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An analysis of the characteristics of firms and universities in shaping geographical distance of university-industry linkages

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An analysis of the characteristics of firms and universities in shaping geographical distance of university-industry linkages

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Abstract

University has been playing an increasing role in supporting innovation. In this way, university-industry linkages has become a growing subject in the literature, in order to understand how these relationships are shaped on space. Recent issue is about the role of geographical distribution of these relations, since geographical proximity can provide important benefits for firms in accessing these sources of information and new knowledge. The aim of this paper is to examine the main factors that affect geographical distance of university-industry linkages, by analysing both sides of collaboration, the characteristics of firms and universities.

Several studies show that there are important benefits related to the co-location of firms' R&D staff and academic researchers (Jaffe, 1989; Audrescht & Feldman, 1996; Arundel & Geuna, 2004; D'Este & Iammarino, 2010; De Fuentes & Dutrenit, 2014). However, recent analyses show that, several times, firms prefer to collaborate with geographically distant universities, since there are some factors that stimulate firms to go far to interact with university (D'Este & Iammarino, 2010; Laursen et al, 2011; Muscio, 2013).

Hence, the main question that the literature are trying to answer is why firms go far to interact with university. General results points to two main drivers. First, firms look for distant universities when they cannot find local high-performance academic research. Second, firms must have high absorptive capacity in order to be able to search for universities that are able to solve their innovative problems. Previous studies show important evidence to this debate. However, they left an important gap that requires deeper analysis, since evidence presented in previous studies are based only on information about the university (D'Este & Iammarino, 2010; Muscio, 2013) or only of the firm (Laursen et al, 2011; De Fuentes & Dutrenit, 2014).

Linked to this issue, this paper aims to contribute to this debate not only by presenting new evidence on the main drivers of the pattern of geographical distance of university-industry linkages, but also by presenting a comprehensive analysis of the collaboration by using complete information of both universities and firms. To do that, a wide-ranging database of interactions between university and industry was used in the scientific fields of Engineering and Agrarian Sciences in Brazil.

Main results of the empirical analysis show that bigger firms with higher absorptive capacity tend to interact with more distant research groups, which shows the importance of the skills of the firm to find universities, local or distant, that are able to solve their innovative

problems. On the side of the university, larger research groups and those who perform higher quality academic research presents higher average geographical distance of interactions, which shows that they are able to attract more distant firms to collaborate.

Keywords: geography of innovation; university-industry linkages; absorptive capacity; academic research quality; policy.

JEL Codes: O18; O31; R12; R58

An analysis of the characteristics of firms and universities in shaping geographical distance of university-industry linkages

Introduction

University has been playing an increasing role in supporting innovation. Academic research is an important source of new knowledge for producers, which has motivated firms to seek university in order to establish collaboration and accessing new knowledge. In this way, university-industry linkages have become a growing subject in the literature, in order to understand how these relationships are shaped. One of the recent issues on this debate is about the role of geographical distribution of these relations, since geographical proximity can provide important benefits for firms in accessing these sources of information and new knowledge. Linked to this issue, the aim of this paper is to examine the main factors that affect geographical distance of university-industry linkages, by analysing both sides of collaboration, the characteristics of firms and universities.

Several studies show that there are important benefits related to the co-location of firms' R&D staff and academic researchers (Jaffe, 1989; Audresch and Feldman, 1996; Arundel and Geuna, 2004; D'Este and Iammarino, 2010; De Fuentes and Dutrenit, 2014). However, recent analyses show that, several times, firms prefer to collaborate with geographically distant universities, since there are some factors that stimulate firms to go far to interact with university (D'Este and Iammarino, 2010; Laursen et al, 2011; Muscio, 2013). Therefore, there is conflicting evidence about the patterns of the spatial distribution of university-industry linkages.

Hence, the main question that the literature are trying to answer is why firms go far to interact with university. General results point to two main drivers. First, firms look for distant universities when they cannot find local high-performance academic research. Second, firms must have high absorptive capacity in order to be able to search for universities that are able to solve their innovative problems. Previous studies show important evidence to this debate. However, they left an important gap that requires deeper analysis, since evidence presented in previous studies are based only on information about the university (D'Este and Iammarino, 2010; Muscio, 2013) or only of the firm (Laursen et al, 2011; De Fuentes and Dutrenit, 2014).

Linked to this issue, this paper aims to contribute to this debate not only by presenting new evidence on the main drivers of the pattern of geographical distance of university-industry linkages, but also by presenting a comprehensive analysis of the collaboration by using complete information of both universities and firms. Other contribution of the paper is to analyse the geographical pattern of university-industry linkages to a developing country, Brazil, since all previous analysis was applied to developed countries, mainly to European countries (exception to De Fuentes and Dutrenit, 2014, who did the analysis to Mexican case).

