual" is often considered the effect of the technological change on the productivity. In this sense, these studies seek to find measures for technological change (improvement in capital, quality of work and R&D activities) in order to explain the residual productivity growth (Cassiman & Golovko, 2011; Griliches, 1979, 2000; Huergo & Jaumandreu, 2004; Ortega-Argilés, Potters, & Vivarelli, 2005; Tsai & Wang, 2004; Wakelin, 2001).

However, there is no consensus regarding the most appropriate way of measuring productivity. In the international literature, most studies use two productivity measures: Work Productivity (WP) and Total Factor Productivity (TFP).

The purpose of this article is to investigate the relationship between innovation and production performance of Brazilian companies, as measured by Work Productivity (WP) and Total Factor Productivity (TFP). The explanatory variables are divided into four groups: business characteristics, technological expertise, industry classification and innovation indicators, measured by new products and processes, organizational change and technology index.

The proposed methodology for this study is based on the estimation of econometric models: Cross-section analysis for the year 2008; and panel data analysis for the years 2003, 2005 and 2008. The data were provided by the Brazilian Institute of Economic Geography (IBGE) from the crossing of Annual Industrial Research (PIA) and Innovation Research (PINTEC) information with foreign trade records from SECEX/MDIC.

Because of the shortage of studies undertaken on the relation of innovation and productivity at firm level in Brazil, this study contributes to the empirical debate on the subject in Brazil in two directions: testing the relationship between innovation and production performance using two productivity measures enshrined in national and international literature (Work Productivity and Total Factor Productivity); and testing various innovation indicators (product innovation, process innovation, organizational innovation and technology index) also widely used in the literature.

To meet this goal, the paper is organized in five sections, including this brief introduction. The second section presents the theoretical and empirical debate on the influence of innovation on business productivity. The third section describes the methodological procedures and the data used. The fourth section reports the results of the empirical study. Finally, the fifth section summarizes the final considerations.

Innovation and productivity

Theoretical debate

Several papers deal with the impact of innovation on business productivity. Recently, the increase of data available at the firm level and the advancement of econometric techniques have contributed to the growth in empirical studies (Cassiman, Golovko, & Martínez-Ros, 2010; Griliches, 2000; Huergo & Jaumandreu, 2004; Ortega-Argilés et al., 2005; Tsai & Wang, 2004; Wakelin, 2001).

Although there is considerable debate about the productivity measures, there is no consensus on the most appropriate form of measurement. In the international literature, most studies use two measures of productivity: Work Productivity (WP) and Total Factor Productivity (TFP).

WP is commonly calculated as the ratio between the industrial transformation value (ITV) measured by the difference between sales revenue and production costs, and the number of persons employed (PE) in the company (Britto, 2009; Chudnovsky, López, & Pupato, 2006; Mairesse & Mohnen, 2010; Santana, Cavalcanti, & Bezerra, 2011; Van Beveren & Vandenbussche, 2009).

$$\text{Work Productivity} = \text{ITV}/\text{PE} \tag{1}$$

The main advantage of the work productivity measure is the ease of availability of data and the simplicity of calculation. However, some criticisms are raised about this measure of productivity. First, it creates instability in determining how a more efficient material utilization can result in a total productivity gain for the enterprise. Second, this measure shows much more the productivity improvements resulting from efficiencies in material and component procurement than gains from a more efficient use of manpower and energy. In this regard we note that this gain in added value productivity, due to the purchase of lower-cost materials, results in an apparent gain, if considered the possible problems that can lead to making that decision. Third, the labor productivity is sensitive to production adjustments made by companies in function of the number of employees engaged, because if the company reduce the number of employed persons and maintain the value of industrial transformation, the result will be increased productivity.

Other studies use the TFP as a form of incorporating the productivities of each resource into one expression (Cassiman et al., 2010; Griliches, 2000; Ortega-Argilés et al., 2005; Tsai & Wang, 2004; Wakelin, 2001).

One of the main advantages of using TFP is considering the possibility of substitution in the use of the factors by the production process. Another advantage is that it constitutes the most appropriate instrument to measure technical change by industry and the role of intermediate inputs in production. The TFP allows disaggregating the sources of economic growth, making it possible to identify patterns of past growth and evaluate potential tools to encourage future economic growth (OECD, 2005). However, the disadvantage of using a multifactor measure is the difficulty in measuring the various production inputs used in the production process. The difficulty in accurately measuring and aggregating capital input is one of the main criticisms of the TFP.

It is noteworthy that the TFP is quite often used in empirical studies of international economics. Krugman (1994) points out that sustained growth of *per capita* income of a nation only occurs if there is an increase in output per unit of input. An increase in production without an increase in the efficiency with which inputs are used is quite limited. Technological advances have to take into account a continuous increase in total factor productivity and, therefore, a continuous increase in national income.

The standard form of these studies using total factor productivity has been building a variable of capital stock related to knowledge from data on R&D expenditure and introducing it as an additional input in the production function of companies. Specifically, most studies perform a regression to estimate the effects of changes in R&D expenditure variable on production costs, production and productivity, using data from individual companies, industries or countries.

Griliches (2000) divides the econometric studies into two categories: i) the ones estimating the effect of R&D on production or productivity (production function studies); and ii) the ones estimating the effect of R&D on production costs (cost function studies). Both approaches are related, since it is possible to derive a cost function from a production function, and vice versa. However, they use different statistical methods and have different data needs. This article uses the first proposition, in which a production function is estimated.

In pioneering studies, Griliches (1979, 2000) points out that studies using the approach of the production function are more relevant in the empirical literature. Griliches (1979) showed that the relationship between productivity and the weighted average R&D expenditure results in two different processes: i) the production of innovations; and ii) the incorporation of these innovations in the production process.

Calculating TFP is based on the methodology developed by Griliches (2000) and Hall (2011). It is a Cobb–Douglas production function, wherein,

$$Q = AC^{\varphi}L^{\delta} \quad (2)$$

and Q is the *output*, C is the capital stock, L is the work, A is the productivity.

The output (Q) is defined as the difference between net sales revenue and raw materials, auxiliary materials and components (including packaging materials, fuels used as raw materials and lubricants), which allows for a better proxy of the firm's added value (Hulten, 2000).

