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Looking at both sides: how specific characteristics of academic research groups and firms affect the geographical distance of university–industry linkages

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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 firms with higher absorptive capacity and larger 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

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 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 formed. One recent issue in this line of enquiry 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 characteristics of both sides of the collaboration – firms and universities.

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Several studies show that the co-location of firms' research and development (R&D) staff and academic researchers engenders important benefits (Arundel & Geuna, 2004; Audretsch & Feldman, 1996; D'Este & Iammarino, 2010; De Fuentes & Dutrénit, 2014; Jaffe, 1989). However, recent analyses show that firms often prefer to collaborate with geographically close universities; but there are certain factors that can induce firms to collaborate with universities in geographically distant locations (D'Este & Iammarino, 2010; Laursen, Reichstein, & Salter, 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 can 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 & Iammarino, 2010; Muscio, 2013) or firms (De Fuentes & Dutrénit, 2014; Laursen et al., 2011) only.

Linked to this issue, this paper aims to contribute to existing research by providing new evidence on specific factors that affect the geographical distance of university–industry linkages. To do so, it uses comprehensive information on both universities and firms to analyse such collaborations and examines geographical patterns of university–industry linkages in a developing country, Brazil, while most previous analyses have focused on developed countries, mainly European countries. However, it is important to note that the main aim of this research is to examine the factors that affect interactions between universities and firms, and an analysis of the geographical distance of university–industry collaborations may be one way to understand patterns of such collaborations.

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, and 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 larger 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 can solve their innovation problems. On the university side, high-performance and large research groups tend to engage in collaborations at a higher average geographical distance, indicating that such research groups can attract more distant firms as collaboration partners.

This paper is organized as follows. The next 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. The following section then provides a brief description of the data and the empirical model. The fourth section presents the results and discusses the effects of the characteristics of firms and research groups on the geographical distance of university–industry linkages. Finally, the last section offers some concluding remarks and policy implications.

Main conceptual remarks

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 sources of new knowledge that support firms' innovation and as collaboration partners that solve firms' innovation problems (Cohen, Nelson, & Walsh, 2002; Klevorick, Levin, Nelson, & Winter, 1995; Nelson, 1959). 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 this way, firms' main motivation for collaborating with universities is to identify and exploit technological opportunities. However, firms have other motivations for collaborating with universities, such as reducing R&D costs (e.g., testing and monitoring activities) and substituting in-house innovation activities with external sources that often operate with subsidised costs (Arza, 2010; Bekkers & Bodas-Freitas, 2008; Bonaccorsi & Piccaluga, 1994).

In recent decades, analyses of university–industry linkages have devoted increased attention to the role of geographical proximity in collaborations 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 have found empirical evidence of the presence of geographically bounded spillovers from academic research to industrial innovation (Anselin, Varga, & Acs, 1997; Arundel & Geuna, 2004; Audretsch & Feldman, 1996; D'Este & Iammarino, 2010; De Fuentes & Dutrénit, 2014; Jaffe, 1989; Laursen et al., 2011; Mansfield & Lee, 1996).

Agglomeration effects are also noted as important benefits of the 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, as such firms' innovation efforts are both aided and promoted. Indeed, firms with closer proximity to knowledge-generating centres can gain a competitive advantage from the increased potential for university collaborations, and 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 processes through frequent personal interactions and face-to-face contacts, engendering benefits to firms located near scientific and technological centres (Abramovsky, Harrison, & Simpson, 2007; Arundel & Geuna, 2004; D'Este, Guy, & Iammarino, 2013; Fritsch & Slavtchev, 2007; Muscio, 2013; Ponds, Oort, & Frenken, 2007).

By contrast, recent studies show that firms often search for high-quality, geographically distant universities that can solve their innovation problems (D'Este & Iammarino, 2010; De Fuentes & Dutrénit, 2014; Laursen et al., 2011; Muscio, 2013). Thus, although geographical proximity is one factor that determines whether a firm will collaborate with academic partners in order to benefit from enhanced interactive learning through co-location, other factors may influence a firm's decision to collaborate with a certain university since the firm may require a broad set of academic capabilities to help solve its innovation problems (Bishop, D'Este, & Neely, 2011; D'Este et al., 2013). If a firm requires unique, complex and tacit knowledge, it will seek out a university that can 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 in innovation (Gertler, 2007). However, there are several other sources of tacit knowledge sharing, which arise through different types of proximity among economic agents (Boschma, 2005).