To do that, a comprehensive database of interactions between university and industry was used in the scientific fields of Engineering and Agrarian Sciences in Brazil. Main data came from the Brazilian Ministry of Science and Technology and gathers information on the activities of research groups in Brazil and their interactions with firms. This database includes the main characteristics of the research groups, and information about interactive firms was added.

Main results of the empirical analysis show that bigger firms with higher absorptive capacity tend to interact with more distant research groups, which shows the importance of the skills of the firm to find universities, local or distant, that are able to solve their innovative problems. On the side of the university, larger research groups and those who perform higher quality academic research presents higher average geographical distance of interactions, which shows that they are able to attract more distant firms to collaborate.

This paper is organised into four sections, excluding this introduction. The first section presents the main conceptual debates the geographical distance university-industry linkages and the effects of characteristics of the firms and research groups. Section two presents a brief description of the data and the empirical model. Section three presents results and discusses the effects of characteristics of the firms and the in research groups over geographical distance university-industry. Finally, section four presents final remarks and some policy implications.

1. Geographical distance and university-industry linkages

The role of university and academic research in fostering innovation is a growing subject in the literature. Many studies have focused on the importance of university as source of new knowledge, supporting firms' innovation and collaborating to solve innovative problems (Nelson, 1959; Klevorick *et al.*, 1995; Cohen *et al.*, 2002). In general, authors agree that university is a very important source of firm innovation, and this importance grows in industries closer to the scientific and technological base (Klevorick *et al.*, 1995). University research is also important not only to suggest new ideas for industrial R&D projects, but also to collaborate to the conclusion of ongoing projects (Cohen *et al.*, 2002).

Recent analysis of university-industry linkages have increased attention on the role of geographical proximity in collaboration between academic research and industrial R&D. Some of them have empirically demonstrated the benefits associated with the co-location of universities and firms (Jaffe, 1989; Audretsch and Feldman, 1996; Mansfield and Lee, 1996; Anselin *et al.*, 1997; Arundel and Geuna, 2004; Laursen *et al.*, 2011; D'Este and Iammarino, 2010; De Fuentes e Dutrenit, 2014).

Geographical areas with dense spatial concentrations of universities and firms can give rise to important benefits to local firms, both in assisting with and promoting innovative efforts. Firms with closer proximity to knowledge-generating centres are able to gather an important competitive advantage because of the benefits associated with the increased potential for university interactions. In addition, firms located close to universities are more likely to benefit from local knowledge spillovers that came from academic research because the dissemination of knowledge can be facilitated by local communication networks between firms and universities. Proximity of firms and universities facilitates the interactive learning process through frequent personal interactions and face-to-face contact, thereby favouring firms located near centres of scientific and technological expertise (Arundel and Geuna, 2004; Abramovsky *et al.*, 2007; Fritsch and Slavtchev, 2007; Ponds *et al.*, 2007; D'Este *et al.*, 2013; Muscio, 2012).

On the other hand, recent studies show that firms usually go far to search for well-qualified universities that are able to solve their innovative problems (D'Este and Iammarino, 2010; Laursen *et al.*, 2011, Muscio, 2013; De Fuentes e Dutrenit, 2014). In

this way, it is worthy to assume that geographical proximity is one of the factors that determines to which university the firm will interact with, since co-location facilitates interactive learning. Nevertheless, geographical proximity is not the only cause for a firm's decision to interact with a certain university, because firms are looking for broad academic skills that can help them in solving their innovation problems (Bishop *et al.* 2011; D'Este *et al.*, 2013). When firms need unique, complex and tacit knowledge, they will look for a university that is able to solve their problem, regardless of where that university is located.

In this way, the analysis of how university-industry linkages are shaped on space requires a deeper examination, in order to catch the main factors that influence the geographical distance of interactions. In fact, the main factor that explains the importance of geographical proximity is the need of tacit knowledge required for innovation (Gertler). However, there are several other forms of sharing tacit knowledge, which are configured through different types of proximity among economic agents (Boschma, 2005).

It is important to note that firms interact with university because they need to get access to new knowledge to foster innovation. If the firm is able to find geographically close high-qualified university, which is able to help in solving innovative problems, the firm will probably interact with it. However, if the local university is not well-qualified to help producers, the firm has to be able to search, and find, a non-local university that have the main skills to help the firm to solve its innovative problems. In this way, even with the literature points a set of benefits of the co-location of university and firms, local interaction will only occur if two main factors are simultaneously met. First, if the local university is qualified to assist in solving the innovative problems of the firm. Second, if the firm is not able to search well-qualified non-local universities.

