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The impact of innovation activities on productivity and firm growth: evidence from Brazil

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Abstract:
Using micro data from Brazilian manufacturing firms, this paper investigates the impact of a wide set of innovation activities on firms' total factor productivity (TFP) and its subsequent effect on firm growth, measured by sales. Controlling for size and age of the firms, productivity levels and productivity growth of firms over time are found to be key drivers of firm size adjustments. The activities leading to higher productivity levels are organizational change, cooperation with clients, human capital development, ICT usage, product innovation and learning by exporting, with an R&D effect only in the long run. Though the intensity with which firms engage in these innovation activities is sector dependent, innovation activities are in all sectors important for explaining sales growth differences, also in the more traditional sectors in which Brazilian firms have a competitive advantage.

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1. Introduction

In recent years, Brazil has shown signs that it is recovering from a two decade period of stagnation. It has been able to play an increasingly important role in international trade, production and investment, and became competitive in international markets in traditional sectors such as fresh and processed food products, leather and wood products. This pattern of emerging success has given rise to a significant amount of research, which mostly measures and documents the performance of the economy at the aggregate or sector level and hides the large firm heterogeneity that characterizes most productive sectors. The micro-evidence providing insights into the factors that underlie firm's competitiveness is less abundant, not only for Brazil but for developing countries more generally.

Using micro level data from Brazil this paper therefore seeks to analyse two related key indicators of corporate success – productivity and firm growth – and the driving forces behind them. More specifically, a first objective is to better understand what affects the level of productivity in firms in Brazil. There is an active research area that seeks to explain the substantial and persistent heterogeneity in productivity across firms. From theoretical insights and the large amount of studies conducted for OECD countries, it is well established that these productivity differences are to a large extent related to differences in knowledge. In the empirical literature on industrial economies, the inputs and outputs of the knowledge creation process - mostly measured by R&D, patenting and more recently product and process innovation - are found important determinants of the productivity of the firm.

However, for developing and emerging economies the relevance of R&D and patenting statistics is often rightly questioned. A majority of firms in developing countries realise productivity gains by undertaking efforts that bring them closer to the technological frontier, by absorbing and adapting externally developed knowledge, rather than from creating new knowledge within the firm. Yet, empirical evidence covering a larger set of innovation activities and learning mechanisms that can affect firm performance in developing country firm is rather thin and this may have several reasons. One reason may be the fact that firm level data are just recently being collected systematically in developing countries. Secondly, when productivity of developing country firms is investigated using firm level data, the focus of attention is mostly drawn to the investment climate and other institutional factors that are beyond the control of the firm (Bastos and Nasir, 2004, Dollar et al., 2003, Eifert et al., 2005) and less to the individual efforts of the firm to build up competences. Finally, there is also an ongoing debate on how to measure learning in developing country firms. R&D and patent statistics may be imperfect measures even for industrial countries, for developing countries the ways firms build competences is multifold and consequently it gets even more difficult to construct indicators that measure them effectively. Jointly these factors have lead to a shortage of evidence on the innovation-productivity nexus for developing countries, and this paper addresses this caveat. It sheds light on a larger set of learning mechanisms at the level of the developing country firm and presents insights into their impact on the evolution of total factor productivity.

Subsequently this paper analyses the relationship between productivity and firm growth. The literature on firm growth occupies an important place in the study of firm dynamics and for most theoretical models explaining firm growth, productivity is the key factor. In models of passive learning (Lucas, 1978, Jovanovic, 1982), firms adjust their size level to bring it in accordance to their productivity level, which they discover post-entry. Hence, more productive firms grow faster, all else equal. In models of active learning (e.g. Pakes and Ericson, 1990), firms can actively increase their productivity over time. The empirical literature, however, tends to omit productivity levels or productivity growth in the growth equation but uses size and age variables instead to test alternative theories of firm growth. The analysis in this paper tests active and passive learning more explicitly, by entering productivity levels and productivity growth directly into the growth equation.

This paper thus provides a clearer picture of how precisely productivity levels are build up at the firm level and how these efforts affect firm growth. It analyses a broader set of innovation activities and organizational change at the firm level and investigates whether they affect the evolution of total factor productivity (TFP) over the period 2000-2002. Next, integrating these findings with literature on firm growth, the impact of productivity and productivity growth on the growth of the firms' sales is investigated controlling for important other determinants such as firm size and age, sector of activity and some institutional factors. The impact of several different innovation activities on firm growth is also measured directly, by estimating a reduced form of the model for a longer period of time, 1997-2002.

The structure of the paper is as follows: In section two the major findings of the theoretical and empirical literature are presented. In section three the data are discussed. Section four explains the empirical approach for calculating TFP, it develops the estimating equation for productivity and firm growth and shows how the variables are defined. The results of the Brazilian sample of firms are presented in section five. Section six concludes.

2. Firm growth and learning: an overview of empirical findings

2.1. Innovation and productivity in developing countries

The determinants of productivity and productivity growth have been largely documented for industrial countries, where innovation is widely regarded as the key to growth. Firms invest in R&D to develop new products and processes. By investing in research, patenting and licensing they stay at the cutting edge of technologies. An interesting overview of studies for OECD countries, their methodologies and their major findings is given by Sanghoon Ahn (2001, p.47-50).