Firms collaborate with universities because they require access to new knowledge in order to foster innovation. If a firm can find a geographically close, high-quality university that can help solve its innovation problems, the firm will likely collaborate with it. However, if a local university is not able to 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 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 the firm's in solving its innovation problems; and 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 the effect of the quality of academic research on the geographical distance between collaborating firms and universities. Specifically, collaborations involving firms and high-quality research university departments tend to occur at greater distances (D'Este & Iammarino, 2010; Muscio, 2013). Moreover, as indicated by the curvilinear relationship between the quality of research and the distance of collaboration, collaborations with top-ranked university departments involve significantly shorter distances than collaborations with mid-ranked university departments (D'Este & Iammarino, 2010). Additional drivers of long-distance collaboration between universities and firms include the applicability of research to industrial purposes and the mobility of academic researchers (Muscio, 2013). These analyses nevertheless use information on universities only.

Other research using information on firm characteristics 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. Hence, the analysis provides rich information on the innovation efforts of firms but little information on their academic partners or 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 tends to be associated with more geographically distant collaborations (Laursen et al., 2011).

Factors affecting the geographical distance of university–industry linkages

Spatially bounded knowledge spillovers from university research to industrial innovation can play an important role in fostering firms' R&D activities. However, it is common to find firms collaborating with universities at great geographical distances. An examination of the effect of specific characteristics of both firms and universities engaged in university–industry linkages on the geographical distance of such collaborations is thus important.

Regarding the characteristics of research groups, the quality of academic research is an important factor that determines whether firms collaborate with certain universities.

Firms primarily collaborate with top universities to gain access to the state-of-the-art knowledge they generate, including complex and tacit knowledge. As the generation of advanced or radical innovation requires a unique set of knowledge, which is more often found in top universities, such universities can master a broad and complex set of capabilities that can help support firms' innovation process (Bishop et al., 2011; D'Este & Iammarino, 2010; Laursen et al., 2011). 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 may also affect university–industry linkages (De Fuentes & Dutrénit, 2012). As a research group with more technicians and researchers certainly has more accumulated capabilities, derived from both previous research projects and previous collaborations with firms, larger research groups can not only share broader and more complex knowledge with firms but also overcome barriers to collaborating with industry partners. Finally, the lifetime of the research group (team age) may influence university–industry linkages (De Fuentes & Dutrénit, 2012).

In addition to the characteristics of research groups, the characteristics of partner firms may influence their decision to collaborate with a certain university. Such factors 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 & Levinthal, 1990). Firms with greater absorptive capacity tend to collaborate with universities more often because they can better exploit the benefits of collaborating with academic research partners (Balland, 2011; Boschma & Ter Wal, 2007). 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. Specifically, 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 & Lukas, 2001). Although small firms may seek collaborations with universities, larger firms tend to seek such collaborations more often in order 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, as such firms can more easily manage and incur the costs of long-distance collaboration (Levy, Roux, & Wolff, 2009). By contrast, small and medium-sized firms tend to rely more on their local environment in research collaborations since collaborations over long distances tend to require a broad set of capabilities and incur substantial costs (Muscio, 2013).

Although 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 dataset that provides rich information on firm characteristics 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, apart from Muscio (2013), most previous scholars measure the quality of academic research by using a broad proxy, the RAE - Research Assessment Exercise evaluation, instead of the number of publications per researcher, which could be 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.

Empirical analysis

Main features of university–industry linkages in Brazil

As in developed countries, university research has been playing an increasing role in fostering firms' innovation in Brazil (Albuquerque, 2007; Fernandes et al., 2010; Rapini et al., 2009; Suzigan, Albuquerque, Garcia, & Rapini, 2009). Engineering and agrarian sciences are the most important scientific fields in which universities collaborate with industry, as the primary economic activities in Brazilian industry are manufacturing and agribusiness (Suzigan et al., 2009). Among the main collaborators with universities are both low- and medium-tech industries, such as mining, oil and gas, and high-tech industries, such as biotechnology (Chaves, Carvalho, Silva, Teixeira, & Bernardes, 2012).¹

University–industry linkages in Brazil are characterized by a strong unequal regional distribution (Figure 1). The geographical concentration of collaborative firms and universities is due to the regional distribution of both private R&D activities and high-quality universities, which are both concentrated in the southern part of the country. Regarding policy, several policy incentives foster innovation by encouraging collaboration between firms and universities, and most of these incentives are similar to those offered by developed countries. In general, these are federal government-coordinated policies that are, in some cases, focused on specific sectors, such as information and communication technologies and biotechnology.

