Innovation, urban attributes and scientific structure: a Zero-Inflated-Poisson model for biotechnology in Brazil

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ABSTRACT

The paper assesses the extent to which the environment is associated with the incidence of innovation. Patents filed are used as proxy for innovation and Brazilian municipalities are the spatial unit. Two dimensions related to the location are taken into account: the presence of science and technology infrastructure and urban attributes, identified here as economic scale, industrial scale, modernity and urban hierarchy. The object of analysis is the biotechnology sector, a segment of high technological complexity, which is expected to be more sensitive to the environmental variables. Results show the importance of the public sector on the technological output as the findings indicate the importance of investing in urban structure, especially in regions with a lower level of economic development. Factors such as specialized services sector, degree of centrality and industrialization level are critical for the upgrade of non-innovating municipalities to the innovation generating group. This means that incentive policies regarding science and technology can be more successful if they encompass investments in qualification and modernization of the cities and their urban infrastructures.

Keywords: innovation; urban attributes; scientific structure.

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1. INTRODUCTION

The relationship between Science and Technology (S&T) has been widely assessed on several perspectives. From a theoretical point of view, many models have been proposed to characterize these interactions. Some of them recognize that the association between S&T forms a spiral in which scientific and technological production influences each other mutually and continually.

More recently, however, several contributions discussing the localized character of scientific and technological production have been published in the scientific literature. Basically, these studies recognize that beyond the S&T spiral, there is an urban dimension which may strongly influence this relationship.

A number of studies have point to the large asymmetry in the spatial distribution of innovation and knowledge. Most of these analyzes aim at explaining the reasons for the worldwide concentration of the rate of technological production in which certain regions play the role of inducing innovation, while others seem to be relegated to the role of adopters.

In some segments of the technology frontier, such as biotechnology, spatial concentration tends to be even more significant. From a regional economic perspective, these segments are polarizer[4] and consequently are located in huge industrial areas affording high urban costs. These sectors also require better urban infrastructure and qualified labor force. The total costs are in general higher, albeit balanced by a diversified offer of factors of production, which is the basic condition for companies with a higher technological complexity.

The aim of this paper is to assess the extent to which the environment is able to influence the incidence of innovation. We use as proxy for innovation the patents filed and as spatial unit of analysis the Brazilian municipalities. We consider two dimensions related to the location: the presence of scientific structure and urban attributes, identified here as economic scale, industrial scale, modernity and urban hierarchy. The object of analysis is the biotechnology sector, a segment of high technological complexity, which is expect to be more influenced by the environment.

2. THE BIOTECHNOLOGY SECTOR IN BRAZIL

Throughout the 20th century, Brazil have been to a process that fostered the biotechnology sector. This was mainly due to the governmental efforts focusing on the expansion of the scientific and

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[4] The term "polarizer" refers to the fact that companies which innovate and stand out are centripetal, meaning that they have relevant agglomerative power.

technological base of competence of teaching and research institutions. In addition, many incentive programs favoring biotech companies such as the provision of resources and the encouragement of university-industry interaction have been implemented.

The first public efforts focusing the biotechnology sector trace back to the 70's. Although at that time the activities were not called biotechnological, they covered the scientific and industrial sectors which were users of the classic biotechnology techniques. The actions were promoted by the National Council for Scientific and Technological Development (CNPq) and the FINEP (Studies and Projects Finance Organization), founded in 1951 and 1965 respectively. The 70's were also marked by the establishment of the Brazilian Agricultural Research Corporation (Embrapa), which not only supported but also promoted the development of agricultural research[5].

Despite the strengthening of the sector proportioned by those institutions, Brazilian companies which operated in the early 80's still worked basically with classical biotechnology. Moreover, the companies were concentrated in the South-southeast hub, due to the concentration of the country's economic resources in this region (Souza, 2001). The first governmental aid to biotechnology was given in 1980 through the Genetic Integration Program, which involved the participation of FINEP. Also in this period, actions at the state level began to be implemented. Examples are the programs of the São Paulo Research Foundation (FAPESP), the establishment of the Business Incubator BIO-RIO Foundation(1988) and the Biominas Foundation (1990).

The Program of Support for Scientific and Technological Development (PACDT) was a federal government initiative, performed together with the Inter-American Development Bank (IDB), which aimed to develop S&T at the national level. Furthermore, during the 90's, the Industrial Property Law was approved[6].

According to Silveira *et al* .(2004), perhaps the most important action that stimulate R&D&I (Research, development and innovation) in Brazil was the Brazilian Program on Human Resources for Strategic Areas (RHAE), currently managed by the CNPq. The program was created in 1987 to support the qualification of human resources in technological innovation, and biotechnology was one of the areas considered as priority. As a result, "there was in a short time, the formation of a qualified professional workforce able to work on joint projects involving the participation of academic and business sectors." (Silveira *et al*., 2004:38).

A recent examination of the government incentive reveals that the investment in qualified professional formation is still being performed, and more than that, has expanded over the years. As examples we

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[5] Embrapa, under the Ministry of Agriculture, Livestock and Supply (MAPA), was established in 1973. The institution operates through research units, departments and administrative units, present in almost all Brazilian states. Currently, Embrapa has about 9,200 employees, of which about 2,200 are researchers.
[6] The Industrial Property Law has three main goals: the creation of establishing strategic partnerships environment among universities, technological institutes and companies, stimulating the participation of S & T institutions in the innovation process, and encouragement of in company innovation.

have the expansion of multidisciplinary doctoral programs, encompassing the environment, biotechnology, supplies, social sciences and humanities areas. (CGEE, 2010).

Table 1 show that the number of multidisciplinary doctorate programs has grown about 730% from 1998 to 2008.