There are some evidence of how the quality of academic research affects the geographical distance between firms and university that collaborate. Using a database of research funds granted in the UK between 1999-2003 (EPSRC), D'Este and Iammarino (2010) have found that interactions involving firms and high quality research university departments, measured by RAE evaluation, tend to occur at greater distances, even controlling other factors, such as the department's size and the amount of funding received from firms. Additionally, the curvilinear relationship between the quality of research and the distance of interaction shows that top-ranked university departments exhibited significantly shorter distances in comparison to interactions with mid-ranked university departments (D'Este and Iammarino (2010).

High-quality academic research and the applicability of the research to industrial purposes are also drivers of long-distance collaboration between university and industry, as well as the mobility of academic researchers (Muscio, 2013). These results were obtained from a database of 197 Italian university departments in the Engineering and Physical Sciences. Data were analysed using an Ordered Logit model for collaborations in increasing levels of distance, such as same province, region, country, within the European Union and other countries and encompasses only information regarding the university (Muscio, 2013).

Other evidence shows that the presence of a local high-qualified university department favours local interactions, especially for low R&D expenditures firms (Laursen *et al.*, 2011). This result was found using data from the UK Innovation Survey 2005, which has information of the main features of the firm. In this way, the analysis is

quite rich regarding the innovative efforts of the firms, but have little information about the academic partner, including the geographical distance among them. To define the main determinants of long-distance interaction and its relation to the quality of university research, it was used a Nested Logit model, in which the decision to interact locally or not is subject to the first step of the model. At the first step, the analysis evaluated the factors that affect the firms' decision to cooperate with university and, at the second step, if it will be local or not (over 100 miles). The main conclusion is that there are two main factors affecting the geographical distance of the interaction: the quality of research, measured by RAE evaluation, and the intensity of firms' R&D expenditure. The lack of high-qualified local partner favours interactions over longer distances.

This debate shows that both characteristics of the firms and of the university presents important effects concerning the geographical distance of the interactions between firms and universities. Looking first at the features of research groups, the quality of academic research is an important aspect for the firms' decision to interact to a university. The primary benefit for firms interacting with top universities is access to state-of-the-art knowledge generated by high academic performance. In fact, the generation of more advanced or radical innovations requires a differentiated set of knowledge, which is more easily found at top universities (D'Este and Iammarino, 2010; Laursen et al., 2011; Bishop et al., 2011). Thus, the excellence of academic research can be an important aspect for the decision of the firm to interact with certain university, in order to contribute their innovative efforts. The interaction with high-performance universities is based on the share of complex and tacit knowledge, one of the primary characteristics of state-of-the-art knowledge. These universities are able to master a broad and complex set of capabilities, which can be a very important factor in fostering the innovative process of the firm. In this way, geographical proximity is particularly important if the interactions encompass the sharing of tacit and specific knowledge, which requires frequent face-to-face contact and professional mobility (Bishop *et al.*, 2011).

The size of research group is another factor that affects university-industry linkages (De Fuentes and Dutrénit, 2012). A research group with more technicians and researchers certainly has more accumulated capabilities, which arises from both previous research projects and the experience of interactions with firms. In this way, larger groups are not only able to share broader and more complex knowledge with firms but they are also better able to overcome barriers to interacting with industry. The lifetime (team age) of research group is another relevant factor that influence university-industry linkages (De Fuentes e Dutrénit, 2012). The characteristics of researchers can be connected with the firm's benefits, and the team age is one of this characteristics.

In addition to the features of the research groups, the characteristics of firms that interact can also influence the decision to what university they will interact with. In particular, two factors that influence this decision are the absorptive capacity of the firm, firm's size and industrial sector (Cohen et al, 2002).

Taking first the absorptive capacity of the firm, it relates to firm's ability to evaluate, assimilate and take advantage of available external knowledge (Cohen and Levinthal, 1990). Firms with greater absorptive capacity tend to interact more with university, since they are able to get higher benefits from the collaboration with academic research (Boschma and Ter Wal, 2007; Balland, 2011). In addition, these firms

are also able to search for capabilities in universities that better fit their innovative problems. The firms' absorptive capacity relates in a special way with local and non-local university-industry linkages. Firms with low absorptive capacity depend more on the geographical proximity to universities to interact with them, regardless of the quality of academic research. On the other hand, firms with high absorptive capacity have a greater range of potential academic partners, going beyond to the geographically close environment to interact with university. This occurs because these firms can incorporate more efficiently knowledge generated by the most qualified research groups and can get better ways to search and coordinate their activities with non-local universities (Laursen et al., 2011). This is particularly important when firms cannot find local universities that can help them to solve innovation problems (Bishop *et al.* 2011).

