

## THE ROLE OF FIRM AND TERRITORY IN INNOVATIVE ACTIVITIES IN BRAZILIAN POST-OPENING ECONOMY

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### Abstract

The aim of this paper is to estimate the role of territory and the individual firm in innovation in the Brazilian industrial economy after the trade-opening period from 1998 onwards. This study is based on a database whose micro-data are a merger between the Technological Innovation Survey (PINTEC) and the Yearly Industrial Survey (PIA) of the Brazilian Institute of Geography and Statistics (IBGE). These micro-data are analyzed by the logit regression method as well as using hierarchical regression models. The main results reveal that firm-level variables and region-level variables are complementary but with the former having more impact on the propensity to innovate than the latter.

**Keywords:** innovation; firm; region; hierarchical regression models; Brazil

**JEL classification:** R10; R30; O30.

### Resumo

O objetivo desse artigo é identificar o papel do território e da firma na inovação da economia industrial brasileira após o período de abertura econômica em 1998. Esse artigo baseia-se em uma base de dados cujos microdados são provenientes da fusão da Pesquisa de Inovação Tecnológica (PINTEC) e da Pesquisa de Inovação Industrial (PIA) do Instituto Brasileiro de Geografia e Estatística (IBGE). A base de dados é submetida a métodos de regressão logística e hierárquica. Os principais resultados revelam que variáveis ao nível da firma e região são complementares, sendo que os primeiros possuem impacto superior sobre a propensão a inovar das firmas em relação aos últimos.

**Keywords:** inovação; firma; região; modelos hierárquicos; Brasil.

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## 1 Introduction

This article starts out from two theoretical sources dealing with the factors that determine innovation. The first treats innovation as the result of a set of incentives and restrictions internal to the firm. The work of Dosi (1988), Nelson & Winter (1982), Lundvall (1992), Richardson (1972), Penrose (1959), Chandler (1977), Grant (1996) and Foss (1997) are found within this framework. Such works consider the large business organization as the principal agent in the innovative process, because it takes the initiative in the process and possesses most of the resources necessary for it. Besides, part of this theoretical framework includes firm internal knowledge related characteristics, the firm's absorptive capacity and a rationale for a firm to have external knowledge relations, being known as "the knowledge based view of the firm".

The second theoretical source focuses on the contextual conditions linked to specific territorial and urban factors in which innovation occurs, as in the work of Carlino et al. (2007), Markusen et al. (1986) and Feldman & Florida (1994). These last are good representatives of this viewpoint, emphasizing that the capacity to innovate is located beyond the limits of the organization, as innovation no longer falls within the domains of the inventor, of the risk-taking entrepreneur, of the capitalist with a keen eye, or of the resource-rich large corporation. On the contrary, innovation has its sources in a wider spatial and social structure, which is defined by a landscape of agglomerated and synergistic economic and social institutions. This means that geography possesses a central role in the innovative process. Accordingly, innovation is, above all, a geographical process.

The motivation of this article is based on the potential for the integration of these two theoretical approaches, considered as supplementary to each other, instead of considering them separately. Innovation, in this way, can only be truly understood if the conditioning factors internal to the company and the role of external players, territorially speaking, are identified. Because of this, all the effort expended in trying to integrate the neo-Schumpeterian work to theories that emphasize the role of the territorial environment contributes to develop what Dosi (1988) called the regional economy of technical change. The consideration itself of the properties of innovation permits the conclusion that it is a complex process because it involves various players, in the same way that territory is also a social construct arising out of the actions of players in space (Markusen 2005).

In order to achieve this aim, the article is based on a rich and unique database organized for the period 1998-2000 by the Institute of Applied Economic Research (*Instituto de Pesquisa Econômica Aplicada* – IPEA) and the Center for Regional Development and Planning (*Centro de Desenvolvimento e Planejamento Regional* – CEDEPLAR). The original data stems from microdata of the Technological Innovation Survey (*Pesquisa de Inovação Tecnológica* – PINTEC) and the Annual Industrial Survey (*Pesquisa Industrial Anual* – PIA) of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE), covering the period 1998-2000. Our methodological approach takes into account the contribution of endowments more related to firms and those linked to territory. It is carried out by means of logistic and hierarchical regression models. The latter provides the distinctive advantage of carrying out estimates while simultaneously considering both levels of variable sets which characterize the problem under study.

Two hypotheses are tested in this study for the Brazilian manufacturing firms. The first is that regional attributes are complementary to attributes internal to firms, despite their varying importance according to the type of innovation under consideration. The second is that intra-regional technological-knowledge externalities, measured by patents per capita and R&D expenditure, exert significant effects on firms' innovation. That is, knowledge externalities internal to the regions may play an important role in innovation in countries where the disparity in knowledge between the regions is very high.

The first hypothesis is expected to be confirmed because there are theoretical arguments and some previous empirical evidence that validate it. Among factors internal to the region which generate or make possible the ability to innovate within the firm, the following stand out: skilled specialized local labor force; R&D structure; infrastructure for technology transfer; service infrastructure for specialized business; performance and level of specialization of regional economic structures; locational factors linked with urban and cultural amenities; "institutional robustness"; proportion of unionized workers in the region; level of urbanization and place in urban hierarchy; concentration of federal financial resources for basic research and defense spending (Sternberg & Arndt (2001); Harrison et al. (1996); Markusen et al. (1986); Amin & Thrift (1994)).

## **2 A Brief Review of the Literature**

### **2.1 Internal and External Determinants of Innovation in the Firm**

The factors cited above act in the sense of increasing the potential of the firm to generate differentiated productive services, understanding by company a combination of accumulated tangible and intangible assets (Penrose 1959). Depending on the manner in which these resources are combined they can give rise to different services. Resources are therefore regarded as a set of potential new services. Penrose's emphasis was on the role of human resources, especially the entrepreneur, who provides corporate services related to the task of applying part of the firm's resources in investigation and creation of new and profitable productive trajectories in its process of diversification.

In his turn, Chandler (1977, 1962, 1992) emphasizes capacity-building in organizations as a basis for understanding the innovative power of large companies. He makes firms the main players shaping the territorial environment in which they are inserted. In Nelson (1996)'s proposal of a summary of theoretical elements by Chandler, Penrose and neo-Schumpeterian formulations, he characterizes the firm as a set made up of strategy, organizational and productive structure and core capabilities. In this sense, the theoretical perspective so-called "the resource-based perspective" emphasize that differences in firm's resource endowments cause performance differences (Foss 1997). Firms seek to create, maintain and renew competitive advantage in terms of their resource side. Based on this perspective, the firm is an entity that seeks to match the opportunities of the environment with what the firm is capable of doing.

On empirical grounds, Sternberg & Arndt (2001) test the influence of firm and regional-level variables on the innovative behavior. The authors reach the conclusion that regional variables exert weaker influence on innovation than firm variables. Such a conclusion weakens the theorizing regarding the piv-

total role of territory to innovate, confirming previous findings of the literature on the complementary nature of the role played by organizational internal capabilities and territorial emersion, as pointed out by Harrison et al. (1996). This influence is also nuanced, depending on the type of innovation. Whereas regional variables were more heterogeneous in their impact on product innovation, in process innovation the only relevant variable was the proportion of local workers employed in manufacturing. For product innovation, technical and scientific staff and proximity to reputable research institutions exerted highly positive effects and regional research capability proved to be the most important territorial variable. In contrast, four out of the five variables related to the firm, when positive, increase the firm's probability of generating product innovations. Company size and R&D expenditures had small relevance in increasing tendency toward innovation, in the case of products. The significant variable with the greatest impact was permanent research and development. Regarding process innovations, the number of employees mattered having positive impact on the probability of innovating. The remaining variables were not statistically significant. The role territorial link networks formed by firms showed for process innovation statistical significance both at intra-regional and inter-regional levels. In the case of product innovation it was not significant.