Table 1 – Number of doctoral programs by knowledge area, Brazil (1998-2008).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total[7]	782	789	802	912	923	942	1.058	1.097	1.185	1.245	1.320
Multidisciplinary	10	12	15	21	24	22	33	36	43	69	83

Source: elaborated by the authors, from CGEE 2010.

However, despite of the government incentives since the 1970s, "biotechnological innovations did not occur with the same dynamics as in developed countries" (Souza, 2001, p. 42), so we may conclude that the State participation in S&T was bellow the actual needs of the country.

National biotechnology companies' turnovers are an indicator of the segment performance in recent years. In Brazil, the stock market is not a viable measure to analyze the financial performance of biotechnology firms, since only one of them, the BIOMM, has launched IPO[8] to date. According to the results of a survey by Biominas Foundation, the number of companies that do not profit increased from 17.8 % in 2008 to 19.7 % in 2010. Furthermore, even companies longer established in the market are not able to profit high sums; in 2010, only 16 % of the 10 to 15 year old companies profited more than R$ 1 million.

According to Albuquerque (1995), one possible explanation for this performance is that, despite having built a national structure of S&T, Brazil has not been able to do the catching up process, that is, to reach a level of technological development level similar to the more technologically advanced countries. Souza (2001) offers three explanations, namely (i) low offer of adequate financing mechanisms; (ii) excessive and generalized protection of the segment and (iii) low qualification of productive workforce.

An additional explanation is linked to the characteristics of the environment in which the research centers and these companies are inserted in. Recently, there has been an increase in the literature regarding the geographical issue as a determinant in the innovation process. These studies try to understand the relative role of location in the innovation process of firms regions and countries.

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[7] Total of doctoral programs in 8 fields, namely: Sciences, Agricultural Sciences, Biological Sciences, Health Sciences, Exact and Earth Sciences, Human Sciences, Social Applied Sciences, Engineering, Linguistics, Languages and Art.

[8] Initial Public Offering.

Although innovation is crucial for the development of biotechnology, the results obtained so far do not match the investments received. For that reason, the question that arises is whether the innovation is being stimulated in the correct manner. It is therefore necessary to know what are the factors determining innovation in this segment and in what proportion.

3. INNOVATION DETERMINING FACTORS: THE ROLE OF THE URBAN

Many are the studies investigating the decisive factors which trigger firm innovation.. Some works analyze the influence of the intrinsic characteristics of the companies (De Negri, 2006), while others evaluate the impact of the institutional, scientific or spatial environment in the ability of innovating (Avellar, 2009); (Albuquerque *et al.*, 2002; Montenegro *et al.*, 2009). Trying to compare these dimensions, some studies measure internal and external attributes effects in a company (Harrison, 1996; Stenberg e Arndt, 2001 e Gonçalves *et al.* (2006).

In the light of these contributions, this article aims to corroborate the hypothesis that the geographical space plays a crucial role in the incidence of innovation[9], seeking to identify the impact of several spatial variables and of scientific structure on the occurrence of innovation. Hence, it is important to analyze the contributions of the literature on the effects of location effects for productive activity as well as for innovation

Many contributions on the incorporation of the spatial issue as a determining factor to the innovation process have been published recently. These studies aim to understand the relative role of the location on the innovative process in the companies, regions and countries. Their main conclusions suggest that innovation and knowledge generating processes are interactive and local. This happens because, as stated by Lastres *et al.* (1999), "interaction among local agents from the same location favors the process of innovation generation and distribution."

The first significant contribution in economics to the understanding of the dimension of the locality to innovation was made by Marshall in the end of the 19th century. This author analyzed the organizational pattern of clusters of small firms in England, developing the concept of industrial districts. The effects of the concentration of economic activities in a given geographic territory were called either economy of agglomeration or external economies of scale. External economies of scale are externalities generated in a certain sector or industry level. They are classified either as static (associated with an increase in the firm's productivity) or dynamic (related to an increase in the growth rate of the firm). In its static form, the economies of agglomeration are divided in localization

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[9] Although this work has a highly spatial focus, it does not disregard the influence of internal attributes on the firm's innovation capability. As mentioned in the scientific literature, the internal and external attributes influence each other, being the effect of the firm's training complementary to the territorial insertion of companies.

and urbanization economies. The former is external to the firms, though internal to an activity sector, while the latter is external to the firms and industry.

Glaeser *et al*. (1992), distinguish two groups of externalities under the dynamic form, both related to the growth of a given location or region. The first is known as Marshall-Arrow-Romer (MAR) externalities, since they derive from the theoretical propositions of Marshall (1890), Arrow (1962) e Romer (1986). They are related to the localization economies because they also highlight the benefits of the concentration of firms in the same industry, but in a dynamic way. On the other hand, the Jacobian externalities are generated due to the diversity of the industries or sectors that interact in a given locality.

Fujita & Thisse (1996) suggest that the majority of the sources of agglomeration economies (dynamic or static) arise from the geographically concentrated industrial production. This means that they are external to a firm, but internal to industry. The three sources of economies, which are internal to industry, are: (i) specialized workforce and knowledge production from human capital accumulation and social interactions; (ii) availability of supplies and resources required to production and (iii) present infrastructure in industrial districts which are a kind of positive externality generated by the agglomeration.

External economies of scale are, therefore, the result of the geographic concentration of plants and firms of a specialized industry, as the increase of the productivity of the factors is a result of the specialization gains. According to Marshall (1980), the three sources or externalities of scale which come from specialization gains are: input sharing – the use of supplies common to all the firms; labor market pooling, which is the existence of a labor market for the specialized workforce, and finally knowledge spillovers, which are the advantages from the exchange of knowledge among firms and individuals involved in the production process.

