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An exam of the role of the geographical proximity for the
university-industry linkages

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Abstract

It is widely recognized in the literature that the clustering of firms can generate benefits for the local firms, especially in terms of the creation and diffusion of knowledge among producers. One of the main sources of this new knowledge is the academic research, which can contribute to the innovative efforts of the firms, mainly when researchers in university and industry can cooperate by build joint research projects. Many authors (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 papers, patents and informal contacts. Second, geographical proximity can encourage cooperation between academic researchers and the R&D staff in the firms.

Based on these statements, it was done an empirical research by using data from the Brazilian Research Council (CNPq), collected at the CNPq Directory of Research Groups of Brazilian universities. This database allows the identification of 2,108 interactive research groups, among 19,470, that declared that they have interactions with 3,068 firms. By the localization of both firms and university research groups, it was possible to gather information about the geographical pattern of university-industry linkages.

Keywords: knowledge spillovers, industrial clusters, university-industry linkages

Track: U – Innovation and regional development

An exam of the role of the geographical proximity for the university-industry linkages

1. Introduction

Innovation and technological change by firms depends upon the creation and the diffusion of new knowledge. As pointed by Nelson (1959), knowledge can be seen as a non-rival production asset and the knowledge spillover is a typical externality, since few agents investing in R&D activities and technological development will end up facilitating other agent's innovation efforts.

Many studies, such as Jaffe et al (1993) and Audrescht & Feldman (1996), could identified the existence of spatially-mediated knowledge spillovers, since the investment of R&D by firms and universities "spills over" for other firms to exploit them into new products and new process, by the creation of new knowledge. In this way, the ability to receive knowledge spillovers is influenced by the distance from the knowledge source, which means that geographic concentration should be observed.

The literature had found many sources for the local knowledge spillovers. One of them is the academic research, in which the new knowledge created by the university can spillover for the firms and can foster their innovative efforts. In this way, the academic research can have an important role for the firms' innovative activities, not only as an important source for new information, but also for the knowledge sharing process through the university-industry linkages. In this paper, it was presented an empirical investigation on the importance of geographical proximity for the university-industry linkages, in order to exam if the proximity between academic research and the firms R&D is an important factor for the knowledge sharing among them. In this way, it was used data from Research Groups Directory in Brazil, in which it can be seen the existence of linkages between academic research and private R&D and the geographic location of both of them. By using this data, it was possible to exam if the interactions between university and industry occur more frequently when these agents are close to each other and in what situations the geographic proximity is more important.

2. Brief conceptual remarks

The geographical concentration of producers and other agents can benefit themselves by the presence of strong externalities, both pecuniary and knowledge externalities. Among the main knowledge externalities, the most important is the huge circulation of information and the knowledge sharing process between local agents. In many cases, the diffusion of information and knowledge occurs within complex social network, in which personal ties among local workers can build trusty relationships among them and allow the circulation of innovation and knowledge.

In this subject, there is a huge debate on the importance of local knowledge spillovers and the main ways to measure them. The firms' R&D activities, the skilled labor and the academic research are among the main ways in which the local knowledge spillovers occur. So, the academic research tends to have an important role for the generation of new knowledge and the spread of this knowledge among local agents.

As stated by many authors, such as Klevorick et al. (1995), that used data from the Yale survey, universities are a very important source of knowledge for the innovative efforts of firms, especially in industries in which new academic research findings are directly connected to industrial innovation. Nevertheless, in the case of developing countries, such as Brazil, this role of the university must be investigate, since the industrial structure of these countries didn't show the strong presence of firms in high-tech industries. In this way, in contrast to the role of the academic research in developed countries, in developing economies the university could have different characteristics and distinct patterns of interactions with firms (Suzigan et al., 2009).

In addition to the importance of the university, and the academic research, for the firms' innovative activities, many authors, such as Jaffe et al (1993) and Audrescht & Feldman (1996), observed that the geographic concentration of the firms and university can be an important factor for the knowledge sharing. In fact, these authors were trying to measure local knowledge spillovers, since they identified the existence of spatially-mediated knowledge spillovers. They also stated that academic research is one of the main ways in that local knowledge spillovers could be seen.

In the same sense, Varga (2000) considered the importance of spatial proximity between university and firms for innovation, especially in high technology industry. He stated that geographic proximity of academic research institutions and industry is an important source of positive knowledge externalities. So, personal network of academic and industry researchers, university spin-off firms and graduated students are the main important channels for the diffusion of the new knowledge from the university to local firms. In this way, the author provides some empirical evidence for the role of the agglomeration effects, by using a modified version of the Griliches knowledge production function, and their positive effects on the geographic concentration of the academic knowledge transfers for the firms.