However, in developing countries, a majority of firms is operating far below the technological frontier, with lower levels of human capital and older vintage machinery. To raise efficiency or establish a better competitive position, firms' efforts are oriented towards developing capabilities to absorb, adapt and master technologies often developed elsewhere in a process of technological learning. Cohen and Levinthal (1989) developed the concept of 'learning' or 'absorptive' capacity to refer to firm's capabilities to identify, assimilate and exploit externally available information. Several authors (eg. Enos, 1992, Lall, 1992, among others, see also UNCTAD 1996 for an overview) termed the technological activities of firms in developing countries by 'technological capabilities', referring to the information and skills - technical, managerial and institutional - that allow firms to utilize equipment and technology efficiently. The concept of innovation is accordingly a much broader one than 'invention', which focuses on novelty and is applicable to frontier shifting new knowledge. Instead, innovation refers to the application of knowledge that is new to the firm and not necessarily new to its competitors, the market or the world. It incorporates a broad set of activities that individual enterprises undertake to gradually absorb knowledge and build upon existing knowledge necessary for efficient production and higher quality output. Minor and incremental rather than radical changes are at the heart of this innovation process in developing countries.

This broader definition of innovation has given rise to a debate on how to measure innovation in developing country firms. In recent years, several initiatives have been undertaken to develop alternative measures of innovation activities and they stress the need to incorporate a larger set of activities that encompass learning in firms than what is needed for OECD country firms (RICyT, Bogotà Manual,2001, UNU/INTECH, 2004, OECD, 2005, Oslo Manual, see annex on innovation surveys in developing countries). Measurement priority is placed on mechanisms of knowledge diffusion which include human resources, linkages with other firms and non-firm organisations, the use of ICT, quality control systems, acquisition of embodied technology, and it should capture incremental and organisational change, which are key to growth in Latin America.

But do these activities have a measurable impact on productivity of firms in developing countries? Micro level evidence of productivity in developing countries that measure the impact of innovation activities is limited. Using data from Tanzanian firms, Goedhuys et al. (2006) found that the traditional technology variables, R&D and innovation output measures, turned out insignificant in explaining productivity differences. Some indirect technological variables such as foreign ownership, ISO certification and the educational level of the general manager seemed to affect productivity, but institutional factors, such as over-regulation, lack of government support, and a deficient health system, were equally important determinants.

2.2. Productivity and firm growth

In a competitive setting, higher levels of productivity also translate into superior performance in terms of firm growth. The literature on firm growth was initially inspired by Gibrat (1931), who stated that firm growth is a random process. The literature that subsequently developed (see Bartelsman et.al. (2004) for an overview p.1-6; and also Sanghoon Ahn, 2001 p.12) focused on demonstrating the opposite, that firm growth is actually determined by a set of factors related to the efficiency or productivity of the firm. Using evidence from a variety of countries, studies focused on the relationship between firm size and growth, a relation found negative and explained in a context of increasing returns to scale: firms tend to enter small and to reach the minimum efficient scale of operations, they have to grow quickly into a larger size. If they don't, they operate on a scale disadvantage and the probability of failure and exit is higher. As a result, surviving firms in small size cohorts demonstrate a higher growth rate than firms above the MES. In the same logic, the variability in growth rates is also higher for smaller firms (e.g. Evans (1987), Dunne and Hughes (1994), Cabral and Mata, 2003).

Growth is also found to be related to firm age (Evans, 1987; Dunne and Hughes, 1994). A process of passive learning is responsible for this: firms enter the industry without a priori knowledge about their efficiency. Once in business, they learn about their own efficiency level and adjust the scale of operations accordingly, with more efficient firms growing larger. It is mainly during the early years of operations that adjustments in size take place, and therefore young firms that have newly entered the industry grow faster.

The literature on firm growth in developing countries has also paid attention to the institutional barriers to firm development, such as poorly functioning financial markets and regulatory barriers. While financial constraints are also found to affect firm growth in OECD countries (Cabral and Mata, 2003, Beck et al., 2005) they may be even more severe in developing countries were financial markets are less developed and biased against small firms depriving them from necessary resources (Sleuwaegen and Goedhuys, 2002). With respect to regulatory constraints, Fisman and Svensson (2006) found corruption and taxation to hamper firm growth in Uganda.

In the next sections the analysis will focus on uncovering the determinants of productivity in a sample of Brazilian manufacturing firms, and the further effect of productivity and productivity growth on firm growth, controlling for firm age, size, and sector – to capture differences in minimum efficient scale and market structure - and location effects – reflecting regulatory factors.

3. Data

The empirical analysis uses the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003. The data collection is part of a larger and ongoing program coordinated by the World Bank that implements Investment Climate Surveys in many countries using a harmonised master questionnaire. The objective of the ICS is to obtain firm level data that allow analysing the conditions for investment and enterprise growth in the country. As such, the many aspects of the business environment that influence the investment decisions and performance of the firms were tackled, in a number of sub-questionnaires. A set of questions was asked on the history of the firm, the background of the entrepreneur and manager, the acquisition and status of equipment and technology, the firm's human resource management, innovation activities, and institutional constraints to growth and investment. Survey data were collected through intensive interviews with owners and managers of firms.

The data set of Brazil contains information on 1642 manufacturing firms which represent a stratified random sample, stratified on the basis of size, sector and location. The firms are selected from nine sectors: food industries (CNAE[1] code 150), textiles (CNAE 170), clothing (CNAE 180), leather products (CNAE 190), chemical products (CNAE 240), machinery (CNAE 290), electronics (CNAE 320), auto-parts (CNAE 344), furniture (CNAE 361). The entire size spectrum of firms is represented. A majority of firms is from São Paulo and Minas Gerais, but in total 13 states are covered by the sample. These are Rio de Janeiro, Santa Catarina, Rio Grande do Sul, Paraná, Goiás, Mato Grosso, Ceará, Paraíba, Maranhão, Bahia, Amazonas. Within the selected sectors, the sample gives a fair representation of the total population with respect to the size and location dimension. More detailed information on the sample and sampling procedure can be found in World Bank (2005).