Database

To examine how the characteristics of universities and firms affect the geographical distance of university–industry linkages in Brazil, a specific dataset derived from various 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 using the Lattes platform, which provides a broad set of data on the activities of academic research groups in Brazil.² This dataset covers the main characteristics of academic research groups, such as the scientific field, number of researchers, research performance and collaborating firms. To these data, information



Figure 1. Regional distribution of collaborative firms and research groups.

on firms, such as size, industrial sector and labour force qualifications, from the Brazilian Ministry of Labour were added. Further, information on the geographical distance between the firm and the research group in collaboration, measured as the distance (km) in a straight line between the georeferenced coordinates (latitude and longitude) of the zip code (ZIP) for the firm and research group, was added.

Therefore, the final database includes 4337 collaborations involving 3063 firms and 1738 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 nine researchers; and the average lifetime of a research group is 10 years. Moreover, in a large share of firms (25%), at least 42% of the employees have an advanced degree. Regarding number of employees, substantial variation exists within the sample: firms in the first quartile have fewer than three employees, whereas firms in the last quartile have more than 248 employees.

Econometric analysis

An empirical model is estimated using this dataset 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 in line with the 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 2009–10 period; 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 an advanced degree, and the firm's size (*SizeF*), measured as the number of employees in logarithmic form (Table 1).

Controls are also added to consider exogenous factors related to the locational pattern of the firms and research groups, as locational factors can also affect a firm's decision to collaborate with a certain research group (D'Este & 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*).³ Firms located in denser urban areas can

Table 1. Description of the variables.

Variable	Description	Source
<i>DistColl</i>	Distance (km) 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
<i>Quali</i>	Number of articles per researcher, 2009–10	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 a higher education degree (undergraduate or higher)	RAIS, 2008
<i>SizeF</i>	Logarithm of the number of employees in the firm	RAIS, 2008
<i>AgglomLev</i>	Urban population density in the micro-region in which the firm is located	IBGE, 2000
<i>K-index</i>	Krugman's specialization index for the micro-region in which the firm is located	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 research and development (R&D) researchers per 10,000 workers of the municipality in which the firm is located	RAIS, 2008
<i>Financ</i>	Dummy for finance	CNPq, 2010
<i>MacroR_F</i>	Dummy for firm's Brazilian macro-region	CNPq, 2010; IBGE
<i>MacroR_G</i>	Dummy for research group's Brazilian macro-region	CNPq, 2010; IBGE
<i>Metro</i>	Dummy for metropolitan region	
<i>SciField</i>	Dummies for scientific fields ^a	CNPq, 2010
<i>Ind</i>	Dummies for industries ^b	CNPq, 2010
<i>CollType</i>	Dummies for different types of collaboration ^c	CNPq, 2010

Notes: ^aAgrarian sciences, food technology, zootechnics, 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; and 4: electrical and biomedical engineering.

^bAdvanced knowledge providers, mass production goods, supporting infrastructure services, personal goods and services (Castellaci, 2008). Remaining industries were grouped into three additional sectors: agricultural, extractive industries and other.

^cR&D collaborative projects, technology transfer, consultancy, engineering and software development, material supply, training and other.

Source: Authors' original work.

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 specialization index (*K-index*), which measures the relative level of regional industry specialization or diversification (Crescenzi, Rodríguez-Pose, & Storper, 2007). Economic diversity can play an important role in fostering interactive learning and innovation because a diversified environment can create greater opportunities for firms to imitate, share, and recombine ideas and practices across industries (Glaeser, Kallal, Scheinkman, & Shleifer, 1992; Storper & Venables, 2004). Additionally, heterogeneity in local capabilities can stimulate the exchange and cross-fertilization of existing ideas and the generation of new ideas across different industries (Duranton & Puga, 2001; Storper & Venables, 2004). 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*) is included to capture differences in collaborative patterns among firms located in the main metropolitan regions of Brazil. To control for other locational factors, dummy variables that capture 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 across Brazilian regions are used.

