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# Innovation Strategies, Process and Product Innovations and Growth: Firm-Level Evidence from Brazil

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Abstract

Using World Bank ICS data from Brazilian manufacturing firms, this paper identifies innovation strategies of firms - in particular internal technology creation (make) and external technology acquisition (buy)- and their effect on successful process and product innovations. It also explores the importance of innovations for firm growth. Successful process and product innovations occur mostly through technology acquisition, mostly embodied in machinery and equipment, either alone or in combination with internal technology development. The option of only relying on internal development is less performing. The results indicate that innovative performance is an important driver for firm growth. It is particularly the combination of product and process innovations that significantly improves firm growth. Both innovation and growth performance are supported by access to finance. Skills of workforce and management matter, but not necessarily tertiary education levels. The impact of international linkages on innovative and growth performance is mixed.

## *1. Introduction*

Technological progress is at the heart of development. But the innovation process that underlies technological progress in developing countries has very different characteristics from that in developed countries. Given the technology gap developing countries are facing, the bulk of technological progress in these countries largely occurs through the absorption and adaptation of pre-existing technologies, rather than the invention of entirely new technologies. These technologies are often sourced from abroad.

What matters most for technological development is the speed with which technology diffuses within a country. Empirical evidence shows an important divergence across developing countries in the speed of diffusion within countries and their role for growth (World Bank, 2008). Many developing countries have a business environment that constrains firm's absorption of new technologies and performance. Among the macro-factors identified as potential barriers for growth and the adoption of new technologies are heavy regulatory burden, the quality of institutions, severe financial constraints and macro-economic uncertainty (Bastos and Nasir, 2004, Dollar et al., 2003, Eifert et al., 2005). In addition, technology diffusion depends on the extent to which firms are exposed to and able to efficiently absorb foreign and new vintage technologies – through trade, FDI and migration of human capital.

Firms are the basic mechanism by which technology spreads within an economy. However, what is still lacking in the literature is robust firm level evidence on what effectively drives, or hinders, firms in developing countries to adopt new technologies and effectively absorb them into a better firm performance.

To shed more light on the link between adoption of new technologies, innovation, productivity and firm growth in the context of a catching up economy, this paper analyses micro-evidence from a sample of manufacturing firms from Brazil. In recent years, Brazil has been able to play an increasingly important role in international trade, production and (R&D) investment. While this pattern of emerging success has given rise to a significant amount of research documenting the performance of the economy at the aggregate or sector level, the micro-evidence on the factors that underlie firm success is less abundant.

This paper, using data from the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003, tries to contribute to the literature on technological progress and development in several ways. Taking a micro-econometric perspective, it investigates in more detail what drives or impedes firms to introduce new products and processes and how important innovative performance is for firm growth. Our focus on Brazil allows analysing the case of a mid-income country in fast development, where the interplay between diffusion (buy) and creation (make) of new technologies, is centrepiece for sustaining growth. Also on the role of foreign technologies, trade and FDI, Brazil is an interesting case. Although it has recently opened up to the global economy, it still carries the reminders of a closed economy set-up, relying on its own large internal market, protecting "local champions" in strategic sectors, and with a strongly supported public sector R&D in specific technology and geographic areas.

Before we present our results in section 5, we first review several strands of the literature (section 2), discuss the specifics of Brazil (section 3) and introduce our data (section 4).

## *2. Literature review*

Several strands of the literature are relevant for understanding the link between innovation and firm growth in developing countries: the macro-economic literature on innovation and growth, the literature on FDI, technology spillovers and growth, and the literature explaining firm growth.

It is now widely recognized in the **macro-economic** literature that **R&D and innovation** are a major driver of economic **growth**. Since the classic "Solow residual" paper (Solow, 1956), it has been recognised that rates of factor accumulation do not account for the major part of economic growth. The endogenous growth literature (see Romer, 1994; Grossman and Helpman, 1991; Aghion and Howitt 1998) identifies commercially oriented innovation efforts as a major engine of this technological progress and productivity growth. The rate of growth of a country is determined by its initial level of development, the creation of new knowledge within the country and the absorption and exploitation of knowledge, independently of where it is created. Particularly knowledge spillovers have been identified as important drivers in endogenous growth models (a.o. Grossman and Helpman, 1991). These knowledge spillovers need not be confined to domestic borders, with international transfer of technology, through trade (exports and imports) or FDI, an important source for growth especially for catch-up countries.

Within this macro-perspective, a first factor explaining cross-country differences in their innovation-growth nexus is the level of development. Technological diffusion is slow at very low levels of development, in part because of difficulties in affording new technologies, in part because low levels of human capital severely constrain technological progress. At some level of development, however, the pace of technological diffusion becomes less obvious, with a high cross-country variance in technology adoption, even across countries at similar development level. One explanation for this heterogeneity in diffusion rates at higher income levels is the divergence in the countries' ability to effectively absorb new technologies (Lall 1992). Accessed knowledge needs to be combined with a sufficiently developed "absorptive capacity" (Cohen and Levinthal, 1989) or "social capability" (Abramovitz, 1986) in order to deliver growth. This absorptive capabilities depend on many factors, including the extent to which a country has a technologically literate workforce and a highly skilled elite; promotes an investment climate that encourages investment and permits the creation and expansion of firms using higher-technology processes; permits access to capital; and has adequate public sector institutions to promote the diffusion of critical technologies where private demand or market forces are inadequate (Worldbank, 2008).

A second set of factors explaining the divergence in countries' performance is a divergence in own indigenous innovative capacity, which becomes increasingly important as a country progresses closer to the technology frontier (Hoekman, Maskus and Saggi, 2005). First, own R&D complements the adoption of existing technology because it is a component of absorptive capacity. Foreign technologies frequently need to be modified so that they are suitable for domestic circumstances. Countries tend to acquire technology more readily when domestic firms have R&D programs and when public research laboratories and universities have relatively close ties to industry. But, at higher levels of development, own R&D increasingly may also start to substitute adoption of existing technologies, allowing generation of new technologies, particularly in these areas where the country has developed comparative strengths.

Empirical macro-analysis confirms the importance of innovation for catch-up (Nelson, 1993; Kim, 1997). Fagerberg et al. (2007) and Fagerberg and Srholec (2008) for a large cross-section of countries find significant effects of technological capacity (both creation and absorption) to be significantly related to growth. But although a well functioning innovation system seems critical for development, they also confirm the importance of governance and the quality of institutions.