Despite the advances in the means of communication, the geographic proximity is still a relevant factor when it comes to sharing technical and organizational information. According to Feldman (1994), "knowledge crosses corridors and streets easier than continents and oceans". Storper & Venables (2003) argue that the geographic proximity is an important issue for environments where the asymmetry of information prevails – key characteristic on the majority of innovative activities. The fundamental aspect of the geographic proximity is the so-called face-to-face contact. Benefits from this method of communication are related to its main features: the possibility of assisting the resolution of incentive problems, facilitating socialization and learning; and provision of psychological motivation. Finally, the face-to-face contact is a key element to what they call buzz of the city, which is, the hustle and bustle of informal and social relations in the urban environment, which will largely determine the flourishing of the corporate innovative action.

Rodríguez-Pose & Crescenzi (2006) also highlight the importance of geographic proximity to the incorporation of the spillover effect. The authors developed a model that compares, concomitantly, the effects of three factors on Europe's innovating capacity: (i) investment in Research & Development, patents and economic growth; (ii) local systems of innovation; and (iii) diffusion of knowledge spillover. The results reveal the importance of geographic proximity to knowledge transfer, since the diffusion of ideas is highly related to distance[10].

Besides the effect of the geographic proximity on knowledge transfer, there has been a greater concern regarding the incorporation of the urban attributes as decisive to the innovation capacity of some regions. Urban attributes may be understood as the variables which define or constitute cities or other central locations, such as total population, industrial production, modern productive services and urban amenities.

Several authors evaluate the link between urban attributes and R&D activities or industrial productivity. Albuquerque *et al*. (2002), analyzed the association between the production of items at urban scale and patent production, showing that "economic-urban scale dimension in Brazil is still more relevant than the production of patent in explaining the behavior of scientific production.

Urban amenities have been increasingly incorporated as crucial to residential location decisions (Smith *et al*., 1988), to productive decisions (Granger & Blomquist 1999) as well as to aspects associated to urban and regional development and growth. Sivitanidou & Sivitanidou (1995) relate amenities with the distribution of scientific activities; Angel (1989) define them as a key factor to the gathering of scientists and technicians, Blomquist *et al*. (1988) take the amenities as critical to quality of life and urban centers scale. Glaeser *et al*. (2001) relate higher urban growth rates to the presence of developed amenities in a given urban area.

In Brazil, there are few works concerned with the relationship between urban amenities and regional development. Marcedo & Simões (1989), for instance, links the urban amenities to intra-urban spatial structures and their growth potential.

Another role of the urban attributes in the economy refers to their ability to enhance the economies of agglomeration arising from external economies of scale or local externalities. Freitas (2012) shows that that technology-intensive industries and financial services are relatively concentrated in diversified urban centers due to available advantages, which are able to increase productivity. The finding is particularly interesting since biotechnology is a capital intensive sector, which recognizes the importance of analyzing the effects of locality on the sector's innovative activity. Still, recent contributions from scientific literature which come closer to the locality importance approach to the segment, mainly analyze the formation and the effects of the

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[10] According to Machado *et al*. (2012), urban amenities are a "set of public assets and services that generate positive externalities for the local population and visitors."

Studies such as those from Souza (2001), Botelho (2004), Carrijo (2005), Rosa (2005), Judice (2005) and Ferrado (2008) try to identify the profile of the companies, their skills of internationalization and innovation, the scientific and technological infrastructure of the region as well as the institutional environment they are inserted

The main conclusion of these authors is that, although having developed some internationally recognized projects, Brazilian technological PLAs are still incipient (Souza, 2001). The main problems identified as barriers to the establishment of the biotechnology clusters are the low interaction among the agents, particularly the universities, the bottlenecks in the institutional environment in the provision of financing sources and the weakness of the governance structure.

The aforementioned works were not sufficient to analyze the relevance of the urban environment to the innovative activity of the national biotechnology sector. As stated before, the present study aims to incorporate these issues in the analysis, rating how the availability of urban attributes together with presence of the technical and scientific may influence the innovation incidence in biotechnology.

4. METHODOLOGY

4.1. Database

A) National Industrial Property Institute (INPI)

INPI is the Brazilian agency responsible for trademarks registration and concession for patents, industrial design, technology transfer, geographic indication, computer software and integrated circuit topography. Information from the agency was consulted in order to obtain the listing of biotechnology patents filed recently. This variable was used as proxy for innovation[11].

The database used in this article was built by Dias (2012). The International Patent Classification (IPC) [12] was used to identify biotechnology patents. As this database has no restrictions regarding the date of filing date, we extracted all patents applications published online by INPI residents from 1975 to 2008. Nevertheless, the amplitude of the period of analysis is not a limitation, since 90.1% of the patents were filed after the 90's, with 71.1% of the total after 2000. We found 1,232 patents related to biotechnology filed at the INPI made by residents.

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[11] The discussion concerning the use of patents as proxy for innovation is wide and not consensual. It is not the aim of this article to deepen in this discussion. For detailed information on the theme, see: Pavitt (1988), Griliches (1990), Pavel *et al*. (1995).

[12] IPC was established by the Strasbourg Agreement in 1971, and provides a hierarchical system for classifying patents according to the different technological areas to which they belong to. There is no single category provided by IPC that fits patents in biotechnology, as this area encompasses a group of related technologies. Thus, in 2005, the Organization for Economic Cooperation and Development (OECD) published a guide with a list of 30 IPC codes corresponding to biotechnology patents for the production of biotechnological statistics. For the analysis of patents in biotechnology it was used as the search filter these 30 IPC codes suggested by the OECD.

Table 2 – Number of biotechnology patents filed by residents at INPI (1975-2008), according to type of filer, Brazil.