These results led the authors to the conclusion that it is more likely that firms with favorable internal endowment will be capable of innovating, even in a region with unfavorable influences than the other way round. In unfavorable environments, the firm may develop strategies to overcome such restrictions. Development of inter-regional networks is an example of such strategies. Therefore, according to the authors, the regional environment, despite its influence on the firm's innovative behavior, can never be considered more important than firm's capabilities of processing information and working in networks. This statement adds weight to building capabilities and competences within firms, giving high priority to theories by Chandler (1992), Penrose (1959) and Nelson & Plosser (1982).

Méndez (2002) also acknowledges that both internal organization and territorial environment affects innovation together in a complementary fashion, although their importance varies according to the type of company. Small companies may rely more on their networks in surrounding areas to innovate, since there are myriad restrictions, such as insufficient financial resources, lack of technical personnel and less access to technical and market information.

Regarding the second hypothesis, the expectation of its confirmation is linked to the literature that highlights the importance of external factors in the generation of innovations. According to Dosi (1988), innovations depend of a set of "non-tradable interdependencies" and "contextual conditions". The "non-tradable interdependencies" are associated with the public part of knowledge or the non-appropriable private part of knowledge, that is, that part of knowledge used in company innovation, but not appropriated exclusively by it. These interdependencies between sectors, technologies and companies take the form of technological complementarities or synergies, which can constitute collective assets of groups of companies within countries or regions and/or can be internalized by companies.

The interdependencies that are not appropriated give rise to spatial groupings of companies which take advantage of the positive externalities of such

knowledge overflows. The mechanisms through which these overflows occur, and their geographical limits, are investigated by some authors. The consensus is that the overflows are geographically limited in space, which functions as an intermediary by facilitating interaction and communication, in addition to increasing the intensity of seeking and the coordination between the players (Feldman & Florida 1994, Jaffe 1989).

Although many studies discuss relative impacts on the capacity to innovate of attributes internal to the firm and to the territory, little is known about how these factors work in late-industrializing countries such as Brazil. The objective of this article is thus to find evidence about the relative importance of firms and territory regarding Brazilian firms' innovation capabilities, comparing these results with those available for developed countries.

The following section focuses on characteristics of the process of technical change in late-industrializing countries and particularly in Brazil after trade opening and privatizations in the 90s. The third section describes methodological aspects related to regression models and specifications, to variables as proxies of firm and region attributes and to the database. The fourth section contains the results and the fifth the conclusions.

## **2.2 The limits of Brazilian late industrialization to technological innovation**

In late-industrializing countries, the way that a firm's organization and territory complement each other in the innovation process must take into account the characteristics of the peripheral institutional environment regarding innovation. Such an environment can be regarded as the so-called national innovation system, which provides the institutional and infrastructural base to technological change (Nelson 1988, Lundvall 1992).

The Brazilian innovation system is characterized as poorly developed and immature (Albuquerque 2000) inasmuch as it suffers from: *i*) low involvement of manufacturing firms in innovation; *ii*) reduced internal innovative effort by firms, as shown by the small share of R&D expenditure in the total amount of innovation expenditure compared to the share of expenditure on machinery and equipment; *iii*) non-continuous nature of innovation activities, shown by the relative weight of occasional R&D; *iv*) incremental nature of the innovative process based on absorption of diffused technologies of leading countries by means of machinery and equipment imports, other external knowledge purchases (such as patents, licensing and know-how) and, last but not least, the strong presence of multinational companies' subsidiaries in both science-based and scale-intensive sectors; *v*) low level of inter-relations among agents making up the national innovation system, in particular weak links between scientific knowledge institutions, such as the universities, and manufacturing firms.

The characteristics above depict many limitations of Brazilian firms. If indeed companies are the main protagonists in the innovation process, how can regional scale elements in the national innovation system contribute to generation of innovation, compensating for these organizational limitations?

Whereas regions are important for innovation even in countries with low territorial inequality they are much more relevant in the case of countries with strong territorial unbalance, as is the case of Brazil. This is due to high regional heterogeneity in terms of indicators related to the university system

(number of establishments, professorship and students' background) and to the regional infrastructure for research and learning at the institutional and company levels (Diniz & Gonçalves 2001).

Historically, the Brazilian economic development process is characterized by deep social and regional inequalities (Azzoni 1997). The Southeast and South regions have the largest share of industrial production, the best academic university and research system, an integrated urban network and the most dynamic industrial centers. The Center-West and the North are agricultural and mineral frontiers, less prepared for the development of more intensive knowledge industries. And the Northeast is home to nearly a third of the population but has low levels of economic development, poor levels of education and living standards (Diniz & Gonçalves 2001).

More recently, a database organized by the IPEA and the CEDEPLAR based on a pool of data sources, mainly from micro-data of the PINTEC and the PIA of the IBGE, gave rise to a series of articles organized by De Negri & Salerno (2005).<sup>1</sup> These studies reinforce regional inequalities from another point of view. The Brazilian industrial firms are classified into three groups according their innovative capability and exhibit distinctive patterns of regional distribution as well as locational requirements.

According to their competitive strategy of product differentiation in the period 1998-2000, Brazilian industrial firms<sup>2</sup> were classified into three categories: 1) Category A: firms introducing product innovation on the Brazilian market and with export premium price of 30%; 2) Category B: firms which export and are not included in category A or firms which do not export but have efficiency standards (labor productivity) similar to the export firms of this category; 3) Category C: the residual firms which do not innovate and do not export.

The distribution of industrial value-added in Brazil shows high level of spatial concentration. Comparatively, the 250 major municipalities account for 98% of the total of industrial value-added (IVA) of type A companies, 87% of IVA of type B companies and 78% of IVA of type C companies.

Firms in category A have superior technological standards because they innovate and differentiate products. They have advanced competitive strategies focused on high value-added new goods. They are, in general, leading manufacturing firms with large market shares and belong to more dynamic product markets. Although they represent no more than 1.7% of the total number of industrial firms, they account for 26% of overall sales and 13.2% of industrial employment. Thus, it is in this group that the largest firms can be found. Their average sales are approximately 5.3 times higher than those in category B and close to 104 times higher than those in the third category. Productivity of these product-innovating firms, when measured by the ratio value added to employment, is 67% higher than that of firms with standardized goods. The category A firms are very unevenly distributed among municipalities in Brazil. The presence of this category of firm occurs in 465 municipalities, mainly in the Southeast Region and the State of São Paulo. The area surrounding the São Paulo metropolitan area tends to be most preferred by these industrial companies. In the North Region, only five municipalities

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<sup>1</sup>Details of the methodology for construction of the database can be found in De Negri & Salerno (2005).

<sup>2</sup>In this text "firm" stands for "local production unit". Any regional study should take into account the existence of local production units since a firm may have several production units.

have type A companies, while the Southeast Region have 234 municipalities with type A companies.

Firms in category B are mostly scale-intensive firms producing intermediate standardized goods and having technological upgrading based mainly on process innovations. They represent 21.3% of all firms, 62.6% of total industrial sales and 48.7% of all industrial employment in the country. The main competitive strategy of this type of firm is towards costs reducing rather than value-added increasing by new product introduction, more common in category A companies. Thus, they are operationally up-to-date, regarding manufacturing, production management, compliance-quality management and logistics, but have lower capacity regarding R&D, marketing and brand management. Out of a total of 5,507, the category B firms are located over 1,561 Brazilian municipalities. The B companies do not really need to be present in large urban areas. Based on spatial autocorrelation statistics, Domingues & Ruiz (2005) emphasize that agglomeration of type A firms seems to attract type B firms, but the opposite is not true. This locational requirement is explained by the fact that the latter firms benefit from external savings stemming from downward linkages between type B suppliers and type A users of industrial inputs.

