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University-industry linkages and the role of the geographical proximity

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University-industry linkages and the role of the geographical proximity

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Abstract

The main aim of this paper is to exam the local dimension of the university and industry linkages. It is widely recognized in the literature that academic research is an important source of new knowledge to the innovative efforts of the firms. Many authors, such as Audrescht and Feldman (1996), Acs and Varga (2005), Breschi and Lissoni (2009), have shown that academic research is positively correlated with firms' innovation at the geographical level. There are two reasons that are pointed out for this correlation. First, there are many ways in which knowledge generated by academic research can spill over to the firms, such as research papers, patents and informal contacts. Second, geographical proximity can encourage cooperation between academic researchers and the R&D staff in the firms.

In this way, this paper tries to measure empirically the geographical dimension of the university-industry linkages in Brazil, in the same way to the first effort presented in ERSA 2010 (Garcia et al, 2010). To do that, it was used data from the Brazilian Research Council (CNPq), collected at the CNPq Directory of Research Groups of Brazilian universities. The data shows that in 2008 there were 22,797 research groups from 422 institutions. Among these research groups, 2,726 declared that they have interactions with more than 3,800 firms, which means 5,132 interactions between university and industry.

Data were organized both in firm-level and in research group-level; allow the identification of the localization of the firm and of the research group. Among the 5,132 interactions between firms and research groups, it was possible to see that 43.6% of interactions occur inside the same city; 51.2% inside the same region; and 75.3% in the same state. These results show the importance of the local dimension of the interactions between academic research of the university and innovative efforts of the firms. In addition, it was done some empirical tests in order to identify the main factors that contribute to foster university-industry linkages.

Track: N. Entrepreneurship, networks and innovation

Keywords: economic geography, innovation, knowledge spillovers, university-industry linkages

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Introduction

The university-industry linkages have been increasingly recognized as important sources for innovative activity in companies since the knowledge generated by academic research in universities can serve as important inputs to the innovative efforts of companies. In this context, the complexity of knowledge involved in the interactions between universities and businesses requires frequent information and knowledge exchange, which can be facilitated by face-to-face meetings between the agents involved. Because of this characteristic, geographical proximity can be an important factor in stimulating university-industry linkages since the concentration of agents can stimulate the maintenance of contacts between researchers and allow the formation of local networks of knowledge.

Based on this assumption, this paper provides the results of an investigation into the role of geographic proximity to foster university-industry linkages. To achieve this, data from the Census 2008 CNPq Directory of Research Groups Base Lattes is used to assess whether the university-industry linkages among Brazilians are measured by spatial or geographic factors. Besides the descriptive analysis of data from the Directory of Research Groups, a model is presented to assess more accurately the importance of geographic proximity to the establishment and maintenance of interactions between research groups registered in the Lattes database and businesses with whom such groups interact.

To develop this argument, firstly the text presents a brief theoretical and conceptual discussion. Then, in section 2, the database and some results from the descriptive analysis of the information are shown. In section 3, the model developed is presented and in section 4, some of its main results. At last, we present some final remarks.

1. University-industry linkages and the importance of geographical proximity

The university plays a widely recognized role for its development and dissemination of new knowledge into the economic system. The increasing complexity of knowledge required for the promotion of innovative activities in enterprises encouraged the increasing use of external sources of scientific and technological knowledge, as the university.

This importance was attested by several authors such as Nelson (1959) and Klevorick et al. (1995). The work of Klevorick et al. (1995), which used data from the Yale survey, shows that universities represent a very important source of knowledge for firms' innovative activities, especially in industries in which the

university scientific research development is more closely linked to the innovation in companies.

Given the importance of academic research into the economic system as a whole, we highlight the role and the characteristics of different ways of university-industry interactions. Besides representing an important source for the promotion of firms' economic activities, the ways of university-industry interactions can enhance the results of knowledge and information exchange. One of the most important ways in which this might occur is mainly through the establishment of joint projects involving academic researchers and the firms' R&D department.

In addition to the development and dissemination of knowledge to the economic system, universities also play a role in promoting and supporting regional development. Several authors suggest that universities are the central piece for the promotion and support of competitive advantages of certain regions.

In fact, since the pioneering work of Jaffe (1993), several authors have devoted significant efforts to understand the role of geographic proximity in shaping the ways of relationships. The work of Jaffe (1993) was able to identify that university academic research is able to generate significant local knowledge dissemination, since this study has found a local positive correlation between private activities of patenting and academic research. In the same vein, Audrescht and Feldman (1993) showed that innovation at regional level is positively correlated with the geographic concentration of universities and industries' R&D expenditure.