The survey collected data for the period 2000, 2001 and 2002. The data set thus provides historical data – on sales, raw materials, capital, labour - that allow estimating productivity in 2000 and 2002. Additionally, the sales value was also asked for the year 1997, which permits investigating sales growth over a longer period of time: 1997-2002.

[1] The CNAE (Classificação Nacional de Atividades Econômicas) is the Brasilian national classification which is closely linked to the CNAE (International Standard Industrial Classification) revision 3 and 3.1.

Due to missing values for some of the key variables, the number of firms used in our analysis is reduced to 1352, distributed over the different size classes and sectors as shown in table 1.

INSERT TABLE 1

4. Empirical methodology and variables

4.1. Total factor productivity index

To analyse firm productivity, total factor productivity (TFP) is calculated for the years 2000 and 2002 following the methodology developed by Caves et al. (1982) and used in Aw et al. (2003) which accounts for endogeneity of factor inputs. The methodology consists of constructing an index of productivity, whereby each firm's level of output and inputs are compared to those of a hypothetical firm, whose input and output values take the arithmetic mean values of log output, log input, and the respective input cost shares over all firms in the industry in a specific year. Hence, a non-parametrically calculated TFP index for each firm is obtained, which represents the relative productivity of the firm in its sector. The appendix provides more details on the calculation of the TFP index.
Total factor productivity growth (TFPG) for each firm, is further defined as (subscripts for firm i are omitted in the equation):

$$TFPG=\ln TFP_{02}-\ln TFP_{00} \qquad (1)$$

To analyse the impact of different innovation activities on the evolution of TFP over time at the firm level, a partial adjustment model is estimated of the following form:

$$\ln TFP_{02}= f(\ln TFP_{00}, X_k) \qquad (2)$$

TFP in 2002 is explained by TFP in 2000 which is expected to be significant as it is observed in the literature that the heterogeneity between firms is persistent over longer periods of time: highly productive firms with a greater stock of knowledge in one year tend to be highly productive in subsequent years as well. In equation (2), X_k is a vector of k innovation activities that represent the change in the firms' stock of knowledge that capture the active learning process of the firm leading to a change in productivity over time.

4.2. Firm growth

In line with the literature on firm growth, the basic empirical model for the growth equation is a general growth function g in size (S) and age (A):

$$g = \frac{S_{t'}}{S_t} = g(S_t, A\ ) \tag{3}$$

where $S_{t'}$ and S_t are the size of a firm in end period t' – here 2002- and in beginning of period t - 2000 - respectively and A is the age of the firm in 2003.

This functional relationship is augmented with more direct measures of productivity. To test explicitly whether higher levels of TFP translate into superior firm growth as proposed by passive learning models, the TFP level at the beginning of the period, 2000 is added as an explanatory variable, while active learning reflected by TFP growth over the same period 2000-2002 is also included (TFPG).

Approximating the growth function g through a second order logarithmic expansion of a generalised function relating growth to size and age and adding the productivity variables for active and passive learning, the estimating equation corresponds to the following form:

$$\frac{\log(S_{t'}) - \log(S_t)}{d} = a_0 + a_1 \log(S_t) + a_2 [\log(S_t)]^2 + a_3 \log(A) + a_4 [\log(A)]^2 + a_5 \log(S_t) * \log(A) + a_6 TFP_t + a_7 TFPG + \sum bZ \tag{4}$$

where d stands for the number of years over which growth is measured and a are coefficients. Z is a vector of control variables, accounting for sector and location differences and the impact of access to credit, while b represents the vector of corresponding coefficients.

Subsequently, a sales growth equation is estimated for a longer period of time, from 1997-2002. As the data for calculating TFP in 1997 and TFPG over the period 1997-2002 are not available, a reduced form is estimated in which a vector of innovation variables X is directly entered into the growth equation:

$$\frac{\log(S_{t'}) - \log(S_t)}{d} = a_0 + a_1 \log(S_t) + a_2\left[\log(S_t)\right]^2 + a_3 \log(A) + a_4\left[\log(A)\right]^2 + a_5 \log(S_t) * \log(A) + \sum bZ + \sum cX \qquad (5)$$

The dependent variable corresponds to an average annual sales growth rate. Also in this equation, sales growth is explained by beginning-of-period size, size in 1997 (S_t), and firm age in 2003 (A). Sectoral and locational control variables are also included in a vector Z of control variables. The relationship between firm growth and size and between firm growth and age can be analysed by calculating the respective partial derivatives[2] (as explained by Variyam and Kraybill, 1992).