Type	Total
Academic	383
Individual	322
Company	270
Government	257
TOTAL	**1.232**

The limitation of this database for use in this study lies in the fact that it does not specify the municipality of the filer. For this reason we removed from the analysis those patents whose owners were individuals. Thus, the analysis was restricted to the production of technology by companies, universities and government.

The identification of the municipality was carried out through a method used by Albuquerque *et al*. (2002), which involves data crossing from INPI (identification of the holder) with the information from RAIS (which connects the holder with the municipality). The crossing of this information allowed the identification of the municipality source of 895 biotechnology patents distributed in 226 Brazilian municipalities.

The data assembled in this study contribute to the characterization of the regional differences in terms of technological production in biotechnology. The filing of patents in Brazil is highly concentrated in some municipalities, as a result of the continental dimension and regional disparities of the country. Graph 1 shows the distribution of biotechnology patents per municipality in Brazil.

We observe that 98% of the Brazilian municipalities have no patent in biotechnology filed by residents either through universities, companies or government. On the other hand, among the municipalities with at least one patent filed, 85% have between 1 and 10 patents, and of these, the majority (58%), have only one patent filed.

The municipality with the greatest number of patents filed is São Paulo, highlighting the participation of academic and governmental institutions. Among the governmental institutions, The State of São Paulo Research Foundation FAPESP (56 patents) and São Paulo IPT –Institute for Technological Research (21 patents) stand out. In the academic sphere, the largest filer is the University of São Paulo (61), followed by State University Julio de Mesquita (18).

Rio de Janeiro houses the government agency with the largest number of patents filed: Oswaldo Cruz Foundation (FIOCRUZ) with a total of 69 patents. Also noteworthy are the Federal University of Rio

de Janeiro and Petrobras with 38 and 35 patents filed respectively. The latter is the Brazilian company with the largest number of patents in biotechnology.

Brasília's prominence, however, must be carefully analyzed. The city has 83 patents in biotechnology, 40 of them filed at INPI by Embrapa. As Embrapa operates nationwide all its patents are filed at its headquarters, which is located in Brasília. Another prominent institution in the city is the University of Brasília (UnB), with 30 patents filed.

Graph 1- Biotechnology patents distribution filed by residents at INPI (1975-2008), Brazil (by municipalities)
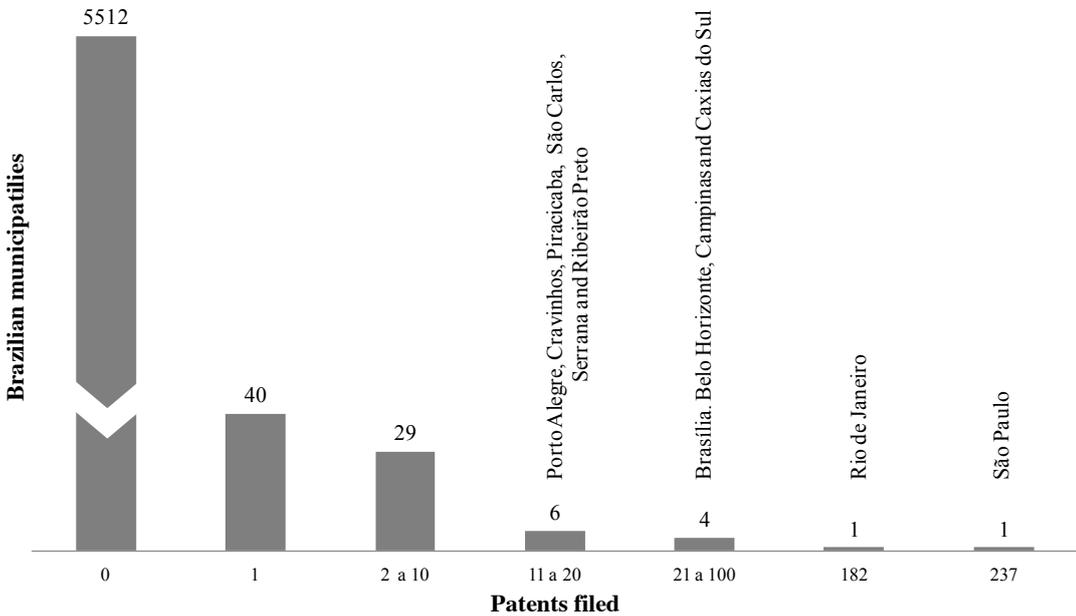
Source: elaborated by the authors from Dias, 2012

Compared to developed countries, the level of spatial concentration of technological activities in Brazil is even greater. Crescenzi *et al*. (2007) carried out an analysis covering all economic sectors aiming the comparison of the spatial distribution of patents in the USA and Europe. The results indicate that the level of concentration is similar in both regions, yet very lower compared to the results shown in Brazil: in the USA and Europe, the 20 most innovating regions have 70% of all the patents filed, while in Brazil this number exceeds 95%. GRAF 2. depicts the difference in the concentration of innovative activities among Brazil, USA and Europe.