Such empirical evidences suggest that location of complementary resources between universities and the industry can increase the opportunities for competitive local businesses. Furthermore, academic research may have the effect of raising the technological opportunities for local companies, with significant consequences for the support of Science, Technology and Innovation areas and intensification of university-industry linkages.

From these pioneering works, many others have sought to increase the understanding of the geographical proximity role between universities and businesses. (Barthelt et al. 2004; Maskell, 2001, Breschi and Lissoni, 2001, Storper and Venables, 2004; Crescenzi et al. 2007; Varga, 2000, Asheim and Gertler, 2004). These studies sought to emphasize the main role of geographical proximity as a facilitator of knowledge exchange among economic agents, with special emphasis on the forms of relationship between the industry and the university.

One main point arising from this research perspective is that geographical proximity is able to create a suitable environment for the exchange of knowledge and information among the agents in which each is sustained by face-to-face interactions allowing the development of local networks of knowledge in which several actors are involved. These local networks of knowledge are encouraged by the existence of trust relationships among economic agents and are embodied by the recurring presence of informal contacts between staff and the establishment of relations of reciprocity and

mutual understanding (Asheim and Gertler, 2004). Anyway, as pointed out by Boschma (2005), geographical proximity among economic agents is not a sufficient condition to establish reciprocal relationships between them. For these relations to be created and maintained by agents, it is necessary other forms of proximity between them, such as cognitive, social, organizational and institutional.

This point is of great importance for the analysis of university-industry linkages. Geographical proximity to the university enables professionals involved in innovative activities in businesses to participate in networks of information and academic communities. The interactions with the local partner university is the gateway to companies in these networks, since it is through these relationships that necessary trust is built for the learning and the knowledge sharing process to occur. To maintain these relationships, companies often allocate resources to the development of research activities at the university, through mechanisms such as sponsored research, student scholarships, equipment access, among others (Laursen et al., 2010).

In addition, there are several empirical studies that indicate the importance of geographical proximity in shaping the university-industry interaction. For example, Arundel and Geuna (2004) showed that when the knowledge involved in the university-industry linkages is encoded and somewhat complex, geographical proximity tends to play a minor role. On the other hand, when the knowledge involved is tacit and personal contact is crucial for the exchange of information, geographical proximity is of great importance. In general, the smaller the distance between the university and the industry the easier the interaction due to reduced costs involved in the exchange of knowledge. Mansfeld and Lee (1996) and Laursen et al (2010) add in this context the quality of scientific research carried out in the universities. For these authors, geographical proximity between university and companies tends to be particularly important when it comes to universities with significant academic output.

Thus, it reinforces the importance of geographic proximity to the promotion and maintenance of university-industry linkages, since it allows the establishment of contacts face-to-face towards solving problems and building trust relationships between the agents. The successful experiences of university-industry linkages show that companies seek knowledge generated by the universities through several ways, ranging from informal contacts to the sharing of knowledge through the establishment of formal joint research projects. By establishing such relationships with the universities, companies can explore a number of mechanisms with the aim of narrowing down relationships with important sources of new knowledge, even if costly in terms of resources involved.

2. The university-industry linkages in Brazil

The university-industry linkages in Brazil have been the subject of several studies as Rapini et al. (2009), Suzigan et al. (2009) and Fernandes et al. (2010), which reveals a growing interest in understanding the role of universities for the development and dissemination of new knowledge and for the encouragement of innovative activities in companies. Some of these works, as is the case of Rapini (2009) and Suzigan (2009), use database from the CNPq Directory of Research Groups Base Lattes as one of the elements for the evaluation of university-industry linkages. Having these works as examples, this article also investigates the importance of geographical proximity for interactions between academic research groups and companies.

The CNPq Directory of Research Groups is the broadest source of information about the activities of research groups in Brazil because it gathers and organizes data on these activities by collecting information from these groups' leaders. The main unit of analysis in this paper is a group of researchers, students and technicians working on developing a single line of research following a certain hierarchical structure based on the experience and technical-scientific skills.

The database of research groups gather information about the personnel involved (researchers, students and technicians); lines of research and field of knowledge; academic production (measured by scientific publications and patents); interactions with companies and other institutions (and the types of interactions that are performed).

Despite being the most extensive database in Brazil, the CNPq Directory of Research Groups Base Lattes¹ presents some methodological problems that need to be mentioned. The main one is that the database acquired is achieved voluntarily by the leaders of research groups, without further examination of its consistency. This means that while some researchers give high importance to the consistency of information, others do not. Thus, it is quite reasonable to assume that university-industry linkages are underestimated in the CNPq Directory of Research Groups.

