An analysis of the influence of the characteristics of firms and academic research groups on the geographical distance of university-industry linkages

Renato Garcia – Instituto de Economia da Unicamp
Veneziano Araújo - Universidade Federal de São Paulo
Suelene Mascarini - Escola Politécnica da USP
Emerson Gomes dos Santos - Universidade Federal de São Paulo
Ariana Ribeiro Costa - Escola Politécnica da USP

Abstract

This paper examines factors that affect the geographical distance of university-industry linkages by analysing specific characteristics of both sides of the collaboration - firms and universities. Previous studies have provided important evidence related to this issue; however, they have used data from either firms or universities. Therefore, this paper contributes to existing research on this issue by using information on both collaboration partners. For this purpose, data from the Directory of Research Groups in Brazil are used to estimate an empirical model. The main results indicate that higher absorptive capacity and bigger firms tend to collaborate with research groups that are more geographically distant. Further, on the university side, high-performance and larger research groups tend to attract firms that are more geographically distant as collaboration partners. Long-distance collaborations therefore usually occur when firms require high absorptive capacity and when they cannot find high-quality local universities.

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

JEL Codes: O18; O31; R12

Área ANPEC: Economia Industrial

Uma análise da influência das características das firmas e dos grupos de pesquisa acadêmicos sobre a distância geográfica das interações universidade-empresa

Resumo

Este trabalho examina os fatores que afetam a distância geográfica das interações universidade-empresa, por meio da análise de características específicas tanto de empresas como de universidades. Estudos prévios apresentaram evidências importantes a esta questão, mas utilizam dados somente das empresas ou das universidades. Assim, a contribuição deste trabalho reside no uso de informações sobre as duas partes envolvidas nos projetos de colaboração. Para isso, foi estimado um modelo empírico usados usando dados do Diretório dos Grupos de Pesquisa da base Lattes do CNPq. Os principais resultados indicam que firmas maiores e com maior capacidade de absorção tendem a colaborar com grupos de pesquisa geograficamente mais distantes. Além disso, do lado da universidade, grupos de pesquisa maiores e com melhor desempenho acadêmico tendem a atrair firmas mais distantes geograficamente como parceiros de colaboração. Assim, colaborações a longa distância ocorrem usualmente quando as empresas possuem elevada capacidade de absorção e não encontram universidades locais de alta qualidade.

Palavras-chave: geografia da inovação; interação universidade-empresa; capacidade de absorção; qualidade da pesquisa acadêmica; politicas.

An analysis of the influence of the main characteristics of academic research groups and firms on the geographical distance of university-industry linkages

Introduction

Universities have been playing an increasingly important role in supporting innovation. Academic research constitutes an important source of new knowledge for producers, and firms have thus sought to establish collaboration with universities in order to access new knowledge. Accordingly, university-industry linkages have become a growing subject of interest in the literature, as studies aim to understand how these relationships are shaped. One recent issue in this line of inquiry concerns the geographical distance of university-industry linkages, as geographical proximity can provide important benefits for firms in terms of access to new sources of information and new knowledge. Linked to this issue, this paper aims to examine the main factors that affect the geographical distance of university-industry linkages by analysing the characteristics of both sides of collaboration—firms and universities.

Several studies show that the co-location of firms' R&D staff and academic researchers engendered important benefits (Jaffe, 1989; Audretsch and Feldman, 1996; Arundel and Geuna, 2004; D'Este and Iamarino, 2010; De Fuentes and Dutrénit, 2014). However, recent analyses show that firms often prefer to collaborate with geographically distant universities, as certain factors can induce firms to collaborate with universities in geographically distant locations (D'Este and Iamarino, 2010; Laursen et al., 2011; Muscio, 2013). Therefore, evidence regarding the spatial distribution of university-industry linkages is conflicting.

Hence, one of the main questions that the literature aims to answer is why firms collaborate with geographically distant universities. The results generally point to two main drivers. First, firms seek out distant universities when they cannot find high-quality academic research locally. Second, firms must have high absorptive capacity to search for local or non-local universities that are able to solve their innovation problems. Previous studies provide important evidence related to this issue. However, an important research gap that requires deeper analysis remains, as evidence from previous studies is based on information about either universities (D'Este and Iammarino, 2010; Muscio, 2013) or firms (Laursen et al., 2011; De Fuentes and Dutrénit, 2014) only.

Linked to this issue, this paper aims to contribute to existing research by providing new evidence on specific factors that affect geographical distance of university-industry linkages. In addition, the paper uses comprehensive information on both universities and firms to analyse such collaborations. In addition, it examines geographical patterns of university-industry linkages in a developing country, Brazil, whereas most previous analyses have focused on developed countries, mainly European countries. However, it is important to note that the main interest of research is to exam the factors that affect the decision of the firm to interact with university, and the analysis of the geographical distance of university-industry collaborations could be a way to understand patterns of collaboration between university and firms.