Other important feature that affect interaction to universities is the firm's size. In general, larger firms interact more to university, since they have more internal skills to develop a wider range of collaborations with academic research (Fritsch and Lukas, 2001). In this way, notwithstanding small firms can also have demands for interactions with university, larger firms tend to report more benefits from interactions with universities in order to obtain new information, professional recruitment and application of external knowledge in their innovative activities (Bishop et al., 2011). Most firms that carry out R&D in collaboration with research institutes are large ones. In general, larger firms can more easily deal with long-distance interactions and incur the costs of this type of interaction (Levy et al., 2009). Small and medium firms tend to rely more on local environment to interact to university, since interaction over long distances tend to require wider capabilities and could be more costly (Muscio, 2013).

Previous studies presented important evidences, but they leave some gaps that need to be deepened, especially regarding to a comprehensive analysis that consider together the characteristics of both the firm and the university. The study of Laursen et al (2011) is based on a dataset that is very rich regarding the features of the firms, but little information is presented about the university. On the other hand, D'Este & Iammarino (2010) and Muscio (2013) have used almost exclusively information about the characteristics of the university. Regarding the geographical level, analysis are often quite broad and aggregate. Concerning information of the academic research quality, previous studies have measured it at the department level, which means that they are considering that the average qualification of the department do not differ too much among their research groups, even in large departments. Finally, the quality of academic research is usually measured, except for Muscio (2013), by a wide proxy, the RAE grade, instead of using the publications by researcher, which is a more appropriate variable for assessing the quality of academic research.

In order to fill these gaps, this paper deals to examine the main factors that affect geographical distance of university-industry linkages. To do that, an empirical model was built in order to examine the main characteristics of the firms and of the research groups that affect the geographical distance of the interactions.

2. Empirical analysis

2.1. Main features do the database of university-industry linkages in Brazil

In order to examine how the characteristics of the university and firms affect the geographical distance of university-industry linkages in Brazil, it was exploited a specific dataset derived from the collection various sources data. The sample of interactions of firms and university was gathered from the Brazilian Ministry of Science and Technology, at the CNPq Directory of Research Groups of the Lattes database, which provides a broad set of information on the activities of academic research groups in Brazil¹. This dataset covers the main characteristics of the academic research groups, such as its scientific field, the number of researchers, its research performance and the firms with whom it interacts². To these data, it was added information of firms, such as size, industrial sector, and qualification of the labour force, from the Brazilian Ministry of Labour. Further, it was also added information about geographical distance of the interaction between the firm and the research group, measured by the distance in kilometres, in a straight line, from the georeferenced coordinates (latitude and longitude) of the zip codes (ZIP) of firms and research groups.

Therefore, the final database includes 4,337 interactions that involves 3,063 firms and 1,738 Engineering and Agrarian Sciences research groups in 2010 from all Brazilian regions³. On average, firms interact with 1.42 research groups and the research groups report collaboration with 2.49 firms. The average number of published papers per researcher is 15; the average size of research group is 9 researchers; and the average lifetime of research groups is 10 years. Moreover, a large share of the firms (25%) has at least 42% of higher degree employees. Regarding firm's size (SizeF), there are big differences in the sample: the first quartile of the firms have less than 3 employees and the last quartile has more than 248 employees, including the largest firm that has more than 130 thousand employees (the Brazilian National Army).

2.2. Econometric analysis

Using this dataset, an empirical model to examine how geographical distance of university-industry linkages in Brazil is affected by the main characteristics of firms and research groups was built.

The dependent variable is the geographical distance between the research group and the firm (*DistInt*). The definition of the geographical distance as the dependent variable is related to the main aim of the paper, which is to examine the main factors that affect the way in which university-industry linkages are shaped on space. In this way, independent variables were defined by those characteristics of research groups and firms that can affect the geographical distance of collaboration. The selected

¹ CNPq is the Brazilian Council for Scientific and Technological Development, an institution of the Brazilian Ministry of Science and Technology that is dedicated to the promotion of scientific and technological research.

² In Brazil, some studies, such as those by Rapini *et al.* (2009), Suzigan *et al.* (2009) and Chaves *et al.* (2012) have already used this database to analyse the role and the importance of interactions and to evaluate how knowledge created by universities has been used by firms.