In order to carry out the assessment of geographical proximity importance to the university-industry linkages, this study used information from the Census 2008 Directory of Research Groups database, in which was added other information for the model developed. In the 2008 Census, 22,797 research groups information can be found. Of this total, 2,121 groups of 248 institutions have indicated that they have interactions with 3,601 companies, accounting a total of 5115 interactions².

¹ The Directory of Research Groups shows the existence of 5132 interactions between research groups and firms. However, the database used in this work has been reduced to 5115 interactions, since it was not possible to identify the geographic location of all interactive companies. Besides that, the database also contains no information about the localization of companies that interacted with these research groups.

² In fact, the directory shows that there are 2,726 interactive groups. However, when comparing with the data from the Current Base of CNPq, it was only possible to collect information from

2.1 Main features of the base directory

The database used in this work involved geographical location of the interactive groups and companies with whom they interact in three geographic levels: state, meso and micro. Thus, the information concerning these interactions is shown in Table 1³.

Table 1 - Main information collected from the CNPq Research Groups Directory - 2008

Data on the research group level	Name
	University
	Localization
	Leader
<hr/>	
Data on the firm level	Knowledge area
	Name
	Fiscal code (CNPJ)
	Localization
<hr/>	
	Type of interaction
	ISIC (CNAE)

Source: CNPq Research Group Directory, 2008

It was possible to draw some general features of the database as a result of this collection of information about interactive research groups from the CNPq Directory of Research Groups Base Lattes.

From the point of view of companies that interact with the research groups, there is a concentration of companies in some sectors especially oil, petrochemical, power and heavy industries like steel, cement and cellulose. From the ten most interactive companies, eight of them have sectors in these areas, to which they represent institutions of research and in the agricultural area (Table 2)⁴. The sum of these interactions represents 6% of the total, and which only 60 companies have more than 5 interactions with research groups.

2,121 groups that interact with companies. Thus, in this paper, the universe of interactive groups is composed of 2,121 groups.

³ The Directory of Research Groups shows the existence of 5132 interactions between research groups and firms. However, the database used in this work has been reduced to 5115 interactions, since it was not possible to identify the geographic location of all interactive companies. Besides that, the database also contains no information about the localization of companies that interacted with these research groups.

⁴ This concentration of interactions with companies in these sectors has already been observed in the information of previous years (Garcia et al, 2010).

Table 2 – Top 10 firms that interacts with firms and its main industry

	Firm	Interactions	Industry
1	EMBRAPA	70	Agrarian Research
2	Petrobrás	60	Oil and Gas
3	CEMIG	30	Energy Distribution
4	Votorantim	28	Non-metallic mineral products and others
5	CNPq	26	Research finance
6	CHESF	26	Energy Distribution
7	BRASKEM	20	Petrochemical
8	Eletróbrás	17	Energy Distribution
9	Gerdau	16	Steel
10	EPAMIG	15	Agrarian Research

Source: CNPq Research Group Directory, 2008

Important information about the interactions is the areas of knowledge involved in the projects developed between companies and groups. As pointed out by Metcalfe (2003), since some areas of scientific knowledge such as engineering, pharmacy and agronomy are closer to the technological and productive activities of companies, it is natural that these areas have a higher volume of interactions. This point can be clearly seen in the Brazilian case, since the Engineering and Agricultural Sciences are those that have more interactions with companies (Table 3)⁵.

Table 3 – Number of interaction by knowledge area

Knowledge area	Interactions	%
Engineering	1,938	37.89
Agrarian Science	1,067	20.86
Healthy Science and Biology	871	17.03
Natural and Earth Sciences	632	12.36
Human and Social Sciences	607	11.87
Total	5,115	

Source: CNPq Research Group Directory, 2008

As we can see on the table, almost 60% of all interactions are from the Engineering and Agricultural Sciences, where 38% from Engineering and 21% from Agricultural Sciences.

Other information that can be extracted from the Directory of Research Groups is regarding the types of interaction. When completing the questionnaire, a list of fifteen possible types of interactions is presented to research groups, to

⁵ From the five areas of knowledge presented, "Engineering", "Agricultural Science", "Natural Science" "Earth Science" correspond exactly to the Major Areas defined by CNPq.

which it should be pointed out up to three types of interactions that the group carried out with companies.

From this list, it was possible to obtain an interaction pattern. For a better understanding of these types of interaction, they were grouped into bidirectional or unidirectional in which the direction of knowledge developed was indicated (from the research group to the industry or from the industry to the research group). Due to their complexity, the bidirectional interactions tend to involve a more intense exchange of information and knowledge and, therefore bring wider benefits to the parties involved.