Graph 2 – Total patent distribution: Brazil, USA and Europe
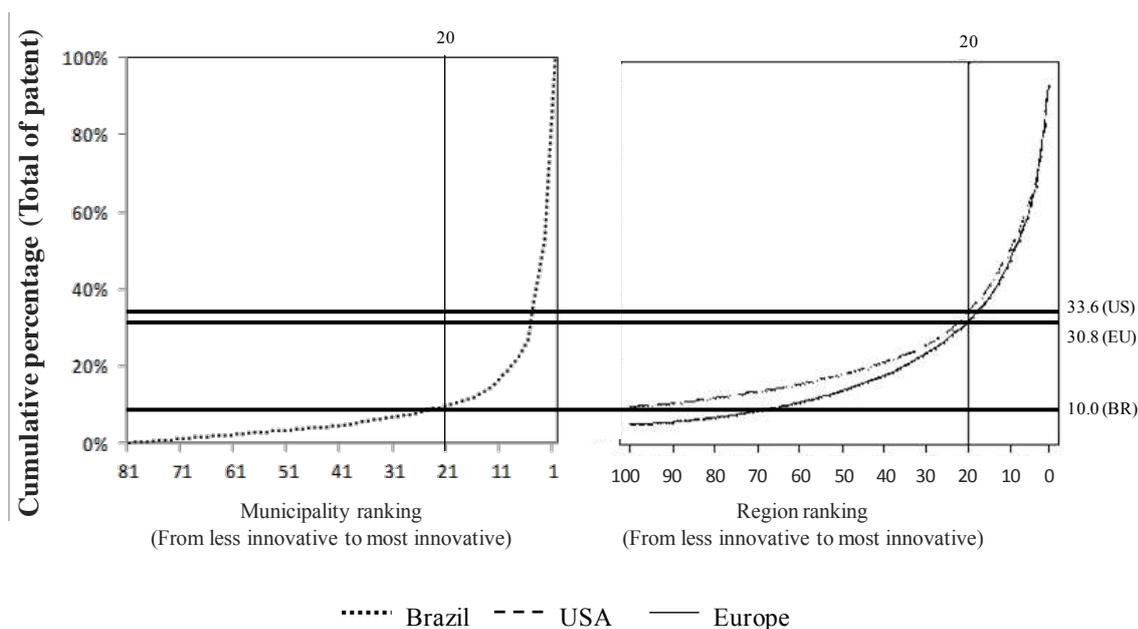
Source: elaborated by the authors and Crescenzi *et al.* (2007).

B) Research Groups Directory (CNPq)

The National Council for Scientific and Technological Development (CNPq), agency under the Ministry of Science, Technology and Innovation (MCTI), has as its main attributions to promote scientific and technological research and foster the formation of Brazilian researchers. The Council has a directory which gathers information about research groups in activity in the country. For this study, we extracted from this database information regarding the scientific production and the density of labor in the biotechnology sector.

One of the greatest advantages of the directory for this research is to indicate the municipality of the groups and their members (masters and doctors) as well as of their articles. Another positive fact also mentioned by Rapini (2007) is that the directory boundaries have constantly grown through the years, so that it is possible to suppose that the database is representative of the national scientific community. Nevertheless, it is important to mention that the directory is built on information provided by researchers who integrate the groups, meaning that the data's authenticity may be arguable. Moreover, there may be biotechnology researchers who are not involved in the research groups therefore not contemplated in the database.

The directory information was accessed through software developed by EconoInfo[13], specifically for this article. It researched the key words individually, accessed the results of each one of the research groups, and extracted the data that was then gathered.

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[13] EconoInfo (*www.econoinfo.com.br*) is an IT company which focuses on financial market driven research and development technologies as well as the gathering of socioeconomic and financial data.

The final database comprises 3,388 biotechnology research groups, corresponding to about 12.3% of the total amount of research groups of Brazil[14]. These groups are distributed over all Brazilian states, though concentrated in only 255 municipalities.

Among the available information in the Directory, three variables were selected to estimate the influence on the probability of innovation in a particular municipality: (i) the number of research groups in biotechnology in the municipality, (ii) number of doctors involved in biotechnology research groups from 2007 to 2010, and (iii), the number of paper published in national and international scientific events by the members of the biotechnology research groups from 2007 to 2010.

C) Municipal Urban Attributes Indicators

The selection of urban variables attempted to incorporate economic, social and demographic criteria, emphasizing the role of municipalities in biotechnology technological production. For that reason, we used variables expressing different urban attributes, as summarized in the following chart.

Chart 1 – Municipal urban attributes variables used in the estimative

Urban Attribute	Indicator / Variable
Urban scale	Municipal population logarithm
Industrial production	Industrial scale (*dummy*)
	Industrialization rate
Complexity of the tertiary sector	Modern services density (*dummy*)
Connectivity	Digital Inclusion (*dummy*)
	Internet access index
Urban hierarchy	Centrality

Source: elaborated by the authors, 2013.

- *Population:*

Indicates the logarithm of the municipality population in 2010, as available on the 2010 Demographic Census by IBGE.

- *Industrial Production:*

It is an indicator of the relevance of industrial activities, built from Lima (2012). The data was obtained from IBGE using the following classification:: 01 indicates irrelevant industrial areas (industrial work <1,000); 02 indicates intermediate industrial areas (from 1,000 to 2,000), and 03 indicates relevant industrial areas ($\geq$ 10,000).

- *Industrialization rate:*

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[14] Based on the 2010 census from CNPq, there are 27,523 research groups in Brazil.

This indicator was elaborated by Garcia&Simões (2012), from the following mathematical expression:

$$IDc_m = \frac{a.v_{m,i}}{(PIB_m)}\left(1 - e^{-\left(\frac{-\ln(0,05)}{PIB_{ref}}PIB_m\right)}\right) \tag{1}$$

Where $a.v_{m,i}$ is the value added of the industrial sector of the municipality m; PIB_m is the municipal gross domestic product and PIB_{ref} is the reference municipal gross domestic product. The reference GDP is equal to the highest municipal GPD of the State to which belongs the municipality in question. The information on the industrial value added and the GDP are provided by IBGE.

- *Modern services density:*

This variable was elaborated by Lima (2012) and represents the proportion of urban workers in the service sector as telecommunication, finances and insurance, legal, accounting and auditing, consulting, advertising, engineering, architecture, design and other technical and professional services provided to companies, auxiliary services from industry and technological and scientific institutions. The data was collected from IBGE. The municipalities were split in two groups: those with a low density of modern services, i.e. with indicator below 0.005 and, those probability density functions.

