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University-industry collaboration on innovation: does geographical distance matter?

Ina Drejer

Aalborg University
Department of Business and Management
id@business.aau.dk

Christian Richter Oestergaard

Aalborg University
Department of Business and Management
cro@business.aau.dk

Abstract

Studies have shown that collaboration with universities has a positive impact on firms' innovation performance. But only a minority of firms engage in such collaboration. A range of studies have focused on what characterises the firms that do collaborate with a university, and find that an important characteristic is that the firms are located close to the university. Most of these studies assume ? implicitly or explicitly ? that firms collaborate with one university only, and are based on limited information on which organizations actually collaborate. However, as illustrated in the present paper, among those firms that engage in collaboration with universities, there is a tendency to collaborate with more than one university, which challenges the findings regarding the role of geographical distance. In the present analysis we study which factors influence the probability of firms collaborating with specific universities, and argue that geographical distance to a large extent is a proxy for employee-driven relations to the collaborating university. The analysis reveals that when other factors are included, the importance of geographical distance for university-industry collaboration diminishes considerably. The analysis is based on a combination of detailed register data and innovation survey data for 2,183 innovative Danish firms during the period 2010-2012.

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Studies have shown that collaboration with universities has a positive impact on firms' innovation performance. But only a minority of firms engage in such collaboration. A range of studies have focused on what characterises the firms that do collaborate with a university, and find that an important characteristic is that the firms are located close to the university. Most of these studies assume – implicitly or explicitly – that firms collaborate with one university only, and are based on limited information on which organizations actually collaborate. However, as illustrated in the present paper, among those firms that engage in collaboration with universities, there is a tendency to collaborate with more than one university, which challenges the findings regarding the role of geographical distance. In the present analysis we study which factors influence the probability of firms collaborating with specific universities, and argue that geographical distance to a large extent is a proxy for employee-driven relations to the collaborating university. The analysis reveals that when other factors are included, the importance of geographical distance for university-industry collaboration diminishes considerably. The analysis is based on a combination of detailed register data and innovation survey data for 2,183 innovative Danish firms during the period 2010-2012.

1. Introduction

A growing literature emphasizes the importance of university collaboration for firm innovation. Studies find that high-tech firms, especially those with strong relationships with universities, have more patents yet lower costs for internal research and development than businesses with no such relationships (George et al., 2002); that larger manufacturing firms that have collaborated with universities for the purpose of innovation have higher revenues from new or improved products (Lööf and Broström, 2008); and that collaboration with universities leads to higher productivity and innovation with greater novelty in manufacturing firms (Hanel and St-Pierre, 2006).

Despite the apparent advantages from such collaborations, the majority of innovative firms do not draw directly on knowledge from universities in their innovation activities (Laursen and Salter, 2004; Drejer et al. 2014). This is also found in the recent European innovation survey from 2012. It shows that 13 percent of the innovative European firms cooperate with universities or other higher education institutions¹. There are several barriers for university-industry collaboration, which may be related to differences in incentives and orientation in relation to openness between universities and industry, as well as potential conflicts regarding intellectual property (Bruneel et al., 2010). Lack of absorptive capacity can also be an important barrier since it is mainly firms with highly educated employees that do collaborate with universities (Bruneel et al., 2010; Laursen et al., 2011).

Studies of university-industry collaboration tend to be based on limited information on which organizations actually collaborate. The question of whether a firm collaborates with one or more university is also seldom addressed. As documented in the present paper, a considerable proportion of the firms that collaborate with university, do so with a multiple of universities. Therefore it is relevant to explore in more detail what influences firms to collaborate with specific universities rather than treating “university” as a uniform entity.

Previous studies have found that firms are more likely to collaborate with their local university, indicating that geographical distance plays a role for university-industry collaboration (Arundel and Geuna, 2004; Broström, 2010; D’Este et al., 2012). However, this might be a sum of several different motivations of firms for collaboration with the local university, such as bounded rationality, social responsibility, and a regional identity. Furthermore, university-industry collaboration is often explained by the search process of firms, but universities also search for collaboration partners. The increasing public pressure on universities for collaborating more with industry has made universities active in recruiting companies as partners in publicly funded research projects. However, given that firms are likely to collaborate with more than one university, other factors than geographical distance must influence firms’ choices of specific universities as collaboration partners.