Another result from these macro-empirical studies is no or little support for openness to trade and foreign direct investment to matter for innovation and growth (Fagerberg and Srholec, 2008). Although many endogenous growth models have emphasized technology spillovers from the North to the South as a vehicle for productivity growth of the South (e.g. Grossman and Helpman, 1991), the empirical evidence zeroing in on the effects of **international technology transfer** is less clearcut (Hoekman and Smarzynska Javorcik, 2006). Although earlier studies based on industry level cross-sectional data found statistically significant horizontal spillover effects in developing countries (Blömstrom and Persson, 1983; Blömstrom, 1986; Kokko, 1994), more recent studies using panel data sets, correcting for firm or sector specific fixed effects,) find no positive within-industry spillover effects for developing countries (e.g. Görg and Greenaway, 2003).

One explanation for the difficulty to find evidence of positive spillovers from openness is the confounding impact of competitive effects from open markets (Markusen and Venables, 1999). In addition, the potential benefits from FDI may not materialize, as multinational firms may protect their core know-how from dissipating to local rivals (Veugelers and Cassiman, 2004). An additional critical factor to exploit spillovers is the technological capability of indigeneous firms (Blomström and Kokko, 1998). Most of the empirical studies on developing countries have failed to find robust evidence of positive knowledge spillovers from multinational investment, accounted for by the lack of absorptive capacity in these host countries (*e.g*. Aitken and Harrison, 1999, Dunning and Narula, 2000).

Overall, the macro and trade literature paints a complex relationship between indigenous efforts of technology development (technology make) and the acquisition and absorption of externally developed (foreign) technologies (technology buy) along the development path of a country. R&D and innovation seem important for development, but are no panacea for success. Depending on the initial country conditions, flanking conditions such as education, finance, quality of institutions, governance and openness, need to be factored in.

Our analysis takes the relationship between technology make and buy and performance, together with its flanking conditions to the level of individual firms. More particularly, we want to examine, within the settings of a particular developing country, what effectively drives or impedes individual firms' innovative performance and their growth.

The literature explaining **firm growth** has shown that growth is largely a stochastic process where many unidentified and unobservable (firm-specific) factors are responsible for the growth performance of firms. However, since the seminal work of Jovanovic (1982) the theoretical literature developed the idea that firm growth is also a learning process, by which firms discover their true efficiency levels and adjust their size accordingly. This learning process is most apparent shortly after entry, explaining why small and young firms growth faster, once they discover in confrontation with the market that they can stand up to competition.

Pakes and Ericson (1998), building further on Jovanovic (1982), developed an 'active' learning model, in which the efficiency level can be actively raised by firm-specific investments in innovation activities and R&D, thereby opening up the growth perspectives of firms. In this respect, several authors, following the evolutionary theory of economic change (Nelson and Winter, 1982), have pointed at the importance of 'technological capabilities' of firms in developing countries as the knowledge and skills - technical, managerial and institutional – necessary for firms to utilize equipment and technology efficiently (e.g. Enos, 1992, Lall, 1992, see also UNCTAD, 1996, for an overview). Firms build up these technological capabilities in a process of technological learning, by engaging in a wide variety of activities, such as research, training, technology licensing, investment in new vintage machinery and ICT, aimed at introducing products and production processes that are new to the firm and reinforce the firm's competitive position.

The more broader literature on firm growth in developing countries has paid particular attention to institutional barriers hampering firm development, such as poorly functioning financial markets and regulatory and institutional barriers, e.g. Sleuwaegen and Goedhuys (2002), finding financial and institutional constraints to growth in Côte d'Ivoire, and Fisman and Svensson (2007) finding corruption and taxation to hamper firm growth in Uganda.

Empirical evidence on the innovation-growth relationship for firms in developing countries is relatively scarce, related to difficulties to measure innovation and data scarcity.

## *3. The case of Brazil*

As our analysis uses firm level evidence from Brazil, this section characterizes the country specific setting of the data, particularly with respect to its innovation position, its development process and the flanking macro-conditions.

With the largest population in Latin America and the Caribbean, Brazil has reached in the past few years important economic, social and environmental advances, including macroeconomic stability and significant reductions in poverty (OECD, 2006). The country has expanded beyond agricultural commodities and low value-added manufacturing, to become a global competitor within the aerospace industry's regional transport jets subsector. Through joint ventures with multinational corporations (MNCs), the country also has developed information and communications technology (ICT) and software industries that serve domestic and regional markets. However, in other high-tech, high-growth sectors, Brazil is falling behind global competitors, particularly in Asia.

Despite some advances in microeconomic and institutional reforms, and star performance by selected companies in selected areas, activity by the private sector in general remains stifled by various barriers and regulations that prevent the country from achieving its full growth potential. Identified bottlenecks for growth include inadequate infrastructure, poor business climate, high tax rates, high cost of credit and rigid labour markets. The size of the government and its distorting impacts are also an obstacle, and the quality of governmental services in relation to expenditures remains relatively low compared to other countries (OECD, 2006).

With its history of import substitution, Brazil remains a relatively closed economy with little international competition in many of its sectors (OECD, 2006). Average import tariffs are high in comparison with the OECD area, reducing access by the business sector to imported inputs embodying modern technologies. While the country has lowered barriers that were left over from its previous import substitution policies, it has moved to protect and foster those technology sectors that thrived under the barriers. This has included regulations on joint ventures with multinational corporations and technology licensing agreements – meant to support innovative capacity building within Brazil. Although Brazil, unlike other developing countries, does not seem to be particularly attractive from a labour cost/quality standpoint, FDI has continued to flow into the country, attracted by the large (potential) market. But this growth in FDI is mostly concentrated in the service sector, with less emphasis on technology-related motives for FDI in technology intensive sectors[1], which can be related to technology transfer restrictions and limited IPR enforcement. [2]

Brazil has made great strides in developing its innovation system (de Brito Cruz and de Mello, 2006). Brazil is Latin America's largest and most innovative economy, with about 1 percent of its GDP going to R&D in 2000-03 (Lugones, Suarez, 2007, p.156). However, most of Brazil's R&D is coming from the public sector, with the private sector scoring low[3] and advancing on a specialisation path that requires little investment in R&D. The comparatively low number of patents awarded to Brazil is a reflection of the low commercialisation of innovation. Domestic patents are predominately granted to state-owned or semi-public enterprises [4] rather than the private sector. MNCs are granted very few due to the costs and delays of the IPR structure. Only in a handful of industries, e.g. aerospace and deep-sea drilling, Brazil's innovative capabilities are able to compete with industrialised countries. While there is a growing number of technology-intensive, highly-productive small and medium businesses, many still do not invest heavily in innovation (de Brito Cruz and de Mello, 2006).