The work of Arza and Varquez (2010) on the university-industry linkages in Argentina reinforces this perception. Their findings show that the interaction channels between universities and companies in Argentina that provide greater benefits for the agents are the bilateral ones. Thus, according to the authors, the bi-directional channels of interaction represent the main means for the provision of intellectual benefits for researchers and for the encouragement of innovative activities from companies.

The examination of the types of university-industry linkages in Brazil shows that the bilateral interactions dominate. The interactions involving two-way flows of knowledge represent more than 70% of all interactions (Table 4).

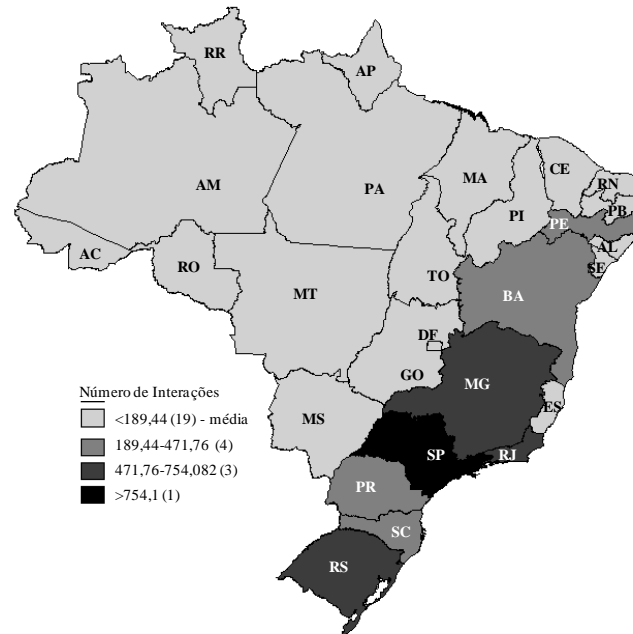
Table 4 – Direction of the knowledge flow in university-industry linkages

Direction	No.	%
Bi-directional	3,627	70.9
To the firm	952	18.6
To the research group	262	5.1
Others	274	5.4
Total	5,115	

Source: CNPq Research Group Directory, 2008

From the stand point of university-industry interaction geographical distribution, it is observed an important concentration of interactive groups in the South, Southeast regions besides Bahia and Pernambuco as shown Figure 1.

Figure 1 – Regional distribution of the university-industry linkages in Brazil, 2008



The geographic location of interactive groups is convergent with the concentration of other indicators, both economic as the level of economic activity in general and academic as the scientific production. Anyway, the first six states ranking in the number of interactions of companies are in these two regions and accumulate 73% of the total interactions.

This geographic concentration is also verified when considering the micro regions. Taking the state of São Paulo as an example, its five main micro regions in terms of number of interactions (São Paulo, Campinas, São José dos Campos, Ribeirão Preto and São Carlos) are responsible for 18.2% of all interactions in the country. This is largely explained by the presence of a significant academic activity in these regions, which is strongly reflected in important interactions with companies.

From the standpoint of university-industry linkages, it is important to examine whether the relationships that are established between the universities research groups and the R&D department in companies occur in the same geographical space. Table 5 shows the co-localization of interactive research groups and companies.

Table 5 – Co-localized university-industry linkages

Localization	Interactions	%
State	3,865	75.6
Mesorregion	2,882	56.3
Microrregion	2,628	51.4
Total	5,115	

Source: CNPq Research Group Directory, 2008

As the table shows, 75.6% of university-company interactions occur within the same state, which reveals the importance of relations of co-located interactions among agents. However, as pointed by some authors, as Breschi and Lissoni (2001), the state is not viewed as the most appropriate geographical unit for the importance of university-industry linkages, since the dissemination of knowledge usually occurs in geographic areas more restricted than the state.

In this way, it is important to analyze the importance of knowledge flows in smaller geographic areas such as the meso and micro regions. Even through the table analysis, it is possible to see that 56.3% of interactions occur in the same meso region and 51.4% in the same micro region. Thus it is possible to verify the importance of local flow of knowledge for the promotion of university-industry linkages, since the relationship between industry and university research groups have found an important local character. This result is convergent with the results of analysis of other countries, discussed in section one, in which was possible to observe, in other experiments, that there are significant geographical mediations for university-industry linkages. This means that geographical proximity is an important factor to stimulate interactions between universities and companies. In large measure, the importance of geographical proximity is justified on the grounds that the passing of implied, specific and complex knowledge cannot do without the more specific forms of interaction among agents, as is the case of face-to-face interactions.