The capital stock (C) is measured by the perpetual inventory method based on the flow of annual business investment. The perpetual inventory method is an indirect method of calculation through the sum of the accumulated investments which, appropriately depreciated, converge over time to the fixed capital stock of the companies. Thus, the existing capital stock over the previous year is depreciated, and added to this are the current year‘s investments (Griliches, 2000; Hulten, 2000; Parisi, Schiantarelli, & Sembenelli, 2006). Thus:

$$C_t = (1 - \gamma)C_{t-1} + I_t \quad (3)$$

The value of work (L) is measured by the wages paid excluding the wages paid to employees in R&D. To measure the equation the following logarithm is applied:

$$\ln q_{it} = \ln A_{it} + \varphi \ln C_{it} + \delta \ln L_{it} \quad (4)$$

Hence, the total productivity of factors *é* represented by:

$$PTF = \ln A_{it} = \ln q_{it} - \varphi \ln C_{it} + \delta \ln L_{it} \quad (5)$$

For the above, according to literature, there is no consensus on the productivity measures. Thus, this study aims to investigate empirically whether innovation promotes the productivity of Brazilian companies, and in order to do this we use the two productivity measures presented earlier: Work Productivity and Total Factor Productivity.

Empirical evidences

A wide range of international studies have investigated the relationship between the innovative behavior of the firm and its production performance, measured by productivity. In a pioneering study for the United Kingdom, Wakelin (2001) examines the relationship between spending on R&D and productivity growth (TFP) at enterprise level, using the panel data method. The Cobb–Douglas function is estimated for 170 companies in the period from 1988 to 1992. Among the findings it appears that the coefficient associated with spending on R&D is positive and statistically significant indicating its influence on the productivity of firms. However, the relationship loses significance when the fixed effects at industry level are included. To capture the effect by sector on the relationship between productivity growth and spending on R&D, two variables were included: the R&D of other companies in the same sector and spending on R&D weighted by the costs of innovation of supplier industries. As a result the study shows that the variation of technological opportunity in each sector seems to play an important role in the effectiveness of expenditure on R&D.

Huergo and Jaumandreu (2004) developed a study of companies in Spain, testing the influence of the variables age and innovation in TFP growth. The implemented methodology is the panel data analysis for a sample of 2300 companies in the period between 1990 and 1998. The results show that, when entering the market, companies have a higher productivity than the others; however, the productivity tends to converge to the industry average. Furthermore, the study shows that the process innovations for these companies produce an increased productivity that persists for years.

In the same analytical perspective, Ortega-Argilés et al. (2005) investigated the relationship between spending on R&D and TFP for companies in Europe in the period from 2000 to 2005. Through the panel data estimation in 532 companies, the main results of the study showed that the coefficient associated with the stock of knowledge is positive and statistically significant, indicating that there is a positive relationship between stock of knowledge and productivity. They emphasize even that the impact is more significant in medium-high and high-tech sectors than in low-tech sectors.

In a comparative study, Griffith, Huergo, Mairesse, and Peters (2006) estimated the effect of innovation on the total productivity of factors for four European countries: France, Germany, Spain and the United Kingdom. The authors describe the relationship between spending on R&D, innovation and productivity, using the CDM[1] (Crépon-Duguet and Mairesse) model. The econometric results suggest that the impact of innovation on productivity is remarkably similar in the four countries, although the authors found interesting differences, particularly the variation in productivity associated with higher or lower technological intensity of the industrial sector.

Along these same lines, Rogers (2006), also for the United Kingdom, examines the relationship between spending on R&D and productivity (TFP) over the period 1989–2000. The calculation of productivity is based on the estimation of a Cobb–Douglas function for a sample of 719 companies and estimation of the OLS model and panel data. The results indicated that in the United Kingdom, the impact of R&D spending on productivity is lower than in other advanced economies. Moreover, the returns of expenditure on R&D have been relatively stable over the decade of the 1990s. In an aggregate analysis the results suggest that spending on R&D is low relative to GDP, which seems to reflect the limited opportunities for companies and their inability to add value in the production process.

For Italian companies, Parisi et al. (2006) developed a study investigating the relationship between product and process innovation and productivity (TFP). In addition, they investigated the role of R&D and investment in fixed capital in the increase in likelihood of introducing innovations. The methodology used was the panel data analysis for 5000 companies between the years 1992 and 1998. The results show that process innovation has a great impact on productivity. Furthermore, the expenditure on R&D is positively associated with the probability of introducing a new product, while spending on fixed capital increases the likelihood of introducing a process innovation. However, the effect of fixed investment on the probability of introducing a process innovation is enhanced by the presence of R&D departments within the company. This result implies that the expenditure on R&D can affect productivity growth, favoring the absorption of new technologies.

In a similar study Mairesse and Robin (2009) investigated the effect of innovation on labor productivity for French companies in the periods 1998–2000 and 2002–2004. To control the effects of selection bias and endogeneity, non-linear simultaneous equations were used, forming a system of five equations based on the CDM model. The results found suggest that, in both periods, product innovation seems to be the main driver of labor productivity, while the influence of process innovation is rather insignificant.

Cassiman et al. (2010) associate innovation, productivity and export for manufacturing firms in Spain. Among the findings is the conclusion that the product innovations positively affect labor productivity of the enterprises and lead to small non-exporting businesses becoming exporters. The authors used unbalanced panel data of small and medium-size enterprises for the period 1990–1998. The sample consists of 1256 companies from 20 industrial sectors. The study showed that the coefficient associated with process innovation is positive and statistically significant for productivity; however, it shows no evidence of a stimulus of export capacity.

Although fewer in number some studies have also been conducted for developing countries. Miguel Benavente (2002), using data from Chilean companies, analyzed the impact of spending on R&D and innovation on the labor productivity of these companies. The methodology used was a model of ordinary least squares, and the study concludes that R&D and innovation activities are related to company size and market power. However, in the case of Chile, for the short term, productivity is not affected by innovation or by spending on R&D.

Tsai and Wang (2004) developed a Cobb–Douglas production function for 156 major companies listed on the Taiwan Stock Exchange. The econometric results obtained with the panel data method, suggest that between 1994 and 2000, the coefficient associated with the expenditure on R&D has a positive sign and is statistically significant, indicating the existence of a positive relationship between R&D and a company's productivity (elasticity equal to 0.18). Another result pointed out by the author is that this impact was much higher for companies in high-tech sectors (0.3) than for companies in low-tech sectors (0.07).

Zhang, Sun, Delgado, and Kumbhakar (2011) investigate the relationship between spending on R&D and productivity of Chinese high-tech companies. To compare the performance of companies, the authors divided China into three regions and built a Cobb–Douglas production function. Subsequently they used a semi-parametric approach to model the heterogeneity among the provinces in the period 2000–2007. The results suggest that the relationship between spending on R&D and productivity in the different regions is very heterogeneous as productivity in the eastern and central regions significantly increases; however, the relationship is not true for the western region.

In order to find evidence of the relationship between innovation and productivity in developing countries, Chudnovsky et al. (2006) studied a sample of 718 Argentinean companies. The econometric results show that spending on R&D, spending on machinery and equipment and the size of the company have a positive impact on the propensity to innovate. The study reveals further that innovative companies have a higher productivity than non-innovative ones.