For this purpose, a comprehensive database of university-industry collaborations in Brazil in the scientific fields of Engineering and Agrarian Sciences was used. The primary data came from the Brazilian Ministry of Science and Technology, which gathers information on the activities of research groups in Brazil and their collaborations with firms. The database includes information on the main characteristics of these research groups. Information on their collaborating partner firms was added.

The results of the empirical analysis show that bigger firms and firms with higher absorptive capacity tend to collaborate with research groups that are more geographically

distant, indicating that firms must have the capability to find universities, whether local or distant, that are able to solve their innovation problems. On the university side, high-performance and large research groups tend to engage in collaborations at higher average geographical distances, indicating that such research groups are able to attract more distant firms as collaboration partners.

This paper is organised into four sections beyond this introduction. The first section presents the main conceptual background related to geographical distance and university-industry linkages and discusses the characteristics of firms and research groups as factors affecting the geographical distance of university-industry linkages. Section two then provides a brief description of the data and the empirical model. Section three presents the results and discusses the effects of the characteristics of firms and research groups on the geographical distance of university-industry linkages. Finally, section four offers some concluding remarks and policy implications.

1. Main conceptual remarks

1.1. Geographical distance and university-industry linkages

The role of universities and academic research in fostering innovation is a growing subject of interest in the literature. Many studies have examined universities as source of new knowledge that supports firms' innovation and as collaboration partners that solve firms' innovation problems (Nelson, 1959; Klevorick et al., 1995; Cohen et al., 2002). In general, studies confirm that university research is a very important source of firm innovation, particularly for industries closer to the scientific and technological base of an innovation system (Klevorick *et al*., 1995). University research not only provides new ideas for industrial R&D projects but also facilitates the completion of ongoing projects in firms (Cohen *et al*., 2002).

In the last decades, analyses of university-industry linkages have devoted increased attention to the role of geographical proximity in collaboration between academic research and industrial R&D, and some of these analyses have empirically demonstrated the benefits associated with the co-location of firms and universities. In general, these studies found empirical evidence of the presence of geographically bounded spillovers from academic research to industrial innovation (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 and Dutrénit, 2014).

Agglomeration effects are also pointed as important factors that benefit co-location of university research and industrial R&D facilities. Geographical areas with dense spatial concentrations of universities and firms can engender important benefits for local firms, both aiding and promoting their innovation efforts. Firms with closer proximity to knowledge-generating centres are able to gain a competitive advantage from the increased potential for university collaborations. Moreover, firms located proximate to universities can benefit from local knowledge spillovers from academic research through the dissemination of knowledge in local communication networks between firms and universities. Proximity between firms and universities also facilitates interactive learning process through frequent personal interactions and face-to-face contact, engendering benefits to firms located near scientific and technological centres (Arundel and Geuna, 2004; Abramovsky *et al.*, 2007; Fritsch and Slavtchev, 2007; Ponds *et al*., 2007; D'Este *et al*., 2013; Muscio, 2013).

By contrast, recent studies show that firms often search for high-quality, geographically distant universities that are able to solve their innovation problems (D'Este and Iammarino, 2010; Laursen *et al.*, 2011, Muscio, 2013; De Fuentes and Dutrénit, 2014). Thus, while geographical proximity is one factor that determines whether a firm will collaborate with academic partners to benefit from enhanced interactive learning through co-location, other factors may influence a firm's decision to collaborate with a certain university, as the firm may require a broad set of academic capabilities to help solve its innovation problems (Bishop *et al.* 2011; D'Este *et al.*, 2013). If a firm requires unique, complex, and tacit knowledge, it will seek out a university that is able to solve its innovation problems regardless of the university's geographical location.

Accordingly, a deeper examination of the geographical distance of university-industry linkages is required to examine the main factors that influence the geographical distance of such collaborations. In fact, the main factor affecting the role of geographical proximity in university-industry linkages is a need for tacit knowledge required for innovation (Gertler, 2003). However, there are several other sources of tacit knowledge sharing, arising through different types of proximity among economic agents (Boschma, 2005).

Firms collaborate with universities because they require access to new knowledge to foster innovation. If a firm is able to find a geographically close, high-quality university that is able to help solve its innovation problems, the firm will likely collaborate with it. However, if a local university is not able address the firm's innovation problems, the firm must have the capability to search for, and find, a non-local university that can help the firm to solve its innovation problems. Hence, although the literature identifies a set of benefits associated with the co-location of universities and firms, local collaborations between universities and firms will occur only if two main factors are simultaneously met: first, the local university is qualified to assist in solving the firm's innovation problems; second, the firm does not have the capability to search for a high-quality non-local university as a collaboration partner.