Breschi & Lissoni (2001) also pointed out the importance of the “knowledge externalities bounded in space”, since firms that are operating nearby important knowledge sources tend to be more innovative than rival firms located elsewhere. They also emphasize the importance to increase empirical research on local knowledge spillovers for a better understanding of their nature and their main characteristics¹. In a more recent paper, the authors (Breschi & Lissoni, 2009) illustrate the role of knowledge spillovers by exam the contribution of mobile inventors and the network of inventors to the diffusion of knowledge across firms and within regions. However, their results show that the effect of spatial proximity on knowledge diffusion is not so strong, since the main channel for the knowledge diffusion was the co-inventors network, which is not necessarily spatial concentrated.

In this paper, we try to contribute for this debate, by looking for the knowledge sharing through the university-industry linkages and exam the role of the geographic concentration to stimulate the diffusion of information and knowledge.

3. Methodological remarks

In order to evaluate the role of the geographical proximity to the university-industry linkages, it was used a database from the Research Groups Directory

¹ Breschi & Lissoni (2001) argue that “the concept of local knowledge spillover is no more than ‘a black box’, whose content remain ambiguous” (p. 976).

of CNPq – Brazilian National Council for Scientific and Technological Development, an institution of the Brazilian S&T Ministry (MCT).

The CNPq Research Groups Directory was developed by the Brazilian Research Council (CNPq) to gather and organize information regarding research activities in Brazil, by asking for the leader of the research group information about their activities². The database information are related to human resources, such as researchers, students and technical staff; main research lines; knowledge specificities; academic production, measured by scientific publications, patents, and artistic production; industrial sectors connected with the research groups activities; and patterns of interaction of the research group with firms.

Since 2002, it was included in the CNPq Research Groups Directory specific questions about university-industry linkages, which are an important source of information about the patterns of interaction between firms and universities in Brazil (Suzigan et al, 2009). Nevertheless, there are some methodological problems in the collection of data that should be pointed out. The main important lack in the database is that the adherence to the CNPq Directory is spontaneous and data is collected by self-declaration, without any consistency exam. So, there is high possibility that the interactions between the research groups and firms are underestimated in the CNPq Directory database³.

3.1. Description of the data and the control groups

In this paper, it was obtained the data from the Census of 2004, since more recent data was not available. According to which, there were 19,470 research groups encompassing 77,649 researchers from 375 different institutions. However, it was selected only groups that declared that had linkages with industry. Table 1 shows the lists of variables selected for analysis. The location data on the firms were obtained by crossing firm data (the Fiscal Code - CNPJ) with information the Brazilian Fiscal authority, which enable the gathering of the firm's home state.

² The notion of “research group” adopted by the database is “a group of researchers, students and technical support staff that is organized around the development of scientific research lines following a hierarchical ruled based in the expertise and in the technical-scientific competence”. The group members usually share facilities and physical location (Suzigan et al., 2009).

³ For a description of the main characteristics, and problems, of the database of the Research Groups Directory of CNPq, and its methodological problems, see Rapini e Righi (2006).

Table 1 – Main information collected from the CNPq Research Groups Directory - 2004

| | |
|----------------------------------|----------------------------------|
| Data on the research group level | Name |
| | Leader |
| | State |
| | Affiliated university |
| | Main knowledge area |
| Data on the firm level | Specific knowledge area |
| | Name |
| | Fiscal Code (CNPJ) |
| | State of the unit that interacts |
| | Type of interaction |
| | ISIC (CNAE) |

Source: CNPq Research Groups Directory – 2004.

The information related to geographical location in this set of variables is the location both of the research group and of the firm with which it interacts. In order to declare the linkage with firms, the research group leader may register more than one type from a list of possible interactions. Since the leader can mark more than one type of linkage with the same firm, interactions may reflect repetition. Therefore, for the empirical analysis, the repetitions that included different types of relations were removed, to ensure that each pair “research group-firm” was counted only once. So, each register of the database contains one research group and one interactive firm.

Thus, a matrix was constructed taking the absolute interaction values between each state of Brazil. This enabled an analysis of the university-firm linkages based on three different dimensions: within the state; outside the research group’s home state; and of the research group of a given state with firms in immediately neighboring states (i.e., states bordering on the research group’s home state). This analysis allows checking the importance of state location regarding university-firm linkages. For example, it could be seen if most of the interactions take place within the state or the interactions outside the home state are centered in the neighborhood. By this way, it will be possible to infer the importance of geographic proximity for the construction of university-firm linkages, in convergence with the literature.