4.3. Innovation Variables

A first set of variables relates to innovation variables that capture a *change* in the knowledge stock of the firm between 2000 and 2002 and capture learning. These variables include not only the R&D variable, which has received most attention in the literature, but also a larger set of variables that represent minor and incremental change, the use of ICT and organisational change found important in Latin America (Bogotà Manual, 2001). In estimating equation (2) these learning variables include training of permanent workers (TRAINING), whether firms entered into a new joint venture with another firm (NJV) or into a new licensing agreement (NLA), whether they cooperate with clients to acquire new technology (DCOOPCLIE), the use of a website in interaction with clients and suppliers (WEBSITE), and product and process innovation (PRODUCT, PROCESS). Also, firms that have started exporting in the period 2000-2002 (EXPORTNEW) may have been newly exposed to foreign markets, which often results in

[2] The partial derivatives g_s=(dlnG/dlnS) and g_a=(dlnG/dlnA) allow to test for alternative theories of firm growth. Gibrat's law implies that the partial derivative g_s equals zero. Alternatively, a negative relationship between firm size and growth implies that $g_s<0$.

a productivity surge due to a learning-by-exporting effects which are observed for several developing country firms (eg. Van Biesebroeck, 2005, for African firms; Fernandes and Isgut, 2005 for Colombian firms)

An alternative estimation is also done explaining the level of productivity in 2002 as a function of technology variables that reflect the *stock* of knowledge resulting from previous efforts. These include the skills level of the management (EDUCGM) and the labour force (LFHIGH), as measured by their level of education, whether the firms use technology licensed from a foreign owned company (LICENCE), and whether they hold a quality certificate, such as an ISO certificate (ISO). As technology within a multinational group is often sourced from the foreign parent company, the effect of being an affiliate of a foreign firm is also accounted for (MNE). Table 2 presents all the variables used in the analysis, it explains how they are defined and shows some summary statistics. Mean values are given, along with standard deviations for continuous only.

TABLE 2

5. Results

5.1. Innovation activities in Brazil

Table 3 gives a more detailed picture of the innovation activities of the Brazilian firms in the sample. More specifically the activities are presented for firms of different size and active in different sectors to demonstrate sector differences.

It can be seen that the proportion of firms that is undertaking innovation activities is strongly and positively related to firm size, measured in terms of employment. This is true for the *change* variables and as a result also the knowledge *stock* variables show to be size related. Strong sector differences are also observed, with generally more innovation activities in the sectors of machinery, electronic products and auto-parts and less in the more traditional sectors. The sector of chemical products invests most heavily in human capital, with the highest incidence in training and the highest levels of education of management and work force. This sector also has by far the highest capital intensity, which may explain the accordingly high human capital development efforts.

TABLE 3

5.2 Innovation and productivity

Table 4 shows the results of the productivity equation (2). The productivity level of the firm in 2002 is explained by the level of productivity in 2000 and a set of innovation variables related to the *change* in the knowledge stock (column 1) and related to both knowledge *change* and *stock* variables (column 2). As the TPF index is calculated at the sector level, no sectoral control variables are included. Instead location variables are included to account for institutional factors that may affect productivity of firms such as the regulatory environment, provision of business infrastructure and corruption that may differ across states.

TABLE 4

The partial adjustment models shows that the level of TFP in 2002 is largely determined by its level in 2000, confirming the persistence of productivity differences across firms. Firms that are highly productive in one period tend to be highly productive in the next period as well. The effect is highly significant. However, also the innovation variables turn out to be important productivity shifters. Interestingly, not R&D seems most important – the effect is positive but small and insignificant -, but engaging in new joint ventures and new license agreements in the period 2000-2002, as well as training are the more important learning mechanisms. Also using a more close interaction with the product market through the use of a website and cooperation with clients help firms to raise their productivity levels, relative to their competitors. These findings provide supportive evidence for the often heard statement that firms in Brazil and Latin America have realized productivity gains through organizational change. Only process innovation produces an unexpected result: the firms that have introduced process innovation in 2000-2002 have lower levels of TFP in 2002. One interpretation could be that firms that experienced they were about to be competed out of the market undertook process innovation in order to reduce costs and survive. There are indications that process innovation was indeed inspired by survival concerns in a fierce competitive setting.

Firms were indeed asked to indicate what their motives were to engage in product and process innovation. The motive to reduce costs was for 60% of the firms competitive pressure from domestic and foreign competitors. The motive to develop new products on the contrary was mainly pressure from clients (62%) and only for 34% the result of pressure from competitors.

Adding knowledge stock variables to the equation slightly reduces the coefficient of TFP00 and the other variables as well as their significance, probably due to the multicollinearity that may exist among the variables. All variables have the right sign, except for process innovation. The education of the manager and quality certification are related to higher levels of productivity

5.3. Determinants of firm growth

Table 5 presents the estimated coefficients and t-ratios for the growth equation over the period 2000-2002 (column 1) and the reduced model over the period 1997-2002 (column 2). It should be noted that only surviving firms are included in the data set, implying that the findings of the empirical analysis are restricted to survivors. This may induce a selection bias which raises the magnitude of the negative coefficient of the size and firm age variable as the variability in growth rates among small and young firms is high and contracting firms in small and young cohorts are more likely exit. Other studies (eg. McPherson, 1996) analyse the possible selection bias resulting from the exclusion of exiting firms on the growth relationship and find this bias to be insignificant. For our sample it is difficult to assess the magnitude of the impact of the selection bias, for data on exiting firms are not available, hence the size and age variables have to be interpreted with caution. However, since productivity levels and productivity growth are directly included in the equation, the selection bias is less a problem than when size and age variables are used to test active and passive learning processes.

Another problem in the estimation may relate to a possible endogeneity bias in the reduced model originating from the variables RD, TRAINING which are measured in

2002. To account for this, the endogenous variables were instrumented[3] and their predicted values were used in the growth equation.
Standard errors are estimated using White's consistent estimator (White, 1980).