In the next sections, an empirical model will be presented to examine such relationships and establish some control variables to conclude with greater certainty that geographical proximity is an important factor for the establishment and maintenance of interactions between universities and businesses.

3. University-industry linkages and geographical proximity: an empirical analysis

The analysis of university-industry linkages in Brazil reveals the important role of geographical proximity, since the occurrences of interactive relationships between research groups and companies in the same geographical area increased.

To reinforce these findings and understand specific aspects of university-industry linkages, we developed an empirical model in order to verify the importance of geographical proximity to the establishment and maintenance of interactions between the industry and the university research groups. The model developed in this article draws heavily on previous works such as Varga (1998), Crescenzi et al (2007), Cabrer-Borrás & Serrano-Domingo (2007) and Ponds et al (2010), in which showed the need to identify correlated variables in the same geographical space. Thus, there is a particular concern in understanding the effects of geographical proximity on university-industry linkages. The main assumption of this analysis is that companies can benefit from the geographical proximity between these interactive research groups. Therefore, we decided to formalize the interactions between universities and businesses in a region as follows:

$$IE_{iT} = f(IU_{i,T-t}, wIU_{i,T-t}, PD_{iT})$$

In this model, the variable IE represents the interactions of businesses from region i on the period T ; the variable IU represents the interactions between universities on the region i and the variable wIU shows the geographical distance effect IU of neighbor regions, that is the effect of the research groups interactions of neighbor regions i on the interactions with the industry.

From this, an estimated model was developed in which the variables are substituted by proxies. Furthermore, some control variables were inserted as follows:

$$IE_{i,T} = \beta_0 + \beta_1 IU_{i,T-t} + \beta_2 wIU_{i,T-t} + \beta_3 PDind_{i,T} + \beta_4 PDuniv_{i,T} + \beta_5 ED_{i,T} + \beta_6 DENS_{i,T} + \beta_7 VAInd_{i,T} + \varepsilon_i$$

The IE count represents the total companies interactions in the region i in period T . Thus, for each interaction registered in a group from any location with a company in region i , it is accounted one interaction.

Among the independent variables the IU is at first place, which represents the sum of the interactions of research groups in region i in $T-t$ with companies,

that is, for each interaction recorded by a research group in region i add 1 to IU . However, in order to avoid concurrency problems, a dated measure system was used in which data from the 2004 CNPq Directory Census of Research Groups.

To measure the geographic effects, a matrix that considers the industry interactions in region i with research groups of neighboring regions, was created. Thus, the variable wIU is able to measure the interactions effects of research groups from neighboring regions to region i ⁶.

The analysis of this variable allows us to measure the spatial effects that permeate the university-industry linkages, so that the existence of significant effects between wIU (the variable that measures geographic effects) and the dependent variable (interactions with businesses) reveal the existence of important space run over in interactions between academic research groups and companies, since this variable measures the effect that the activities of research groups engaged in a neighboring region have on the interactions with companies of a certain specific region. Thus, the positive effects identification between these two variables indicates that activities of an academic research group of neighboring regions have positive impacts on the interaction with companies from a given region.

Another dependent variable is the industrial R&D (PDInd), since the existence of innovative efforts from firms in a given region tends to encourage the maintenance of interactions between companies and research groups. Since there is no data on private expenditures of R&D in micro-regional level, a qualification proxy for workers was used in the regional industry, which represents a good measure of innovative efforts in the companies. The adoption of this proxy is justified by the fact that the innovative efforts of companies are performed by highly qualified professionals. The proxy used was the participation of employees with higher education in the manufacturing industry.

One more dependent variable is the R&D University (PDuniv), since we have adopted the assumption that the existence of active academic groups in the region is an important element for stimulating interaction with companies. As a proxy for university R&D, we have used the number of PhDs with full dedication to teaching and research per thousand inhabitants. This proxy represents the university research in the region, since the activities of academic research assume the existence of highly qualified researchers, which implies a low number of doctorate graduates dedicated to teaching and research.

Besides all the factors that influence the university-industry linkages, other three control variables have been included. The first measure was the complexity of the region's industrial structure, measured by using an indicator of specialization (or diversification) from the local activity (ED). This measure aims to evaluate the impact on university-industry linkages from a more specialized or diversified region (Duraton & Puga, 2001; Schiffaureova & Beaudry, 2009; Crescenzi et al,

⁶ The spatial matrix is represented by n by n regions matrix, to which it is attributed 1 to regions with common extension border and / or nodes with another region and 0 otherwise, what makes up the type queen matrix. The weights matrix provides balance to the interactions of research groups' relatively inverse to the distance of neighboring regions.