The work carried out for a sample of companies in Brazil reveals results differing from the international pattern. Goedhuys (2007), using micro data from the World Bank (World Bank, 2003) for Brazilian industrial companies, investigates the effect of innovation on the TFP and its subsequent effect on the company's growth as measured by sales. The methodology used is

[1] Recently, Crépon, Duguet, and Mairessec (1998) empirically integrated the relations between products of the knowledge production function and productivity, and built a system of equations in order to correct the selection endogeneity and bias in the structure of the system.

the ordinary least squares method and it reveals that the activities with greater impact on productivity levels are organizational change, cooperation and development of human capital. While innovation has a positive and statistically significant coefficient associated with the company's growth, we found no evidence of the impact of product and process innovation in TFP.

Silva (2009) sought to identify the characteristics of the technological innovation of Brazilian industry through acquisitions of machinery and equipment and expenditures on R&D and its relationship with the TFP. As a result the author points out that the investment decision is subject to financing and to innovations developed by suppliers or other group companies, as well as a limited influence of competitive conditions. In turn, investments in R&D are more linked to companies targeting mainly the domestic market, however, with foreign capital participation. Still, there was a higher marginal productivity of the expenditure on R&D - in relation to the acquisition of machinery and equipment - in the process of innovation in the Brazilian industry. In fact, the results support the view of the existence of technological dependence of a portion of Brazilian industrial companies on their suppliers or other group companies.

In order to measure the relationship between capital stock, expenditure on R&D, and productivity of labor, Britto (2009) shows in a panel of 2047 Brazilian companies for the years 2000, 2003 and 2005, that the capital stock has a positive impact on work productivity. Estimates found show an elasticity of the intensity of physical capital investment (0.21%) of greater magnitude in relation to investment in R&D (0.16%). Thus, the results suggest that the adoption of a strategy of increasing productivity through the acquisition of machinery and equipment is more effective for Brazilian companies. Another important result indicates that the qualification of the workforce shows a productivity-elasticity bigger than 1.

Santana et al. (2011), in order to analyze the effects of technological innovation on work productivity in the Brazilian industry between 1996 and 2009, applied a panel data study using the GMM estimator in two stages. The results suggest that innovation increases productivity and even more intensively in sectors with greater international insertion.

Based on the theoretical debate and the total of the evidence presented, this paper contributes to the empirical debate on testing how different indicators of innovation influence the behavior of two productivity measures (WP and TFP) in Brazilian companies. Fig. 1 summarizes the main contributions of the empirical, national and international debate on the relationship between innovation and productivity.

Methodological notes

Presentation of the database

The database used for the realization of this empirical study refers to data crossing of the PIA – Annual Industrial Research – and PINTEC – Innovation Research, both from IBGE, with foreign trade records from SECEX/MDIC. It is noteworthy that this research is the first at a national level, in order to exclusively raise information about the innovative activities of the Brazilian industry, i.e., prior to it there was no joint national effort in this direction, leaving the task to local, regional or sector studies.

The methodology of PINTEC follows the pattern of research conducted by the European Community (Community Innovation Surveys – CIS), which also follow the Oslo Manual, developed by the OECD (Organization for Economic Cooperation and Development), ensuring international comparability. However, some issues, while focusing on important aspects of innovation, have limitations. Being based on the Oslo Manual as methodology, PINTEC tends to focus on the most characteristic aspects of companies located at the technological frontier or close to it. In the case of companies in developing countries like Brazil, which are characterized by still developing their skills, especially those intermediate; only the minority of businesses dominate the most advanced capabilities. Therefore, since many of the indicators used do not seek to capture such intermediate levels of capacity, characteristic of most companies, some criticism aimed at the traditional indicators to measure innovation when used in the context of late-industrializing economies apply to PINTEC (Lourdes & Figueiredo, 2009).

The survey consists of formal companies with ten or more employees belonging to the segments of mining, manufacturing and some selected services. In the case of the manufacturing industry, PINTEC is censitary for the group of industrial companies with five or more employees and random for other. For the composition of the random layer, in addition to adopting stratified sampling techniques proportional to the size, it assumes the premise that innovation is a rare phenomenon, which justifies assigning a higher probability of selection to those companies that have greater potential for innovation; this it is expressed by means of some of the firm's observed characteristics as having filed patent, received funding/grant for innovation, was innovative, performs R&D, among others. This most likely does not cause bias in the results since the weight of each company in the sample is inversely proportional to its probability of selection.

To investigate the relationship between innovation and productivity this study tests two dependent variables (WP and TFP) and a set of independent variables organized into four categories: business characteristics, technological capacity, the industry's characteristics and indicators of innovation as shown in Table 2.

WP is calculated from the relationship between the Industrial Transformation Value (ITV) and persons employed, both provided by the PIA. The TFP variable is calculated from an estimated production function by regression of the increase in output on the increase in input according to the work of Huergo and Jaumandreu (2004) and Parisi et al. (2006). In the econometric approach, the residue of the regression is interpreted as increase in TFP resulting from technology. Thus, the variables selected were; i) ITV which is defined as the difference between the Gross Value of Industrial Production (VBPI) and the Cost of Industrial Operations (COI). The ITV is a proxy of the Value Added (VA), which according to the national accounts is the sum of compensation of employees and gross operating surplus, minus subsidies to the activity; Labor (L) estimated by the structure of spending on payroll (salaries, wages, benefits, Social Security and other values calculated in the salary expense category of PIA); Capital (C) calculated as the amount spent by

Year	Author	Country	Related Variables	Econometric Method	Result
Developed countries					
2001	Wakelin	United Kingdom	TFP, Spending on R&D	Panel	Associated coefficient positive and statistically significant.
2004	Huergo and Jaumandreu	Spain	TFP and product innovations	Panel	Associated coefficient positive and statistically significant.
2005	Argilés, Potters and Vivarelli	Europa	TFP, Spending on R&D	Panel	Associated coefficient positive and statistically significant.
2006	Griffith *et al*	France, Germany, Spain and United Kingdom	TFP, Spending on R&D, Innovation	CDM	Associated coefficient positive and statistically significant.
2006	Rogers	United Kingdom	WP, Spending on R&D	OLS/ Panel	Associated coefficient positive and statistically significant.
2006	Parisi, Schiantarelli and Sembenelli	Spain	TFP, new products and processes and spending on R&D	*Probit*	Associated coefficient positive and statistically significant for spending on R&D.
2009	Mairesse and Robin	France	WP P product and process innovation	Simultaneous Equations	Associated coefficient positive and statistically significant for product innovation.
2010	Cassiman, Golovko and Martinez-Ros	Spain	TFP, product and process innovation and Export	Panel	Associated coefficient positive and statistically significant for product and process innovation
Developing countries					
2002	Benavente	Chile	WP, spending on R&D, new products	OLS	Associated coefficient not significant for spending on R&D and new products
2004	Wang	Taiwan	TFP, spending on R&D	Panel	Associated coefficient positive and statistically significant.
2006	Chudnovsky, López and Pupato	Argentina	WP, new products and processes	CDM	Associated coefficient positive and statistically significant.
2011	Zhang *et AL*	China	TFP, spending on R&D	Panel	Associated coefficient positive and statistically significant for more industrialized regions.
2007	Goedhuys	Brazil	WP, new products and processes	OLS	Associated coefficient not significant.
2009	Silva	Brazil	TFP, spending on R&D and Machinery and Equipment	CDM	Associated coefficient positive and statistically significant for product innovation and not significant for process innovation.
2009	Britto	Brazil	WP, spending on R&D and spending on Machinery and Equipment	Panel	Associated coefficient positive and statistically significant for spending on Machines and Equipment
2011	Santana, Cavalcanti and Bezerra	Brazil	WP, product and process innovation.	Associated coefficient positive and statistically significant.	Associated coefficient positive and statistically significant.