- *Digital inclusion*

This variable was created in two steps. First, with data from the 2010 Census we calculated an indicator, as proposed in Garcia & Simões (2012), which is the ratio between the number of households with computers and the total number of households.

$$IIDU_m = \frac{DCU_m}{DTU_m} \tag{2}$$

Where DCU_m is the number of households with computers in the municipality m and DTU_m is the total number of households in the same municipality. After that, the variable was turned into a *dummy* variable so that municipalities with the index below 0.5 were considered as having a low level of digital inclusion.

- *Internet access index:*

This indicator, elaborated by Garcia&Simões (2012), was obtained by dividing the number of households with computers with Internet access and the total amount of households. Both information comes from the 2010 Demographic Census:

$$IAIU_m = \frac{DCIU_m}{DTU_m} \tag{3}$$

Where $DCIU_m$ is the number of households with computers with Internet access in the municipality m and DTU_m is the total amount of households in the municipality.

- *Centrality:*

This is an indicator of urban hierarchy. The goal is to demonstrate that the level of centrality l of a city indicates its importance regarding the spatial interactions it establishes with other urban centers in its macro-regional environment. This variable was built from the REGIC (Areas of Influence of Cities) released by IBGE in 2007.

4.2. Zero-Inflated Poisson Model

There are cases in which the dependent variable in a model is a non-negative integer or a countable number, as is the case of patents. Unlike the classical regression model, the dependent variable in a model of count-data is discrete and has a probability distribution assuming only *non-negative integer values*. The standard model of count-data is one that uses the Poisson distribution, also known as the rare event distribution. Given the rate of occurrence of an event, μ the discrete variable Y follows a Poisson distribution with the following probability function (pdf):

$$\mathbf{Pr}[\boldsymbol{Y}, \boldsymbol{y}] = \frac{e^{-\mu}\mu^{y}}{\boldsymbol{y}!}, \boldsymbol{y} = \mathbf{0}, \mathbf{1}, \mathbf{2}, \dots, \boldsymbol{n}. \tag{4}$$

Where E[Y] = V[Y] = μ. In other words, the mean is equal to the variance, a property known as equidispersion.

In practice, however, cases of overdispersion are common, that is, the variance is higher and not equal to the mean in Poisson distribution. This phenomenon may occur due to many factors, namely mean variability, excessive amount of zeros, correlation among individuals and non-observed variables.

In this article, the dependent variable is the number of patents (a proxy for innovation) by municipality. As mentioned, only 226 Brazilian municipalities have some patent filed at INPI, which means that the model depicts zero inflation due to the high number of municipalities (98% of the total) without any patent. This overdispersion can lead to serious underestimation of the standard errors and poor interference on the regression parameters (Hinde & Demétrio, 1998). Consequently, as the Poisson distribution becomes inadequate, it must be adjusted.

The first work to consider an alternative approach to counting with too many zeros was Lambert's (1992). The methodology was applied to a model which analyzed fabrication defects in manufactured products and was named *Zero-Inflated Poisson Regression* (ZIP).

In this approach there are two processes to model the response variable. For each *i* the first process is chosen with probability ρ_i, while the second process is chosen with probability 1- ρ_i. The first process only generates zeros, while the second, g ($y_i|x_i$), generates the other countable data via a Poisson distribution or Negative Binomial[15], as follows:

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[15] This article uses the Poisson distribution.

$$y_i \sim \begin{cases} 0, & probability \ \rho_i \\ g(y_i|x_i), & probability \ 1 - \rho_i \end{cases} \qquad (5)$$

{Y=y$_i$|x$_i$} probability is:

$$\Pr(Y = yi|xi, zi) = \begin{cases} \rho_i(z_i\gamma') + \{1 - \rho_i(z_i\gamma')\}g(0|x_i)\}, & if \ y_i = 0 \\ \{1 - \rho_i(z_i\gamma')\}g(0|x_i)\}, & if \ y_i > 0 \end{cases} \qquad (6)$$

Where z_i is the vector of regressors in the first stage of the Zero-Inflated model. The mean and variance of the *Zero-Inflated Poisson* (ZIP) model are:

$$\begin{cases} E(y_i|x_i, z_i) = \mu_i(1 - \rho_i) \\ V(y_i|x_i, z_i) = \mu_i(1 - \rho_i)(1 + \mu_i\rho_i) \end{cases} \qquad (7)$$

Given that the parameter ρ_i is a probability, there is the restriction $0 \leq \rho_i < 1$. When $\rho_i > 0$, we say that V(y$_i$) is being inflated. In other words, there is overdispersion due to the excessive amount of zeros. When $\rho_i = 0$, V(y$_i$), the standard binomial model variance is reduced.

In order to verify whether the Zero-Inflated Model estimates the chances of innovation incidence more adequately than Poisson regression, the Vuoung's (1989) test for model selection was used.

The test applies the principles of a classical LR test (Likelihood Ratio)The null hypothesis is that the two models are equally adequate to explain the incidence of innovation against the alternative hypothesis that one of the models (in this case, the Zero-Inflated Model) is more accurate.

The test statistics, called *z-vuong*, was positive and significant (z = 3,07 Pr>z = 0,0011), indicating the Zero-Inflated model as more appropriate than the Poisson regression to estimate the probability of innovation occurrence.

5. ANALYSIS OF THE RESULTS

The objective of this paper is to analyze to which extent the urban attributes and the scientific structure influence the incidence of innovation. As previously described, the subject matter is the biotechnology sector and the spatial unit is the Brazilian municipalities.