Category C firms do not differentiate products and have lower productivity. They do not export, are smaller and generally employ price-competition strategies. They account for 77% of all Brazilian industrial firms, 11.5% of overall sales and 38.2% of employment. The category C firms are more spread across the territory and occur in 2,100 municipalities. According Domingues & Ruiz (2005), these types of firms tend to locate outside the large industrial agglomerations because of the high costs associated with urban agglomerations can only be supported by categories A and B firms. On the other hand, few type C firms can be found in major agglomerations, "occupying interstices of the metropolitan space and offering products of low unit price and high transportation cost, including some standardized food products".

Given this framework of existing inequalities among regions, which is reproduced at lower territorial scales, inter-relations between entrepreneurial capacity to innovate and regional development take on leading roles in the country's innovation process. This is due to the fact that parallel to the creation of new market opportunities for firms, innovation also brings development for the regions. Thus, innovation has attracted increasing attention as an instrument for industrial and regional policy, including objectives such as fostering development in backward regions (Sternberg & Arndt (2001); Malecki (1997)).

By classifying the Brazilian industrial firm into three types according their innovative capability, this database allows addressing the contribution of endowments more related to firms and those linked to territory. This aim can be only tackled by means of this database in Brazil, because of issues related to sample representativeness by municipalities.

### 3 Methodology

#### 3.1 Database and Variable Descriptions

##### Database

The database used in this article is organized by the IPEA and the CEDEPLAR based on a pool of data sources, mainly from micro-data of the PINTEC and the PIA of the IBGE, covering the period 1998-2000. The integration of the several databases was carried out through the National Corporate Taxpayers Registry (CNPJ). The classification of the participant companies in PINTEC in categories A, B and C was guaranteed because all of them also participated in the PIA-2000. However, the inverse was not true. It was therefore necessary to apply a methodology that allowed identification in PIA, which possesses in its sample certain representativeness by municipalities, the companies that innovated, generating new products for the market where they were active. PINTEC-2000 possessed 8,195 companies with more than 30 people occupied. Of these, 7,941 also replied to the complete questionnaire of the PIA-2000, which represented 21,746 companies with more than 30 people occupied, when expanded by the PINTEC expansion factor. The companies that participated in the PIA census, which completed the complete model of the questionnaire of the Brazilian Institute of Geography and Statistics (IBGE), totalled 24,263.

The classification of the PIA companies could use three of the four indicators through which the PINTEC companies were classified, such as: the fact of the firm being or not an exporter, work productivity and its exports price-premium. Information, however, on whether it had innovated or not, was not available for all the companies of the PIA sampling plan. The option adopted was that of classifying the companies based on estimated probability of a firm being innovative of new products for the market, starting from PINTEC. Company matching was carried out by means of a probabilistic model. In this way, for 7,941 companies, the classification was made simply by comparison of the PINTEC and PIA questionnaires, in view of the fact that all these companies participated in these two research projects. The remainder, 16,322 companies, was submitted to a probit regression which evaluated the probability of the firm being innovative, this having to be equal to or higher than that of the other 7,941. Should the firm meet this prerequisite, it would be considered a new product innovator for the market.

De Negri & Salerno (2005) summarize the whole methodological procedure, as done below:

- a) direct utilization of the PINTEC firms data, if these also made up part of the PIA sampling plan in the period 1998-2000.
- b) probabilistic matching carried out for companies present in the PIA, but that did not participate in PINTEC;
- c) estimation of the probabilistic model for companies with 30 or more people occupied, that participated simultaneously in the two sampling plans (PINTEC and PIA), in 2000;
- d) weighting of the model by the PINTEC expansion factor, so that the sum of the observations represents the universe of the industry;



- e) definition of the binary dependent variable as the condition of being innovative of new products for the domestic market and of the independent variables as characteristics of the companies, their personnel occupied, sectors and units of the federation (states) to which they belong;
- f) calculation of the propensity score of all the companies;
- g) grouping of the companies in four sets according to whether they are or not exporters and have a foreign origin in order to reduce the variance of the propensity score and increase the efficiency of the estimate criterion;
- h) calculation of the average and standard deviation of the propensity score of the innovating companies of new products in each of the four groupings created;
- i) identification of the innovating companies of new products if the propensity score is equal to or higher than the average, adding or subtracting fractions of the standard deviation of the propensity score of the innovating companies of their group;
- j) classification of the companies in the project categories (companies A, B and C), after arbitrary choice of the fraction of the standard deviation;
- k) definition of the calibration criterion for the choice of the fraction of the standard deviation, obtaining, in the PIA-2000, the percentage figure of companies in the project categories that was near that of the PINTEC-2000;
- l) choice of the average of the propensity score as that which adjusts better;
- m) estimation of the condition of being or not innovative of new products for the market based on the model and the average propensity score of the groupings of companies.

After estimation of the probabilistic model, the averages of various characteristics of the companies of each of the three project categories were compared to check the consistency of the classifications of the sampling plan of PIA and PINTEC. Close resemblance was found between these characteristics, confirming the consistency of the procedures carried out.

This database covers, therefore, the post trade-opening and privatization period in the late nineties and early years of this decade. Thus, industrial firms were already more exposed to import competition and benefited more from international technology transfers of both tangible technologies, especially capital goods, and intangible ones, such as licensing, R&D purchases and external technological services. Additionally, privatization of both intermediate goods and public-utility companies changed their behavior and innovating strategies.

#### Model's variables

The starting point of econometric specification follows Sternberg & Arndt (2001) in order to provide an international empirical comparability, in this

case with regions of the European Union countries. Some adaptations were made in order to contemplate availability of variables in the database.

These authors use introduction of product innovation and, alternately, introduction of process innovation, as a dependent dummy variable in the 1995-1999 period. Nevertheless, the database used is restricted to small and medium-sized industrial firms. The first methodological difference in this article is the use of a sample of industrial firms not limited to small and medium-sized companies. The second regards the dependent variable, which refers to categories of companies with different innovation strategies, from those centered on new processes (predominantly in category B companies) to new products, which allow the firm to lead domestic product markets and charge premium prices in the international market. Inasmuch as our estimates are carried out by each category of firms (A and B) one can compare each result with the empirical international bench mark.

Departing from these sample procedures we used two dependent variables. The first is a dummy which receives the value of 1 if the firm is in category A and zero if it is in categories B or C. The second, whose sample is restricted to firms in categories B and C, the dummy receives the value of 1 if the firm is in category B and zero if it is in C. That is, the first dependent variable regards innovating firms which introduce product innovations able to capture premium price in international markets. The second one includes the remaining innovating firms: product innovators without international premium prices and process innovators which either export or do not export but have similar efficiency standards.

The firm-level variables are: size of the firm, in-house R&D expenditure, total innovation expenditure (not including in-house R&D expenditure), origin of the capital and differences in technological opportunities among sectors, connected to four major product-market categories: extractive products, durable consumer and capital goods, intermediary goods and nondurable consumer goods.

The firm size variable is included to control the influence which differences in size have on the capacity to innovate. This argument, which goes back to Schumpeter (1961), associates positively capacity for innovation and firm size. Internal expenditure on R&D is included because it is the principal mechanism for identifying, assimilating and exploiting information or knowledge already existing in the environment, as well as for producing new knowledge useful in innovation (Cohen & Levinthal 1989).

Other disbursements with innovation, in addition to R&D, are considered to capture the contribution of the purchase of unincorporated forms of technological knowledge for innovation, which traditionally are very important in developing countries (Fransman 1985). The control of the origin of capital is included because the participation of branches of multinational companies has always characterized the industrialization process of Latin American economies, conditioning, in the last resort, the innovation process in countries. There is evidence that multinational companies participate actively in the process of technological up-dating of countries such as Brazil, allowing the introduction of products and processes new to the Brazilian market, although already existing in the international market (Gonçalves & França 2008). Intersectoral differences in innovation are considered by means of the durable and capital goods producing sectors, intermediary and non-durable consumption goods and mineral extraction goods because technological op-

portunity varies intensely between sectors (Scherer 1965, Pavitt 1984).