Fig. 1. Summary of empirical work on innovation and productivity.
Source: Authors.

the company on the acquisition of assets (machinery, real estate, equipment and other fixed assets less the decrease in the value of the same assets according to the perpetual inventory method. The data used for the capital stock were obtained from a study conducted by the Institute of Applied Economic Research (IPEA) for companies that make up the micro-data from PIA and made available by IBGE.

As regards the first category of explanatory variables, it appears that the characteristics of the companies are described by the variables persons employed, age and origin of capital. There is evidence that companies of bigger size, know-how and with more interaction with foreign markets present a greater productivity (Griffith et al., 2006; Huergo & Jaumandreu, 2004; Parisi et al., 2006; Rogers, 2006).

The variables that represent the technological capacity are: employed persons with college education, external financing percentage, cooperation for innovation and training and, finally, intensity of R&D and investments in machinery (Goedhuys, 2007; Griffith et al., 2006; Huergo & Jaumandreu, 2004; Mairesse & Robin, 2009; Rogers, 2006). Several studies have demonstrated a positive relationship between qualification and productivity. According to these authors, this ratio is explained by quality gains, reduced costs and learning (Fig. 2).

The technology classification proposed for this article is based on Lall (2000), who combines the taxonomy proposed by Pavitt (1984) with the typology of technological intensity of the OECD. The author suggests a classification by indicators of technological activities of manufactured goods,

Variable name	Description	Expected sign	Cross section	Panel
A) Company characteristics				
PO	Employed persons	+	X	X
PO^2	Square of employed persons	+	X	X
AGE	Years since the formal start of the company	+	X	X
ORIGIN OF CAPITAL	Binary variable: 0 – company does not possess foreign capital participation 1 – company possesses foreign capital participation.	+	X	X
B) Technological capacity				
SKILL	Percentage of employed persons with more than 12 years schooling.	+	X	X
FINANCING	Percentage of external financing	+	X	X
COOPERATION	Binary variable: 0 – company does not participate in cooperative arrangements 1 – company participates in cooperative arrangements.	+	X	X
TRAINING	Binary variable: 0 – company does not conduct training 1 - company conducts training.	+	X	X
PATENT	Company obtained patent. Binary variable: 0 – industry with low and medium-low technological intensity 1 – industry with high technological intensity.	+	X	X
R&D	Intensity of R&D: Spending on R&D in relation to net revenue	+		X
M&E	Intensity of Investment in machinery: Spending on M&E in relation to net revenue	+		X
C) Characteristics of the industrial sector in which the company operates				
HIGH TECH	Company that belongs to high technological intensity sectors according to Lall (2000). Binary variable: 0 – industry with low and medium-low technological intensity. 1 – industry with high technological intensity.	+	X	
MEDIUM TECH	Company that belongs to medium technological intensity sectors according to Lall (2000). Binary variable: 0 – industry with low and high technological intensity. 1 – industry with medium technological intensity.	+	X	
LOW TECH	Company that belongs to low technological intensity sectors according to Lall (2000). Binary variable: 1 – industry with high and medium technological intensity. 0 – industry with low technological intensity.	-	X	
D) Innovation indicators				
INOVA	Binary variable: 0 – company did not introduce new or significantly improved product or process. 1 – company introduced new or significantly improved product or process.	+	X	X
INOVA_PROD	Binary variable: 0 – company did not introduce new or significantly improved product. 1 – company introduced new or significantly improved product.	+	X	X
INOVA_PROC	Binary variable: 0 – company did not introduce new or significantly improved process. 1 – company introduced new or significantly improved process.	+	X	X
INOVA_ORG	Binary variable: 0 – company did not introduce new management techniques to improve routines and work practices within the company 1 – company introduced new management techniques to improve routines and work practices within the company.	+	X	X
TI	Standardized indicator oftechnological capabilities (lall, 1987, 1992; wignaraja, 2011, avellar and carvalho, 2013). Selected technological Capabilities: 1. Improvement of equipment; 2. License for technology use; 3. Quality improvement; 4. Improvement or adaptation of products; 5. Introduction of new products; 6. R&d activity; 7. Subcontracting; 8. Technology networks.	+	X	X

Fig. 2. Description of variables.
Source: Authors.

proposing four groups of technological intensity: goods intensive in natural resources; low technological intensity; medium technological intensity; high technological. Goods intensive in natural resources depend on the availability of local resources and are therefore related to the country's comparative advantages. The sectors of "low intensity" have price as the major determinant of competitiveness. These sectors belong to traditional industries such as textiles, footwear, and industries of low technology aggregation such as household appliance manufacturers. Companies belonging to the sector "medium intensity" use complex technologies and have moderate spending on R&D, comprising the sectors of capital goods and certain consumer durables. Finally, those belonging to the "high-intensity sectors" are characterized by advanced technologies and high spending on R&D, which provides a strong tendency to product innovation. These sectors comprise the pharmaceutical, aeronautical industry, and data processing. For simplicity, this article has joined the sectors of natural resources and low technological intensity together.

The fourth category of variables presents the innovation indicators: product innovation and/or process; innovation in product; process innovation; organizational innovation and the technology index (TI). The TI used in this study is based on Lall's studies (1987, 1992) wherein said author constructs an indicator to measure the technological capabilities of companies based on different kinds of innovative. Lall (1987, 1992), Wignaraja (2011), and Avellar and Carvalho (2013) organize the technological capabilities of the companies into three groups of technical functions: investment, production and networks. For sampling companies, these functions are identified in the following variables: (i) improvement of equipment; (ii) licensing of technology; (iii) improvement in quality; (iv) adaptation and improvement of products; (v) the introduction of new products; (vi) research and development activities (R&D); (vii) subcontracting; and (viii) participation in technology networks. For each company a score of 1 is assigned when this technological capacity is present. The investment category is represented by the activities (i) and (ii); the production category is represented by four activities (items iii–vi); and the networks category comprises items (vii) and (viii). Finally, the result is normalized to a value between 0 and 1. This number can be interpreted as the total score of technological capabilities of each company. It is important to note that this indicator has been used in several empirical studies for emerging countries.