Prior research provides some evidence regarding how the quality of academic research affects the geographical distance between collaborating firms and universities. Collaborations involving firms and high-quality research university departments tend to occur at greater distances (D'Este and Iammarino, 2010; Muscio, 2013). Additionally, the curvilinear relationship between the quality of research and the distance of collaboration indicates that collaborations with top-ranked university departments involve significantly shorter distances than collaborations with mid-ranked university departments (D'Este and Iammarino, 2010). Furthermore, the applicability of research to industrial purposes are also drivers of long-distance collaboration between universities and firms, as well as the mobility of academic researchers (Muscio, 2013). However, these analyses use information on universities only.

Other research using information on the characteristics of firms shows that the presence of a high-quality local university favours local collaboration, especially for firms with low R&D expenditures (Laursen et al., 2011). These results, however, are based on data from the UK Innovation Survey 2005, which provides. Hence, the analysis provides rich information on the innovation efforts of firms but provides little information on firms' academic partners, as well as the geographical distance between them. The main conclusion is that two factors affect the geographical distance of scientific collaborations: the quality of research and the intensity of firms' R&D expenditures. The lack of a high-quality local partner favours geographically distant collaboration (Laursen et al., 2011).

1.2. Factors affecting the geographical distance of university-industry linkages

Spatially bounded knowledge spillovers from university research to industrial innovation can play an important role to foster firms' R&D activities. However, it is usual to find firms collaborating with universities at great geographical distances. In this way, it is important to exam how specific characteristics of both firms and universities engaged in university-industry linkages affect the geographical distance of such collaborations.

Regarding the characteristics of research groups, the quality of academic research is an important factor that determines whether a firm collaborates with a university. The primary benefit of collaborating with top universities for firms is access to state-of-the-art knowledge generated by such high performance universities. In fact, the generation of advanced or radical innovations requires a unique set of knowledge, which is more often found in top universities (D'Este and Iammarino, 2010; Laursen et al., 2011; Bishop et al., 2011). Thus, academic research excellence is an important factor that determines whether a firm collaborates with a certain university to help support its innovation efforts. Collaboration with high-performance universities is based on access to complex and tacit knowledge, one of the primary characteristics of state-of-the-art knowledge. Such universities are able to master a broad and complex set of capabilities that can help support a firm's innovation process. In this way, geographical proximity is particularly important if the collaboration involves the sharing of tacit and specific knowledge, which requires frequent face-to-face contact and professional mobility (Bishop *et al.*, 2011). The size of the research group is another factor that may affect university-industry linkages (De Fuentes and Dutrénit, 2012). A research group with more technicians and researchers certainly has more accumulated capabilities, derived from both previous research projects and previous collaborations with firms. Thus, larger groups can not only share broader and more complex knowledge with firms but also overcome barriers to collaborating with industry partners. The lifetime of the research group (team age) is another relevant factor that may influence university-industry linkages (De Fuentes and Dutrénit, 2012).

In addition to the characteristics of research groups, the characteristics of partner firms may influence firms' decision to collaborate with certain universities. In particular, factors that influence this decision include the firm's absorptive capacity, size, and industrial sector (Cohen et al., 2002).

Absorptive capacity refers to a firm's ability to evaluate, assimilate, and exploit available external knowledge (Cohen and Levinthal, 1990). Firms with greater absorptive capacity tend to collaborate more often with universities because they can better exploit the benefits of collaborating with academic research partners (Boschma and Ter Wal, 2007; Balland, 2011). In addition, such firms have the ability to search for universities with capabilities that better fit their innovation problems. Firms' absorptive capacity thus has a special relation with the geographical distance of university-industry linkages. Firms with low absorptive capacity depend more on geographical proximity to universities and less on the quality of universities' academic research in determining their collaboration partners. By contrast, firms with high absorptive capacity have a greater range of potential academic partners. Indeed, as these firms can more efficiently incorporate knowledge generated by the most qualified research groups and more effectively search for and coordinate their activities with non-local universities (Laursen et al., 2011), they can go beyond their geographically proximate environment to find academic partners. High absorptive capacity is thus particularly important when firms cannot find local universities that can help them solve their innovation problems (Bishop *et al.*, 2011).

Another important factor that affects scientific collaboration is firm size. In general, larger firms collaborate more with universities because they have more internal

capabilities to develop a wider range of collaborations with academic research partners (Fritsch and Lukas, 2001). Although small firms may seek collaborations with universities, larger firms tend to seek such collaborations more often to obtain new information, enhance their professional recruitment, and facilitate the application of external knowledge in their innovation activities (Bishop et al., 2011). Indeed, most firms that collaborate in R&D with research institutes are large firms, as large firms can more easily manage and incur the costs of long-distance collaboration (Levy et al., 2009). By contrast, small and medium-sized firms tend to rely more on their local environment in research collaborations, as collaborations over long distances tend to require a broad set of capabilities and incur substantial costs (Muscio, 2013).