Of all the variables cited, only the first two above coincide with the specification in Sternberg & Arndt (2001) because of differences in the variable set of the two surveys. In addition to the reasons specified above, the variables which capture intersectoral technological differences and those that measure external disbursements with innovation and the origin of company capital possess the role of substituting two variables which the authors above included in their study, in accordance with the following explanation.

In order to substitute the variable related to the frequency of internal R&D expenditure we used the four product-market categories since they reflect differences in technological opportunities due to specific technological regimes, with distinct R&D frequencies. In fact, the alternative of using 2-digit CNAE sectors would more precisely capture sectoral differences in these opportunities. However, two levels of estimation of the hierarchical model restrict use of several variables. Inclusion of 22 sectoral dummies could result in non-convergence of the model.

Regarding variables of firm's network innovation, both internal and external to the region, we used two proxies: intensity of external innovation expenditure (that is, except in-house R&D) and origin of its capital. The former represents technological transfers especially via purchase of machinery and equipment and R&D acquisition, which supposes innovation networks external to the firm. The second refers to transfers from abroad via internal hierarchy of foreign companies, that is an innovation network internal to the firm. These two types of technology transfer are the most frequent innovation networks in late-industrializing countries, *i.e.*, connections with suppliers of capital goods and technological services and intra-firm knowledge exchanges of multinational companies.

We used the following variables to measure the influence of the regional environment in which the firms are located: adult population schooling, industrialization level, patenting per capita, R&D expenditure intensity, accessibility to São Paulo, and industrial and technological scales. This specification closely resembles that of Sternberg & Arndt (2001). For the core-periphery accessibility the European Commission index, which defines how much a region is at the periphery of development, was substituted for the accessibility to the city of São Paulo, considering its central position in the Brazilian urban hierarchy. We included the industrial and technological-scale variables in order to measure effects of agglomeration economies. Presumably, they are indirectly linked to intra-regional networks which reflect local positive externalities since innovation depends both on concentration of industrial activities and existing technological production in the region, respectively. How can these regional variables affect innovative behavior of the individual firm and, therefore, its position in the hierarchy of Brazilian firms?

Access to the city of São Paulo is a form of assessment of the extent to which distance to the main Brazilian manufacturing and financial center affects a company's propensity to innovate, which is decisive in the definition of its hierarchical position. We expect that this variable is significant and its negative sign reveals the centrality of the city in terms of knowledge urban hierarchy. Diniz & Gonçalves (2001) claim that the metropolitan area of São Paulo, despite problems of excessive urban agglomeration and traffic congestions, is still the primary location for development of intensive knowledge-related activities, due to modern services and presence of the headquarters of

the main Brazilian and multinational companies. Although this metropolitan area now has a lower share in the Brazilian industrial production, it is noticeable that it is still the preferred location of the most important Brazilian innovating companies.

Schooling level, in turn, measured here by the percentage of the population over 25 years of age with 11 years or more of education, reflects the existence of a regional labor market which can influence locational preferences of firms more sensitive to employees' skills to innovation generation. In the case of product-innovating firms with premium export prices (category A), this variable is expected to be positive and significant, while it is less important for process-innovating companies with homogenous products (predominant in category B), which employ less qualified labor than the former. The findings of De Negri & Salermo (2005) show that Brazilian manufacturing firms which employ more qualified labor are better able to differentiate their products and ensure their quality. The category A firms have employees with approximately nine years of schooling on average, while category B firms employ individuals having on average 7.6 years of schooling.

Taking into account the Marshallian external pecuniary economies, the industrialization level of the region is expected to act as an important determinant of a firm's propensity to innovate, in our case, its propensity to be classified as category A or category B. However, it is our belief that the industrial environment generating pecuniary externalities is more important for innovations in type B companies than for innovations in type A companies, due to locational patterns of these two types of company. The B companies seek to exploit scale economies internal to both the company and the localized industrial agglomeration, while they do not depend on the innovating urban diversified environments which generate the so-called Jacobian externalities (Jacobs 1969).

Thus, most firms in category B tend to seek either specialized peers agglomerations or A firms' agglomerations where they are suppliers in the production chain. Others seek specific locational advantages, *e.g.* proximity to sources of raw materials. In the case of manufacturing sectors which produce intermediary inputs, most common in type B firms, the requirements for supply of urban services are low and they could be located relatively far away from large urban agglomerations, as in the case of integrated steel-working plants. Type A Brazilian companies would, on the contrary, have greater need for locations in large urban centers, and, thus, higher tolerance for high urban costs, since part of their locational requirements is intimately linked to intensive information and knowledge activities, with strong territorial bases in more developed metropolitan areas (Lemos et al. 2005*a,b*).

Regarding the variables of patents per capita and R&D in the region, there is strong evidence that they measure different aspects of the Brazilian innovation system. According to Albuquerque (2000), sectors prone to patenting can reach a high number of patents even if little investment is made in formal R&D. Since Brazil has low participation in patents of more advanced and sophisticated technological classes (Albuquerque 2005), the variable of patents per capita is expected to capture the level of regional innovation, thus capturing as well any tendency to make use of technological knowledge externalities. The variable of R&D in the region, on the other hand, seeks to capture a different aspect of the innovation system, considering that this type of expenditure is regarded as a pre-requisite for identification, assimilation

and exploration of information or knowledge previously in existence in the environment (Cohen & Levinthal 1989). Other types of externalities may be derived from this type of expenditure, which justifies spatial agglomeration of firms to take advantage of efforts undertaken by neighboring R&D departments of both large companies and state research institutions.

Scale variables are expected to be significant and positive in both innovation categories, given the importance of agglomeration economies for the birth of innovations.

Last but not least the territorial scale is a relevant aspect of our database. Instead of a selected sample of regions, such as that used by Sternberg & Arndt (2001) for the European Union, our regions comprise the universe of the Brazilian territory. We chose the micro level for our territorial scale since the municipality level is too small and the states excessively large. We believe that the *micro-region* as defined by the Brazilian Institute of Geography and Statistics (IBGE) is suitable to undertake this study, providing simultaneously statistical power for the estimates, territorial diversity based on a reasonable set of municipalities, spatial economic scale and a comparative basis regarding the international literature.<sup>3</sup>

### 3.2 Logit and Hierarchical Regression Model

Evaluation of the contribution of endowments more related to firms and those linked to territory is carried out by means of logistic and hierarchical regression models. The latter provides the distinctive advantage of carrying out estimates while simultaneously considering both levels of variable sets which characterize the problem under study. The first level refers to characteristics of individuals, namely the firms, while the second level refers to characteristics of the regions in which the firms are located.

According to Raudenbush & Bryk (2002), the use of hierarchical models meets the following pre-requisites: 1) avoiding the need for choosing the most appropriate level for dealing with data (more aggregated or disaggregated), thus avoiding ecological and atomistic fallacy problems (Hox 1995); 2) avoiding violation of the assumption of independence of observations; and 3) not ignoring dependence between the two levels of data aggregation, which could violate the hypotheses of homoscedasticity and independent and identically distributed error terms in the linear regression model.

The logistic regression model can be formalized as follows (Greene 2003):

$$Y_{ij}^* = \beta_{kj} X_{ij} + \varepsilon \quad (1)$$

Where,

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<sup>3</sup>The variables tested as determinants of the firm's innovative behavior differ from the great majority of the variables used in the research design by IPEA and CEDEPLAR in order to avoid any risk of tautology. The latter includes only the following firm-level variables: number of employees, industrial value-added/sales ratio, dummy for origin capital, dummy for technological capability investments, average years of schooling of employees, average length of tenure, average wages of employees, dummy for export and import conditions, dummy for export premium price, expenditures with royalties and technical assistance as percentage of sales, profits as percentage of sales, dummies for 3-digit industrial classification (CNAE sectors) and dummies for Brazilian states. Our purpose was to identify the contribution of variables, both firm and regional-level, that go beyond the IPEA and CEDEPLAR's categorization.