The effects of the scientific structure were captured by three variables, namely (i) biotechnology research groups; (ii) doctors involved in biotechnology research groups and (iii) published

As in 4C, the following variables were used to identify the urban attributes effects (herein identified as the presence of urban scale, industrial scale, qualified tertiary sector, connectivity and urban hierarchy): (i) municipality population, (ii) industrial scale, (iii) industrialization index, (iv) modern services density, (v) digital inclusion, (vi) Internet access index and (vii) centrality.

The Zero-Inflated Poisson (ZIP) has been used since it is the most adequate to the situations in which there is an excessive amount of zeros in the dependent variable. As described, in the ZIP model there

are two steps to model the response variable. Firstly, the zeros are modeled, i.e. the municipalities that do not have biotechnology filed patents by INPI residents. In the second stage, we estimate the count-data represented here by the municipalities that generate innovation, or, in other words, have patents filed.

To develop the assessment, it has been used in both stages variables which represent both the urban and technical-scientific dimension. Table 3 summarizes the results achieved for both groups.

Table 3 – Results from the Zero-Inflated Poisson Model (ZIP) [16]

Variable	Coefficient (IRR[17])
Municipalities without patents – (Zero modeling; Logit[18])	
Municipality population (logarithm)	0,29
	(9,43)
Industrialization index	0,01**
	(1,67)
Internet access index	0,00*
	(1,61)
Centrality	0,63**
	(0,18)
Biotechnology research groups	0,96
	(0,06)
Biotechnology doctors	1,00
	(0,01)
Biotechnology scientific articles	1,00
	(0,00)
Constant	1.380,22*
	(0,67)
Municipalities with patents – (Countable data modeling; Poisson)	
Municipality population (logarithm)	1,38
	(0,29)
Industrial production (*dummy*)	2,05*
	(0,40)
Modern services scale (*dummy*)	0,51
	(0,36)
Digital inclusion (*dummy*)	2,15

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[16] The adjusted standard deviations are between the parentheses right under the coefficients. The individual coefficients are statistically relevant in the level of *5% and **10%.
[17] Incidence Rate Ratio.
[18] Since the Logit model has been used, the coefficients presented refer to the calculation of their exponential value.

	(0,84)
Centrality	0,78
	(0,21)
Biotechnology research groups	0,97*
	(0,00)
Biotechnology doctors	1,00*
	(0,00)
Biotechnology scientific articles	0,99**
	(0,00)
Constant	0,34
	(0,07)

First, we discuss the results for the majority of the observations, i.e. the share of municipalities that do not have patents. This group is formed by 5,483 municipalities which represents 98% of the total, and the estimated coefficients represent the probability of a municipality of being zero, that is, not filing patents. In this group of analysis the estimates indicate that besides the constant, only the variables related to the presence of urban attributes are statistically significant.

When the group of municipalities without patents is analyzed, the central conclusion is that regional factors are determinants in their permanence in the current group they belong today. Thus, in order to enter the group which generate innovations, a city must rely on the presence of urban attributes.

In general, is not enough to possess a highly developed scientific structure if this is not accompanied by the economic and regional development of the municipality. Nevertheless, few exceptions exist. This is the case of municipalities where the patents filed are concentrated only in one institution and that the choice of the municipality was not oriented by the pursuit of urban attributes. These cases will be discussed later.

Regardless of these specific facts, it is possible to conclude that the urban factors are the ones that determine the migration of the municipalities without patents to the group of those which generate innovations. More specifically, these urban factors are industrial production, connectivity and urban hierarchy.

The results indicate that the urban scale, represented here by the size of the population, is not relevant to prevent the municipality from generating innovation. The explanation is related to the importance of the variable centrality. Even if the municipality has a small population, the probability of not having patents decreases if the municipality exhibits greater centrality on its surroundings. In other words, the higher the centrality, the lower the chance of the municipality to remain in the group that do not

generate innovation. Another significant variable refers to the industrial scale, represented by the industrialization index.

It is possible to infer that the more industrialized is the municipality; the more likely it is to have patents filed.

Industry is a relevant factor as it acts not only on the supply but also on the demand side. In the first case, the existence of industries from the biotechnology sector may increase the availability of qualified workforce, increasing the chance of technological production. A diversified industry, on the other hand, generates positive Jacobian externalities for the region, attracting investments and people providing knowledge spillovers on issues common to any industry, such as management and structured labor market.

The results also suggest that regions with higher levels of Internet access have less chance of being a municipality without patents. In other words, an increase in connectivity causes a reduction of the chances of the municipality being kept in the group of municipalities without patents. Such conclusion is quite significant, as the subject matter is a technological frontier sector, considerably depending on a modern structure to produce results, as well as the possibility of sharing information not only in a regional but also in a global level.

The main conclusion of the analysis of the municipalities without patents may be summarized by the interpretation of the constant variable. If all the other variables are equal to zero, the municipality might have technological production. Neither having urban attributes nor scientific structure virtually drops to zero the chances of a municipality having a patent filed.

Conversely, the results are very different from innovation generating municipalities. As mentioned, the estimations come from the analysis of count-data which, in this case, represent the smallest share of the observations, as only 81 Brazilian municipalities, among a total of 5,564, have biotechnology patents filed at INPI.

This result indicates that the spatial distribution of the technological production in Brazil, using the patents as a proxy, has a strong tendency of concentration in few locations. The 20 most innovative municipalities correspond to 90% of all filed patents.

Besides the findings related to the concentration of the technological production in Brazil, the results show that the scientific structure has a significant importance for the municipalities that have patents filed, contrary to what occurs for the municipalities without patents. Regarding the urban attributes, only the variable industrial scale was significant for municipalities generating innovation.

Regarding the scientific structure, all three variables were statistically significant, revealing that for municipalities that already have patents filed. A strong scientific structure is what determines the continuity and the frequency of occurrence of innovation.