A first barrier to effective R&D performance in Brazil is the lack of skills. The percentage of students graduating from high school is still very low (de Brito Cruz and de Mello, 2006). In addition, there are only a limited number of science and technology programmes in tertiary education resulting in a shortage of highly skilled workers and researchers, especially in the fields of natural and exact sciences and engineering, needed for technological development of technology intensive industries (Lugones, Suarez, 2007). Most universities have typically been teaching institutions with few links to Brazilian businesses. Reforming universities to be more connected with the industrial sector has been on the agenda of the Brazilian government

[1] In the UNCTAD, WIR 2005 report, Brazil was ranked by responding firms as only 19th prospective location for R&D 2005-2009, China first, India 3th, and Russia 6th

[2] These tech transfer restrictions include licensing agreements with the government, which have helped protect specific industries such as aerospace, but have been harmful to most sectors. For international corporations, foreign patents require importers to pay a licensing fee if there is no local production involved with the product. While this has severely limited foreign patent holders, the main motivation has been to increase foreign direct investment and technology transfer opportunities by encouraging importers to invest in local production facilities.

[3] 80 percent of Brazilian researchers carry out their activities within public institutions (universities or research centres).

[4] Eg Petrobras is the company that files the most patents in Brazil and the Brazilian company with the most patents filed in the United States)

for some time, with various programmes aimed at strengthening ties being implemented with limited success (Katz, 2000). Most of the recent expansion in the number of higher education degrees awarded is accounted for by private institutions, where quality concerns are present.

A second barrier is access to finance. Despite macroeconomic stabilisation since the mid nineties, the cost of capital still remains high in Brazil. Another factor limiting the innovation potential is ICT usage. The Brazilian telecommunications equipment industry was initially a protected "infant industry" in Brazil. Trade barriers were erected to allow the industry room to grow. Government-sponsored R&D efforts in communications hardware and software helped to create a viable indigenous sector that was capable of serving the local market. Nevertheless, the use of ICT technologies is less widespread in Brazil than in countries with comparable development (Szapiro, 2003).

Another relevant obstacle is the widespread confusion and lack of information among many companies regarding government-sponsored innovation initiatives. To increase the involvement of the private sector, the government has instituted several financial incentives (de Brito Cruz and de Mello, 2006). Many are targeted at specific industries, such as aerospace and IT. During the economic recessions and crises of the 1990s, funding for science and technology programmes was severely cut (Cassiolato et al., 2003). The funding for innovation that was available to firms was directed to purchase capital equipment rather than for R&D. To address the issue of small firm innovation in the late 1990s, the federal government created a number of new programmes and initiatives targeting the small and medium enterprise (SME) sector, to stimulate their use of new technologies (Lemos, 2000). Several governmental organisations are involved; however there is no single coordinating agency.

Overall, the recent fast development of Brazil provides an interesting case to examine the interplay between diffusion (buy) and creation (make) of new technologies, as centrepiece for sustaining growth, with many of the flanking conditions for an innovation-growth nexus in development. Also on the role of foreign technologies, trade and FDI, Brazil is an interesting case. Although it has recently opened up to the global economy, it still carries the reminders of a protectionist focus in strategic sectors, with a strongly supported public sector R&D in specific technology and geographic areas.

## *4. Data and methodology*

### 4.1. Data

To analyse the link between technology creation and adoption, innovation and firm growth, we use the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003. The survey collected data for the period 2000, 2001 and 2002[5], through intensive interviews with owners and managers of firms. The data collection is part of a larger 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

[5] Additionally, the sales value was also asked for the year 1997, which permits investigating sales growth over a longer period of time: 1997-2002.

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. The survey provides more information on a wider variety of factors affecting technological innovation and firm performance than the Brazilian Innovation Survey 1998-2000[6], which was restricted to a more limited and focused set of questions on innovation.

The ICS dataset allows constructing innovative strategies, along both a "make" and a "buy" option, the innovative performance of the firms, along the process as well as product innovation dimension and the growth performance of the firms. In addition, it allows for a rich set of controlling factors. Beyond the typical firm size and age variables, as well as sectoral and regional classification, the dataset also allows identifying

- the leading or lagging position of the firm in the technology space;
- as a crucial component of absorptive capacity, the human capital of the firm (both its work force as its management), which can be characterized by secondary and tertiary education levels; we also can identify the use of ICT.
- the financial constraints firms face in doing business
- the exposure to international technology and competition, investigated through multiple channels: foreign ownership, exports, imports of components, competition from imports

The main disadvantage of the dataset is the restriction to a cross-section dimension only. The lack of a panel data structure of the dataset particularly restricts the growth part of the analysis.

The ICS data set of Brazil contains information on 1642 manufacturing firms, which represent a random sample, stratified on the basis of size, sector and location. The firms are selected from nine manufacturing sectors[7]. Within the selected sectors, the sample gives a fair representation of the total population with respect to the size and location dimension[8]. More detailed information on the sample and sampling procedure can be found in World Bank (2005). Due to missing values for some of the key variables, the number of firms used in our analysis is reduced to 1563, distributed over the different size classes and sectors as shown in table 1.

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[6] This survey was coordinated by the Brazilian Geographic and Statistical Institute (IBGE), and gathers information from 10328 firms. The questionnaire follows methodology proposed by the Oslo Manual (OECD, 1997). Access to the data for research is restricted, in contrast to the World Bank ICS data, which are more accessible. Summary tables are available on the IBGE website, results of the survey data are discussed in De Negri and Turchi (2007).

[7] Food industries (CNAE 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 CNAE (Classificação Nacional de Atividades Econômicas) is the Brasilian national classification which is closely linked to the ISIC (International Standard Industrial Classification) revision 3 and 3.1, at least up to the 2-digit level.

[8] 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.

*Insert table 1*

## 4.2. Methodology

Using the ICS information, we investigate the firm, industry and regional characteristics that can explain a firm's innovation performance and its impact on firm growth. Table A1 in Appendix provides a description of all the variables used in the analysis.

### *4.2.1. Innovation strategies: make and/or buy*

We first identify firms' innovation strategies, on both the "make" and "buy" dimension. In the questionnaire, firms were asked about their major ways of acquiring new technology. Firms could report up to three important strategies. As observed in many other developing countries and in line with expectations, firms reported that the most important channel for new technology acquisition was by investing in machinery and equipment that embodied newer vintage technology, followed by in-house development of new technology[9]. Hiring of key personnel came in third position. Other less frequently mentioned strategies consisted of sourcing from a parent company, licensing technology from other firms, developing technology in collaboration with clients or suppliers, or universities, or from trade fairs, exhibitions and study tours.