$Y_{ij}^*$  = continuous latent variable, non-observable, which represents the capacity to innovate of firm  $i$  in region  $j$ ;

$X_{ij}$  = vector of  $k$  independent variables;

$\beta_{kj}$  = vector of  $k$  parameters to be estimated by the model;

$\varepsilon$  = normally distributed error term with a mean of zero and constant variance.

The hierarchical generalized linear model employed is in accordance to Raudenbush & Bryk (2002),<sup>4</sup> taking the following form:

$$\eta_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \beta_{3j}X_{3ij} + \beta_{4j}X_{4ij} + \beta_{5j}X_{5ij} + \beta_{6j}X_{6ij} + \beta_{7j}X_{7ij} + \varepsilon_{ij} \quad (2)$$

where subscripts  $i$  and  $j$  are indices, respectively, for level 1 and 2 units and  $\eta_{ij}$  is the logarithm of the odds ratio of success (in our case, log-odds ratio of innovation). Furthermore,

$\beta_{0j}$  = intercept;

$\beta_{kj}$  = parameters to be estimated by the model;

$\varepsilon_{ij}$  = random error term;

$X_{1ij}$  = dummy variable, which receives value if the company has more than 50% of its capital held by foreigners (a multinational subsidiary), and zero otherwise;

$X_{2ij}$  = dummy variable, which takes on the value of unity if the company produces goods from the extractive industry, and zero otherwise;

$X_{3ij}$  = dummy variable, which takes on the value of unity if the company produces durable consumer goods and capital goods, and zero otherwise;

$X_{4ij}$  = dummy variable, which takes on the value of unity if the company produces intermediate goods, and zero otherwise;

$X_{5ij}$  = size of the firm, measured by the logarithm of employees;

$X_{6ij}$  = R&D intensity, measured by logarithm of in-house R&D expenditure in relation to sales of the firm;

$X_{7ij}$  = intensity of innovation expenditure (except in-house R&D), as measured by the ratio of logarithm of total innovation expenditure of the firm (machinery and equipment, R&D purchase, other external knowledge, training, industrial projects and introduction of market innovation) to firm's output;

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<sup>4</sup>The HLM 5.0 statistic package is used in estimation of the hierarchical regression.

The  $\beta$  estimates in the equation above make possible to generate a predicted log-odds ratio, considering the chosen link function. Thus, the conversion of the log-odds ratio into a predicted probability for innovation is achieved by computing:

$$\varphi_{ij} = \frac{1}{1 + \exp(-\eta_{ij})}$$

In its simplest case, the level-2 model will contain a random term, with  $\beta_0$  labeled as random effect variable and expressed as follows:

$$\beta_{0j} = \gamma_{00} + u_{0j}, \quad (3)$$

with  $u_{0j} \sim N(0, \tau_{00})$  and,

$\gamma_{00}$  = average of log-odds ratio of innovation across regions;

$\tau_{00}$  = variance of the log-odds ratio regional average.

After estimation of this simpler case, which is also labeled unconditional multilevel model and checking if variance is significantly different from zero<sup>5</sup>, we proceed to step-by-step inclusion of variables explaining the intercept. At this point, variance in this model becomes conditional. Inclusion and statistical significance of these explanatory variables mean that the average probability of a firm being innovative varies among regions due to characteristics of the context in which they are located. These contextual characteristics can be represented as shown in the following model:

$$\beta_{0j} = \gamma_{00} + \sum_{s=1}^7 \gamma_{07} Z_{7j} + u_{0j}, \quad (4)$$

where,

$Z_{1j}$  = regional accessibility, measured by the distance from the largest city in the region to the reference city (São Paulo);

$Z_{2j}$  = regional schooling level of adult population;

$Z_{3j}$  = regional industrialization level, measured by the percentage of the regional work force employed by industries;

$Z_{4j}$  = regional innovation index, measured by the ratio patent applications to regional population;

$Z_{5j}$  = regional R&D intensity index, measured by the ratio R&D regional expenditure to regional industrial value-added;

$Z_{6j}$  = regional industrial scale, measured by the proportion of regional industrial output to national industrial output;

$Z_{7j}$  = regional technological scale, measured by the proportion of regional patent applications to the total of national patent applications.

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<sup>5</sup>Whenever variance is not significantly different from zero, there is no statistical justification for inclusion of variables explaining the intercept.

The specification above makes it possible to test the hypothesis which states that intra-regional technological-knowledge externalities, measured by patents per capita and by the regional R&D intensity index, affect innovation in Brazilian manufacturing firms significantly, controlling for other variables which the literature regards as relevant to regional innovation.

In order to guide contextual variable inclusion and estimates its importance in terms of explaining intercept variability, the following expression is used:

$$\text{Percentage of Explained Variance} = \frac{\hat{\tau}_{00(\text{unconditional})} - \hat{\tau}_{00(\text{conditional})}}{\hat{\tau}_{00(\text{unconditional})}}$$

In the next section we describe the database and the dependent and independent variables included in this model.

## 4 Regression Results

The regression models for category A companies estimate factors contributing to the firm's propensity to be A (dummy value of 1)<sup>6</sup>, *i.e.*, a product innovating firm with export premium price (at least 30%). And the models for category B companies estimate the propensity of a firm to be B (dummy value of 1), *i.e.*, a process-innovating in the domestic market and occasionally product-innovating with no export premium price, which can be both exporters and non-exporters with similar productivity levels. In summary, estimation of the firms' propensity to innovate is made indirectly by means of a typology based on their marketing and innovating activities. In short, firms are roughly divided into product-innovating per excellence (A firms), which have product differentiation as their main competitive strategy, and process-innovating firms, with more homogenous products, and competitive strategy focused on efficient production processes.

### 4.1 Results for category A Firms

Table 1 shows the first specification of the hierarchical model, which was estimated for category A innovating companies. It is the unconditional model, in which no regional variable is incorporated at level 2 (model 1A). The main use of this model is testing the null hypothesis of no difference between the intercept coefficients in Brazilian micro-regions. This hypothesis is not rejected (see bottom part of table). This means that level-2 variables need not be included in the explanation of intercept variability, given that it may be considered fixed among Brazilian micro-regions. This is no different from saying that in order to evaluate the importance of regional variables the logit regression model is sufficient. Model 1B is estimated with no random effects, yielding results similar to 1A.

Table 2 contains three models constructed in line with the logistic specification suggested by Sternberg & Arndt (2001), thus enabling comparison of results, given some differences in dependent and explanatory variables.

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<sup>6</sup>In the complete sample, B and C firms are represented by a dummy which receives zero as its value.



**Table 1:** Unconditional Hierarchical Model for Category A Firms

Fixed Effect	Model 1A		Model 1B	
	coefficient	p-value	coefficient	p-value
Intercept	-3.81	0.00	-3.74	0.00
Access to São Paulo	-	-	-	-
Industrialization Level	-	-	-	-
Regional R&D Intensity	-	-	-	-
Industrial Scale	-	-	-	-
Technological Scale	-	-	-	-
Foreign capital origin	2.24	0.00	2.26	0.00
Extractive Products	0.27	0.34	0.23	0.41
Durables and Capital Goods	1.30	0.00	1.34	0.00
Intermediate Goods	0.68	0.00	0.72	0.00
Firm Size	0.17	0.00	0.18	0.00
Innovation Expenditures	0.12	0.00	0.11	0.00
In-house R&D	0.02	0.00	0.02	0.00
Random Effect				
Variance Component	0.14	0.50	-	-
Explained Variance	-			

Source: Author, based on database built from PIA/PINTEC/ABC-Espacial (IBGE;IPEA; CEDEPLAR).