It is worthy to keep in mind that these analyses may be heavily influenced by the spatial distribution of economic activity in Brazil, which is strongly concentrated in the Southern states of the country. Therefore, following the Jaffe et al (1993) contribution, it was created a control group to handle this

problem⁴. Nevertheless, probably the concentration effect of economic activities in Brazil may not have been entirely neutralized, since that there could be a larger number of interactions with firms in Brazilian's Southern region. In this case, it is important to separate the relations that are due to the proximity of the firms with the research groups and those that are due to economic concentration in this region.

Because of this, two control samples were built. The first consists on the randomization within the groups of the interactions of each field of knowledge (77 fields). As each line of the established database represented one pair "research group-firm", a new pair was drawn for each entry of the group on this list. Thus, it was ensured that the firm could interact with any research group, the groups' probability not depending directly on their location.

In the second control sample, a similar process was used. For each certain firm within each field of knowledge, a group was drawn to be its pair in the interaction. Here the repetition of research groups was allowed and any research group having an equal probability. Thus, we ensured that within any knowledge area, firm interacted with research groups with the same probability for any group and, again, without depending directly on location.

3.2. Database and descriptive statistics

Of the research groups found in the 2004 database, 2,108 groups from 217 different institutions indicated some type of linkages with firms. This shows that of all the research groups in the database (19,470), only 10.8% declared some type of interaction. As for the institutions, 57.8% had research groups that presented some kind of linkages with firms (217 out of the 375 in the database). The declared interactions between research groups and firms totaled 8,817. After elimination of duplications, which came from the research group that selected more than one type of interactions with the same firm, 4,880 interactions were identified among the pairs "research group-firm", and compound the universe for the empirical model.

⁴ In their work, Jaffe et al (1993) created a control group with the objective to separate what factors were due to geographic proximity from what were due to the pre-existing pattern of geographic concentration of technological activities.

As for the distribution of the interactions with Brazilian universities, the top 10 institutions with the largest volume of interactions accounted for 41% of the total and 8 of them were in the South or Southeast regions (Table 2).

Table 2 – Top 10 universities with higher university-industry linkages

| University | State | Region | Interactions | % |
|--------------|---------|-----------|--------------|--------------|
| USP | SP | Southeast | 394 | 8,1 |
| UFSCar | SP | Southeast | 258 | 5,3 |
| UFRGS | RS | South | 232 | 4,8 |
| UFSC | SC | South | 212 | 4,3 |
| UFV | MG | Southeast | 169 | 3,5 |
| UNESP | SP | Southeast | 157 | 3,2 |
| Embrapa | Brazil* | - | 150 | 3,1 |
| UFRJ | RJ | Southeast | 148 | 3,0 |
| UFPE | PE | Northeast | 141 | 2,9 |
| UFPR | PR | South | 141 | 2,9 |
| Top 10 | | | 2,002 | 41,0 |
| Others | | | 2,878 | 59,0 |
| Total | | | 4,880 | 100,0 |

* Embrapa has many units in Brazil.

Source: CNPq Research Groups Directory - 2004

Looking at the distribution of interaction among the 2,108 research groups, it was not possible to identify any substantial concentration. The single exception concerned to one research group from UFSCar (the Federal University of São Carlos), which declared maintaining linkages to 199 firms, or 4.1% of the total. In the order side, from the point of view of the firms that interact with research groups, it is also unable to identify a greater concentration. The three firms most often mentioned by the research groups were: Petrobras, the stated-owned oil Brazilian company and one of the Brazilian firms that presents more huge innovative efforts; Embrapa, an agricultural research institute that is quite important in Brazil and that interacts both with universities and with firms ; and Cemig, a power transmission and distribution enterprise (

Tabela 3).

Tabela 3 – Main firms that interacts with university

| Ranking | Firm | Interactions |
|----------------|--|---------------------|
| 1 | Petrobras - Petróleo Brasileiro S.A. | 71 |
| 2 | EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária | 66 |
| 3 | CEMIG - Companhia Energética de Minas Gerais | 32 |
| 4 | Eletronorte - Centrais Elétricas do Norte do Brasil S.A. | 24 |
| 5 | Aracruz Celulose S.A. | 22 |
| 6 | FINEP - Financiadora de Estudos e Projetos | 21 |
| 7 | CHESF - Companhia Hidro-Elétrica do São Francisco | 19 |
| 8 | USP - Universidade de São Paulo | 15 |
| 9 | CVRD - Companhia Vale do Rio Doce | 15 |
| 10 | Cenibra – Celulose Nipo-Brasileira S.A. | 15 |
| 11 | Suzano Bahia Sul Papel e Celulose S.A. | 14 |
| 12 | Furnas Centrais Elétricas S.A. | 13 |

Source: CNPq Research Groups Directory – 2004.