Econometric specifications

The methodology proposed for this article uses two models: a cross-section analysis for 2008, and a panel data analysis (balanced) for the years 2003, 2005 and 2008. This research aims to examine how innovation (measured for new products, processes, organizational changes and Technology Index) influence the productivity of Brazilian companies.

The panel data models differ from models with temporal data and cross-section, given the dual character that assigns each variable:

$$Y_{it} = a + bX_{1it} + bX_{2it} + u_{it} \tag{6}$$

with $i = 1,\ldots,N$ the individuals (N individuals, countries, regions, companies, sectors). $t = 1,\ldots,T$ the periods of time (T periods).

If for each individual i the same number of temporal data is available, the panel is called balanced. If the number of temporal data is not the same for all individuals, the panel is called unbalanced.

In models that use "fixed effects", the estimation is made assuming that the heterogeneity of individuals is captured in the constant part, which is different from individual to individual: the constant part a_i is different for each individual, capturing invariant differences in time (for example, country size, natural resources and other characteristics that do not vary in the short term). In models with "random effects", the estimation is made introducing the heterogeneity of individuals in the error term.

The Hausman test was used to decide which model was the most appropriate: the model of random effects (H_0) or the model of fixed effects (H_A). The test is presented in the following form:

$$H_0 = Cov(a_i, X_{it}) = 0 \,(\text{random effect})$$

$$H_A = Cov(a_i, X_{it}) \neq 0 \,(\text{fixed effect})$$

Under the null hypothesis, the estimates of the model with random effects are consistent and efficient. Under the alternative hypothesis, the estimators *GLS* with random effects (and *OLS*) are not consistent, but the estimators with fixed effects are consistent. This is one of the advantages of models with fixed effects, since it allows endogeneity of the regressors.

Thus, the general equation of the model to be estimated can be described by:

$$\begin{aligned}\text{Productivity} &= \alpha + \lambda_1\text{Employed Persons} + \lambda_2\text{Employed Persons}^2 + \lambda_3\text{age} + \lambda_3\text{Foreign Capital}\\ &+ \beta_1\text{Skiill} + \beta_2\text{Financing} + \beta_4\text{Cooperation} + \beta_5\text{Training} + \beta_6\text{Patent} + \beta_7\text{R\&D} + \beta_8\text{Spending}\\ &\text{Machinery} + \pi_1\text{hightech} + \pi_2\text{mediumtech} + \boldsymbol{\mu_3}\textbf{Innovation Indicator}\end{aligned} \tag{7}$$

Empirical results

Descriptive analysis

The analyzed data base is formed by the three editions of PINTEC (2003), PINTEC (2005, 2008). The sample is composed of 2846 enterprises and is the result of the cross-section of the surveys of 2003, 2005 and 2008. Of these companies 503 (17.67%), 642 (22.56%) and 1701 (59.77%) belong respectively to the sector of low, medium and high technology according to the 2008 edition of PINTEC.

Table 1
Descriptive statistics – continuous variables – mean, standard deviation and coefficient of variation.

Variables	2003		2005		2008	
	Companies		Companies		Companies	
	Mean	Var. Coeff.	Mean	Var. Coeff.	Mean	Var. Coeff.
PO	765.75 (*1719.05*)	2.2	861.66 (*2008.18*)	2.3	948.92 (*2418.94*)	2.5
AGE	23.63 (*12.03*)	0.5	25.63 (*12.03*)	0.5	28.72 (*12.12*)	0.4
R&D	0.007 (*0.031*)	4.4	0.014 (*0.037*)	2.6	0.006 (*0.032*)	5.3
INOV	0.033 (*0.094*)	2.8	0.040 (*0.41*)	10.3	0.038 (*0.363*)	9.6
M&E	0.02 (*0.07*)	3.5	0.18 (*0.08*)	0.4	0.026 (*0.35*)	0.1
SKILL	0.006 (0.032)	5.3	0.007 (*0.034*)	4.9	0.009 (*0.195*)	21.7
TI	0.33 (*0.22*)	0.7	0.38 (*0.25*)	0.7	0.43 (*0.21*)	0.5
WP	79.05 (*185.45*)	2.3	87.00 (*143.39*)	1.6	106.91 (*225.17*)	2.1
TFP	15.26 (*3.26*)	0.2	15.51 (*3.01*)	0.2	16.33 (*2.94*)	0.2
Total	2846		2846		2846	

Source: IBGE, Innovation Survey (2003, 2005, 2008).
The values in parentheses represent the standard deviation.

Table 2
Descriptive statistics – binary variables – number of companies and %.

Variables	2003		2005		2008	
	Company		Company		Company	
	Freq.	%	Freq.	%	Freq	%
ORIGIN OF CAPITAL	565	19.85	559	19.64	610	21.43
TRAINING	814	28.60	807	28.36	909	31.94
COOPERATION	402	14.13	557	19.57	484	17.01
PATENTS	1295	45.50	1047	36.79	1596	56.08
EXPORT	1909	67.08	1966	69.08	1966	69.08

Source: IBGE, Innovation Survey (2003, 2005, 2008).

Table 1 shows the mean, standard deviation and coefficient of variation of continuous variables analyzed in the study for the three years under review. Table 2 examines the discrete variables of the proposed empirical study and shows the number of companies and their frequency in the sample.

Regarding the behavior of the productivity indicators a growth can be seen in their means over the years analyzed. A positive trend is shown over the period, particularly the WP, which increased 35% for the sample companies between 2003 and 2008. The TFP showed an increase of 7% between 2003 and 2008.

The first category of explanatory variables relate to business characteristics. It appears that, on average, they are companies with more than 500 employees, aged between 23 and 28 years, as shown in Table 1, and about 20% of them have foreign capital (Table 2).

As for the technological capacity indicators (second category) it may be noted that employed persons with college education (SKILL), training and cooperation grew between 2003 and 2008, indicating an improvement in technological capabilities of Brazilian companies in the analyzed period.

The intensity of R&D, innovative spending and spending on machinery and equipment have evolved between 2003 and 2005, however they showed a decline in 2008. This result implies less effort when it comes to innovative expenditures by enterprises in 2008. We highlight the variable R&D intensity which decreased 14.3% compared to 2003.