Model 2A contains all the regional variables used by these authors. However, four additional specifications are included in Table 2 (models 2B, 2C, 2D and 2E), considering the high correlation (63%) between the variables adult schooling and patents per capita and the need to incorporate technological and industrial scale variables, which are also closely correlated with each other and with schooling and patent variables (see Appendix – Table 1).

Regressions were carried out on 28,161 firms, divided among 1,496 in category A, 11,638 in category B and 15,027 in C. For a firm's propensity to be A, variables connected to the firm are generally predominant compared to the importance of territory-level variables taking into account both the number of significant variables and their level of significance. The odds ratio for the firm-level variables reflect their relative importance and are equal to the exponential of the estimated coefficient.

The results show that capital origin is the main determinant of a firm's propensity to be classified as A. Chances of a foreign capital firm to be in category A are more than 9 times greater than the chances of a national company.

It is, however, important to emphasize evidence from other studies that, although more prone to innovate, foreign industrial companies do not have leading roles in carrying out *in loco* internal R&D efforts (Araújo 2005). In other words, in spite of their contribution to national technological development, development of capacity for innovation by means of local externalities spillovers is limited. Their contribution to national technological innovation is restricted since they depend on international intra-firm technology transfers, originating from headquarters abroad.

At sector level, being in the durable and capital goods sectors increases a firm's probability of being A followed by intermediate goods sectors. Belonging to the extractive industry segment seems to contribute less to being an

innovating firm of this type.

Size of the firm also increases the propensity to be A, although exerting less influence than the previous characteristics. This result is in accordance with the so-called “Schumpeterian hypothesis”, which states that larger firms should be more capable of innovating, especially concerning product differentiation (Cohen & Levinthal 1989).

Regarding inputs for the innovation process, in-house R&D expenditure has far less impact on the propensity of the firm to be A than other innovating expenditure. Added to the importance of transnationals, this result reflects firms’ difficulties in internalizing innovation even among these top Brazilian firms which are by definition the most dynamic, and which have the greatest capacity for product differentiation in the country’s industrial structure. This is true despite distribution of internal R&D costs being concentrated in the local company headquarters unit.<sup>7</sup> Therefore, a firm’s innovation process is mainly based on knowledge acquisition, and capital goods and services purchases, instead of in-house R&D efforts. In summary, such a weakness of the leading innovating firms may reflect on the inability to form networks of local externalities fostering innovation in its stricter Schumpeterian sense, which is common in developed countries.

Regional-level variables, in turn, showed a positive and significant effect of the education variable in model 2C, which excludes the patents per capita variable. This evidence corroborates results found by Lemos et al. (2005b), in which category A companies stand out as important users of highly skilled labor.

The city of São Paulo seems to really exert strong attraction of product-innovating top Brazilian companies, since the coefficient of the variable access to São Paulo is negative and statistically significant, no matter what specification is used.

Level of industrialization, measured by the logarithm of manufacturing employment, is a significant locational factor for innovating companies in this category at 3% in the model which excludes patents per capita (2C), although it is not significant in the model which excludes adult schooling (2B). In fact, this variable is expected to be of little relevance for category A innovations, considering the fact that these companies are mostly concentrated in the metropolitan areas of the South and Southeast, especially São Paulo, where the high share of service activities reduces the relative importance of manufacturing.

The other two regional variables which try to identify externalities of technological knowledge (patents per capita and regional R&D expenditure intensity) only patents per capita is significant.

Among variables which capture the influence of agglomeration economies, which are industrial and technological scales, none are verifiably significant (models 2D and 2E). These results are not favorable for manufacturing and technological concentration to explaining product premium innovations and are not expected taking into account the empirical literature on agglomeration economies, specially the findings for Brazil (Galinari et al. 2006). A possible explanation for this apparent paradox is the fact that the accessibility variable may be capturing most of the geographical spillover effects since its signifi-

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<sup>7</sup>In the case of companies with no branches, the local unit and the headquarters are necessarily the same.

Table 2: Logistic Regression Models for Category A Firms

Variables	Model 2A			Model 2B			Model 2C			Model 2D			Model 2E		
	coef.	p-val.	Odds Ratio	coef.	p-val.	Odds Ratio	coef.	p-val.	Odds Ratio	coef.	p-val.	Odds Ratio	coef.	p-val.	Odds Ratio
Intercept	-4.03	0.00	-	-3.90	0.00	-	-4.08	0.00	-	-3.82	0.00	-	-3.79	0.00	-
Region-Level Variables															
Access to São Paulo	-0.11	0.02	0.89	-0.14	0.00	0.87	-0.12	0.01	0.89	-0.18	0.00	0.84	-0.19	0.00	0.83
Adult Schooling	0.01	0.28	1.02	-	-	-	0.03	0.02	1.03	-	-	-	-	-	-
Industrialization Level	0.10	0.10	1.10	0.08	0.17	1.08	0.13	0.03	1.14	0.10	0.08	1.11	0.09	0.11	1.10
Patents per Capita	0.06	0.03	1.06	0.07	0.00	1.08	-	-	-	-	-	-	-	-	-
Regional R&D Intensity	-0.10	0.64	0.90	-0.07	0.76	0.94	-0.03	0.90	0.97	0.05	0.81	1.05	0.09	0.67	1.09
Industrial Scale	-	-	-	-	-	-	-	-	-	0.44	0.58	1.56	-	-	-
Technological Scale	-	-	-	-	-	-	-	-	-	-	-	-	0.00	1.00	1.00
Firm-Level Variables															
Origin of Capital	2.25	0.00	9.44	2.25	0.00	9.52	2.23	0.00	9.32	2.24	0.00	9.43	2.25	0.00	9.45
Extractive Products	0.33	0.24	1.39	0.32	0.25	1.38	0.31	0.27	1.36	0.29	0.30	1.34	0.29	0.30	1.34
Durables and Capital Goods	1.27	0.00	3.57	1.28	0.00	3.60	1.29	0.00	3.62	1.31	0.00	3.69	1.31	0.00	3.71
Intermediate Goods	0.67	0.00	1.95	0.68	0.00	1.97	0.67	0.00	1.96	0.69	0.00	1.99	0.69	0.00	2.00
Firm Size	0.16	0.00	1.17	0.16	0.00	1.18	0.16	0.00	1.17	0.16	0.00	1.18	0.16	0.00	1.00
In-house R&D	0.02	0.00	1.02	0.02	0.00	1.02	0.02	0.00	1.02	0.02	0.00	1.02	0.02	0.00	1.02
Innovation Expenditures	0.12	0.00	1.12	0.12	0.00	1.12	0.12	0.00	1.12	0.12	0.00	1.12	0.12	0.00	1.12
Prob. of Correct Prediction	90,40%	***	***	90,40%	***	***	90,40%	***	***	90,30%	***	***	90,30%	***	***
Log Likelihood	4.072,87	***	***	4.071,68	***	***	4.067,95	***	***	4.062,55	***	***	4.062,24	***	***
Wald Statistic	2.448,2	***	***	2.446,53	***	***	2.450,32	***	***	2.447,07	***	***	2.446,86	***	***

Number of Firms - Category A: 1,496

Number of Firms B and C: 26,665

\*\*\* Statistically significant at 1%

Source: Author, based on database built from PIA/PINTEC/ABC-Espacial (IBGE;IPEA; CEDEPLAR).

cance and coefficient level do not reduce with the introduction of these scale variables.