TABLE 5

The relationship between initial size and growth is significantly negative, implying that smaller firms grow faster than larger ones. The results are consistent with studies conducted in other countries. The quadratic term of size is positive and significant at the 5% level implying that the negative effect of size on growth diminishes for larger size classes. The partial derivative of the growth rate to log size evaluated at the sample mean is negative and equal to -0.10.
The same relationship is also observed for firm age: young firms grow faster than older firms, but the effect smoothens as the firm grows older. The partial derivative of the growth rate to log firm age evaluated at the sample mean is negative and equal to -0.11. These results go against Gibrat's law of random growth, and are more supportive for the models of passive learning in which firms grow quickly into the size that corresponds to their efficiency level, in the first years after entry.

However, more direct evidence on the productivity-growth relationship is found from the estimated coefficients of TFP in 2000 and the growth of TFP over the period 2000-2002. Controlling for firm size and firm age, firms with higher levels of TFP in 2000 experience higher growth rates, all else equal. Firms that moreover increase their productivity level over the same period in an active learning process also grow faster. The further impact of productivity on firm growth is hereby clearly demonstrated.
Firms with access to flexible forms of credit via an overdraft facility with a bank also grow faster, an indication that liquidity constraints may hamper firms' expansion, as observed in other studies. Some sector and location differences in firm growth are found.

In the estimating equation of firm growth over a longer period – 1997-2002 – a larger proportion of the variance is explained, as measurement errors and temporary shocks in

[3] The instruments used were: for TRAINING the degree of unionisation of the labour force and whether the firm is member of a business association; for RD: profitability in previous year, 2001 and whether the firm's major competitor is an imported product;

the size of the firm are normally more levelled out. The sample is also smaller as the youngest firms established after 1997 drop out of the estimation. As a result, the firm age effect becomes much less apparent.

The size effect remains negative and significant, with the positive quadratic term indicating that small firms grow fast but their growth rate flattens out as they grow larger. This may suggest the existence of a minimum efficient scale that firms have to reach.

The innovation variables all come out strongly in this reduced model and with the reduced sample. They have the expected sign, except again for process innovation which remains a bit surprising. Being member of a multinational group raises the expected sales growth with 0.11. Having an ISO certificate and a website also opens up sales growth perspectives, raising expected sales growth by 0.10 and 0.05 respectively. Learning from exposure to foreign markets and foreign technologies is also observed, as firms that were exporters in 1997 (EXPORTBEFORE) seem to experience higher growth rates, as did firms with a licence from a foreign owned company (LICENCE). Human capital development (GMHIGH, TRAINING) also translates in superior sales performance. R&D, while not directly affecting TFPG over the two-year period, does seem to be important when looking at the growth path of the firm over a longer period of time.

A few checks were done to test the robustness of the results. First, to get further insight in the age-growth effect, the estimation was done including in the sample firms that were created in the period 1997-2002, with annual growth measured accordingly over a smaller period of time. With these very young firms included, the negative effect of age on growth reappears, showing that it is indeed in the very first five years of existence that growth rates are high in the sample of survivors. Alternatively, the estimation was done with the reduced sample of 1061 firms of over 5 years of age, while leaving out the quadratic and interaction terms of size and age, including only LSALES97 and LFIRMAGE. The coefficient of LFIRMAGE was then even positive, indicating a U-shaped age-growth relationship.

With respect to the innovation variables, the estimation was repeated entering RD and TRAINING directly in the equation, without instrumenting the variables. This resulted in smaller coefficients for RD (0.04) and TRAINING (0.08) but they remained highly significant. When doing alternatively a two stage least squares estimation, the coefficient of R&D was positive (0.64) and significant, for TRAINING it was also positive (.10) but not statistically significant. The impact of the alternative estimation techniques on the other innovation variables was rather limited, which allows saying that the results are quite stable and robust.

Strong sector effects are observed: firms in the food sector, textiles and chemical products have been able to expand sales most, while firms in machinery and electronics equipment have been less successful. As the more successful sectors are the traditional sectors in which Brazil has a competitive advantage, the estimation is done splitting the sample in the more innovation intensive sectors – chemical products, machinery and electronic equipment, and auto-parts and furniture– and the less innovation intensive sectors: food, textiles, clothing and leather products. This distinction is mainly based on the basis of the findings of table 3. It is done to see whether even in less innovation intensive sector innovation activities at the firm level explain a part of the variation in sales growth, and to see whether in the different subsamples different innovation activities play a role. The results are in column 3 and 4. The most interesting result is that even in the so-called traditional sectors, innovation and learning in firms is important to explain differences in firm growth. This corresponds to the findings that even in traditional sectors the knowledge intensity of production has increased over the last decades (eg. Mytelka, 2000). The magnitude of the effect differs though: while in the traditional sectors the exporting status has been very influential on firm growth, this is not the case for the innovation intensive sectors. Also training and a better skilled labour force have been conducive to sales expansion in the traditional sectors. Apparently, Brazilian firms have been competitive in world food and apparel markets, with a better skilled labour force than their competitors in those markets. In the more innovation intensive sectors, firm growth has been lower, but firms that conduced R&D did better than those who omitted to do so and this effect is larger than in traditional sectors.

6. Conclusion

This paper has presented new evidence on the driving factors behind firm growth in Brazil. In line with the empirical evidence found for OECD countries and the theoretical models on firm growth, superior productivity levels and productivity growth are key drivers of firm size adjustments. Firms with higher initial productivity levels grow faster, as do firms that succeed in raising their productivity levels over time. Young surviving firms grow faster but this seems only in the first five years of activity in which they uncover their productivity level. After that, the relationship ceases to be negative. The same holds for firm size, which can be understood in the context of sunk costs at entry or the existence of a minimum efficient scale.