The fourth category of variables organizes the innovation indicators: innovation of product and/or process, product innovation, process innovation, organizational innovation and the technology index (TI). The indicators innovation of product and/or process, product innovation, process innovation and organizational innovation are shown in Table 3 and indicate a non-uniform behavior over the period. Between 2003 and 2005, the percentage of companies that innovated in product and process increased. In the following period, however, there was a decrease in the percentage of innovative companies, with the exception of organizational innovation.

Regarding the indicator of innovation called technology index (TI), presented in Table 2, we find a positive change for the three periods, highlighting a growth of about 30% of the sample companies. Representing an index that combines several technological capabilities this result points to a growth of technological efforts by firms. In a study on China Wignajara (2011) revealed that the average TI is 0.52. This result suggests that the technological capabilities are lower for Brazilian companies.

Econometric estimates

Tables 4 and 5 show the results of econometric estimates. For the realization of this empirical study Stata software 11was used. All estimates were conducted using the robust command to correct any heteroscedasticity.

Table 3
Behavior of innovation indicators – number of companies.

Variables	2003		2005		2008	
	Company		Company		Company	
	Freq.	%	Freq.	%	Freq	%
INOVATION OF PRODUCT	1243	43.68	1494	52.49	1237	43.46
INOVATION OF PROCESS	1497	52.60	1794	63.04	1428	50.18
INOVATION OF PRODUCT OR PROCESS	1798	63.18	2187	76.84	1697	59.63
ORGANIZATIONAL INOVATION	1900	66.76	1882	66.13	2090	73.44

Source: IBGE, Research Board, Industry Coordination, Technological Innovation Survey (2003, 2005, 2008).

In Table 4, the columns 1–5 present results of the OLS model for the sample of Brazilian companies. The purpose of these estimates is to test the effect of innovation on work productivity.

The model results corroborate with several international studies (Cassiman et al., 2010; Mairesse & Robin, 2009; Miguel Benavente, 2002).

Concerning the variable cooperation, there is a coefficient associated positively and significantly with respect to work productivity. Such positive and significant relationship between cooperation and work productivity is evidenced in some international studies (Crespi & Zuniga, 2010; Griffith et al., 2006). This result suggests that companies that participate in cooperative arrangements become more productive than companies that do not.

When analyzing the influence of technological intensity in the sector on productivity, we note that the results are significantly positive only for the companies with medium technological intensity. Ortega-Argilés et al. (2005), in a study on Spain, point out that companies in highly technological intensive sectors gain more efficiency with innovative efforts and therefore have better productivity performance. The authors report that the growth of productivity in companies of low and medium technological intensity is dependent on physical capital investment. Thus, these results suggest that in the case of Brazil the relationship between technological intensity and work productivity is more related to efforts in the acquisition of machinery and equipment for innovation.

Regarding innovation indicators, a pattern of behavior is identified where the associated coefficients are positive and statistically significant in relation to work productivity. As regards the first indicator of innovation, INOVA (column 1), the associated coefficient is positive and statistically significant at 5% for the year 2005, indicating that developing new products or processes positively affects work productivity.

With regard to the product innovation indicator (INOVA_PROD), we perceive a positive and significant effect for the years 2005 and 2008 in work productivity. In studies on France and Spain, Mairesse and Robin (2009) and Cassiman and Golovko (2011) respectively found similar results. Crespi and Zuniga (2010) in a comparative study for countries in Latin America, found evidence of the positive impact of product innovation on work productivity for Argentina, Chile, Colombia and Uruguay.

Observing the innovation of process indicator, the results are less robust. For the year 2005 the associated coefficient is positive and significant at 10%. However, for 2008 the results are not significant. This result is similar to what Mairesse and Robin (2009) identified for French companies: product innovation affects productivity, while process innovation was not significant. This relationship is also investigated by Griffith et al. (2006), and the results show that innovation of process is one of the determinants of productivity to France, Spain and the United Kingdom, but not for Germany.

The coefficient associated with organizational innovation is positive and significant for the years 2005 and 2008. Thus, it is suggested that organizational changes stimulate work productivity of Brazilian companies. Finally, TI, the proxy for innovative efforts of companies, has a associated coefficient positive and significant at 1% for the year 2005.

The columns 6–10 of Table 4 show the results of the OLS model, testing the effect of innovation in total factor productivity. The results of the models differ from some international studies, especially those for developed countries. However, in some studies in developing countries, the results are coincident.

It is emphasized in both models that the TFP is related positively with age, capital source and medium technological intensive sectors. The age variable suggests that companies with more time on the market are more productive. In a study with a sample of Spanish companies Huergo and Jaumandreu (2004) showed an opposite result. According to this study, age has a negative and statistically significant coefficient associated to total factor productivity. The reason would be that the younger Spanish companies are better able to meet the changes in productivity standards. This divergence can be explained by the composition of the samples in both studies. The average age of the companies surveyed by Huergo and Jaumandreu (2004) is 35 years, while Brazilian companies have on average 28 years. Another important aspect is that the coefficient associated with the variable cooperation is positive and significant for models 8 and 9. Goedhuys (2007) found evidence for a similar sample of Brazilian companies. The positive results of cooperation in the TFP were even more significant when associated with organizational changes.

Regarding the innovation indicators we note that the associated coefficients were not significant. While for developed countries positive pattern are found between innovation and TFP (Griffith et al., 2006; Huergo and Jaumandreu, 2004; Ortega-Argilés et al., 2005; Rogers, 2006), for developing countries the result are often different (Britto, 2009; Goedhuys, 2007; Miguel Benavente, 2002; Zhang et al., 2011).

Table 4
OLS model with lagged variables for 2008.