Taking the 12 more important firms that had linkages with university in Brazil, the mains industries are energy, including oil; pulp and paper; and one mining firm, which is one of the biggest in the world. Besides these firms, one can see that there is also one agricultural research institute (Embrapa), one innovation promotion agency (Finep) and one university (USP, the University of São Paulo)⁵.

Other information available in the database concerns the distribution of the interactions over the different knowledge areas. Many authors, such as Metcalfe (2003), pointed out that some fields of knowledge, such as engineering, pharmacology, agronomy, computing and medicine, because of the nature of their academic activities, tend to be closer to the problems of the society and of the firms, bridging the gap between academic activities and applied research within firms. In the case of university-firm interactions in Brazil, it can be seen the importance of the various types of Engineering and Agricultural Sciences, areas in which the number of interactions was the largest (Table 4).

⁵ The presence of a university and a financial institution for innovation in this database shows a clear mistake in the filling of the form of the CNPq Research Groups database.

Table 4 – Number of interactions in each field of knowledge

| Knowledge areas | Interactions | % |
|------------------------------|---------------------|--------------|
| Engineering | 1.916 | 39,3 |
| Agrarian Science | 976 | 20,0 |
| Healthy Sciences and Biology | 744 | 15,2 |
| Natural and Earth Sciences | 607 | 12,4 |
| Human and Social Sciences | 428 | 8,8 |
| NA | 209 | 4,3 |
| Total | 4.880 | 100,0 |

Source: CNPq Research Groups Directory – 2004.

These data show the role of these two knowledge areas in their interaction with firms. Probably, a high share of the interactions of these research groups with firms is characterized by more routinized and codified activities that are not less intensive in terms of flows of tacit knowledge, such as laboratorial tests and essays or the supply of specialized input.

To evaluate the intensity of knowledge flows between firms and universities, it must examine the types of relations that the leaders of the research groups pointed out. When filling out the form, the leader of the research group was required to name the type of interaction that it engaged in regarding each firm with which the research group interacted – of the 15 types presented, the leader could select as many types as he or she felt were appropriate.

Table 5 shows all the different types of interaction that the research group leaders pointed out – before duplications were removed. Some of these flows are unilateral, moving from the research group toward the firm or vice-versa. This is the case of technology transfers and product developments. Others, such as joint research, have a typically bilateral nature, with information flows tending to be greater and stronger in terms of tacit, specific and complex knowledge.

Table 5 – Types of interaction between university and industry

| <i>Type of interaction</i> | <i>Total</i> | <i>%</i> | <i>Flow toward</i> | |
|---------------------------------------|--------------|--------------|--------------------|-----------------------|
| | | | <i>Firm</i> | <i>Research group</i> |
| Short-term R&D collaborative projects | 2422 | 27.5 | x | X |
| Technology transfer | 1472 | 16.7 | x | |
| Long-term R&D collaborative projects | 1206 | 13.7 | x | X |
| Consultancy | 680 | 7.7 | x | |
| Other | 513 | 5.8 | | |
| Training | 510 | 5.8 | x | |
| NA | 407 | 4.6 | | |
| Material supply | 385 | 4.4 | | X |
| Non-routinized engineering | 324 | 3.7 | x | |
| Software development | 254 | 2.9 | x | |
| Technology transfer | 220 | 2.5 | | X |
| Training | 181 | 2.1 | | X |
| Software development | 102 | 1.2 | | X |
| Non-routinized engineering | 97 | 1.1 | | X |
| Material supply | 44 | 0.5 | x | |
| Total geral | 8817 | 100.0 | | |

Source: CNPq Research Groups Directory – 2004.

The most common type of interaction is the “Short-term R&D cooperative project,” which corresponds to 2,422 interactions or 27.5%. The second is “Technology transfer for the firm” and the third is “Long-term R&D cooperative projects,” with 1,472 interactions or 13.7%. These results show that a substantial part of the interactions takes place via joint research projects, which require high knowledge content and information flows in two directions.

Another way of analyzing this information is to group the types of relations, according to their nature, into four categories: with no clear technology transfer, unidirectional from the firm toward the group, unidirectional from the group toward the firm and bidirectional (Table 6).

Table 6 – Direction of the knowledge flow

| Type of interactions | Interaction | % |
|-----------------------------|--------------------|--------------|
| Bi-directional | 3,628 | 41,1 |
| To the firm | 3,284 | 37,3 |
| To the research group | 985 | 11,2 |
| NA | 920 | 10,4 |
| Total | 8,817 | 100,0 |

Source: CNPq Research Groups Directory – 2004.