Interestingly, the activities that Brazilian firms undertake to reach higher TFP are also documented. While R&D is indeed found important, especially for firm performance in the longer run, other variables reflecting organizational change, cooperation with clients, human capital development, ICT usage, product innovation and learning by exporting are especially important. Though the intensity with which firms engage in these innovation activities is sector dependent, the innovation activities are in all sectors important variables for explaining sales growth differences, also in the more traditional sectors in which Brazilian firms have a competitive advantage.

Table 1: composition of the sample

	Small *10-29 workers*	*Medium* *30-99 workers*	*Large* *100+*	*All firms*
Food	19	22	62	103
Textiles	27	27	34	88
Clothing	134	158	66	358
Leather	40	57	39	136
Chemicals	18	35	18	71
Machinery	52	50	54	156
Electronics	19	28	11	58
Auto-parts	22	42	51	115
Furniture	102	103	62	267
Total	433	522	397	1352

Table 2: Construction and definition of the variables.

DEPENDENT VARIABLE	DEFINITION	MEAN (STD)
TFP02	Total factor productivity of the firm in 2002, as calculated from the index specified in equation (2)	-1.08 (1.26)
SGR2	Average annual sales growth over the period 2000-2002, calculated by (ln(sales2002) – ln(sales2000))/2	0.05 (0.25)
SGR9702	Average annual sales growth over the period 1997-2002, calculated by (ln(sales2002) – ln(sales1997))/5	0.11 (0.31)
EXPLANATORY VARIABLES		
TFP00	Total factor productivity of the firm in 2000, as calculated from the index specified in equation (1)	-1.16 (1.30)
TFPG	Total factor productivity growth, being TFP02-TFP00	0.07 (0.64)
LFIRMAGE	Age of the firm, in log	2.74 (0.78)
SLAGE	squared LFIRMAGE	8.12 (4.32)
LSALES00	Sales of the firm, in 2000, in log	14.68 (1.94)
LSALES97	Sales of the firm, in 1997, in log	14.33 (2.24)
SLSALES00	Squared LSALES00	219.40 (59.22)
SLSALES97	Squared LSALES97	210.50 (65.72)
SALES00AGE	=LSALES00*LFIRMAGE	40.90 (14.93)
SALES97AGE	=LSALES97*LFIRMAGE	42.43 (13.96)
INNOVATION VARIABLES		
MNE	Dummy =1 if the firm's principal shareholder is a foreign company	0.04
NJV	Dummy =1 if the firm entered into a new joint venture in 2000-02	0.05
NLA	Dummy =1 if the firm entered into a new licensing agreement in 2000-02	0.08
ISO	Dummy =1 if the firm has ISO certification	0.19
RD	Dummy =1 if the firm invests in R&D or design	0.49
PRODUCT	Dummy =1 if the firm developed a major new product line or upgraded an existing product line in the last three years (2000-02).	0.68
PROCESS	Dummy =1 if the firm introduced new technology that has substantially changed the way the main product is produced, in 2000-02.	0.69
LICENCE	Dummy =1 if the firm uses technology licensed from a foreign-owned company	0.08
WEBSITE	Dummy =1 if the firm uses a website to interact with clients and suppliers	0.74
EDUCGM	Dummy =1 if the firm has a general manager with a graduate or postgraduate degree or diploma of tertiary college	0.51
TRAINING	Dummy =1 if the firm offers formal training to their employees	0.67

LFHIGH	Proportion of the labour force with higher education [0,1]	0.08 (0.10)
EXPORTBEFORE	Dummy =1 if the firm started exporting before 1997	
EXPORTNEW	Dummy =1 if the firm started exporting in the period 2000-02	0.10
DCOOPCLIE	Dummy =1 if the firm finds cooperation with clients a major way of acquiring technology	0.23
CONTROL VARIABLES		
Sector dummies		
CNAE150	Food industries	
CNAE170	Textiles	0.07
CNAE180	Clothing	0.26
CNAE190	Leather	0.10
CNAE240	Chemical products	0.05
CNAE290	Machinery	0.12
CNAE320	Electronic equipment	0.04
CNAE344	Auto-parts	0.09
CNAE361	Furniture	0.20
Location dummies:		
SP	Sao Paulo	
RJ	Rio de Janeiro	
MG	Minas Gerais	0.14
SC	Santa Catarina	0.10
RS	Rio Grande do Sul	0.12
PR	Paraná	0.11
GO	Goiás	0.05
MT	Mato Grosso	0.02
CE	Ceará	0.06
PB	Paraíba	0.03
MA	Maranhao	0.01
BA	Bahia	0.05
AM	Amazonas	0.01

Note: the mean values are calculated for the sample containing 1352 firms, except for the variable SGR9702, LSALES97, SLSALES97, SALES97AGE which are based on the reduced sample of 1080 firms.