While previous studies have provided important findings, some research gaps remain, and a comprehensive analysis of the characteristics of both firms and universities in research collaborations is required to fill these gaps. Laursen et al. (2011) uses a data set that provides rich information on the characteristics of firms but little information on universities. By contrast, D'Este and Iammarino (2010) and Muscio (2013) almost exclusively use information on the characteristics of universities. With regard to geographical distance, previous analyses are often quite broad, reporting aggregate results. Further, except in Muscio (2013), the quality of academic research is generally measured by using a broad proxy, the RAE evaluation, instead of the number of publications per researcher, which is a more appropriate measure for assessing the quality of academic research. Finally, previous studies have measured academic research quality at the department level; thus, they rely on the assumption that the average qualification level of university departments does not substantially differ among research groups, even in large departments.

To fill these research gaps, this paper examines the main factors that affect the geographical distance of university-industry linkages. For this purpose, an empirical model is estimated to examine the main characteristics of firms and research groups that affect the geographical distance of scientific collaborations.

2. Empirical analysis

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

As in developed countries, university research has been playing a growing role in fostering firms' innovation in Brazil (Albuquerque, 2007; Suzigan et al, 2009; Rapini et al, 2009; Fernandes et al, 2010). Engineering and Agrarian Sciences are the most important scientific fields in which universities collaborate with industry, in convergence with the Brazilian industrial structure, where manufacturing industries and agribusiness are the main important economic activities (Suzigan et al., 2009). Among the main sectors that collaborate with the university, it is possible to find low and medium-tech industries, such as mining and oil and gas, and high-tech ones, such as biotechnology (Chaves et al., 2012).

University-industry linkages in Brazil is characterised by a strong unequal regional distribution (Figure 1). The geographical concentration of both collaborative firms and university is due to the regional distribution of private R&D activities and of high quality universities, both concentrated in the Southern part of the country. Regarding policy, there are several policies incentives to foster innovation by encouraging collaboration between firms and universities, and most of them are similar to those in developed countries. In general, these are federal government coordinated policies and,

in some cases, focused on specific sectors, such as information and communication technologies and biotechnology.

Figure 1 – Regional distribution of collaborative firms and research groups

2.2. Database

To examine how the characteristics of universities and firms affect the geographical distance of university-industry linkages in Brazil, a specific data set derived from various data sources is exploited. The sample of collaborations between firms and universities was gathered from the Brazilian Ministry of Science and Technology by exploiting the CNPq Directory of Research Groups of the Lattes database, which provides a broad set of data on the activities of academic research groups in Brazil[1]. This data set covers the main characteristics of academic research groups, such as the scientific field, number of researchers, research performance, and collaborating firm. To these data, information on firms, such as size, industrial sector, and labour force qualification, from the Brazilian Ministry of Labour was added. Further, information on the geographical distance between the firm and the research group in collaboration, measured as the distance in kilometres in a straight line from the georeferenced coordinates (latitude and longitude) of the zip code (ZIP) for the firm and research group, was added.

Therefore, the final database includes 4,337 collaborations involving 3,063 firms and 1,738 Engineering and Agrarian Sciences research groups in 2010 from all Brazilian regions. The average firm is involved in collaborations with 1.42 research groups, and the average research group is involved in collaborations with 2.49 firms. The average number of published papers per researcher is 15; the average size of a research group is 9 researchers; and the average lifetime of a research group is 10 years. Moreover, in a large share of the firms (25%), at least 42% of the employees have a higher degree. Regarding number of employees, substantial variation exists within the sample: firms in the first

[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. Previous studies, such as Suzigan et al. (2009), Rapini et al (2009) and Fernandes et al (2010) had also used this database to analyse university-industry linkages in Brazil.

quartile have fewer than 3 employees, whereas firms in the last quartile have more than 248 employees.

2.3. Econometric analysis

An empirical model is estimated on this data set to examine how the main characteristics of firms and research groups affect the geographical distance of university-industry linkages in Brazil.

The dependent variable is the geographical distance between the research group and the firm in logarithmic form (*DistColl*). The use of geographical distance as the dependent variable is line with the main aim of the paper, which is to examine the main factors that affect the geographical distance of university-industry linkages. Further, the independent variables are those characteristics of research groups and firms that may affect the geographical distance of such collaborations. The selected characteristics of research groups are the quality of academic research (*Quali*), measured as the number of published papers per researcher during the period 2009-2010; the size of the research group team (*SizeG*), measured as the number of researchers; and the research group lifetime (*TimeG*). At the firm level, the selected characteristics are the firm's absorptive capacity (*AbsorCF*), measured as the share of employees with a higher degree, and the firm's size (*SizeF*), measured as the number of employees in logarithmic form (Table 1).