Analyzing the table, it is possible to see that the most common types of relationships are bidirectional. In other words, they involve the creation and the maintenance of complex knowledge flows and information exchange both toward the firms and toward the universities. This means that both university and industry can benefit themselves by the interactions. For the firms, academic research is not only an important source for their innovative efforts, but also cooperation with the research groups can help in their in-house problem-solving process. For the university, linkages with industry can make them perform better their research activities.

4. Results on the local dimension

Using the database of the CNPq Research Groups Directory, which was explained and characterized above, the data were treated in order to identify the importance of the local dimension of the university-industry linkages. By this way, this paper tries to contribute for a better understand of the role of the geographic concentration of economic agents, looking specifically to the academic research and firms' innovative efforts. Therefore, it must be highlighted the pioneering work of Jaffe et al (1993), who identified the existence of "spatially-mediated knowledge spillovers", in which academic research have a distinctive role.

4.1. Regional distribution of firms and university

A preliminary analysis of university-industry linkages shows that there is a clear regional concentration of research groups and firms in Brazilian's Southern regions. It became apparent that out of all the research groups that declared maintaining linkages with firms, taking interactions as the unit of analysis, more than half of the interactions involved research groups from three Southern and Southeastern states: São Paulo, Minas Gerais and Rio Grande do Sul. If it is added other states in these regions (Rio de Janeiro, Paraná and Santa Catarina), it turns out that they account for 78% of the interactions of the database. Therefore, more than three quarters of all university-industry linkages in Brazil originate from research groups in the Southern part of the country (Table 7).

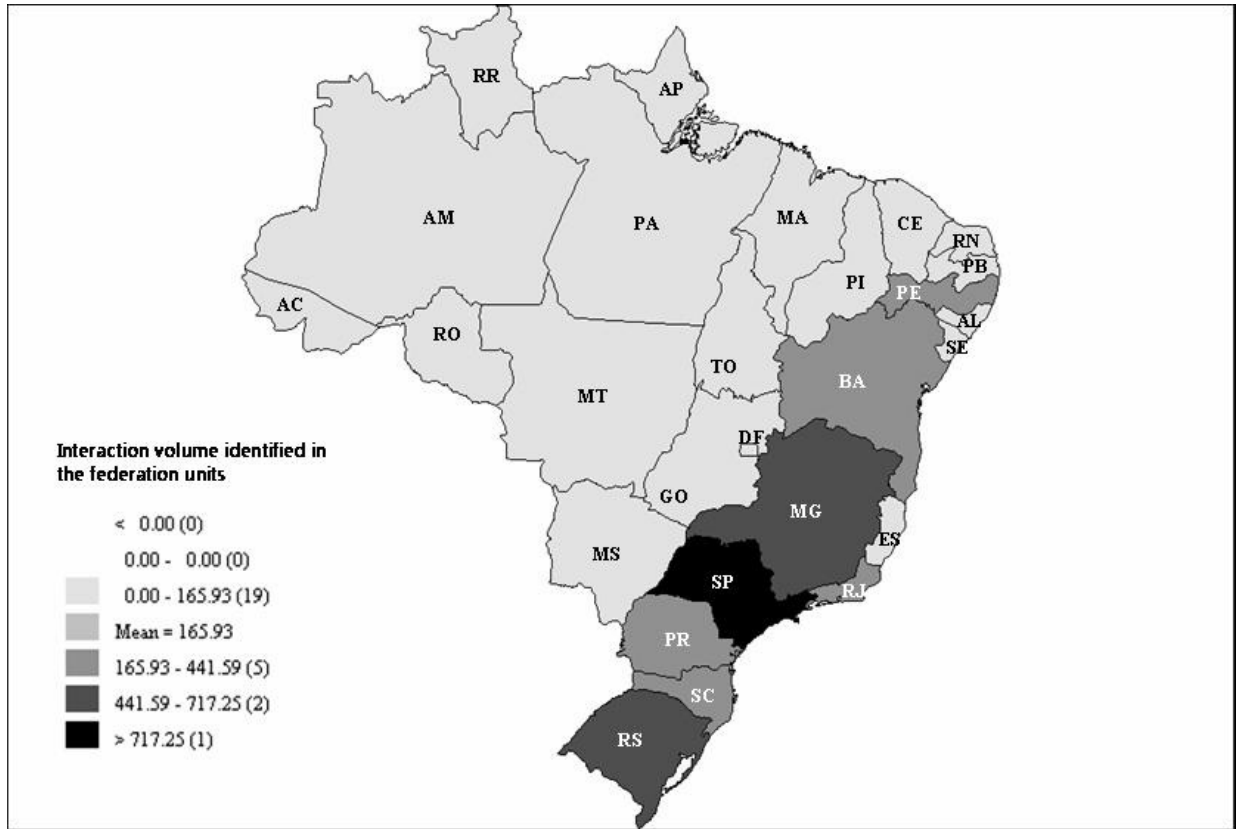
Table 7 – Geographic distribution of the university-industry linkages in Brazil