Table 3 A: Learning activities : proportions of firms

	RD	*TRAINING*	*PRODUCT*	*PROCESS*	*NJV*	*NLA*	*WEBSITE*
Small firms (1-29 employees)	0.37	0.47	0.62	0.64	0.01	0.03	0.55
Medium sized firms (30-99)	0.51	0.68	0.70	0.71	0.04	0.07	0.78
Large firms (100+ employees)	0.60	0.87	0.73	0.72	0.09	0.14	0.89
Food industries	0.42	0.75	0.61	0.68	0.06	0.06	0.70
Textiles	0.43	0.67	0.64	0.55	0.08	0.03	0.77
Clothing	0.46	0.61	0.65	0.72	0.01	0.07	0.65
Leather	0.51	0.65	0.54	0.72	0.02	0.07	0.69
Chemical products	0.42	0.83	0.66	0.45	0.07	0.11	0.86
Machinery	0.61	0.67	0.77	0.77	0.07	0.13	0.86
Electronic equipment	0.60	0.83	0.81	0.67	0.14	0.09	0.86
Auto-parts	0.49	0.86	0.77	0.67	0.12	0.13	0.90
Furniture	0.51	0.57	0.73	0.72	0.02	0.04	0.70

Table 3 B: Knowledge stock variables : proportions of firms

	LICENCE	*GMHIGH*	*LFHIGH*	*ISO*
Small firms (1-29 employees)	0.03	0.36	0.08	0.06
Medium sized firms (30-99)	0.05	0.50	0.08	0.16
Large firms (100+ employees)	0.17	0.69	0.09	0.36
Food industries	0.03	0.60	0.08	0.22
Textiles	0.04	0.67	0.09	0.14
Clothing	0.05	0.40	0.06	0.06
Leather	0.06	0.39	0.05	0.07
Chemical products	0.11	0.79	0.20	0.30
Machinery	0.19	0.60	0.18	0.28
Electronic equipment	0.16	0.69	0.17	0.41
Auto-parts	0.18	0.63	0.10	0.67
Furniture	0.03	0.43	0.07	0.09

Table 4: Productivity and innovation activities: partial adjustment model

	Knowledge change variables	*Knowledge stock and change variables*
Dependent variable:	TFP02	TFP02
TFP00	0.812***	0.796***
	(60.56)	(0.021)
RD	0.035	0.028
	(0.035)	(0.035)
DCOOPCLIE	0.067*	0.075**
	(0.039)	(0.037)
TRAINING	0.135***	0.089**
	(0.037)	(0.038)
WEBSITE	0.110***	0.088**
	(0.041)	(0.038)
EXPORTNEW	0.059	0.041
	(0.056)	(0.064)
NJV	0.218***	0.140*
	(0.080)	(0.084)
NLA	0.116*	
	(0.063)	
LICENCE		0.068
		(0.071)
ISO		0.147***
		(0.046)
GMHIGH		0.091***
		(0.035)
LFHIGH		0.141
		(0.171)
MNE		0.153
		(0.124)
PRODUCT	0.030	0.016
	(0.037)	(0.036)
PROCESS	-0.102***	-0.079**
	(0.036)	(0.037)
constant	-0.286***	-0.364***
	(0.056)	(0.061)
N	1352	1352
Adj. R^2	0.775	0.783

Note: standard errors in parentheses; the estimations included 12 location dummy variables. Significance levels: *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table 5: Sales growth equations

	Sales growth 2000-02	*Sales growth 1997-2002*	*Sales growth 97-02 CNAE 150, 160, 170, 180 (traditional sectors)*	*Sales growth 97-02 CNAE 240, 290, 320, 344, 361 (innovation intens. sectors)*
Dependent variable:	SGR2	SGR9702	SGR9702	SGR9702
LFIRMAGE	-0.247***	0.133*	0.042**	0.034**
	(0.076)	(0.077)	(0.017)	(0.015)
SLAGE	0.021**	0.012	-	-
	(0.011)	(0.013)		
LSALES00	-0.174***	-	-	-
	(0.063)			
SLSALES00	0.004**	-	-	-
	(0.002)			
SALES00AGE	0.005	-	-	-
	(0.006)			
LSALES97	-	-0.253***	-0.138***	-0.147***
		(0.041)	(0.009)	(0.008)
SLSALES97	-	0.004***	-	-
		(0.002)		
SALES97AGE	-	-0.014*	-	-
		(0.006)		
TFP00	0.053***	-	-	-
	(0.010)			
TFPG	0.202***	-	-	-
	(0.020)			
MNE	-	0.115***	0.104	0.123**
		(0.039)	(0.167)	(0.047)
EXPORTBEFORE	-	0.051***	0.109***	0.010
		(0.019)	(0.033)	(0.025)
ISO	-	0.102***	0.109***	0.126***
		(0.019)	(0.036)	(0.026)
WEBSITE	-	0.054***	0.042**	0.084***
		(0.013)	(0.020)	(0.021)
LICENCE	-	0.010	0.002	0.022
		(0.028)	(0.040)	(0.039)
GMHIGH	-	0.023**	0.031	0.031
		(0.012)	(0.019)	(0.019)
LFHIGH	-	0.078	0.259*	0.125
		(0.078)	(0.147)	(0.089)
RD	-	1.165***	0.249**	0.614***
		(0.097)	(0.108)	(0.096)
TRAINING	-	0.348***	0.772***	0.593***
		(0.058)	(0.092)	(0.069)
PRODUCT	-	0.001	-0.003	-0.000
		(0.012)	(0.020)	(0.019)
PROCESS	-	-0.008	-0.007	-0.042**
		(0.012)	(0.020)	(0.020)
OVERDRAFT	0.063***	-	-	-
	(0.016)			
CNAE150	0.029	0.340***	-	-