We concentrate on the two major innovation strategies, capturing the most frequently used channels: developing technology within the firm, i.e. the MAKE option versus the technology acquisition or BUY option. For the latter, we include acquiring new technology embodied in new machinery, in key personnel as well as licensing-in technology [10].

We construct different exclusive categories for the firm's *innovation strategy* (I): firms that only report in-house development of technology (*MakeOnly*); firms that only have external technology acquisition embodied in machinery and key personnel (*BuyOnly*); and firms that combine own development activities with embodied technology acquisition (*Make&Buy*) and finally firms that have no such innovation strategy of developing technology nor buying technology (*NoMake&Buy*) [11].

### *4.2.2. Innovative performance: introducing new products and/or processes*

Having identified a firm's innovative strategy, we then link the technology "make" or "buy" strategy to the innovative performance of firms. We measure innovative performance by the introduction of a new production processes that substantially changed the way the main product is produced (*PROCESS*) and/or the successful introduction of new products (*PRODUCT*), both over the three year period 2000-2002. We also construct exclusive

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[9] This was also observed in the Brazilian Innovation Survey 1998-2000: acquisition of machinery and equipment accounts for half of innovation expenditures, followed by R&D, accounting for 25% of expenditures. These proportions differ from developed economies, where R&D is relatively more important, eg. Germany, 55%, the Netherlands 74% (Peirano, 2007).

[10] We checked the robustness of our analysis to alternative compositions of the BUY strategy. Most notably, we also concentrated the BUY strategy on the buying of equipment only, which is by far the most commonly chosen BUY option. Most results (unless otherwise stated) are robust to the composition of the BUY strategy.

[11] These firms may still be acquiring technology but from less explicit innovation strategies, than the ones included in the MAKE and BUY category.

categories: product innovators alone (*PRODONLY*), process innovators alone (*PROCONLY*), combined product and process innovators (*PPI*) or none of both (*NOPPI*).

Innovation – both product and process innovation - is modelled following a probit model, which relates the probability of being an innovator to the characteristics of the firm (X) and the underlying innovation strategies (I). Our set of independent firm characteristics includes the typical size, age, sector and regional dummies. Our main variables of interest are the set of innovation strategies (I): *MakeOnly*, *BuyOnly*, *Make&Buy*, with *NoMake&Buy* being the reference category.

In addition other variables that are likely to influence innovative performance are included in the equation. These are the technology position of the firm in its market (T), the absorptive capacity in the firm (AC), foreign linkages and exposure (F), competitive pressure (C) and financial constraints (FIN). They are measured through various proxies, shown in table A1 in Appendix. We thus estimate the following model:

$$PRODUCT_i^* = \alpha X_i + \beta I_i + \gamma T_i + \delta AC_i + \varepsilon F_i + \zeta C_i + \eta FIN_i + \upsilon_{1i}$$
$$PRODUCT_i = 1 \text{ if } PRODUCT_i^* \geq 0 \text{ ; } PRODUCT_i = 0 \text{ if } PRODUCT_i^* < 0 \quad (1)$$
$$PROCESS_i^* = \alpha X_i + \beta I_i + \gamma T_i + \delta AC_i + \varepsilon F_i + \zeta C_i + \eta FIN_i + \upsilon_{2i}$$
$$PROCESS_i = 1 \text{ if } PROCESS_i^* \geq 0 \text{ ; } PROCESS_i = 0 \text{ if } PROCESS_i^* < 0 \quad (2)$$

We also conduct a bi-variate probit analysis explaining process and product innovations jointly, using the same set of variables as regressors. The bivariate probit regression takes the correlation between PROCESS and PRODUCT into account explicitly:

$$E[v_1] = E[v_2] = 0, Var[v_1] = Var[v_2] = 1, Cov[v_1, v_2] = \rho, \quad (3)$$

*4.2.3. Growth performance*

Having analyzed the innovative strategies and performance of firms in a first step, the analysis in a second step assesses the relationship between innovation and firm performance. We use as measure of firm performance, average annual sales growth over the period 2000-2002[12].

In line with the literature on firm growth (Evans, 1987, Sleuwaegen and Goedhuys, 2002), the basic empirical model for the growth equation is a general growth function g in size (S) and age (A):

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

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 additional variables that are expected to be related to growth. Our major variables of interest are the various innovative performance

[12] Alternatively we also check robustness of our results using a longer time period for growth over the 1997-2002 period.

indicators (INNO). In addition, we also add a few variables to capture access to finance (FIN), foreign linkages (F) and absorptive capacity (AC) which are directly affecting growth.

We approximate the growth function g through a second order logarithmic expansion of a generalised function relating growth to size and age and we add the growth shifting variables. The resulting estimating equation corresponds to the following form:

$$\frac{\log(S_{t'}) - \log(S_t)}{d} = a_0 + a_1 \log(S_t) + a_2\left[\log(S_t)\right]^2 + a_3 \log(A) + a_4\left[\log(A)\right]^2 + a_5 \log(S_t) * \log(A) + a_I INNO + a_8 FIN + a_9 F + a_{10} AC \qquad (4)$$

where $d$ stands for the number of years over which growth is measured and $a$ are coefficient vectors.

In line with this model, our dependent variable corresponds to an average annual sales growth rate over de period 2000-2002. The explanatory variables are as defined in table A1 in Appendix and include beyond innovative performance, the OVERDRAFT variable to consider financial constraints (FIN); MNE and EXPORT for international linkages (F) and GMHIGH for the quality of human capital (AC).

Our major variable of interest is the effect of innovative performance on sales growth. Simply including the innovative performance, either through the PROCESS and PRODUCT dummy or the exclusive categories (*PRODONLY, PROCONLY, PPI, NOPPI*) in the growth equation may result in their coefficients being badly estimated, because of endogeneity: faster growing firms may have a larger incentive and capacity to introduce new innovations. Unfortunately our dataset does not allow a sufficient lagging of the innovative performance variable or forwarding of the growth results. Furthermore, unobserved firm-specific effects in the innovation performance regression can cause the coefficient of the innovation variables in the growth regression to be biased, if they also enter the growth error term, as an unobserved explanatory factor for growth as well. Panel data would allow including firm fixed effects. Our data set does however not permit a panel data structure.