| Ranking | Location of the Research groups | | | Location of the firms | | |
|---------|---------------------------------|-------|-------|-----------------------|-------|-------|
| | State | n. | % | State | n. | % |
| 1 | São Paulo | 1,227 | 27,4 | São Paulo | 1,308 | 29,2 |
| 2 | Minas Gerais | 607 | 13,5 | Rio Grande do Sul | 484 | 10,8 |
| 3 | Rio Grande do Sul | 551 | 12,3 | Minas Gerais | 469 | 10,5 |
| 4 | Rio de Janeiro | 424 | 9,5 | Rio de Janeiro | 454 | 10,1 |
| 5 | Paraná | 385 | 8,6 | Paraná | 358 | 8,0 |
| 6 | Santa Catarina | 305 | 6,8 | Santa Catarina | 295 | 6,6 |
| 7 | Pernambuco | 186 | 4,2 | Bahia | 212 | 4,7 |
| 8 | Bahia | 225 | 5,0 | Distrito Federal | 199 | 4,4 |
| 9 | Distrito Federal | 107 | 2,4 | Pernambuco | 153 | 3,4 |
| 10 | Ceará | 77 | 1,7 | Pará | 88 | 2,0 |
| 11-27 | Others | 386 | 8,6 | Others | 460 | 10,3 |
| | Total | 4,480 | 100,0 | Total | 4,480 | 100,0 |

Source: CNPq Research Groups Directory – 2004.

Additionally, the participation of the research groups from the less important states is fairly low. Taking the 17 states with less interaction, they account for only 8.6% of total interactions. Map 1 clearly illustrates this situation, highlighting the pattern of high regional concentration of the university-firm interactions in Brazil.

Map 1 – Regional distribution of the university-industry linkages in Brazil



From the standpoint of the firms that interact with research groups, the circumstances are no different, as shown in Table 7. The six states that are the site of the most important interactive firms, in terms of the number of interactions, are the same states as those of the research groups, with small changes in the positions of some of them. However, the Southern concentration remains unchanged.

4.2. The role of proximity for the university-industry linkages

As stated above, the main objective of this paper is to exam the importance of geographic proximity for the university-industry linkages. To do that, it was constructed a database, using data form the CNPq Research Groups Directory with location of firms and research groups that interacts in Brazil. The unit of analysis for the locational pattern of both firms and universities was the states of Brazil.

However, a caveat regarding the level of the analysis should be pointed, since states are a too broad and large unit of geographic location to measure the knowledge sharing and the diffusion of information through local knowledge spillovers. This warning was made Breschi & Lissoni (2001), which stated that it is difficult to assume that academic researchers and the R&D staffs in a given state are more likely to meet face-to-face contacts. Some Brazilian states are larger than entire European countries and it is less probable that local agents in the whole state interact with the same facility. The results of Beaudry & Schiffauerova (2009) reinforce this problem, since the results of empirical tests applied to larger areas turned out to be far less significant than those of areas with lower geographic aggregation. So it would be better if it were possible to use data less aggregated at the regional level⁶. Other important evidence that points out to the importance of concentration is the number of interactions within the states, i.e., those linkages of firms and research groups of the same state. As indicated by Zucker & Darby (1996) and Audrescht & Feldman (2003), the proximity of the main sources of knowledge facilitate the access to differentiated knowledge flows and reduce the time involved in firms' learning processes.

Returning to the analysis of the database, it is worth to stand that out of the 4,480 interactions, 3,208 occur within states, which means that 71.6% of the total university-industry linkages take place within the same state. This result shows the importance of geographic proximity for the interaction between the academic research and the firms' innovative efforts, not only because of the knowledge flows generated by the university activities, but also by the easy to establish joint projects and cooperation based on face-to-face contacts. By this result, it could be conclude that geographical concentration is an important factor for the university-industry linkages.