#### 4.2 Results for Category B Firms

In this section, factors explaining the tendency of a firm to be classified as B are estimated. Type A companies were removed from the sample and the dependent variable receives the value of one if the company belongs to category B and zero if it falls under category C. Exclusion of A firms in regression of B firms is in accordance with the assumption of technological progression from one firm category to the next. Approximately 1,496 local units were removed from the sample, leaving 11,638 units in category B and 15,027 in category C. Table 3 contains six different specifications for explaining a firm's propensity to be a category B company, with the B and C company sample. According to Raudenbush & Bryk (2002), the coefficients estimated by these models can be interpreted as the expected difference in the log-odds ratio of a firm being B, associated with the increase of one unit in the explanatory variable, all else remaining constant, as well as the value of the random effect ( $u_{0j}$ ).

Model 3A, which is unconditional, only has level-1 variables (firm attributes). Successive inclusion of explanatory variables at level 2, from Model 3B to 3F, increased explained intercept variance from 10.20% to 16.32%. Level-1 variables had very stable coefficients regardless of the model specification, which indicates robustness of attributes of firms as explanatory factors for B firms. Thus, analysis of Model 6A results serves as analytical reference for level-1 variables.

Except for the dummy variables which represent the intermediate-goods sector and in-house R&D expenditures, all estimated parameters are verifiably highly significant and have the expected direction. If the firm belongs to a multinational group, the expected log-odds ratio for a firm to fall under category B is 3.17, which is 23.81 times higher than the odds ratio of a national firm in the sample set. Since the estimated coefficient for this variable is the one with highest absolute value, this means the presence of firms which are subsidiaries of multinational companies is the main entrepreneurial characteristic in terms of impact in the probability of a firm being classified as B, *i.e.*, scale-intensive, specialized in homogenous products, exporting (mostly) and focused on process innovation. This result illustrates rather well how the fact that a firm's efforts toward innovation in Brazil is still greatly influenced by technology transfers, especially know-how, resources, products and processes developed by headquarters for later adaptation in the incumbent economy.

As in the case of type A firms size is positively associated with the log-odds ratio of a firm to be B, suggesting, according to literature, that larger firms are better prepared for successful innovation. An increase of 1.12 units (one standard deviation) in the size of the company leads to an increase in the log-odds ratio of 0.5152 or to a relative odds ratio of  $\exp(0,5152) = 1,6740$ . These results corroborate the "Schumpeterian hypothesis" of the importance of size for Brazilian manufacturing B firms for their capacity to innovate and grow.

In terms of technological efforts, there is a clear preponderance of external innovation expenditure over in-house R&D given its non significance. In addition to purchases of knowledge incorporated into machinery and equipment this comparison also shows the importance of acquiring external disem-

bodied knowledge to innovate in B companies. This is an important difference of B firms from the A firms. These, unlike B firms, undertake some internal R&D effort despite being less important than external innovation expenditure.

Unconditional intercept variance estimates in Table 3, *i.e.*, random effects of the models, show that the probability value enables rejection of the null hypothesis at 0.1% that the intercept is fixed, in favor of the alternative hypothesis that Model 3A intercept is random at level 2. This result justifies inclusion of level-2 variables to model the intercept.

Model 3B, which contains the first regional level-2 variable included in this study, shows that the level of industrialization explains intercept variance, by approximately 10.20%. This means that 10% of the variation in the average tendency of a company to fall under the B category is explained by the differences, in terms of in differences of industrialization level observed among micro-regions.

With successive inclusion of explanatory variables at level 2, the percentage of variance explained in models 3C to 3F increases gradually to 16.32%. Model 3F contributes most to explaining this variance, despite some variables included, such as access to São Paulo and R&D intensity in the micro-region, are not statistically significant. Thus, in this model, approximately 16% of the variance is explained by inclusion of level of industrialization and patents per capita.

Access to the São Paulo micro-region does not seem to be a fundamental determinant of this category, unlike category A companies whose proximity to a network of highly qualified services matters. On the other hand, the percentage of adults with over 11 years of education is relevant as a locational requisite for type B companies at the 10% level (model 6E).

The second most important variable to explain intercept variance is patents per capita. This means that the probability of finding an innovating B company is higher when the micro-region has high performance in terms of patents per capita. This evidences that an effort to innovate exists as a result of patenting activities in locally established B firms, which may enable intra-micro-regional technological knowledge spillovers among companies. The search by B firms for more innovating regions may reflect locational strategies to take advantage of these externalities, albeit taking place in segments of lesser technological intensity. As shown by Albuquerque (2005), the Brazilian patenting activity is predominant in low to middle-technology sectors, as in the scope of “family consumption” and “mechanical components”, with little emphasis placed on the scope of more advanced technology, such as “biotechnology”, “semiconductors” and “organic and macromolecular chemistry”.

Findings that the most relevant regional variables are level of industrialization and patents per capita lead us to conclude that type B firms have locational behavior of greater proximity to industrialized regions with large consumer markets compared to C firms, which are more geographically spread out and seek local and regional markets. According to Lemos et al. (2005a), type B companies follow a locational behavior intended to maximize internal scale advantages either being durable consumer-goods producers or intermediate goods ones. Thus, part of the B firms tends to agglomerate with each other or among A companies. Others search for specific locational advantages, such as proximity to sources of raw material.

**Table 3:** Hierarchical Model for Innovating Firms – Category B

Fixed Effect	Model 3A		Model 3B		Model 3C		Model 3D		Model 3E		Model 3F	
	coef.	p-val.	coef.	p-val.	coef.	p-val.	coef.	p-val.	coef.	p-val.	coef.	p-val.
Intercept	-2.42	0.00	-2.94	0.00	-2.81	0.00	-2.81	0.00	-3.08	0.00	-2.92	0.00
Industrialization Level	-	-	0.24	0.00	0.23	0.00	0.22	0.00	0.23	0.00	0.18	0.00
Access to São Paulo	-	-	-	-	-0.07	0.07	-0.07	0.07	-0.01	0.76	-0.01	0.76
Regional R&D Intensity	-	-	-	-	-	-	0.13	0.62	0.14	0.59	-0.04	0.87
Adult Schooling	-	-	-	-	-	-	-	-	0.04	0.04	-	-
Patents per Capita	-	-	-	-	-	-	-	-	-	-	0.21	0.00
Origin of Capital	3.17	0.00	3.17	0.00	3.17	0.00	3.17	0.00	3.17	0.00	3.17	0.00
Extractive Products	0.43	0.00	0.44	0.00	0.45	0.00	0.45	0.00	0.46	0.00	0.46	0.00
Durables and Capital Goods	0.64	0.00	0.64	0.00	0.64	0.00	0.64	0.00	0.64	0.00	0.64	0.00
Intermediate Goods	0.04	0.26	0.03	0.27	0.04	0.24	0.04	0.24	0.04	0.24	0.04	0.25
Firm Size	0.46	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.45	0.00	0.45	0.00
Innovation Expenditures	0.003	0.02	0.003	0.02	0.003	0.02	0.003	0.02	0.003	0.02	0.003	0.02
In-house R&D	0.003	0.17	0.005	0.16	0.003	0.16	0.003	0.16	0.003	0.16	0.003	0.17
Random Effect												
Variance Component	0.49	0.00	0.44	0.00	0.43	0.00	0.44	0.00	0.43	0.00	0.41	0.00
Variance Explained (%)	-	-	10.20	-	12.24	-	10.20	-	12.24	-	16.32	-
Number of Firms - Category B: 11,638												
Number of Firms - Category C: 15,027												
Source: Author, based on database built from PIA/PINTEC/ABC-Espacial (IBGE;IPEA; CEDEPLAR).												

The variable which measures regional-R&D expenditure intensity is not statistically significant. This finding confirms the small importance of R&D expenditures in the innovation efforts of B firms. On the other hand, the relevance of the patents per capita variable suggests that local technological knowledge spillovers seem to take place for B firms. This tells us that the local innovation networks may favor the location of these firms.