As previously mentioned, the municipalities with the largest number of patents filed are, in general, more urban and economically developed. This is the case, for instance, of São Paulo (257 patents), Rio de Janeiro (182 patents), Belo Horizonte (77 patents), Campinas (77 patents), Caxias do Sul (23 patents) and Porto Alegre (18 patents), which are among the 10 most innovative municipalities and correspond to 70.8% of all the patents filed.

In light of these findings, we conclude that the scientific structure is crucial so that the innovation becomes a perennial process in the municipality. However, the existence of a strong urban structure, industrial scale, and modern services are requirements prior to this process, meaning that the scientific structure keeps the municipality in the group of the most innovative, though is not able to insert it in this very group.

Nevertheless, there are some municipalities which are exceptions, since they are characterized by a heavy scientific structure, yet less developed in urban and economic terms. This is the case of Caxias do Sul (23 patents), Cravinhos (16 patents), São Carlos (14 patents), Serrana (12 patents) which integrate the group of the 15 most innovative municipalities.

The main feature of these municipalities is having the patent filing concentrated in only one institution. In these cases, the choice of the municipality was not determined by the urbanization, industry or qualified tertiary sector, but by particular factors.

In São Carlos, all patents were filed under the Federal University of São Carlos, which offers undergraduate and specialization biotechnology courses. The institution also has a prominent Vegetal Biotechnology department.

Cravinhos and Serrana owe their performance to private sector activities. Cravinhos is the head office of Ouro Fino company, which has been in the production and marketing of pharmaceutical products for animal health market since 1987. In this field, biotechnological routes are constantly used. In Serrana, the PHI Industrial Company is headquartered. It has produced the Biocycle, a biodegradable kind of plastic from sugar cane, for more than ten years now.

Both cases clarify to a great extent why the coefficient of centrality variable was not statistically significant. These municipalities do not need to benefit from centrality to keep on depositing patents. In other words, urban hierarchy is not a determinant factor to the incidence of innovation in this group of municipalities.

Nevertheless, as highlighted in the previous section, centrality is an important factor to the municipalities without patents, as being central means having a greater chance to migrate to the innovation generating municipalities. Therefore, the centrality variable assists in the transition of the municipality to the innovative group, though it is not determining to increase the probability of incidence and frequency of innovation once it is already part of this group. Once again, the key factor

in this case is the presence of scientific structure, here represented by the amount of research groups, doctors and published articles.

The three variables were statistically significant and had very similar coefficients. For each new research group in the city, the likelihood of filing a patent is almost one to zero: for each new research group in the city, the likelihood of filing a patent remains the same.

Similar result is obtained analyzing the number of doctors and scientific articles. *Cæteris paribus*, for each new doctor or scientific article in the municipality, the likelihood of filing a patent remains the same.

Results indicate that the supply side is crucial to the continuity of innovation in municipalities; since scientific production and availability of skilled labor are required to increase the filing of new patents

The results of the model for those municipalities that filed patents also revealed the importance of industrial scale to innovation. The consequence is similar for the municipalities without patents i.e. urbanization economies that correspond to positive externalities generated by industries located in the same area. They are internal to the urban region, though external to firms or industries that benefit from them.

If the industries located in a given city belong to the biotechnology sector (eg pharmaceutical, agricultural industry), they play a fundamental role on the demand, since the geographic proximity will facilitate the relationships among the agents. On the other hand, even if the industries are not from the same sector, they will create positive externalities, such as attraction of labor public investments and knowledge spillovers. This variable has the highest coefficient, indicating its higher importance as compared to the others.

When comparing the two groups (with and without patents), we conclude that municipalities lacking innovative capability need to invest in urban structure and achieve industrial scale in order to increase the probability of innovation. On the other hand, municipalities that generate innovations already have, roughly, a reasonable level of economic and regional development, yet they still need to improve their scientific structure in qualitative and quantitative terms in order to increase the probability of producing new technologies.

6. FINAL CONSIDERATIONS

The aim of this study was to estimate the influence of urban attributes and scientific structure on the probability of innovation in Brazilian municipalities. We used the Zero-Inflated Poisson model (ZIP) to model the data and the biotechnology sector as the object of analysis.

Firstly we analyzed the impact of selected variables on the group of non innovating municipalities i.e. those with no patents and subsequently on the group of municipalities with technological production.

The results reveal that the regional factors are decisive for those municipalities that do not generate innovation remain in this group. The most important features in these locations are the rate of industrialization, access to the internet indicating a higher level of connectivity; and the ability of the municipality to exert and benefit from centrality. On the other hand, for the municipalities that generate innovation, the probability of producing patent is influenced by the existence of industrial scale and scientific structure (doctors and research groups and scientific articles).

Results point out the importance of the public sector on the technological production.as the findings indicate the importance of investing in urban structure, especially in regions with a lower level of regional development. Factors such as a qualified services sector, centrality and industrialization level are critical for the migration of non-innovating municipalities to the innovation generating group. This means that incentive policies regarding S&T can be more successful if they encompass investments in qualification and modernization of the cities and their urban structures.

Additionally the effort of expansion and qualification of the scientific structure in Brazil should be maintained, since we know that science not only leads but also follows up the technological process. We have known that the attempts in this direction have been increasing in recent years, as Brazil has made significant progress in its scientific production and in the formation of specialized human resources. Data from CGEE (2010) show that the number of doctors tripled in the last 10 years, as well as the participation of the country in the publication of scientific articles – from 0.8% in 1992 to 2.7% in 2008 (Unesco 2010, p. 42). Nevertheless, the greatest challenge remains the qualitative technological and scientific development and above all concentrating efforts on minimizing the regional disparities in the generation and dissemination of knowledge.

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