Another way to investigate for the importance of the geographic concentration is to exam the inter-state linkages, looking for interactions between research groups of one state with firms of the neighbor states. In the same way, the exam of neighbor linkages between research groups and firms shows that out of 1,272 inter-state research groups linkages (or 28.4% of the total), 607 are

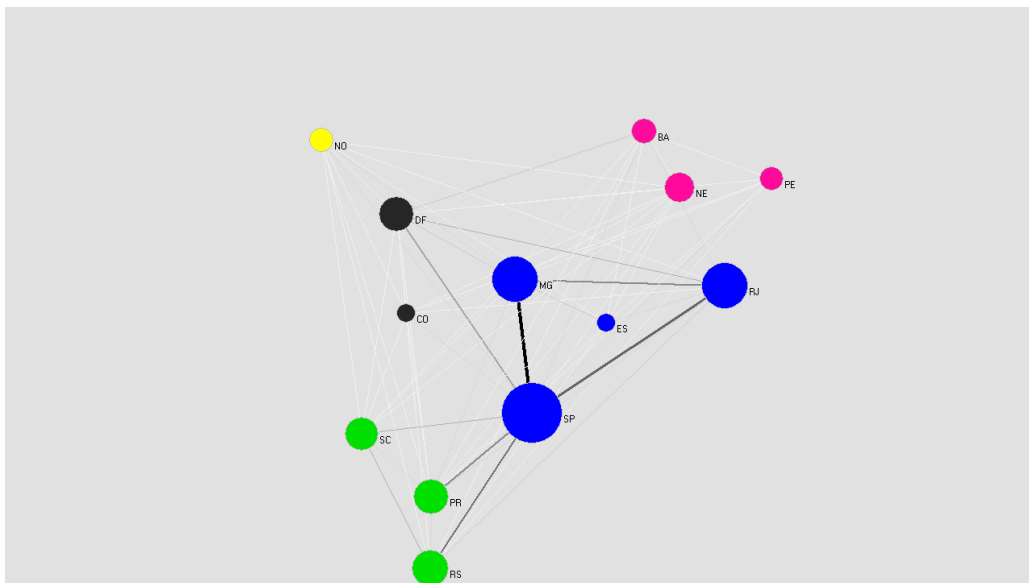
⁶ Brazilian National Institute of Economic Statistics (IBGE) uses lesser aggregated levels, such as the mesorregion and the microrregion. However, data on university-industry linkages was not available.

with firms from neighboring states that share a geographical border. That means that almost half of inter-state linkages are between research groups and firms located in neighbor states.

Looking for the opposite, it is possible to conclude that only around 15% of all linkages between research groups and firms occur in geographic distance, which means out of the inner state and of its neighbors. This is a strong conclusion about the importance of the geographic concentration between university and firms, in which the pool of capabilities, the existence of networks of professionals and the existence of face-to-face contacts are important factors that foster knowledge sharing and information diffusion between university and firms.

This could be clearly seen by using a tool of network analysis. Thus, the university-firm interactions were used to generate an interactions network among the 27 Brazilian states (Figure 1)⁷.

Figure 1 – Inter-state linkages between research groups and firms



Source: CNPq Research Groups Directory – 2004.

By looking at the figure, it is possible to present visually the concentration in the Southern and Southeastern states, given that the number of interactions is reflected in the size of the nodes. The main states in terms of the number of interactions are represented graphically, whereas the others are grouped in

⁷ In this case, the interactions within the state were excluded.

their respective region. Each circle is proportional to the total number of interactions within each state. Thus, once again, the importance of São Paulo, Minas Gerais, Rio de Janeiro and the Southern states stands out visually. Furthermore, through the states' connected lines, one can highlight the greater interactions that take place in states located in the same region or those of locations that are closer, which can bring into evidence the importance of the distance between these states.

In any event, the geographic concentration of the university-industry linkages could be a result of the geographic concentration of the economic activity. Other works, such as Jaffe et al (1993), had stated that pre-existing location factors can determine the existence of local knowledge spillovers, and the same can be applied for the university-industry linkages. Therefore, it is necessary to remove the other pre-existing location factors, in order to isolate the main causes of the geographic concentration between the academic research and the firms' innovative efforts.

4.3. Locational factors for the university-industry linkages: an empirical analysis

In order to remove the pre-existing location factors that influences the geographic concentration of the university-industry linkages, it was conducted an empirical analysis to control these factors. To do that, it was created a control group that was built by the randomization of the linkages and, after that, it was compared the results of the control group and the data from the CNPq Research Groups Directory. This control group was designed to merely remove any pre-existing concentrated interactions bias that is due only to location.

The descriptive results of the data on university-industry linkages show the importance of the geographic proximity for the interactions. In the sample obtained via the database there should be a greater frequency of interactions within the same state. To find out whether this actually occurs, it was necessary to carry out a sample randomization procedure, to reduce endogeneity.

The underlying rationality of this randomization is simple: if geographic proximity has no influence on the interactions between universities and firms, then firms can choose to interact with any research group in any part of the country. Thus, each interaction would have the same probability of occurring with any group

active in that field of knowledge. If after randomization the two populations are different, one can infer that there is a non-random process underlying the interaction occurrences in the same state and therefore that proximity influences the occurrence, or not, of interactions between research groups and firms.