These results reinforce the evidence of the adaptive nature of R&D expenditure in Brazilian industrial firms, since B firms stand for 67% of value added in the national industry. Contrary to developed countries, this type of expenditure with innovation in Brazilian industry is predominantly adaptive, not sharing the level of novelty present in foreign peers. Thus, significance of patents per capita and non-significance of R&D at micro-regional level is coherent with characteristics of the Brazilian innovation system, centered on technological segments of medium and low technological complexity and little reliance on R&D expenditure, which is a diffused practice in companies, particularly those of type B.

The variance proportion explained by level 2 of the model allows for inference of the extent to which regional variables are important requisites for the innovative process *vis-à-vis* those internal to the firms. As shown in Table 3, this proportion of variance is basically explained by two regional variables, which account for 16.32%. This means that approximately 16% of inter-micro-regional variability of the propensity of a firm to be B is due to territorial variables of level of industrialization and patents per capita. In summary, this shows that firm-level variables have greater influence on the propensity to innovate, regarding regional variables, in the case of the Brazilian industry. Table 4 is an extension of Table 3, since it includes scale variables among level 2 variables. Model 4A is the same as 3A, repeated for purposes of calculation of the variance explained at the end of the table. Both variables are noticeably not significant, although level of industrialization is relevant for firms in category B.

## 5 Conclusions

This article sought evidence of the relative importance of variables connected to the firm and territory as determinants of the propensity to innovate in Brazilian industrial firms. We used a typology which defines innovating characteristics of firms which go beyond the usual division between product and process innovations. Its advantage is capture competitive strategies related to product differentiation, productive efficiency and forms of insertion in the export market. Using logistic and hierarchical regression methods we test two hypotheses related to the general objective described earlier: 1) regional attributes are complementary to attributes internal to firm in Brazilian innovating industrial firms, although their importance varies according to the type of firm under consideration and the structural characteristics of these firms (classified as A, B or C); 2) intra-regional technological knowledge externalities, measured by patents per capita and local R&D expenditure intensity, affects significantly and positively Brazilian innovating industrial firms.

Results showed that the first hypothesis is valid for Brazil and consistent to the international empirical literature, emphasizing the clear predominance of variables connected to the firm whatever its type (A or B), both in terms of

**Table 4:** Extended Hierarchical Model for Category B Companies

Fixed Effect	Model 4A		Model 4B		Model 4C	
	coef.	p-value	coef.	p-value	coef.	p-value
Intercept	-2.42	0.00	-2.83	0.00	-2.83	0.00
Industrialization Level	-	-	0.22	0.00	0.22	0.00
Access to São Paulo	-	-	-0.07	0.07	-0.07	0.09
Regional R& D Intensity	-	-	0.10	0.70	0.11	0.66
Adult Schooling	-	-	-	-	-	-
Patents per Capita	-	-	-	-	-	-
Industrial Scale			4.74	0.20	-	-
Technological Scale			-	-	1.88	0.36
Origin of Capital	3.17	0.00	3.17	0.00	3.17	0.00
Extractive Products	0.43	0.00	0.45	0.00	0.45	0.00
Durables and Capital Goods	0.64	0.00	0.64	0.00	0.64	0.00
Intermediate Goods	0.04	0.26	0.04	0.26	0.04	0.25
Firm Size	0.46	0.00	0.45	0.00	0.45	0.00
Innovation Expenditures	0.003	0.02	0.003	0.02	0.003	0.02
In-house R& D	0.003	0.17	0.003	0.16	0.003	0.16
Random Effect						
Variance Component	0.49	0.00	0.44	0.00	0.44	0.00
Variance Explained (%)	-		10.20		10.20	

Number of Firms - Category B: 11,638

Number of Firms: 15,027

Source: Author, based on database constructed from PIA/PINTEC/ABC-Espacial, (IBGE; IPEA; CEDEPLAR).

impact on its propensity to fall into one of these categories and in regard to the significance of the chosen variables.

Origin of capital is the main determinant of innovation in Brazilian industrial companies. This is true for A companies but becomes even stronger for type B companies. However, the role of transnational companies is paradoxical. On the one hand they are important for technological and productive upgrading of the national industrial structure. On the other, they do not play a leading role in in-house *in loco* R&D. In truth, they transfer existing products to their local subsidiaries with varying adaptation efforts. This is strong evidence that the predominant mechanism of technological transfers to Brazilian industrial firms has been maintained via the hierarchy of multinational companies to their subsidiaries, even in the post-opening and privatization period from the late nineties onwards, when a modernizing process of domestic industry was taking place.

Another important determinant of innovation is the size of the firm regardless of its type. This is further evidence corroborating the “Schumpeterian hypothesis” about the ability of larger companies to incorporate technical progress as part of their routines.

The weakness of the national innovation system is visible from the modest contribution of in-house R&D expenditure on the propensity of Brazilian industrial firms to be category A or B firms. This variable has far less impact than the set of external innovation expenditure. Added to the importance of transnational capital, this result reflects the eminently marginal and incremental character of Brazilian innovation, which is more focused on acquisition of external knowledge, goods and services than the internal R&D effort.

Regarding regional variables, São Paulo confirms its power to attract innovating companies in Brazil, given that the coefficient of the variable of access



to São Paulo is negative and statistically significant for the type of innovating firm taken as reference for this study (A companies). Industrialization level is a relevant locational factor for innovating companies, although its importance is more evident in category B companies than in those of category A. The relevant role of adult population schooling in both types of companies is also noteworthy.

Of the two regional variables which seek to capture the existence of intra-micro-regional externalities of technological knowledge (patents per capita and micro-regional R&D intensity), only patents per capita were statistically significant for companies in both categories A and B. This result shows that the second hypothesis in this study is only partially confirmed. Significance of patents per capita and the lack of micro-regional R&D significance is coherent with characteristics of the Brazilian innovation system, centered on technological segments of low and middle complexity and low in-house R&D expenditures, especially for type B firms.

Variables of industrial and technological scales were not significant for classification in both categories of firms, a finding which may best be explained by statistical problems rather than non-relevance of these variables, given their role in theoretical and empirical literature. Their strong correlation with both the accessibility and education variables show the statistical difficulties in handling adequately these scale variables.<sup>8</sup>

Despite methodological differences, some comparisons between this article and Sternberg & Arndt (2001) can be made. The common point is that variables referring to territory are secondary to those regarding the firm. Nevertheless, level of industrialization, patents per capita and R&D intensity of the micro-region increases the probability of innovating, especially product innovations estimated by the propensity to be an A firm. In the case of Brazil, level of industrialization is also important, as well as proximity to São Paulo. The greater the distance to this metropolitan micro-region, the less likely it is to find category A or B companies, although this result is notably more important for category A companies. Schooling of the local working population is also relevant in both cases.

A striking difference between the two studies is the importance of the three R&D dimensions captured by the European survey, considering both a regional indicator, measuring R&D expenditure to Gross Domestic Product, and firm-level indicators, measuring in-house R&D and R&D frequency. In place Europe, they were considered relevant in product innovations, but not in process innovations. In Brazil, internal R&D expenditure is relevant, particularly in category A companies. On the other hand, regional R&D intensity was not significant in any of the regressions, which could reveal differences in the nature of innovations among European countries and late-industrialization countries related to the importance of intra-regional networks to innovate.

Territorial connection networks formed by small and medium European firms were not statistically significant in the model for product innovations. But, in the case of process innovations, statistical significance was found both in intra- and inter-regional links. In the case of Brazil, inter-firm links were indirectly measured by total innovation expenditure external to the firm and

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<sup>8</sup>It should be noted that in Table 1 of the Appendix, for instance, the correlation matrix for the whole sample of companies indicates correlation of these variables with the variable of education of 0.78 and 0.75, respectively.

by origin of capital. Both variables are very important for both categories of firms, corroborating the importance of links between innovators and suppliers of capital goods and subsidiaries with headquarters of multinational companies.

Another difference is found in the fact that size of the company matters considerably in Brazil, but not in the study of the authors mentioned above. The reason for this is probably the inexistence of large firms in the European sample.

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