³ It is worthy to mention that Engineering and Agrarian Science are the scientific fields that presents larger amount of interaction in Brazil (Suzigan *et al.*, 2009).

characteristics of research groups were the quality of the academic research (*Quali*), measured by published papers per researcher in the period 2009-2010; the size of research group team (*SizeG*), measured by the number of researchers; and the research group lifetime (*TimeG*). At the firm level, selected characteristics were its absorptive capacity (*AbsorCF*), measured by the share of employees with high education; and firm's size (*SizeF*), measured by the number of employees (Table 1).

Table 1: Description of variables

| Variable | Description | Source |
|-------------------|---|---------------------------------|
| <i>DistInt</i> | Distance in kilometres in a straight line from the georeferenced coordinates (latitude and longitude) of the zip codes (ZIP) of firms and research groups | API Google |
| <i>O-Dist</i> | 1 – até 100 km, 2 – de 100 km a 500 km; 3 – mais de 500 km. | |
| <i>Quali</i> | Number of articles per researcher (2009-2010) | CNPq, 2010 |
| <i>SizeG</i> | Number of researchers in the research group | CNPq, 2010 |
| <i>TimeG</i> | Research group lifetime | CNPq, 2010 |
| <i>AbsorCF</i> | Share of employees of the firm with higher education | RAIS, 2008 |
| <i>SizeF</i> | Logarithmic number of employees of the firm | RAIS, 2008 |
| <i>AgglomLev</i> | Population density in the region of the firm | IBGE, 2000 |
| <i>K-index</i> | Krugman's index of specialisation in the region of the firm | Original work, using RAIS, 2008 |
| <i>R&D_LG</i> | Number of active, full-time PhD professors per 10,000 inhabitants of the municipality in which the firm is located | INEP, 2009 and IBGE, 2010 |
| <i>R&D_LF</i> | Number of R&D researchers per 10,000 workers of the municipality in which the firm is located | RAIS, 2008 |
| <i>Financ</i> | <i>Dummy for public finance.</i> | CNPq, 2010 |
| <i>MacroR</i> | <i>Dummy for Brazil's macro regions</i> | CNPq, 2010; IBGE |
| <i>SciField</i> | <i>Dummies for scientific fields</i> | CNPq, 2010 |
| <i>Ind</i> | <i>Dummies for industries</i> | CNPq, 2010 |
| <i>IntType</i> | <i>Dummies for different types of interactions</i> | CNPq, 2010 |

Source: Original work.

Controls have also been added in order to consider exogenous factors related to the locational pattern of the firms and research groups. Locational factors can also affect the decision of the firm to which research group it will interact. The first control is the density of the urban population of the region of the firm, so called agglomeration level (*AgglomLev*). Firms located in more dense urban areas can benefit from the presence of broader and diversified local academic skills, which may influence the decision to interact with local universities. Other control for agglomeration effects is the Krugman specialization index (*K-index*), which measures the relative level of regional industry diversification. Economic diversity can play an important role in fostering interactive learning and innovation, since a diversified environment can create greater opportunities to imitate, share and recombine ideas and practices across industries (Glaeser et al., 1992; Storpoer and Venables, 2004). Additionally, heterogeneity of local capabilities can stimulate the exchange and cross-fertilization of existing ideas, as well as generating new ideas through different industries (Storper and Venables, 2004;

Duranton and Puga, 2001). Moreover, variables for academic and industrial R&D (*R&D_LF* and *R&D_LG*, respectively) was included to control local R&D expenditures at both the firm and university levels. Other locational factors also controlled is a dummy to control macro regional differences (*MacroR*), due to the unequal regional distribution of R&D expenditures among Brazilian regions.

A dummy for the scientific fields of research groups (*SciField*) was added, since different scientific fields play different roles in supporting innovation and present different patterns of interaction with firms (Meyer-Krahmer and Schmoch, 1998; Scharfetter et al., 2001; Bekkers and Bodas-Freitas, 2008). Others added dummies were for industry sectors (*Ind*); and for types of interactions (*IntType*), since both different industries (Abramovsky et al, 2007; Scharfetter et al, 2001) and different types of collaboration (Perkmann et al, 2011; D'Este & Patel, 2007) can affect geographical distance of interactions. Finally, it was controlled the patterns of financial support (*Financ*) for the interactions, since different patterns of financial supports may influence in the way and frequency that interactions occurs (De Fuentes and Dutrénit, 2013).

The empirical model was defined as follows:

$$DistInt = Quali + SizeG + TimeG + AbsorCF + SizeF + Controls$$

Table 2 shows the relationship between geographical distance (*DistInt*) and the other variables, such as quality of the research (*Quali*) and size of the group (*SizeG*), at the research groups level, and absorptive capacity (*AbsorCF*) and size of the firm (*SizeF*), at the firm level. It allows comparing the average geographical distance for each of the selected variables. In general, it can be seen that interactions of the research groups and firms from the last quartile present higher average distances than the first quartile, suggesting the existence of positive relations between geographical distance and the selected variables.