2007). The Krugman's specialization index has been adopted for this measure, calculated from the number of employees from each division of the manufacturing industry in the region. This index ranges from 0 to 2 as a region is more diversified and specialized front the general productive structure.

The other two control variables are the population density (Dens) and the participation of the Added Industrial Value in the region (VAInd). These variables allow the controlling, respectively, of the effects of population and industrial density of these regions (Jaffe, 1989). Table 6 shows the set of variables used, their sources and proxies.

Table 6: Variables description

Variable	Description
IE	Number of interaction of the firms of the region; Source: CNPq Census 2008.
IU	Number of interactions of the research groups of the region; Source: CNPq Census 2008
WIU	Number of interactions of the research groups of the region n, spatially weighted by a matrix of distances, type "queen". Source: CNPq Census 2004.
PDind	Share of employees with higher educational level in the manufacturing industry in the region. Source: RAIS 2009.
PDuniv	Number of full-time active professors in universities with PhD level per 1,000 inhabitants. Source: INEP 2009.
ED	Krugman index of specialization (or diversification) by the numbers of employees in each industry 3-dig. Source: RAIS 2008.
Dens	Population density in 2000 in the region n. Source: IBGE.
VAInd	Share of the region value added in the manufacturing industry in 2008. Souce: IPEADATA.

For a statistical analysis of this information, a negative binomial model, an example of that from Ponds et al (2010), has been adopted since this model best fits the distribution of the dependent variable (IE)⁷.

4. Results analyses of the empirical model: the importance of geographical proximity

From the development of the general model and from the organization of databases, the empirical models have been estimated for two different geographic cut outs: the micro and medium-size regions in Brazil.

The reason for these two distinct models is to attempt to find differences between the levels of significance of parameters in these two distinct

⁷ The Directory of Research Groups shows the existence of 5132 interactions between research groups and firms. However, the database used in this work has been reduced to 5115 interactions, since it was not possible to identify the geographic location of all interactive companies. Besides that, the database also contains no information about the localization of companies that interacted with these research groups.

geographic clippings. This way, the differences in the two estimates may be indicators for understanding important features of local flows of knowledge, especially between universities and enterprises.

For the development of the empirical model, it has been carried out initially the application of estimates to the Brazilian micro-regions. For this, data from the 2008 Census of Directory Research Groups of Base CNPq Lattes has been used as the proxy variable IU (regression 1 to 3); and to avoid simultaneity problems, data from the 2004 Census for the outdated variable IU (regressions 1' to 3') has also been used as shown on table 7.

Analyses of the regressions results (1 to 3 and 1' to 3') show that the variable representing the interactions of academic research groups in region i (IU) had a positive and significant sign at the level 0, 1% of significance. This result confirms the perception already found that there is an important relation between the geographic concentration of companies and universities and interactions between these other agents. In other words, companies tend to interact more with universities located in their region, which confirms the local flow of knowledge between these two agents.

Regarding the variables representing the efforts in R&D, Industrial R&D (PDind) and University R&D (PDuniv), it has also been found positive and significant coefficients. Regarding the Industrial R & D, it can be concluded that in regions where companies with greater innovative efforts are located, measured by the presence of skilled labor, it can also be verified more expressive interactions with research groups. This result is convergent with those found by Cabrer-Borrás & Serrano-Domingo (2007,) who verified the existence of a positive relationship between the qualified labor and the innovative performance of Spanish regions⁸.

Referring to University R&D, our results indicate that in regions with larger structures of academic research, as measured by the qualifications of the researchers, it is also possible to find more interactions with companies. This coincides with the argument presented by the authors as Laursen et al (2010), which showed that firms tend to interact more with research groups with better academic performance. In this sense, the greater the effort and the structure of academic research in a university of a certain region, the greater the interactions with local firms.

Thus, the results clearly indicate that the existence of local research efforts both in businesses and universities, is a factor that is able to stimulate local interactions between these agents and therefore, able to enhance the flow of information and knowledge within the local system.

Concerning the dependent spatial variable of interactions (WIU), the model results have indicated that the coefficient presented a positive and significant

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sign. This result reveals the existence of an important spatial element to the occurrence of interactions with firms, since it is possible to identify the existence of interactions between firms in a certain region with research groups from neighboring regions. This means that, with everything else controlled, firms located in regions close to major sources of academic knowledge (*IU* variable) represented by the existence of interactive research groups, tend to benefit from the relationships with these important sources of knowledge.