We thus use a two step procedure in an attempt to improve our estimation while correcting for the potential biases due to endogeneity and unobserved heterogeneity. The two-step procedure uses the predicted values of the innovative performance as instrument in the growth regression (4), derived from the estimations (1)-(3). More specifically, we include in the growth specification the predicted values *PPRODUCT* and *PPROCESS* or their exclusive categories: product innovators alone (*PPRODONLY*), process innovators alone (*PPROCONLY*), combined product and process innovators (*PPPI*).

## *5. The empirical analysis*

Before we present the results from the econometric analysis of firms' innovative performance and growth in section 5.2, we first show some descriptive statistics on firm's innovative strategies, innovative performance and growth in section 5.1.

## 5.1. Descriptive statistics

Table 2 summarizes the information about the firm's **innovation activities**, more particularly who *BUYs* and/or *MAKEs*. 78% of the sample firms acquire technology externally (BUY), embodied in new machinery, key personnel or through licensing (61% if only embodied in new machinery[13]). Somewhat less but still more than half of the sample firms (56%) relies on internal development. The most frequently observed **innovation strategy** is the combination of *Make&Buy* (44%). The exclusive use of external acquisition (*BuyOnly*) is the second most frequently observed observation (34%). Only 12% of the sample firms choose a *MakeOnly* strategy, while 10% of the sample firms report *noMakeorBuy* activities. These are firms that have no innovation strategy or resort to other less frequently observed and more informal ways for acquiring technology (such as trade fairs, exhibitions, consultants, universities, clients, suppliers…).

*Insert table 2 here*

When we split the total sample according to firm characteristics, we find very little differences on the occurrence of Make and/or Buy activities, the biggest differential being between those companies without any Make and/or Buy activities and the rest. Also an econometric analysis trying to explain the MAKE and/or BUY strategies with available firm, industry and regional characteristics reveals very little significant results across innovation strategy categories. The only variable that shows up significantly is the technology leading/lagging position of the firm: technology lagging firms are significantly less likely to choose any MAKE and/or BUY strategy, while technology leading firms are more likely (although not strongly significantly) to choose MAKE and/or BUY, although this effect is only marginally significant. Also marginally significant is the result that a complementary strategy of *Make&Buy* is chosen more by older and larger companies.

Table 2 also shows the **innovative performance** of the different innovative strategies. Two third of all firms report having introduced new processes in the observed period. Companies without a MAKE or BUY strategy are clearly less likely to be able to introduce *new processes* (29%). Interesting to observe is the performance of the *MakeOnly* strategy, which is less performing as compared to an innovation strategy that uses embodied technology acquisition, exclusively or in combination with internal development. This is reminiscent of the importance of technology acquisition rather than own technology development as innovative strategy for firms in developing countries. There is some evidence in favor of complementarity between *Make* and *Buy*, since the highest success rate is observed for the *Make&Buy* strategy (73%). But this is only slightly higher than the performance of the *BuyOnly* strategy (71%).

On average, 66% of all companies report having introduced *new products* in the observed period[14]. The lowest frequency is again observed among the *NoMake&Buy*

[13] This is consistent with findings from the Brazilian innovation survey (IBGE, 2000).

[14] There was also information on whether firms had significantly improved products during the same 3-year period. If we define product innovating firms as those that introduced new or significantly improved products, almost all companies - 94%- report themselves as product innovators, with very little difference between the different innovation strategies, with the exception of the *NoMake&NoBuy* strategy, which "only" has three quarters of these firms being able to introduce new or significantly improved products. The high frequency of reporting introductions of new products makes this variable not useful for analysis. This is why we concentrate the remainder of the analysis on innovative performance on process and new product innovations only.

category, where 34% of firms report to have introduced new products. Again, the highest frequency of product innovation is among the firms in the *Make&Buy* category, though the disparity with the other categories is smaller than for process innovation. The proportions of product innovators do indeed not differ much among the *MakeOnly, BuyOnly* and *Make&Buy* innovation strategies. This implies a wider variety of equivalent strategies that can lead to the introduction of new products.

*Insert table 3 here*

The successful introduction of product and process innovations is highly correlated: 73% of successful process innovators also introduced new products and 74% of firms with successful new product introductions also introduced new processes. Table 3 reports the frequency of occurrence of the exclusive categories of firms: product innovators alone (*PRODONLY*), process innovators alone (*PROCONLY*), combined product and process innovators (*PPI*) or none of both (*NOPPI*). Half of the firms (50%) introduce simultaneously product and process innovations[15]. These companies also report the highest sales growth over the considered period (6.6%), well above the growth performance of firms that introduce only product innovations (4.1%) or only process innovations (4.3%), and significantly higher than the sample average growth rate of 5.2%. This is suggestive of complementarity between product and process innovations (see also Miravete and Pernias (2006) for evidence on complementarity for developed countries). Firms who failed to introduce new innovations (either product or process) have significantly lower sales growth (2.5%). This is reminiscent of the importance of innovative performance for the overall growth performance of Brazilian manufacturing firm.

This first descriptive view of the data suggests

- the importance of embodied technology acquisition as an innovation activity (BUY), with also some support for complementing technology acquisition with in-house development (MAKE).
- a positive link between innovative activities and innovative performance, especially for process innovation, where the BUY option (exclusively or in combination with MAKE) proves particularly favourable.
- innovative performance often involving a combination of product and process innovations.
- innovative performance to be positively associated with higher sales performance, particularly the combined product-process innovations.

The next sections will detail which factors will turn out to be significant drivers in a multivariate analysis of innovative and growth performance.

### 5.2. Multivariate analysis results on innovative performance

In this section, we analyse the determinants of product and process innovations, as indicators of innovative performance. In the next section 5.3, we analyse their impact, separately and jointly, on firm' growth.

[15] Other Brazilian evidence, using CIS-like surveys, found process innovations to be the most common and relevant form of innovations (De Negri et al., 2008).

Table 4 contains the results on innovative performance, with column (1) containing the probit results on process innovation, and column (2) presenting the product innovation probit results. Columns (3)-(4) contain the bivariate probit results for process and product innovations. Overall, although the Chi-sq test for the bivariate probit reveals a significant correlation in error terms (Chi-square 28.1579) the bivariate results do not differ markedly from the simple probit results.

The estimations reveal a strong and significant effect of innovative strategies on innovative performance. All innovative strategies, *MakeOnly, BuyOnly* and *Make&Buy*, have significantly positive coefficients, a result which appears robust across alternative specifications. The size of the coefficients indicates a lower performance of the *MakeOnly* strategy as compared to the *BuyOnly* and *Make&Buy* strategy. This holds for both process and product innovation, but more so for product innovations. The combination of *Make&Buy* has the highest coefficient. This can be interpreted as evidence in favour of complementarity, but the difference with the *BuyOnly* strategy is only minimal. Overall the data seems to suggest that for Brazilian manufacturing firms, it is particularly the BUY strategy that is most associated with innovative performance, particularly for being successful in introducing process innovations. This result is robust to a more narrow definition for BUY, confined to buying technology embodied in equipment only.