Table 2: Average Distance between groups and firms

| | Quali | SizeG | SizeF | AbsorCF |
|--------------------|-------|-------|-------|---------|
| First quartile (a) | 301.5 | 288.2 | 278.8 | 268.6 |
| Second quartile | 306.3 | 328.3 | 277.4 | 291.7 |
| Third quartile | 333.2 | 275.6 | 347.3 | 316.1 |
| Last quartile (b) | 325.1 | 373.9 | 362.6 | 389.6 |
| (b) - (a) | 23.6 | 85.7 | 83.8 | 120.9 |

Source: Original work.

Table 3 shows the descriptive statistics. The average distance between firms and research groups is 316.5 km, but with high variance, and half of the interactions occur within a range up to 82.4 km. On the other hand, 25% of interactions occur on a larger scale to 366.3 km; up to a maximum of 3,344.6 km, which show that in a country of continental dimensions long distance interactions could not be an exception.

Table 3: Descriptive Statistical (N=4,337)

| Variable | Min | First Quartile | Median | Third Quartile | Max | Mean | Std.Dev. |
|-------------------------|------------|---------------------------|---------------|---------------------------|------------|-------------|-----------------|
| DistInt | 0.0 | 6.9 | 82.4 | 366.3 | 3,344.6 | 316.5 | 544.0 |
| SizeG | 0.0 | 5.0 | 8.0 | 12.0 | 54.0 | 9.6 | 6.2 |
| Quali | 0.0 | 4.6 | 10.1 | 19.1 | 144.5 | 14.1 | 14.3 |
| TimeG | 0.0 | 4.0 | 9.0 | 16.0 | 78.0 | 11.3 | 9.9 |
| AbsorCF | 0.0 | 0.02 | 0.2 | 0.5 | 1.0 | 0.3 | 0.3 |
| SizeF | 0.0 | 1.9 | 4.3 | 6.1 | 11.8 | 4.0 | 2.6 |
| Firm's employees | 0.0 | 7.0 | 73.0 | 440.0 | 139,047.0 | 664.4 | 3,381.9 |
| AgglomLev | 0.3 | 67.5 | 337.5 | 1,112.6 | 5,796.0 | 1,207.1 | 1,786.7 |
| K-index | 0.4 | 0.6 | 0.7 | 0.8 | 1.9 | 0.7 | 0.2 |
| R&D_LF | 0.0 | 478 | 663.4 | 942.8 | 1839.3 | 736.5 | 368.5 |
| R&D_LG | 0.0 | 2.1 | 40.3 | 59.8 | 312.3 | 46.3 | 51.0 |

Source: Original work.

3. Results and discussion

Table 4 shows the results of Robust Regression estimation⁴.

Table 4: Robust Regression Results (1) and Ordered Logit (2) (N = 4,337)

| DistInt | [1] | (2) |
|----------------------|-------------------|-------------------|
| SizeG | 0.012* (0.005) | 0.009** (0.003) |
| Quali | 0.006* (0.002) | 0.003* (0.001) |
| TimeG | 0.002 (0.003) | 0.001 (0.002) |
| AbsorCF | 0.580*** (0.12) | 0.472*** (0.070) |
| SizeF | 0.037** (0.013) | 0.013 (0.007) |
| AgglomLev | 0.000*** (0) | 0.000*** (0) |
| K-index | 0.536*** (0.161) | 0.482*** (0.094) |
| R&D_LF | 0.000 (0.000) | -0.000 (0.000) |
| R&D_LG | -0.010*** (0.001) | -0.004*** (0.000) |
| Finac | 0.198** (0.066) | 0.118** (0.390) |
| MacroR | Yes | Yes |
| SciField | Yes | Yes |
| Ind | Yes | Yes |
| IntType | Yes | Yes |
| R² | 0.1645 | 0.064 |

*** p < 0.1%; ** p < 1%; * p < 5%; standard deviation in brackets

Source: Original work.

Looking first at the selected characteristics of the research groups, the quality of the research performed by the group (*Quali*) and the size of the research group (*SizeG*) positively affect the distance of interactions.

Analysing the positive impact of the quality of the research performed by the group (*Quali*), it is possible to conclude that the mean geographical distance between the firm and the research group that interact is greater when high-performance research groups are involved. This result suggests that firms are willing to interact with more distant high-quality research groups to support their innovative efforts, to solve production and operational problems, and to foster the development of new products and processes. Firms seek high-quality research groups for collaborative efforts because they believe that these research groups are more skilled in handling complex problems. This result confirms the primary assumptions presented in the conceptual discussion that firms primarily interact locally; when they are searching for high-quality research groups, they then reach over greater distances to interact to university.