Furthermore, a dummy capturing the scientific fields of research groups (*SciField*) is included because universities' role in supporting innovation and pattern of collaboration with firms may differ by scientific field (Bekkers & Bodas-Freitas, 2008; Meyer-Krahmer & Schmoch, 1998; Schartinger, Schibany, & Gassler, 2001). The inclusion of dummies for scientific fields is also important because they can also control for sectoral policies that encourage university–industry linkages and because they may 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 (D'Este & Patel, 2007; Perkmann, King, & Pavelin, 2011). Finally, because different patterns of financial support may influence the establishment and frequency of university–industry collaborations (De Fuentes & 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

Table 2. Average distance between research groups and firms.

	<i>Quali</i>	<i>SizeG</i>	<i>SizeF</i>	<i>AbsorCF</i>
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: Authors' original work.

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 in the last quartile occur at higher average geographical distances than collaborations between research groups and firms in the first quartile, suggesting that positive relations exist between geographical distance and the selected variables.

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 3344.6 km.

Results and discussion

Table 4 presents the results of a robust regression estimation in which distance (km) is the dependent variable (*DistColl*).

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 may seek high-quality research groups as collaboration partners because they believe that such research groups have greater capabilities for handling complex problems. This finding 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

Table 3. Descriptive statistics ($N = 4337$).

Variable	Min	First quartile	Median	Third quartile	Maximum	Mean	SD
<i>DistColl</i>	0.0	6.9	82.4	366.3	3344.6	316.5	544.0
<i>SizeG</i>	0.0	5.0	8.0	12.0	54.0	9.6	6.2
<i>Quali</i>	0.0	4.6	10.1	19.1	144.5	14.1	14.3
<i>TimeG</i>	0.0	4.0	9.0	16.0	78.0	11.3	9.9
<i>AbsorCF</i>	0.0	0.02	0.2	0.5	1.0	0.3	0.3
<i>SizeF</i>	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	3381.9
<i>AgglomLev</i>	0.3	67.5	337.5	1112.6	5796.0	1207.1	1786.7
<i>K-index</i>	0.4	0.6	0.7	0.8	1.9	0.7	0.2
<i>R&D_LF</i>	0.0	478	663.4	942.8	1839.3	736.5	368.5
<i>R&D_LG</i>	0.0	2.1	40.3	59.8	312.3	46.3	51.0

Source: Authors' original work.

Table 4. Robust regression results ($N = 4337$).

	<i>DistColl</i>
<i>SizeG</i>	0.015** (0.006)
<i>Quali</i>	0.005* (0.002)
<i>TimeG</i>	0.002 (0.003)
<i>AbsorCF</i>	0.535*** (0.12)
<i>SizeF</i>	0.035** (0.013)
<i>AgglomLev</i>	0.000*** (0)
<i>K-index</i>	0.536*** (0.161)
<i>R&D_LF</i>	0.000 (0.000)
<i>R&D_LG</i>	-0.010*** (0.001)
<i>Financ</i>	0.192** (0.066)
<i>MacroR_F</i>	Yes
<i>MacroR_G</i>	Yes
<i>SciField</i>	Yes
<i>Ind</i>	Yes
<i>CollType</i>	Yes
<i>Metro</i>	Yes
R^2	0.1745

Note: *** $p < 0.1\%$; ** $p < 1\%$; * $p < 5\%$; standard deviations are given in parentheses.

Source: Authors' original work.

collaborate with local producers whose demands they can sufficiently meet, showing the importance of the local channel of sharing knowledge. Such 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 because 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 & 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. They also have more experience collaborating with firms, and through such experience, they can gain capabilities for solving problems related to managing interactive projects with firms. This set of capabilities then 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, which limits 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 age 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 than other firms do.

Regarding the selected characteristics of firms, the coefficients for both absorptive capacity (*AbsorCF*) 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 (*AbsorCF*) 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 possess 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 & Breschi, 2012). Extending these findings, the results show that firms with higher absorptive capacity also collaborate with research groups that are more geographically distant.

Despite the importance of locally bounded knowledge spillovers and local channels of sharing knowledge, higher absorptive capacity is a factor that fosters firms' abilities to collaborate with universities at greater geographical distances. With high absorptive capacity, firms can 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 such collaborations entail higher costs. Previous studies show that firms with higher absorptive capacity collaborate more often with universities than other firms (Balland, 2011; Boschma & Ter Wal, 2007). The present 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 more effectively search for and select academic partners.