	(0.025)	(0.035)		
CNAE170	-0.019	0.254***	-	-
	(0.026)	(0.027)		
CNAE180	0.036*	0.012	-	-
	(0.019)	(0.015)		
CNAE190	0.011	0.025	-	-
	(0.022)	(0.019)		
CNAE240	0.080***	0.283***	-	-
	(0.029)	(0.040)		
CNAE290	0.029	-0.058***	-	-
	(0.022)	(0.019)		
CNAE320	-0.018	-0.185***	-	-
	(0.048)	(0.035)		
CNAE344	0.041*	0.027	-	-
	(0.023)	(0.028)		
Rio de Janeiro	-0.015	-0.060***	-0.079**	-0.040
	(0.028)	(0.021)	(0.036)	(0.036)
Minas Gerais	0.039*	-0.053***	-0.072**	-0.001
	(0.020)	(0.018)	(0.033)	(0.027)
Santa Catarina	0.078***	0.016	-0.045	0.070**
	(0.022)	(0.021)	(0.031)	(0.032)
Rio Grande do Sul	0.043**	0.007	-0.053*	0.054*
	(0.019)	(0.018)	(0.028)	(0.029)
Paraná	0.080***	-0.019	-0.078**	0.045
	(0.023)	(0.020)	(0.037)	(0.030)
Goiás	0.091***	-0.024	-0.064	0.099
	(0.033)	(0.035)	(0.053)	(0.067)
Mato Grosso	0.032	0.037	0.069	0.049
	(0.035)	(0.043)	(0.067)	(0.076)
Ceará	0.030	-0.079***	-0.048	-0.026
	(0.025)	(0.025)	(0.033)	(0.062)
Paraíba	0.018	-0.075**	-0.137***	0.064
	(0.035)	(0.029)	(0.045)	(0.072)
Maranhao	0.062	-0.044	-0.033	0.040
	(0.056)	(0.039)	(0.102)	(0.048)
Bahia	0.011	-0.029	-0.152***	0.183***
	(0.027)	(0.033)	(0.041)	(0.054)
Amazonas	0.087*	0.075	-0.115	0.093
	(0.048)	(0.067)	(0.071)	(0.072)
CONSTANT	1.894***	1.886***	1.297***	1.252***
	(0.508)	(0.283)	(0.089)	(0.085)
N	1352	1061	529	530
Adj. R^2	0.3257	0.702	0.586	0.648

Note: robust standard errors in parentheses; Significance levels: *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

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APPENDIX

Calculation of TFP

To analyse firm productivity, total factor productivity levels are calculated for the years 2000 and 2002 following the methodology developed by Caves et al. (1982) and used in Aw et al. (2003) and which accounts for endogeneity of factor inputs. The methodology consists of constructing an index of productivity, whereby each firm's level of output and inputs are compared to those of a hypothetical firm, the reference point, whose input and output values take the arithmetic mean values of log output, log input, and the respective input cost shares over all firms in the industry in a specific year. Hence, a non-parametrically calculated TFP index is obtained for each firm, which represents the relative productivity of the firm in its sector. Additionally the reference points are linked over time.

The index for firm i in year t is defined by:

$$\ln TFP_{i,t} = (\ln Y_{i,t} - \overline{\ln Y_t}) + \sum_{s=2}^{t} (\overline{\ln Y_s} - \overline{\ln Y_{s-1}}) -$$
$$\left[\sum_j \frac{1}{2}\left(\alpha_{i,t,j} + \overline{\alpha_{t,j}}\right)\left(\ln X_{i,t,j} - \overline{\ln X_{tj}}\right) + \sum_{s=2}^{t} \sum_j \frac{1}{2}\left(\overline{\alpha_{s,j}} + \overline{\alpha_{s-1,j}}\right)\left(\overline{\ln X_{s,j}} - \overline{\ln X_{s-1,j}}\right) \right]$$

where LnY and lnX are the log of output and the log of input j of firm i in year t, α is the cost share of input factor j for firm i, .

$\overline{\ln Y_t}$ $\overline{\ln X_{tj}}$ $\overline{\alpha_{t,j}}$ are the mean values of output, input and respective cost shares for the industry in which firm i is active and are thus the values for the reference point or hypothetical firm.

In the analysis, the first year of measurement refers to the year 2000, hence the formula for the TFP index of firm i reduces to :

$$\ln TFP_{i,00} = (\ln Y_{i,00} - \overline{\ln Y_{00}}) - \left[\sum_j \frac{1}{2}\left(\alpha_{i,00,j} + \overline{\alpha_{00,j}}\right)\left(\ln X_{i,00,j} - \overline{\ln X_{00j}}\right) \right] \qquad (1)$$

with j=[1,2] for the two inputs considered in the analysis, capital and labour.

The index for 2002 becomes :

$$\ln TFP_{i,02} = (\ln Y_{i,02} - \overline{\ln Y_{02}}) + \left(\overline{\ln Y_{02}} - \overline{\ln Y_{00}}\right) - \left[\sum_j \frac{1}{2}\left(\alpha_{i,02,j} + \overline{\alpha_{02,j}}\right)\left(\ln X_{i,02,j} - \overline{\ln X_{02j}}\right) + \sum_j \frac{1}{2}\left(\overline{\alpha_{02,j}} + \overline{\alpha_{00,j}}\right)\left(\overline{\ln X_{02,j}} - \overline{\ln X_{00,j}}\right)\right] \quad (2)$$

To estimate TFP, as proposed by equation (1) and (2) for the respective years 2000 and 2002, output Y is measured by value added which equals the value of production minus direct inputs (raw materials) and energy costs.

Labour is the first factor of production and is measured as total number of employees, full time equivalent.

Capital is measured as net book value of machinery, equipment, land buildings and vehicles in the respective years.

Input factor shares are: for labour, the wage bill of the firm over the sum of labour cost and financial costs (interest fees);

and for capital, it is financial costs over the total of labour cost and financial costs. As explained earlier, the index is constructed by comparing the firms to the industry reference point.

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