⁴ Generalized Method of Moments (GMM) is an estimation procedure that allows economic models to be specified when the usual assumption of normality fail. GMM is much more flexible because it does not impose any restriction on the distribution of the data, such as specifying a normal distribution for the errors. Therefore, GMM represents a better approach since the test for data show that they are not normally distributed.

On the other hand, lower-performance research groups interact more locally because the average distance of their interactions is lower. This result demonstrates that mid- and low-quality research groups more commonly interact with local producers whose demands they are better able to address. These research groups may lack capabilities and expertise to justify developing linkages with distant firms because the costs for interacting over distance are higher. Therefore, the importance of lower-performing local universities cannot be underestimated, since local universities are better positioned to collaborate with local firms on simpler problems that do not require access to cutting-edge knowledge or expertise (Mansfield and Lee, 1996).

Other characteristic of the research groups, the size of research group (*SizeG*), also positively affect the geographical distance of the interactions. This result indicates that research groups with more researchers tend to have more distant interactions. These research groups have a broader structure to meet not only local firms, but also firms located in other regions. This broader structure involves greater and more diversified academic capabilities that are able to solve more complex innovation problems, and then they can attract the attention of more distant firms. Normally, larger research groups has more diversified skills, which reflects in the ability to solve more complex innovative problems of the firms. The broader structure is also reflected in greater experience in interacting with firms, since these research groups have capabilities to solve problems related to the management of the interactive projects with firms. This set of capabilities is reflected in the ability to meet not only local firms' problems, but also firms located in regions that are more distant. On the other hand, smaller research groups, with less researchers, do not aggregate a broader set of academic skills, what constrains them from being able to meet firms located in regions that are more distant. Therefore, smaller research groups are able to interact only with local firms.

The last selected characteristic of the research groups was the lifetime of research group (*TimeG*). Results show that the lifetime of the research group presents no significant coefficient, which means that there is no relation between the lifetime and the geographical distance of the interaction. In this way, even oldest and most lasting research groups, and probably with more experienced researchers, do not interact with firms at greater distances.

Regarding the selected characteristics of firms, both absorptive capacity (*AbsorvCF*) and firm's size (*SizeF*) presents positive and significant coefficients, which means that both characteristics positively affect the geographical distance of the interactions.

Analysing first the absorptive capacity (*AbsorvCF*), the positive coefficient shows that firms with higher absorptive capacity interact with more distant research groups. Previous studies show that firms with higher absorptive capacity interact more with universities, since they are able not only to search for academic capabilities that deal with their innovative problems, but also to present academic benefits for research groups, such as ideas to new projects and new insights for the research agenda (Bishop et al., 2011; Tartari and Breschi, 2012). In this way, results show that firms with higher absorptive capacity also interact to more distant research groups, since these firms are more able to search for research groups that meet their demands for their innovative problems, regardless of geographical location. Thus, these firms are less dependent on co-localization with research groups to interact with the university. Furthermore,

problems that these firms seek to solve tend to be more complex, which enables collaboration with distant universities, even with this means that higher interactive costs.

Previous studies show that firms with higher absorptive capacity interact more with firms (Boschma e Ter Wal; Balland, 2011). Results of this paper show that high absorptive capacity firms also interact with more geographically distant universities, since these firms can incorporate more efficiently knowledge arising from high qualified research groups, and has better search engines and selection process of academic activities.

On the other hand, firms with lower absorptive capabilities may find it difficult to locate research groups that are able to address their needs and may consequently interact primarily with local universities. In fact, firms with lower absorptive capability tend to experience fewer complex problems in their production and innovation processes. Lower-performing local universities are usually capable of managing these problems, removing any justification for seeking collaboration with distant research groups.

The other selected characteristic of the firm is the firm size (*SizeF*), which presents positive and significant influence to the geographical distance of university-industry linkages. This result indicates that larger firms not only have better conditions to interact more frequently with universities (Levy et al., 2009; Gallie and Roux, 2010), but also they are better able to interact with research groups at greater distances. This means that they have skills to search for distant research groups and to finance higher costs of the long distance interactions.

Regarding control variables, results can also reveal the role played by locational factors in shaping university-industry linkages on space. First, the positive and significant coefficient of the population density in firms' regions (*Agglom*) indicates that the higher the population density of the region of the firm more geographically distant tend to be university-industry interactions. This result shows that more dense regions present greater possibilities of interaction with universities, given the existence of wider academic skills and research capabilities in these regions. Moreover, these opportunities of collaboration with local universities can enlarge the skills of the firm to interact also with distant universities.