Thus, one can conclude that the existence of bulky structures of academic research in a particular region can benefit not only firms from the same region but also companies from neighboring regions. This reveals the importance of local knowledge spillovers that occurs due to geographical space, not only in the region where these interactive research groups are but also in neighboring regions. Therefore, this result itself is a clear evidence of the presence and the role of local knowledge spillovers.

Analyzing the remaining variables, one can notice the existence of a negative and significant coefficient between Krugman's specialization index, which measures the specialization or diversification degree of the productive structure from the region (*ED*), and the interactions with companies. This means that the more diverse is the region's productive structure, the more interactions between university research groups and companies will occur. Thus, it can be inferred that diversification of regional productive structures is a factor that enables university-industry linkages intensification. This is due largely to the existence of a more expressive pool of skills in the more diverse regions in which it can be verified a set of differentiated services and a broad structure for Science, Technology and Innovation.

In the clustering of agents' benefits analysis in diversified production structures, Storper and Venables (2004) showed that the local flows of knowledge are strongly mediated by face to face contacts, since they allow the transmission and flow of tacit and complex knowledge. Thus, regions where there are more diversified productive structures represent privileged spaces for the dissemination of such knowledge, forming what the authors called the "buzz cities". In Brazil, more specifically in the state of São Paulo, the work of Suzigan et al (2005) showed the existence of a strong convergence between indicators of spatial concentration of industrial activity and indicators of Science, Technology and Innovation.

Finally, no significant coefficients were estimated for the control variables of urban agglomeration (*Dens*) and industrial (*VAInd*). This indicates that it was not possible to conclude what the effect of the agglomeration size is on local firms' interaction.

Besides the empirical model applied to Brazilian micro regions, it has been estimated models that adopted, as the basic geographic unit, meso regions from the country in order to more accurately assess the effects of geographical distance on the university-industry linkages. Through these models, it will be possible to identify the effects of independent variables in broader geographic areas.

For Brazilian meso regions, the same models have been estimated (regressions 1 to 3 and 1 'to 3' in Table 8). By adopting another level of regional clustering, it was possible to verify if the coefficients of each determinant of the empirical model lost its significance, i.e. whether the effects of factors have been altered. The regression results are shown in Table 8.

As we have seen in the estimations results of micro regions, the interaction variables with universities (*IU*), industrial R&D (*PDind*) and university R&D (*PDuniv*) there was positive and significant coefficients, whereas the specialization index of Krugman (*DE*) showed a negative and significant coefficient. These results reinforce the conclusions of previous models in which it was identified the importance of these factors for the interactions between firms and university research groups.

However, the variables estimation at the meso level showed a different result and somewhat interesting for the spatial dependence variable of interactions (*wIU*). When analyzed at the meso level, the variable coefficient *wIU* has showed no significance, unlike what occurred when it was estimated at the micro level. This reveals that the benefits that companies in a particular meso region receive coming from the existence of more complex structures of academic research in neighboring meso regions are quite limited. If spatial effects were important for the analysis of micro regions, we cannot say that these effects exert a similar role when dealing with meso regions.

These results show that as geographical spaces analyzed become more extensive, the interactions tend to become more tenuous, which reveals that the transmission and dissemination of new knowledge tend to become less dense. This highlights and reinforces the importance of localized university-industry linkages, in which face-to-face contacts and frequent interactions, which typically occur in smaller geographic areas, play an important of narrowing down relationships between academic research groups and firms. This demonstrates that the benefits of proximity, and ultimately knowledge flows have important geographical limitations, which also influence the ways of university-industry linkages.

Ultimately, it is possible to infer that these findings reinforce the perception in the literature (as in Audretsch & Feldman, 2003; Breschi & Lissoni, 2001; Asheim & Gertler, 2004; Storper & Venables, 2004) that local knowledge spillovers have clear geographical limitations. Dissemination of information and sharing of knowledge are far more powerful within those limited geographic areas, in which agents are able to establish local networks of contacts where information and knowledge shared will flow⁹.

Finally, Krugman's specialization index coefficient (*DE*) showed to be negative and significant, which indicates that the advantages of the regions with more diversified production structure are also found at the meso levels. Still, just as seen for micro regions, it was not possible to verify that the effects of large

⁹ Exception must be made to non-local social networks of professionals that are created from the existence of common codes of communication and own language, where substantial flows of information and knowledge run outside the site (Asheim & Gertler , 2004).

urban centers (Dens) or industrial concentrations (VAInd) are more important than the other regions, with respect to university-industry linkages.