Variables	Work productivity					Total factor productivity				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PO	−0.005 (0.004)	−0.006 (0.004)	−0.005 (0.004)	−0.005 (0.004)	−0.007 (0.004)	1.686 (183.6)	3.367 (182.4)	2.283 (184.0)	3.526 (184.2)	2.091 (182.2)
PO2	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.013 (0.013)	0.013 (0.134)	0.013 (0.013)	0.013 (0.013)	0.013 (0.013)
AGE	0.339 (0.345)	0.320 (0.343)	0.392 (0.360)	0.362 (0.350)	0.316 (0.341)	2265.2 (1750.5)***	4375.4 (1780.5)***	4419.0 (1785.9)***	4402.7 (1788.3)***	4636.2 (1903.4)***
ORIGIN OF CAPITAL	118.81 (18.861)*	116.83 (18.206)*	119.78 (18.721)*	118.21 (18.508)*	114.25 (17.843)*	14 028.2 (51 604)**	14 355.4 (52 755)**	144 000 (55 241)**	145 268.9 (40 730)**	142 165.5 (49 977)**
SKILL	22.055 (34.770)	21.177 (33.978)	22.939 (34.772)	22.596 (34.543)	22.009 (33.654)	2710.5 (4630.1)	28 704.9 (4630.1)	30 525.3 (45 788.2)	29 188.2 (44798.0)	46 932 (50 633.4)
FINANCING	−0.0504 (0.224)	−0.1038 (0.230)	−0.0068 (0.238)	−0.05054 (0.231)	−0.1698 (0.226)	−591.95 (841.94)	−489.24 (880.46)	−476.80 (879.55)	−445.32 (929.84)	182.23 (961.78)
COOPERATION	32.923 (15.749)***	29.674 (14.864)*	36.129 (14.657)**	32.587 (14.461)**		217 350.2 (114 795)	225 494.2 (115 718)	225 494.2 (115 718)	227 139.3 (113 187.2)	341 262.5 (190 846.6)
TRAINING	46 282.7 (27 730)	55 850** (33 007)	48 663.4 (29 253)	44 972.04 (29 253)	147 257.9 (71 303.5)	36 282.7 (27 730)	95 850** (33 007)	49 663.4 (29 253)	56 972.04 (29 253)	157 257.9 (71 303.5)
PATENT	8.1454 (10.716)	5.3506 (7.622)	−0.1247 (12.215)	2.1889 (8.571)	2.300 (7.764)	129 163.3 (63 127.6)	129 163.3 (63 127.6)	10 355*** (47 374.4)	94 121.77** (30 046.8)	20 868.7 (44 249.1)
HIGH_TECH	15.380 (13.351)	9.4119 (14.206)	19.594 (12.749)	17.6029 (13.073)	8.2613 (14.256)	−36 965.6 (41 980.9)	−31 947.3 (40 492.1)	−25 070.5 (33 688.1)	−25 690.1 (33 276.8)	−20 188.9 (44 667.3)
MEDIUM_TECH	47.746 (12.053)*	45.951 (11.957)*	49.486 (11.509)*	48.044 (11.691)*	43.457 (11.953)*	78 058 (32 004)***	81 096 (30 697)***	81 237 (31 456.8)***	82 643 (30 236.8)***	71 468.2 (33 909.8)***
INOVA2005	15.113 (6.614)**					69 038.4 (84 109.2)				
INOVA2008	12.992 (12.971)					26 598.6 (18 196.8)				
INOVA_PROD 2005		25.472 (7.755)**					14 645.5 (41 928.5)			
INOVA_PROD 2008		14.76 (8.752)***					14 527.0		(17 697.0)	
INOVA_PROC 2005			12.86 (7.0644)***					32 416.2 (22 445.7)		
INOVA_PROC2008			5.4762 (11.421)					25 462.7 (66 104)		
INOVA_ORG 2005				21.694 (6.200)*					4160.3 (20 331.4)	
INOVA_ORG 2008				20.489 (6.778)**					30 676.0 (31 958.0)	
TI 2005					81.240 (19.373)*					362 322 (158 317)***
TI 2008					9.465 (36.310)					−859 474 (576 607)
Observations	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**
***R*-square**	**0.2333**	**0.2343**	**0.2102**	**0.2131**	**0.2400**	**0.4190**	**0.4191**	**0.4191**	**0.4191**	**0.4233**

Notes: (a) Standard Errors between brackets; (b) $***p<0.1$, $**p<0.05$, $*p<0.001$, absence of asterisk represents non-significant coefficient. (c) For models 5 and 10the variable cooperation was excluded to avoid multi-colineariety with the TI variable.
The values in parentheses represent the standard deviation.

Table 5
Panel data model for the years 2003, 2005 and 2008.

Variables	Work productivity					Total factor productivity (residual)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PO	−0.021 (*0.003*)*	−0.021 (*0.003*)*	−0.021 (*0.003*)*	−0.021 (*0.003*)*	−0.020 (*0.003*)*	−74.892 (*11.90*)*	−74.319 (*11.90*)*	−74.653 (*11.90*)*	−74.234 (*11.89*)*	−72.527 (*11.89*)*
PO2	3.240 (*6.300*)*	3.250 (*6.300*)*	3.260 (*6.300*)*	3.250 (*6.300*)*	3.200 (*6.300*)*	0.010 (*0.000*)*	0.010 (*0.000*)*	0.010 (*0.000*)*	0.010 (*0.000*)*	0.010 (*0.000*)*
AGE	5.443 (*0.536*)*	5.435 (*0.536*)*	5.427 (*0.536*)*	5.440 (*0.538*)*	5.692 (*0.566*)*	11.583 (*2095*)*	11.646 (*2095*)*	11.608 (*2095*)*	11.645 (*2101.4*)*	14 461 (*2209.4*)*
ORIGIN OF CAPITAL	25.308 (*9.767*)***	25.235 (*9.767*)***	25.120 (*9.767*)***	25.230 (*9.767*)***	25.385 (*9.767*)***	7885.1 (*38 139*)	8461.1 (*38 142*)	7815.3 (*38 142*)	8502.8 (*38 143*)	10 401 (*38 091*)
SKILL	−5.572 (*12.40*)	−5.731 (*12.40*)	−5.952 (*12.40*)	−5824 (*12.40*)	−5223 (*12.40*)	−5223 (*48 447*)	−83 425 (*48 451*)	−85 457 (*48 431*)	−79 572 (*48 439*)	−22 047 (*48 377*)
FINANCING	−0.028 (0.*130*)	−0.028 (*0.130*)	−0.030 (*0.130*)	−0.030 (*0.130*)	−0.010 (*0.131*)	−21 769 (*51 106*)	−21 192 (*51 1*31)	−21 474 (*51 1*31)	−20 714 (*51 1*10)	−51 079 (*51 1*14)
COOPERATION	5418 (*4.580*)	5.319 (*4.602*)	4.929 (*4.573*)	5.145 (*4.568*)		454 261 (*17 883*)	606 622 (*17 974*)	558 176 (*17 857*)	67 333 (*17841*)	
TRAINING	0.807 (*3.753*)	0.477 (*3.724*)	0.001 (*3.729*)	0.316 (*3.689*)	2.386 (*3.886*)	−18246 (*14655*)	−15187 (*14546*)	−16510 (*14562*)	−14 580 (*14 406*)	5844.7 (*15157*)
PATENT	−2.003 (*4.808*)	0.096 (*3.516*)	1.472 (*3.962*)	0.447 (*3.339*)	−1.010 (*3.447*)	19514.2 (*18773*)	3374.36 (*13730*)	9118.9 (*15473*)	21 334 (*13 039*)	−12 667 (*13 445*)
R&D	−9.927 (*6.388*)	−9.954 (*6.388*)	−9.925 (*6.388*)	−9.966 (*6.388*)	−9.891 (*6.388*)	147 777 (*24 942*)	171 653 (*24 945*)	20 740 (*24 946*)	17 592 (*24 946*)	24 859 (*24 910*)
M&E	−3.911 (*5.479*)	−4.089 (*6.736*)	−4.201 (*6.740*)	−4.096 (*6.736*)	−4.076 (*6.735*)	−24 991 (*26 332*)	−12 392 (*26 307*)	−90.16 (*26 373*)	−1224 (*26 207*)	−17 739 (*26 269*)
INOVA	3.943 (*5.479*)					27 507.19 (*21 395.8*)				
INOVA_PROD		1.390 (*3.984*)					4514.24 (*15 560.0*)			
INOVA_PROC			1.818 (*4.017*)					13 424.39 (15 605.7)		
INOVA_ORG				0.0513 (*3.268*)					590.34 (*12 764.8*)	
TI 2005					−12.155 (*9.511*)					143 607.3 (*37 093*)*
Observations	**8538**	**8538**	**8538**	**8538**	**8538**	**8538**	**8538**	**8538**	**8538**	**8538**
Enterprises	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**	**2846**
R^2 adjusted	**0.262**	**0.261**	**0.249**	**0.259**	**0.260**	**0.362**	**0.362**	**0.362**	**0.362**	**0.362**
Hausman test	**193.67 (*0.000*)**	**196.4 (*0.000*)**	**191.31 (*0.000*)**	**197.32 (*0.000*)**	**189.3 (*0.000*)**	**101.76 (*0.000*)**	**102.77 (*0.000*)**	**102.42 (*0.000*)**	**102.79 (*0.000*)**	**104.3 (*0.000*)**