Second, the positive and significant coefficient that measure the main features of the local productive structure, the Krugman index of specialisation (*K-index*), indicates that firms located in more diversified regions tend to interact more often locally. This relationship can largely be explained by the presence of a broader set of local firms, which tends to increase the heterogeneity of the local industry, including firms with higher capabilities to collaborate with university. Actually, the diversity of the local structure emphasises the importance of urban agglomeration, which allows for the concentration of diversified industry and high-quality academic research centres, which can generate cross-fertilisation effects and can strengthening university-industry linkages. These processes are the central point of the argument that agglomeration in diversified regions can foster different types of interaction among co-located players, such as frequent interactions and face-to-face contact (Storper and Venables, 2004). This result may also suggest that firms located in specialised regions may have considerable difficulty in finding opportunities for collaboration with academic researchers. In such cases, firms may be compelled to seek collaboration with distant

research groups and, in addition, will have more difficulties in building up capabilities to collaborate with university.

Third, the academic R&D (*R&D_LG*) has a significant and negative effect on geographical distance. The higher is local university R&D expenditure, the more localised the interactions with firms become, which means that in regions with higher levels of academic research expenditures, firms tend to interact within shorter distances. The main reason for this is that regions with a wide-ranging pool of academic skills are usually capable of addressing the main needs of the co-localised firms in order to support their innovative efforts. Therefore, firms do not need to search elsewhere for collaboration. In fact, when firms find universities with similar levels of research quality, they will prefer to collaborate with local universities (Laursen et al., 2011), which endorse the importance of spatial co-location and geographical proximity for university-industry linkages. Finally, the positive and significant coefficient of finance of research groups (*Financ*) reveals that research groups that receive finance from firms interact more distance. This indicates that these research groups are able to provide useful knowledge to firms, which leads more distant interactions.

Final remarks and policy implications

Several studies have recognised the role of university-industry linkages in fostering innovation. Recently, studies have sought to understand how these relations are shaped in space, since geographical proximity can provide important benefits related to face-to-face contact and frequent interactions. Even so, firms seek for distant universities to collaborate, searching for specific solutions for their innovative problems. Liked to this debate, this paper aims to examine the main factors that affect geographical distance of university-industry linkages, by analysing both sides of collaboration, the characteristics of firms and universities.

To analyse this issue, a comprehensive database from the Brazilian Ministry of Science and Technology of university-industry linkages in Brazil in the scientific fields of Engineering and Agrarian Sciences was used. The database gathers information of the academic research groups in Brazil, their main characteristics and their collaboration with firms. In this way, contrasting to previous studies, this paper uses a wide database that comprises information from universities and firms that collaborate.

Main results from the empirical analysis, at the university level, show that research groups that perform high quality academic research presents higher average geographical distance of interactions, which means that they interact with local and distant firms. In the same way, larger research groups also present higher average geographical distance. At the firm level, firms that present higher absorptive capacity tend to interact with more distant research groups, which shows that they are able to collaborate both with local and distant universities. Likewise, bigger firms also interact with higher average geographical distances.

In sum, main results show that the decision of the firm to collaborate with university is related to the need to find solutions to its innovative problems. Firms with low absorptive capacity are usually faced with simpler problem, and additionally, they are not able to look for, and to find, more distant research groups to collaborate. For this reason, they tend to interact with local universities. On the other hand, firms with

higher absorptive capacity have to handle with more complex innovative problems, which will require broader, diverse and cutting-edge knowledge. In this way, many times, these firms cannot find local universities that are able to assist them in solving more complex problems, which compel these firms to seek more distant, and higher quality, universities. This is the reason for the higher average geographical distance of the collaboration with firms of the higher academic performance research groups. Furthermore, the specific solutions provided by these research groups counterweight the higher costs of long distance interactions with university.

Finally, findings bring along policy implications. First, results shows the importance of universities for firms' innovation. Therefore, policy should stimulate and strengthen university-industry linkages. Moreover, policy measures should also be designed to strengthen the linkages between high absorptive capacity firms and high-performance research groups because these linkages can be important tools for fostering the innovation in industry, especially when radical or cutting-edge innovations are involved. In these cases, geographical distance is not a barrier to interact, since both high absorptive capacity and high performance university can launch collaboration at long distance. On the other hand, low absorptive capacity firms present difficulty to interact with non-local universities. In this way, policy should work both to strengthen firms' capabilities and to support research development in mid- and low-performance universities. Local problems tend to be simpler and do not require cutting-edge knowledge, which means that local low performance universities are able to address the specific needs of local producers and an important tool for local development.

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