Conclusion

The university-industry linkages have been appointed as an increasingly important source for the firms' promotion of innovative activities. Accordingly, several authors noted that geographical proximity is an important factor for the establishment of university-industry linkages, since it facilitates communication of information and flow and dissemination of tacit, specific and complex knowledge.

The university-industry linkages evaluation in Brazil which was based on the information from the 2008 Census of the Directory of Research Groups/CNPq shows similar results. It shows that the relationship between academic research and innovative activities of companies has a strong local character since 75.6% of interactions occur between companies and research groups in the same state and 51.4% in the same micro region. The empirical model developed also supports this argument since it was found a positive and significant correlation between the occurrence of interactions and the research groups (IE) with independent variables as the presence of active research groups in the region (IU), Industrial R&D efforts (PDind) and academic research activities (PDuniv).

It was also possible to determine that the benefits of proximity, as measured by the interactions of companies in a region with research groups from neighboring regions, occur mainly in smaller geographical boundaries (micro) compared with a wider (meso) geographical breakdown. This result seems to confirm the assumption that local knowledge flows occur mainly in smaller geographical areas where the flow of information and knowledge sharing are permeated by factors that typically occur at the local level.

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Table 7: Results of the Negative Binomial regression – micro regions, Brazil

	IU			IU late		
	1	2	3	1'	2'	3'
Constant	2,286 (0,242)***	2,284 (0,242)***	2,246 (0,243)***	2,393 (0,244)***	2,386 (0,244)***	2,344 (0,245)***
IU	0,012 (0,001)***	0,012 (0,002)***	0,012 (0,001)***	0,011 (0,001)***	0,01 (0,002)***	0,011 (0,001)***
wIU	0,008 (0,003)**	0,008 (0,003)**	0,008 (0,003)**	0,008 (0,003)**	0,008 (0,003)**	0,008 (0,003)**
ED	-2,018 (0,199)***	-2,016 (0,199)***	-1,996 (0,199)***	-2,089 (0,2)***	-2,084 (0,201)***	-2,061 (0,201)***
Pdind	17,358 (1,792)***	17,188 (1,808)***	17,315 (1,789)***	17,275 (1,821)***	17,128 (1,833)***	17,228 (1,817)***
Pduniv	0,973 (0,141)***	0,939 (0,141)***	0,952 (0,141)***	1,036 (0,142)***	0,999 (0,142)***	1,006 (0,142)***
Dens		0 (0)			0 (0)	
VAlnd			10,727 (7,568)			11,917 (7,643)
AIC	AIC: 2371.9	AIC: 2373.2	AIC: 2372.4	AIC: 2379.6	AIC: 2380.8	AIC: 2379.8
Log likelihood	-2.357.876	-2357.17	-2.356.392	-2.365.648	-2.364.782	-2363.84

Standard deviation in the parenthesis

***significance on 0.1%; ** significance on 1%; * significance on 5%; . significance on 10%

Table 8: Results of the Negative Binomial regression – meso regions, Brazil

	IU			IU late		
	1	2	3	1'	2'	3'
Constant	3,069 (0,412)***	3,068 (0,411)***	3,091 (0,412)***	3,2 (0,417)***	3,19 (0,416)***	3,22 (0,418)***
IU	0,007 (0,001)***	0,006 (0,001)***	0,007 (0,001)***	0,006 (0,001)***	0,006 (0,001)***	0,006 (0,001)***
wIU	0,003 (0,002),	0,003 (0,002),	0,003 (0,002),	0,003 (0,002)	0,003 (0,002),	0,003 (0,002)
ED	-1,79 (0,347)***	-1,793 (0,347)***	-1,804 (0,347)***	-1,874 (0,353)***	-1,871 (0,352)***	-1,887 (0,353)***
PDind	16,918 (3,524)***	16,637 (3,58)***	16,985 (3,544)***	16,517 (3,649)***	16,22 (3,7)***	16,585 (3,671)***
PDuniv	1,061 (0,226)***	1,053 (0,227)***	1,066 (0,226)***	1,092 (0,231)***	1,082 (0,231)***	1,098 (0,231)***
Dens		0 (0)			0 (0)	
VAlnd			-1,441 (3,848)			-1,386 (3,935)
AIC	AIC: 2371.9	AIC: 2373.2	AIC: 2372.4	AIC: 2379.6	AIC: 2380.8	AIC: 2379.8
Log likelihood	-976.463	-975922	-976.288	-981.265	-980.546	-981.11

Standard deviation in the parenthesis

*** significance on 0.1%; ** significance on 1%; * significance on 5%; . significance on 10%