Notes: (a) Standard Errors between brackets; (b) ***$p < 0.001$, **$p < 0.05$, *$p < 0.1$, absence of asterisk represents non-significant coefficient. (c) For the panel data model, all estimations used fixed effect in view of the Hausman test. (d) For the models 5 and 10the variable cooperation was excluded to avoid multi-colineariety with the variable TI.

Table 5 shows the results of the panel data models for work productivity and total factor productivity in order to identify the dynamic relation between variables, and also to enable control on possible not-observed heterogeneity between units of analysis. Wooldridge (2010) shows that the panel data models are more effective in analyzing features that may or may not be constant over time, so that time or sectional studies which do not take into account such heterogeneity incur omitted variable bias and produce almost always inconsistent results.

Columns 1–5 show the results of the panel data model for WP. The purpose of the models represented by these columns is to test the effect of five innovation indicators on work productivity. The dependent variable is continuous and identifies the relationship between the Industrial Transformation Value (ITV) and the number of employed personnel. The independent variables related to the characteristics of the company, the company's training and innovation indicators are the same as described before. Two variables of innovative effort were added: Spending on R&D and Expenditures on Machinery and Equipment.

It is found as standard that in both models the variables square of persons employed, age, and origin of capital have a positive and statistically significant associated coefficient. It should be noted that the persons employed variable has a negative and statistically significant associated coefficient, indicating that the company's size has a negative impact on productivity.

The origin of capital variable is a proxy that measures the company's relationship with the external sector. The significant and positive associated coefficient corroborates some studies that show that companies with greater international integration have higher productivity (Goedhuys, 2007; Santana et al., 2011).

Regarding innovation indicators, only the technology index showed significant results. Thus, it appears that product, process, and organization innovation were not significant for work productivity for the sample of Brazilian companies in these estimated models. It is believed that the results found in this study indicating that there is no relationship between innovation (expenditure on R&D, for example) and productivity are to some extent influenced by the sensitivity of the indicators built. The work by Cavalcante, Jacinto, and De Negri (2015) performs a similar empirical study for Brazilian companies and use as an innovation indicator spending on R&D in relation to employed persons. It estimates cross section and panel data models and finds positive and statistically significant associated coefficients, showing a positive relationship between innovation and productivity for Brazil.

Models 6–10 analyze the relationship of innovation with TFP. The results are similar to models relating to work productivity. The associated coefficients of the innovation indicators are not significant, except for the Technology Index.

However, some studies in developing countries show similar results. Goedhuys, Janz, and Mohnen (2006), in a study for Tanzania indicate that technological variables, R&D and product and process innovations did not show positive and statistically significant associated coefficients in relation to Work Productivity. Nevertheless, variables like origin of capital and ISO certification indicated to positively affect productivity. Miguel Benavente (2002), analyzing a sample of Chilean companies, found that company size and market power have an associated coefficient positive and significant for work productivity. On the other side, nor innovative effort, measured by spending on R&D nor innovation achieved significant estimated coefficients. The author suggests that the lack of data associated with the Chilean market structure may explain this result.

Final considerations

In light of the foregoing, it is clear that the relationship between the variables that explain the productive performance of Brazilian companies, as measured by WP and TFP and innovation do not have robust results for a sample of Brazilian companies.

Both models show the pattern that variables related to the characteristics of companies, square of employed persons, age, and origin of capital, present positive and significant associated coefficients. These results suggest that size and participation of foreign capital have a positive influence on the productivity of companies.

The results for the cross section model with lagged variables point to a positive and significant relationship between innovation indicators and work productivity. These results are more evident when observing the lagged variables. However, this relationship is not significant for the TFP.

Another important aspect is related to the technological intensity. Companies of the medium intensity sectors present positive and statistically significant associated coefficients. As pointed out by several studies in international literature, the growth of productivity in low and medium-technology intensity sectors is dependent on physical capital investment. These results thus suggest that, in the case of Brazil, productivity is more related to efforts to acquire machinery and equipment for innovation.

Regarding the panel data models we have not found significant results of the relationship between innovation and productivity. It is believed that the lack of relationship between innovation (expenditure on R&D, for example) and productivity found in this study is to some extent related to the innovation variables obtained by PINTEC and constructed for this study, as the work by Cavalcante et al. (2015) found evidence of a positive relationship between innovation and productivity for Brazil.

It follows, therefore, that innovation produces still incipient impacts on the productivity of the domestic industry. It is important to stress that Brazil's industrial structure is very concentrated in labor intensive sectors of low and medium-low technology. This part of the industrial structure may also have weakened the relationship between innovation and productivity, since innovation in these sectors cannot be considered a key factor in the competitive process.

Based on these discussions a policy agenda can be implemented in order to consolidate the results of innovation in Brazil: i) expansion of sector innovation policies; ii) linkages between technology policies and foreign trade; iii) training of qualified human resources.

Moreover, the need to improve the link between technology policies and foreign trade is evident. In Brazil the most innovative companies are those that are more scale efficient, export and import more, and export higher value-added goods. However, the greater the technological intensity of goods worse is the performance in the trade balance. Hence, it is necessary to create options for technology intensive companies, combining horizontal policy instruments with strategic sector actions which identify relevant opportunities for Brazil in the world market.

Conflicts of interest

The authors declare no conflicts of interest.

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