For each firm that requires knowledge from one of the more than 70 recorded fields of knowledge, a new random group is chosen. In the first control, it was simply re-ordained the occurrences that are already present for each field of knowledge. In the second control, any group that currently interacts in the field has equal probability of being drawn in order to be associated with the firm. Thus, it was generated two control groups with location randomization, with control regarding the field of knowledge and the fact that the groups have technology transfer competences.

First, to see the geographic distribution of the sample's interactions and of the two control groups, we show, on table 8, the occurrence of the interactions with origin and destination (research group and firm) within the same states, in neighboring states and in states that belong to the same regions.

Table 8 – Comparison between the results of the database and the control groups

| N=4480 | Same state | Same region | Neighbors |
|------------------|------------|-------------|-----------|
| Database | 71,6% | 83,4% | 85,15% |
| Control group I | 18,3% | 38,1% | 42,63% |
| Control group II | 15,9% | 36,6% | 40,51% |

Source: CNPq Research Groups Directory – 2004.

For the three groups (two control groups and the database), it was added the road distance between the capitals of the states as a proxy of the distance between research groups and firms that interact. In the case of the interactions within a state, it was added a distance of 100 km, probably more than the mean distance between the firms and research groups within a state. However, as previously mentioned, since we lack knowledge of the location of the cities, we have to use a fixed value. The 100 km distance for the interactions within each state seems reasonable, being almost equal to the distance between the two

state capitals in Brazil that are nearest to each other (Recife and João Pessoa, some 120 km apart) and possibly introduces a bias that runs contrary to the tested hypothesis.

These two control groups, as in the procedure adopted by Jaffe and al (1993), are to be used to carry out a comparison with the data from the Directory database. The hypotheses to be tested are that the mean distance by road between the state capitals, better explained below, are not significant. For this, it was conducted an *F-test* that compares the variables that are independent and paired two by two against the original data and each control group. If it was rejected the original hypothesis (namely, that the means of the data of the control groups are equal), it would be statistically obtained the confirmation that the phenomenon is not random. In other words, it would be possible to confirm that there is a spatial phenomenon at play that drives concentration.

Table 9 – Results of the *F-test* of the database and the control groups

| <i>Variable</i> | <i>obs</i> | <i>mean</i> | <i>std. Err.</i> | <i>std. Dev</i> |
|-----------------|------------|-------------|------------------|--------------------|
| d_amostra | 4480 | 361.09 | 9.17 | 613.58 |
| d_controle1 | 4480 | 1109.42 | 14.96 | 1001.41 |
| combined | 8960 | 735.25 | 9.62 | 910.82 |
| diff | | -748.33 | 17.55 | |
| | | | | t= -42.6487 |
| | | | | Pr(T > t) = 1.0000 |
| d_controle2 | 4480 | 1141.27 | 14.82 | 991.67 |
| combined | 8960 | 751.18 | 9.64 | 912.17 |
| diff | | -780.18 | 17.42 | |
| | | | | t = -44.7798 |
| | | | | Pr(T > t) = 1.0000 |

Source: CNPq Research Groups Directory – 2004.

The *T-test* was used to verify if there were main distance differences between the sample of the database and the two control groups. If it was possible to reject the null hypothesis that the difference between them is zero, it is possible to conclude that in the control group the average of distances is higher than the sample of the database. Looking at the results, it is possible to see that the difference between them and the database is higher than 700 kilometers in both cases. Hence, the *T-test* had rejected the null hypothesis with 1% of significance, which means that distances are lower in the database than in the control groups.

In this way, it is worth to conclude that geographic concentration is very important for the university-industry linkages, with confirm the findings presented on the descriptive analysis. Moreover, this result is convergent with other works that exam the local knowledge spillovers, such as Jaffe et al (1993), and some derived models such as Thompson & Fox-Kean (2005) e Breschi & Lissoni (2006). In this paper, it was used a different variable to measure the knowledge flows, which is the deliberated linkages between university and industry.

Final remarks

The main conclusion of this paper is, by using data from the locational pattern of university-industry linkages, geographic concentration is an important factor that stimulates interaction between academic research and firms' innovative activities.

However, two points should be added to this main conclusion. First, as pointed out by Breschi & Lissoni (2001) state should be not the better proxy of the location-level analysis for the knowledge sharing process.

Second, geographic concentration of university-industry linkages could be influenced by the geographic concentration of the economic activity, in the way Jaffe et al (1993) pointed out in his analysis of the local knowledge spillovers. In order to solve this problem, it was done an *F-test* with the distance between states, comparing the results of the database with two control groups, which allows the confirmation of the same results.

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