Table 1: Description of the variables

Variable	Description	Source
DistColl	Distance in kilometres in a straight line from the georeferenced coordinates (latitude and longitude) of the zip code (ZIP) for the firm and the research group (logarithmic form)	Original work
O-Dist	1 = less than 100 km, 2 = between 100 km and 500 km; 3 = more than 500 km.	Original work
Quali	Number of articles per researcher (2009-2010)	CNPq, 2010
SizeG	Number of researchers in the research group	CNPq, 2010
TimeG	Research group lifetime	CNPq, 2010
AbsorCF	Share of employees of the firm with a higher education degree (undergraduate or higher)	RAIS, 2008
SizeF	Logarithm of the number of employees in the firm	RAIS, 2008
AgglomLev	Population density in the region in which the firm resides	IBGE, 2000
K-index	Krugman's specialisation index for the region in which the firm resides	Original work, using RAIS, 2008
R&D_LG	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
R&D_LF	Number of R&D researchers per 10,000 workers of the municipality in which the firm is located	RAIS, 2008
Financ	*Dummy for finance*	CNPq, 2010
MacroR_F	*Dummy* for firm's Brazilian macro regions	CNPq, 2010; IBGE
MacroR	*Dummy* for research group's Brazilian macro regions	CNPq, 2010; IBGE
Metro	*Dummy* for metropolitan regions	
SciField	*Dummies* for scientific fields*	CNPq, 2010
Ind	*Dummies* for industries**	CNPq, 2010
CollType	*Dummies* for different types of collaboration***	CNPq, 2010

Source: Original work.

* Agrarian Sciences, Food Technology, Zootechnology, Veterinary Medicine, Computing Science and Industrial Design and Agricultural Engineering: 1: Civil, Transportation and Sanitary Engineering; 2: Chemistry, Nuclear, Materials, Metallurgical and Mining Engineering; 3: Aerospace, Mechanics, Naval, Oceanic and Production Engineering; 4: Electrical and Biomedical Engineering.

** Advanced Knowledge Providers, Mass Production Goods, Supporting infrastructure services, Personal goods and services (Castellaci, 2008). Remain sectors were grouped in three additional sectors: Agricultural, Extractive Industries and Others.

*** R&D collaborative projects, Technology transfer, Consultancy, Engineering and Software development, Material Supply, Training and Others

Controls are also added to consider exogenous factors related to the locational pattern of the firms and research groups. Locational factors can also affect a firm's decision to collaborate with a certain research group (D'Este and Iammarino, 2010). The first control is the density of the urban population of the region in which the firm resides, the so-called agglomeration level (*AgglomLev*). Firms located in more dense urban areas can benefit from the presence of broader and more diversified local academic capabilities, which may influence their decision to collaborate with local universities. Another control for agglomeration effects is the Krugman specialisation index (*K-index*), which measures the relative level of regional industry specialisation or diversification (Crescenzi et al., 2007). Economic diversity can play an important role in fostering interactive learning and

innovation, since a diversified environment can create greater opportunities for firms to imitate, share, and recombine ideas and practices across industries (Glaeser et al., 1992; Storper and Venables, 2004). Additionally, heterogeneity in local capabilities can stimulate the exchange and cross-fertilisation of existing ideas and the generation of new ideas across different industries (Storper and Venables, 2004; Duranton and Puga, 2001). Variables capturing academic and industrial R&D (*R&D_LF* and *R&D_LG*, respectively) are also included to control for local R&D expenditures at both the firm and the university level. A dummy variable for metropolitan regions (Metro) was included to capture differences of collaborative patterns among firms in main metropolitan regions in Brazil. To control for other locational factors, a dummy that captures macro-regional differences for both firms (*MacroR_F*) and research groups (*MacroR_G*) due to the unequal regional distribution of economic activity, innovation and research among Brazilian regions is used.

Furthermore, a dummy capturing the scientific fields of research groups (*SciField*) is included, since universities' role in supporting innovation and pattern of collaboration with firms may differ by scientific field (Meyer-Krahmer and Schmoch, 1998; Schartinger et al., 2001; Bekkers and Bodas-Freitas, 2008). The inclusion of dummies for scientific fields is also important because they can also control sectoral policies that encourage university-industry linkages and could affect geographic distance of collaborations. Other dummies capturing industry sector (*Ind*) and type of collaboration (*CollType*) are included, as the geographical distance of university-industry collaborations may differ by both industry (Abramovsky et al., 2007; Schartinger et al., 2001) and type of collaboration (Perkmann et al., 2011; D'Este and Patel, 2007). Finally, because different patterns of financial support may influence in the establishment and frequency of university-industry collaborations (De Fuentes and Dutrénit, 2012), patterns of financial support (*Financ*) for such collaborations are controlled for.