Technology leading firms have a significantly higher likelihood of successfully introducing new processes and products (+12% and +6% respectively), while technology lagging firms have a significantly lower likelihood of introducing process innovations (-7%).

Financial constraints are a significant factor in the innovation process. Companies that are less financially constrained, having overdraft facilities, are more likely to be successful innovators and the effect is strongest for product innovation (+8% against +6% for process innovation).

On the different measures for absorptive capacity, the results suggest that their effect depends on the type of innovation. For process innovation it is not the proportion of employees with tertiary education that matters, but rather the share of secondary education workers and even more significantly the provision of formal training to them. This is reminiscent of the need for an absorptive rather than a creative capacity for process innovations and related to problems associated with tertiary education in Brazil. A general manager with graduate or postgraduate education even adds negatively to innovative process performance. Product innovation on the contrary, appears to be more high-skill intensive, with larger shares of highly educated employees, (secondary, but also tertiary) raising the probability of being a product innovator. Raising the proportion of tertiary educated workers from zero to 20 for instance increases the probability that the firm is a product innovator by 5%[16]. The use of ICT (as measured through e-mail connection) also adds to the probability of successfully introducing new products to the market (+10%), as well as new process innovations (+9%).

[16] The mean proportion of workers with higher education is 0.08, with a standard deviation of 0.09, making this example coincide with the effect about one standard deviation more and less than the mean proportion of high skilled workers. For secondary education, the mean proportion among the labour force equals 0.23, SD 0.20. The effect here is a 2% increase.

Our variables on international linkages as well as on competition, are weak in explaining innovative performance, in various alternative specifications. This is suggestive of the still important influence of a "closed-economy, protection-of-local-firms" perspective in Brazil's innovation policy. Sourcing inputs from a foreign supplier raises the likelihood that a firm introduces new production processes, but the effect is only significant at the 10% level. Having foreign ownership (MNE) or foreign sales (DIRECTEXPORT), or facing competition from imports, seems unrelated to innovative performance. Only competitive pressure from foreign firms has a positive and significant effect on the likelihood that firms develop new products.

*Insert table 4 here*

### 5.3. Multivariate analysis results on growth performance

Table 5 presents our results on sales growth. Our major variable of interest is the effect of innovative performance on sales growth. Simply including the PROCESS and PRODUCT dummy in the growth equation may result in their coefficients being badly estimated, because of endogeneity and unobserved heterogeneity. As explained in the previous section, we use a two-step procedure in an attempt to improve our estimation. The two-step procedure uses the predicted values of the innovative performance as instrument in the growth regression, derived from the bivariate estimations reported in columns (3-4) of Table 4. We first estimate the effect of process and product innovation separately, then their joint impact on growth. Column (4) of Table 5 reports the results on the predicted four exclusive categories: product innovators alone (PPRODONLY), process innovators alone (PPROCONLY), combined product and process innovators (PPPI) or none of both. To check sensitivity of the results to the model specification, we also ran the regression including the original PRODUCT and PROCESS dummy and briefly discuss the results at the end.

*Insert table 5 here*

Our results on growth performance confirm the significance of negative firm size effects. Small firms grow significantly faster in Brazil than larger firms, but with significant evidence of non-linearity in the size effect, as indicated by the squared term. Also younger firms grow significantly faster, especially the very youngest, but no significant interaction effect between size and age prevails.

Our main variable of interest in the growth equation is the innovation performance of the company. Do firms that introduce successfully new product and process innovations also reap the benefits of this in terms of larger sales growth? In the basic specifications, where we separately include PROCESS (col.1) and PRODUCT (col. 2) in the growth equation, the results are positive and significant, with a larger coefficient for product innovation. When including product and process innovation jointly as explanatory variables, the effect of process innovation completely disappears, while product innovation on the contrary shows up as being positively and significantly related to sales growth. The high occurrence of firms doing both product and process innovation is responsible for this effect, and requires the investigation of exclusive innovation categories: product innovators alone (*PPRODONLY*), process innovators alone (*PPROCONLY*), combined product and process innovators (*PPPI*) with none of both the reference category. This is presented in column 4, which reveals a positive effect for firms that implemented product innovation only, an effect that is however not significant. Only those firms that combine successful product innovations with process innovations realize a significantly higher sales growth, supportive of the complementarity between both types of innovations. Firms that introduce only process innovations have lower sales growth rates than firms that are not innovative at all, reminiscent of the cost cutting/restructuring story behind process innovations. The effect is however not significant.

In contrast to the results from innovative performance, having a graduate or post-graduate general manager pays off in terms of higher sales growth performance. While international linkage variables failed to affect significantly innovative performance, they do affect firm's growth performance: companies with foreign shareholders and/or foreign sales have a higher growth rate.

These observed effects are rather consistent in the various specifications. Even the use of the original PRODUCT and PROCESS variables or the exclusive categories, rather than the predictions, does not shift the relative importance of the innovation strategies. For instance, firms that introduce combined product and process innovations have significantly higher growth rates (coefficient=0.04), nearly doubling the expected growth, and the effect is significant at the 1% level. Product only and process only innovation on the other hand do not seem to be correlated with superior growth (non-significant coefficients of +0.02). In this basic model short term credit (coeff.=0.06), higher education of the manager (coeff.=0.03) and prior exporting experience (coeff.=0.05) are equally related with higher growth rates.

## *6. Conclusions*

Using data from the World Bank's Investment Climate Survey (ICS) data collected in Brazil in 2003 for manufacturing sectors, this paper tries to contribute to the literature on technological progress and development by bringing on board a micro-econometric perspective on the factors determining innovative performance and firm growth. Our focus on Brazil allows analysing the case of a mid-income country in fast development, where the interplay between diffusion (buy) and creation (make) of new technologies, is centrepiece for sustaining growth. With a mixed legacy of protectionism and international openness, it is also an interesting case to analyse the importance of international linkages for innovation and growth.

There are a number of interesting findings that appear to be robust across several specifications. First, like in many developing countries, also in Brazil, innovation strategies involve mostly technology acquisition, by acquiring know-how embodied in machinery and equipment, exclusively but also substantially, in combination with own internal development. Secondly, innovative strategies contribute significantly to being able to introduce new innovations. For both process and product innovation the acquisition strategy is dominant, but complementarities with the *make* strategy are also observed: firms that combine *make* and *buy* strategies are the most likely to be successful innovators. The option of relying on internal development is less performing than the acquisition strategy, especially for process innovations.