By contrast, firms with lower absorptive capacity may find it difficult to locate research groups that can address their needs; consequently, they may primarily collaborate with local universities. For these firms, geographical mechanisms of disseminating information and sharing knowledge with universities play very important roles in stimulating collaboration with firms (Arundel & Geuna, 2004; Laursen et al., 2011). Firms with lower absorptive capacity tend to experience fewer complex problems in their production and innovation processes, and thus, low-performance local universities can generally solve these problems, eliminating any justification for seeking collaborations 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 not only for collaborating more frequently with universities (Gallié & Roux, 2010; Levy et al., 2009) but also for coordinating 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.

Effects of the change of the main variables are also examined in the analysis. The results show that firms with 1% more skilled workers with advanced degrees, a proxy for absorptive capacity, collaborate with universities that are, on average, 0.144% farther away. This finding indicates that absorptive capacity is the principal factor that affects the geographical distance of collaborations. In the same way, a 1% increase in the size of the firm is associated with a 0.067% increase in the geographical distance of the collaboration. Regarding the characteristics of research groups, a 1% increase in the

average size of the research group is associated with a 0.159% increase in the number of publications and a 0.035% increase in the geographical distance of the collaboration.

The results for the control variables reveal the effect of locational factors on the geographical distance of university–industry linkages. First, the positive and significant coefficient for the urban 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 clearly shows the importance of the geographical mechanism of knowledge sharing between firms and universities, as noted in 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 specialization index (*K-index*), indicates that firms that are located in more diversified regions tend to collaborate more often with local research groups. This relationship is likely observed because economically diversified regions have a broader set of local firms. Further, such regions likely have more heterogeneous local industries that include firms with greater capabilities for collaboration with universities. In fact, the diversity of the local industry structure highlights the importance of urban agglomeration, which allows for the concentration of diversified industries and high-quality academic research centres, and such concentration can generate cross-fertilization effects and strengthen university–industry linkages. These effects are central to the argument that agglomeration in diversified regions can foster different types of collaboration among co-localized players, such as frequent interactions and face-to-face contacts (Storper & Venables, 2004). By contrast, the results for the Krugman index suggest that firms located in specialized regions may have considerable difficulty finding opportunities to collaborate 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 localized collaborations with firms become. Thus, in regions with higher academic research expenditures, firms tend to engage in collaborations with 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-localized 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 (Larsen 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 can provide useful knowledge to firms, which leads to collaborations that are more geographically distant. Specifically, financially supported collaborations are 19.8% more geographically distant than collaborations with the same features but no funding.

Conclusions and policy implications

Several studies have recognized 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 arising from the potential for face-to-face contact and frequent interaction. Firms may nevertheless seek to collaborate with geographically distant universities in order to identify 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 was added. Hence, in contrast to previous studies, this paper uses a broad dataset comprising information on both universities and firms engaged in research collaborations.

The main findings of 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 can collaborate with both local and distant universities. Similarly, larger 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 – or 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 can 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.

The findings of this paper are based on university–industry linkages in Brazil. As in developed countries, collaborations with universities have been playing an increasing role in fostering innovation in Brazil, and policy measures have been designed to stimulate collaboration between firms and universities. The main findings for Brazilian university–industry linkages are in line with those of previous studies conducted in different institutional settings. This similarity in findings is mainly due to the existence of a set of policy measures in Brazil aimed at fostering innovation through collaboration with universities, which are mainly based on experiences from developed countries, even though important differences in innovation can be found between Brazil and other countries, especially developed countries. Furthermore, the analysis controls the main

institutional differences, such as the unequal geographical distribution of collaborating firms and universities in Brazil (which can also be found in other countries), and differences in sectoral patterns of university–industry linkages.

Overall, the present findings regarding collaborations between universities and industry in Brazil show the importance of firms' absorptive capacity as the main factor that affects the geographical distance of collaborations between firms and universities, even when the characteristics of research groups are also included in the analysis. In this way, the lessons from the Brazilian experience can be very important for understanding the factors that affect university–industry linkages and patterns of the geographical distribution of such linkages.

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 because 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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Notes

1. However, it is important to note that none of these studies examines patterns of the geographical distance of university–industry linkages.
2. CNPq is the Brazilian Council for Scientific and Technological Development, an institution of the Brazilian Ministry of Science and Technology 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), have also used this database to analyse university–industry linkages in Brazil.
3. This variable is calculated at the micro-region level, which can be associated with the European Union NUTS-3 (Nomenclature des Unités Territoriales Statistiques)

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