The empirical model is defined as follows:

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

Table 2 shows the relationships between geographical distance (*DistColl*) and the other variables, such as research quality (*Quali*) and research group size (*SizeG*) at the research group level and absorptive capacity (*AbsorCF*) and firm size (*SizeF*) at the firm level. Accordingly, comparisons of the average geographical distance for each of the selected variables can be made. In general, collaborations between research groups and firms from the last quartile occur at higher average geographical distances than collaborations between research groups and firms from the first quartile, suggesting that positive relations exist between geographical distance and the selected variables.

Table 2: Average distance between research 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 presents the descriptive statistics. The average distance between firms and research groups is 316.5 km; however, the variance is high, as half of the collaborations occur within a distance of 82.4 km. By contrast, 25% of the collaborations occur at a distance greater than 366.3 km, up to a maximum of 3,344.6 km.

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

Variable	Min	First quartile	Median	Third quartile	Max	Mean	Std. dev.
DistColl	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 presents the results for a robust regression estimation in which distance in kilometres is the dependent variable (*DistColl*). Another estimation was made using an ordered logit model that includes three different levels of geographical distance (*O-Dist*) and results are quite similar.

Table 4: Robust regression results (1) and ordered logit (2) (N = 4,337)

	DistColl	O-Dist +
SizeG	0.015** (0.006)	0.018** (0.006)
Quali	0.005* (0.002)	0.005* (0.002)
TimeG	0.002 (0.003)	0.001 (0.003)
AbsorCF	0.535*** (0.12)	0.728*** (0.121)
SizeF	0.035** (0.013)	0.023 (0.013)
AgglomLev	0.000*** (0)	0.000*** (0)
K-index	0.536***(0.161)	0.849*** (0148)
R&D_LF	0.000 (0.000)	-0.000 (0.000)
R&D_LG	-0.010***(0.001)	-0.006*** (0.000)
Finac	0.192** (0.066)	0.192** (0.063)
MacroR_F	Yes	Yes
MacroR_G	Yes	Yes
SciField	Yes	Yes
Ind	Yes	Yes
CollType	Yes	Yes
Metro	Yes	
R^2	0.1745	0.064

Source: Original work.

+ O-Dist - 1 = less than 100 km, 2 = between 100 km and 500 km; 3 = more than 500 km.

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

Regarding the selected characteristics of research groups, the quality of the research performed by the research group (*Quali*) and the size of the research group (*SizeG*) positively affect the geographical distance of university-industry collaborations.

Specifically, the results regarding the positive impact of the quality of the research performed by the research group (*Quali*) show that high-performance research groups are associated with a higher mean geographical distance between the collaborating firm and the research group. This result suggests that firms are willing to collaborate with more distant high-quality research groups to support their innovation efforts, solve their production and operational problems, and foster the development of new products and processes. Firms seek high-quality research groups as collaboration partners because they believe that such research groups have greater capabilities for handling complex problems. This result is consistent with the primary assumptions presented in the conceptual discussion that firms primarily collaborate locally; however, when they are searching for high-quality research groups, they may extend their search efforts over greater distances to obtain an academic partner for collaboration.

By contrast, low-performance research groups engage in more geographically proximate collaborations, as indicated by the lower average distance of their collaborations. This result indicates that mid- and low-quality research groups more commonly collaborate with local producers whose demands they can sufficiently meet,

showing the importance of the local channels of sharing knowledge. These research groups may lack capabilities and expertise to justify the higher costs of developing linkages with distant firms. Low-performance local universities are nevertheless important, 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).

Furthermore, the size of the research group (*SizeG*) positively affects the geographical distance of university-industry collaborations, indicating that research groups with more researchers engage in collaborations that are more geographically distant. Larger research groups have a broader structure that provides them with greater and more diversified academic capabilities to solve more complex innovation problems. In addition, such research groups have more experience collaborating with firms, granting them capabilities for solving problems related to managing interactive projects with firms. This set of capabilities allows larger research groups to solve innovation problems for not only local firms but also firms located in regions that are more distant. By contrast, smaller research groups, which have fewer researchers, do not collectively have a broad set of academic capabilities, limiting their ability to meet the needs of firms located in regions that are more distant. Therefore, smaller research groups generally collaborate with local firms.

Regarding the final selected characteristic of research groups (*TimeG*), the coefficient for the lifetime of the research group is not significant; thus, nothing can be inferred about the relation between the lifetime of the research group and the geographical distance of university-industry collaborations. Hence, even the oldest and longest-lasting research groups, which likely have more experienced researchers, do not collaborate with firms at greater distances more often other firms do.