What is needed in terms of human capital is also surprising: a large share of workers with secondary education is very important for process innovations. It does not require a tertiary skilled workforce to be a successful process innovator in Brazil, which could even work negatively. Product innovation is more high-skill intensive, needing higher shares of highly (university) educated workers, a highly educated management and ICT usage for communicating with the market. This suggests that product innovation, in comparison to process innovation, is a more complex process with multiple inputs requiring more advanced knowledge inputs and absorptive capacity.

Product innovation also translates into superior sales growth rates. This is particularly so when it is combined with process innovation. Process innovation alone, without the introduction of new products, runs the risk of being associated with lower growth performance. It is indeed possible that the benefits of more cost efficient production are only reaped after an initial period of restructuring, beyond what we can measure with our data set. Alternative measures, such as productivity, productivity growth, or profitability, may capture the beneficial influence of process innovation more rapidly.

Another robust factor driving innovative performance is the access to finance. This supports policy interventions to alleviate the financial constraints, by improving financial market functioning and/or providing financial incentives. Finally, our results on international linkages are somewhat mixed. International openness is important for stimulating firm growth performance, but this openness works particularly through competition as an incentive device for cost improvements, stimulating firm growth, but not necessarily as a mechanism for technology absorption improving innovative performance. Again this can be related to the specifics of the Brazilian case, which has for a long time protected local champions in its innovation policy.

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***Table 1: composition of the sample***

| | *Small 10-29 workers* | *Medium 30-99 workers* | *Large 100+* | *All firms* |
|---|---|---|---|---|
| Food | 15 | 33 | 72 | 120 |
| Textiles | 21 | 27 | 54 | 102 |
| Clothing | 95 | 203 | 126 | 424 |
| Leather | 26 | 78 | 56 | 160 |
| Chemicals | 12 | 32 | 34 | 78 |
| Machinery | 43 | 61 | 74 | 178 |
| Electronics | 12 | 39 | 23 | 74 |
| Auto-parts | 16 | 42 | 68 | 126 |
| Furniture | 76 | 136 | 89 | 301 |
| **Total** | **316** | **651** | **596** | **1563** |

***Table 2: Frequency of occurrence of innovation strategies,***

| **Total** | **Frequency of occurrence** | **% process innovators** | **% new-product innovators** |
|---|---|---|---|
| No Make/No Buy | 10% | 29% | 34% |
| Make Only | 12% | 60% | 65% |
| Buy Only | 34% | 71% | 69% |
| Make & Buy | 44% | 73% | 71% |
| | **100%** | **66%** | **66%** |

***Table 3: Innovative performance and sales growth 2000-02***

| | **Frequency of occurrence** | **Sales Growth 2000-02** |
|---|---|---|
| No new product/no process innovation | 222 (14%) | 2.5% |
| Product and process innovators | 788 (50%) | 6.6% |
| Product only innovators | 267 (17%) | 4.1% |
| Process only innovators | 286 (18%) | 4.3% |
| | | |
| Process innovators | 1074 (69%) | 6.0% |
| Product innovators | 1055 (68%) | 6.0% |
| | | |
| **TOTAL** | **1563** | **5.2%** |

***Table 4: Results of the probit and bi-probit analyses explaining process (PROCESS) and product innovation (PRODUCT)***

| | Probit | probit | Biprobit | |
|---|---|---|---|---|
| | PROCESS | PRODUCT | PROCESS | PRODUCT |
| ltl00 | 0.026 | 0.025 | 0.029 | 0.026 |
| | (0.040) | (0.039) | (0.039) | (0.039) |
| lfirmage | -0.086 | 0.040 | -0.088 | 0.036 |
| | (0.062) | (0.063) | (0.062) | (0.063) |
| makeonly | 0.444*** | 0.349** | 0.448*** | 0.354** |
| | (0.160) | (0.158) | (0.160) | (0.159) |
| buyonly | 0.784*** | 0.552*** | 0.785*** | 0.551*** |
| | (0.141) | (0.139) | (0.142) | (0.140) |
| makeandbuy | 0.883*** | 0.586*** | 0.888*** | 0.587*** |
| | (0.139) | (0.137) | (0.140) | (0.138) |
| techleader | 0.352*** | 0.181** | 0.343*** | 0.178** |
| | (0.092) | (0.088) | (0.091) | (0.088) |
| techlaggard | -0.202** | 0.001 | -0.200** | -0.000 |
| | (0.098) | (0.098) | (0.098) | (0.098) |
| overdraf | 0.170** | 0.226*** | 0.170** | 0.231*** |
| | (0.082) | (0.080) | (0.082) | (0.080) |
| lfhigh | -0.143 | 0.775* | -0.128 | 0.778* |
| | (0.396) | (0.428) | (0.393) | (0.425) |
| lfsec | 0.326* | 0.302* | 0.337* | 0.313* |
| | (0.181) | (0.178) | (0.181) | (0.178) |
| gmhigh | -0.193** | 0.028 | -0.194** | 0.027 |
| | (0.080) | (0.078) | (0.080) | (0.078) |
| forfirmexper | -0.214 | -0.007 | -0.217 | -0.012 |
| | (0.137) | (0.142) | (0.136) | (0.141) |
| ltotexper | 0.064 | -0.078 | 0.071 | -0.073 |
| | (0.066) | (0.068) | (0.065) | (0.068) |
| training | 0.272*** | 0.087 | 0.267*** | 0.083 |
| | (0.082) | (0.082) | (0.083) | (0.082) |
| foreignsupplier | 0.140* | 0.104 | 0.139* | 0.107 |
| | (0.075) | (0.074) | (0.075) | (0.074) |
| ict | 0.242* | 0.275** | 0.240* | 0.276** |
| | (0.136) | (0.133) | (0.136) | (0.133) |
| mne | -0.185 | -0.247 | -0.181 | -0.239 |
| | (0.194) | (0.201) | (0.194) | (0.201) |
| export | -0.006 | 0.132 | -0.000 | 0.137 |
| | (0.096) | (0.096) | (0.096) | (0.096) |
| compimp | 0.095 | 0.159 | 0.100 | 0.159 |
| | (0.114) | (0.115) | (0.113) | (0.114) |
| comppressf | 0.122 | | | |
| | (0.127) | | | |
| comppressd | 0.048 | | | |
| | (0.076) | | | |
| comppresspf | | 0.310** | 0.083 | 0.309** |
| | | (0.136) | (0.129) | (0.136) |
| comppresspd | | -0.106 | -0.003 | -0.105 |
| | | (0.081) | (0.083) | (0.081) |
| constant | -0.891*** | -0.961*** | -0.883*** | -0.975*** |
| | (0.264) | (0.260) | (0.262) | (0.261) |
| # Observations | 1563 | 1563 | 1563 | 1563 |