Regarding the selected characteristics of firms, the coefficients for both absorptive capacity (*AbsorvCF*) and firm size (*SizeF*) are positive and significant, indicating that both characteristics positively affect the geographical distance of university-industry collaborations.

The positive coefficient for absorptive capacity (*AbsorvCF*) indicates that firms with higher absorptive capacity collaborate with research groups that are more geographically distant. Previous studies demonstrate that firms with higher absorptive capacity collaborate more often with universities than other firms, as they have greater capabilities for searching for academic partners to solve their innovation problems and provide academic benefits to research groups, such as ideas for new projects and new insights for the research agenda (Bishop et al., 2011; Tartari and Breschi, 2012). Extending these findings, results show that firms with higher absorptive capacity also collaborate with research groups that are more geographically distant. Empirical results show that firms with 25% more skilled workers with higher education degree, the proxy for absorptive capacity, collaborate with universities in average 14.5% more geographically distant. Moreover, this finding shows that the absorptive capacity is the principal factor that affect geographical distance of collaborations.

In this way, despite the importance of the local bounded knowledge spillovers and the local channels of sharing knowledge, higher absorptive capacity is a factor that stimulate firms to collaborate with university at greater geographical distances. High absorptive capacity firms are able to search for research groups that can solve their innovation problems regardless of their geographical location. Thus, these firms are less dependent on co-location with research groups to obtain academic partners for collaboration. Furthermore, these firms tend to face problems that are more complex; thus, they seek collaboration with distant universities even if with such collaboration

entails higher costs. Previous studies show that firms with higher absorptive capacity collaborate more often with universities than other firms (Boschma and Ter Wal, 2007; Balland, 2011). Results show that firms with high absorptive capacity also collaborate with universities that are more geographically distant, as these firms can more efficiently assimilate knowledge from high-quality research groups and can more effectively search for and select academic partners.

By contrast, firms with lower absorptive capacity may find it difficult to locate research groups that are able to address their needs; consequently, they may primarily collaborate with local universities. For these firms, geographical mechanisms of dissemination of information and knowledge sharing with university play a very important role to stimulate collaboration with firms (Arundel and Geuna, 2004; Laursen *et al*., 2011). Firms with lower absorptive capacity tend to experience fewer complex problems in their production and innovation processes, and low-performance local universities can generally solve these problems, eliminating any justification for seeking collaboration with distant research groups.

Regarding the other selected characteristic of firms, firm size (*SizeF*) has a significant, positive influence on the geographical distance of university-industry linkages. This result indicates that larger firms have better capabilities for collaborating not only more frequently with universities (Levy et al., 2009; Gallie and Roux, 2010), but also with research groups that are more geographically distant. Such firms have a broader set of capabilities for searching for distant research groups and managing long-distance collaborations. Moreover, long-distance collaborations with universities entail higher costs, and larger firms are better able to finance such collaborations[2].

The results for the control variables reveal the effect on locational factors on the geographical distance of university-industry linkages. First, the positive and significant coefficient for the population density in the firm's region (*Agglom*) indicates that firms in regions with higher population density tend to engage in university-industry collaborations that are more geographically distant. This finding show clearly the importance of the geographical mechanisms of knowledge sharing between firms and university, as pointed by the conceptual remarks. Thus, more densely populated regions could present greater opportunities for collaboration with universities, given the existence of potential partners with a broader set of academic and research capabilities in such regions. Moreover, opportunities to collaborate with local universities can enhance firms' capabilities for collaborating with distant universities.

Second, the positive and significant coefficient for the measure of the main features of the local productive structure, the Krugman specialisation index (*K-index*), indicates that firms that are located in more diversified regions tend to collaborate more often with local research groups. This relationship likely arises from the existence of a broader set of local firms in diversified regions. Such regions likely have a more heterogeneous local industry that includes firms with greater capabilities for collaboration with universities. In fact, the diversity of the local industry structure emphasises the importance of urban agglomeration, which allows for the concentration of diversified industry and high-quality academic research centres, and such concentration can generate cross-fertilisation effects and strengthen university-industry linkages. These processes are the central point of the argument that agglomeration in diversified regions can foster different types of collaboration among co-localised players, such as frequent interactions and face-to-face contact (Storper and Venables, 2004). By contrast, the results for the

[2] A second model, an ordered logit regression, was estimated in order to compare the effect of size of the department, in the same way as Muscio (2013). The model presents similar inference results regarding the coefficient signs and magnitudes that the original robust regression.

Krugman index suggest that firms located in specialised regions may have considerable difficulty finding opportunities for collaboration with academic researchers. In such cases, firms may be compelled to seek collaboration with distant research groups, and they may have more difficulty building up capabilities for collaboration with universities.

Third, academic R&D (*R&D_LG*) has a significant and negative effect on the geographical distance of university-industry linkages. The higher local university R&D expenditures are, the more localised collaborations with firms become. Thus, in regions with higher academic research expenditures, firms tend to engage in collaborations within shorter distances. This tendency arises because in regions with potential academic partners with a wide range of academic capabilities, local academic partners can usually address the main needs of co-localised firms in supporting their innovation efforts. Therefore, firms do not need to search elsewhere for collaboration partners. In fact, if they are choosing among universities with similar levels of research quality, firms will usually prefer to collaborate with local universities (Laursen et al., 2011). This finding supports the important role of spatial co-location and geographical proximity in university-industry linkages. Finally, the positive and significant coefficient for research group financing (*Financ*) reveals that research groups that receive financing from firms engage in collaborations across greater distances. This result indicates that such research groups are able to provide useful knowledge to firms, which leads to collaborations that are more geographically distant. Precisely, financially supported collaborations are 19.8% more geographically distant than others with the same features but without funding.

Final remarks and policy implications

Several studies have recognised the role of university-industry linkages in fostering innovation, and recent studies have sought to understand the spatial distribution of such collaborations, as geographical proximity can engender important benefits related to face-to-face contact and frequent interactions. Firms may nevertheless seek to collaborate with geographically distant universities to provide specific solutions to their innovation problems. Linked to this issue, this paper examines the main factors that affect the geographical distance of university-industry linkages by analysing the characteristics of both sides of the collaboration—firms and universities.

To examine this issue, a comprehensive database from the Brazilian Ministry of Science and Technology on university-industry linkages in Brazil in the scientific fields of Engineering and Agrarian Sciences is used. This database contains information on academic research groups in Brazil, their main characteristics, and their collaborations with firms. To these data, information on the collaborating firms is added. Hence, in contrast to previous studies, this paper uses a broad data set comprising information on both universities and firms in research collaborations.

The main findings from the empirical analysis at the firm level show that firms with higher absorptive capacity tend to collaborate with research groups that are more geographically distant, indicating that such firms are able to collaborate with both local and distant universities. Similarly, bigger firms collaborate with research groups at greater geographical distances. At the university level, research groups that produce high-quality academic research engage in collaborations at higher average geographical distances, indicating that they collaborate with both local and distant firms. Likewise, larger research groups collaborate with firms at greater average geographical distances.

In sum, the main results show that a firm's decision to collaborate with a university is related to the need to find solutions to its innovation problems. Firms with low

absorptive capacity usually face simpler problems, and they are not able to search for, and find, geographically distant research groups as collaboration partners. For this reason, they tend to collaborate with local universities. By contrast, firms with higher absorptive capacity face more complex innovation problems, which require broad, heterogeneous, and cutting-edge knowledge to solve. Consequently, these firms often cannot find local universities that are able to assist them in solving their complex problems; hence, they seek to establish collaborations with geographically distant, high-quality universities. Accordingly, collaborations between high-performance research groups and firms tend to occur over higher average geographical distances, as the superior academic capabilities of high-performance research groups attract geographically distant firms as collaboration partners. Furthermore, the superior solutions that high-quality research groups can provide outweigh the higher costs of long-distance collaborations.

Findings of this paper are based on the Brazilian experience in university-industry linkages. As in developed countries, collaboration with university has been playing an increasing role to foster innovation in Brazil, and policy measures have been designed to stimulate collaboration between firms and universities. In this way, lessons from the Brazilian experience can be very important to the understanding factors that affects university-industry linkages and its pattern of distribution in geographical space.

Finally, the findings have some policy implications. First, the results highlight the importance of universities for firm innovation. Policy makers should thus aim to stimulate and strengthen university-industry linkages. Moreover, policy measures should be designed to strengthen linkages between high-absorptive capacity firms and high-performance research groups because these linkages constitute important tools for fostering innovation, especially when radical or cutting-edge innovations are involved. In such collaborations, geographical distance is not a barrier to collaboration, since both high-absorptive capacity firms and high-performance universities can launch and maintain university-industry collaborations over long distances.

By contrast, low-absorptive capacity firms have more difficulty collaborating with non-local universities. Hence, policy makers should aim both to strengthen firms' capabilities and to support R&D in mid- and low-performance universities. Low-absorptive capacity firms tend to face simpler problems that do not require cutting-edge knowledge; thus, low-performance local universities are likely able to address the specific needs of local producers, constituting an important tool for local development. In addition, policy makers should aim to stimulate low-performance research groups to engage in knowledge networks, as such networks will help them overcome barriers to collaborating over greater geographical distances by strengthening their academic capabilities and abilities to collaborate at greater distances.

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