The estimation includes eight sector dummies and 12 geographical location dummies. Standard errors in parentheses; *significant at 10%; ** significant at 5%; *** significant at 1%

***Table 5: Innovation and firm sales growth (2000-2002)***

| | Effect of process innovation | Effect of product innovation | Joint effect of product and process innovation | Joint effect of product and process innovation |
|---|---|---|---|---|
| Dependent variable: Sales growth 2000-02 | | | | |
| lssal | -0.185*** | -0.183*** | -0.184*** | -0.184*** |
| | (0.042) | (0.042) | (0.042) | (0.042) |
| slssal | 0.005*** | 0.005*** | 0.005*** | 0.005*** |
| | (0.002) | (0.002) | (0.002) | (0.002) |
| lfirmage | -0.318*** | -0.319*** | -0.319*** | -0.320*** |
| | (0.069) | (0.068) | (0.068) | (0.068) |
| slage | 0.031*** | 0.029*** | 0.030*** | 0.030*** |
| | (0.009) | (0.009) | (0.009) | (0.009) |
| sales00age | 0.006 | 0.006 | 0.006 | 0.006 |
| | (0.005) | (0.005) | (0.005) | (0.005) |
| pprocess | 0.238*** | | 0.045 | |
| | (0.048) | | (0.080) | |
| pproductn | | 0.371*** | 0.323*** | |
| | | (0.064) | (0.107) | |
| pproconly | | | | -0.071 |
| | | | | (0.176) |
| pprodonly | | | | 0.279 |
| | | | | (0.180) |
| pppi | | | | 0.348*** |
| | | | | (0.077) |
| overdraf | 0.051*** | 0.034** | 0.035** | 0.034** |
| | (0.015) | (0.016) | (0.016) | (0.016) |
| gmhigh | 0.043*** | 0.018 | 0.022 | 0.020 |
| | (0.014) | (0.014) | (0.015) | (0.015) |
| mne | 0.077** | 0.075** | 0.077** | 0.076** |
| | (0.037) | (0.037) | (0.037) | (0.037) |
| export | 0.045** | 0.033* | 0.035* | 0.033* |
| | (0.019) | (0.019) | (0.019) | (0.019) |
| constant | 1.813*** | 1.766*** | 1.769*** | 1.818*** |
| | (0.298) | (0.297) | (0.297) | (0.311) |
| # observations | 1503 | 1503 | 1503 | 1503 |
| R-squared | 0.15 | 0.15 | 0.16 | 0.16 |

The estimation includes eight sector dummies and 12 geographical location dummies. Standard errors in parentheses; *significant at 10%; ** significant at 5%; *** significant at 1%

Appendix

***Table A1: Definition of variables***

| | | |
|---|---|---|
| Sales growth 2000-02 | Average annual sales growth over the period 2000-2002, calculated by (ln(sales2002) – ln(sales2000))/2 | |
| PROCESS | =1 if the firm introduced new technology that has substantially changed the way the main product is produced, in 2000-02. | |
| PRODUCT | =1 if the firm developed a major new product line in 2000-02 | |
| *Firm characteristics (X)* | | |
| LFIRMAGE | Age of the firm, in logarithmic terms | 2.68 (0.80) |
| LTL00 | Size of the firm, measured by number of employees in 2000, in log. | 3.91 (1.15) |
| *Innovation strategy (I)* | | |
| MAKEONLY | =1 if firm reports 'in-house development' as major way of acquiring new technology, not 'embodied in machinery, hiring key personnel, licensing' | 0.12 |
| BUYONLY | =1 if firm reports 'new technology embodied in machinery', the 'hiring of key personnel' or 'licensing of technology' as major ways of acquiring new technology; not 'developed in-house' | 0.34 |
| MAKEANDBUY | =1 if firm reports both 'in-house development' and 'embodied in machinery' or 'hiring key personnel' or 'licensing' as major ways of acquiring new technology | 0.46 |
| *The technology position of the firm in its market (T)* | | |
| TECHLEADER | =1 if the firm reports that his technology is more advanced than that of its main competitors | 0.24 |
| TECHLAGGARD | =1 if the firm reports that his technology is less advanced than that of its main competitors | 0.15 |
| *Absorptive capacity (AC), as measured through various proxies:* | | |
| LFHIGH | Proportion of the labour force with higher education [0,1] | 0.08 (0.09) |
| LFSEC | Proportion of the labour force with secondary education as highest level attained [0,1] | 0.23 (0.20) |
| GMHIGH | =1 if the firm has a general manager with a graduate or postgraduate degree or diploma of tertiary college | 0.51 |
| LTOTEXPER | Total number of years of experience of the manager working in this industry, in log. terms | 2.46 (0.69) |
| ICT | =1 if the firm uses a email to interact with clients and suppliers | 0.92 |
| TRAINING | =1 if the firm offers formal training to its employees | 0.67 |
| *Foreign linkages (F)* | | |
| FORFIRMEXPER | =1 if the manager has previously acquired working experience in the same industry, in a foreign firm | 0.08 |
| MNE | =1 if the firm's principal shareholder is a foreign company | 0.04 |
| EXPORT | =1 if the firm is a direct exported prior to 2000 | 0.27 |
| FOREIGNSUPPLIER | =1 if the firm sources its main supply or inputs from foreign owned firms | 0.40 |

| | | |
|---|---|---|
| *Competition (C)* | | |
| COMPIMP | =1 if for the firm's main product the main competitor is an imported product | 0.13 |
| COMPPRESSF | =1 if firm reports that the most important influence/pressure to reduce production costs are foreign competitors | 0.11 |
| COMPPRESSD | =1 if firm reports that the most important influence/pressure to reduce production costs are domestic competitors | 0.49 |
| COMPPRESSPF | =1 if firm reports that the most important influence/pressure to develop new products are foreign competitors | 0.09 |
| COMPPRESSPD | =1 if firm reports that the most important influence/pressure to develop new products are domestic competitors | 0.24 |
| *Financial constraints (FIN)* | | |
| OVERDRAFT | =1 if the firm has an overdraft facility with a formal bank | 0.74 |