The purpose of the present paper is to analyse which factors influence firms’ innovation oriented collaboration with specific universities. The research question is thus whether geographical distance maintains to be an important factor explaining firms’ collaboration with specific universities when other factors, such as employee-driven relations, human capital and general experience from collaborating with universities are included.

¹ Source: Eurostat database for European Union 28 countries. Table updated 30.01.2015

In addition to geographical distance measured as travel distance between firms and universities, the analysis includes information on the educational background of firms' employees, distinguishing between whether the employees have a higher education in general and whether they are graduates from the specific university that the firm collaborates with. We also include firms' collaboration with other universities as an additional measure of general experience from collaborating with the university sector in general.

The analysis is based on a combination of detailed register micro data matched with recent innovation survey data for 2,183 innovative Danish firms. These are used in logistic regression analyses of the factors that influence the likelihood of firms' collaboration with specific Danish universities on innovation.

The paper contributes to the existing literature on university-industry collaboration in several ways. Firstly, we use a large scale sample covering a wide range of industries and focus on collaboration with specific universities whereas most existing studies are based either on small samples or contain limited information on which firms actually collaborate with particular universities located in various regions. Secondly, the detailed firm level data allows studying university-industry collaboration for firms involved in collaboration with several universities. Studies of firms' collaboration with universities on innovation using innovation survey data often investigate the topic as firms' collaboration with one single university or treat university as a uniform identity (see e.g. Laursen and Salter, 2004; Lööf and Broström, 2008; Laursen et al., 2011). In reality many of the university-collaborating firms collaborate with more than one university on innovation. Thirdly, by looking at firms that collaborate with multiple universities, and by having detailed information that reveals whether firms and universities are related through other channels than location, we are able to explore the extent to which geographical distance matters for university-industry collaboration in more detail.

The analyses presented in this paper are of a more general form than the majority of studies in this field. More detailed and generalised information on which factors contribute to explaining firms' collaboration with universities on innovation and on whether the importance of these factors differs between types of universities and regions has important implications for policy aiming at enhancing firms' innovation competences through more university-firm interaction.

The remainder of this paper is structured as follows: Section 2 presents an overview of previous studies of university-industry collaboration on innovation. Section 3 describes the data and the applied logistic regression method. Section 4 presents the findings regarding the effects of different factors on the likelihood of innovative firms' collaboration with universities, followed by the conclusions in section 5.

2. University-industry collaboration on innovation

There is a very large literature showing that knowledge spillovers from universities are local (e.g. Feldman, 1994; Anselin et al., 1997). In addition, several studies show that geographic proximity to public knowledge institutions is important for firms' likelihood for innovation collaboration (Arundel and Geuna, 2004; Broström, 2010). Thus geographical distance appears to be an important factor in facilitating university-industry collaboration on innovation. Fitjar (2014) argues that, ideally, firms should collaborate with the most relevant university on innovation, but they often collaborate with the local university due to three motivations: spillovers, bounded rationality and social responsibility. These motivations affect the firms'

search process and increase the impact of geographical distance. However, universities are also beneficiaries of place-based philanthropy (Glückler and Ries, 2012). The local university is often an important part of a region's identity and very visible in the region by building networks and educating students and by appearing in the local news.

However, several studies are also critical to the role of geography for university-industry interaction. Boschma (2005) argues that geographical proximity is neither a precondition nor a sufficient factor for fostering collaboration, because other types of proximity are needed.² Ponds et al. (2010) find that there are some localized knowledge spillovers from a university stemming from spinoffs and labour mobility, but knowledge spillovers from research collaboration occur over long geographical distances. In addition, the likelihood for firms to collaborate with a local university also depends on the latter's quality, where firms tend to favour high quality universities above short geographical distances (Laursen et al., 2011). Furthermore, co-location with a university does not in itself make a firm a part of the regional networks and cognitive proximity and/or social proximity are also important factors influencing the likelihood of collaboration (Breschi and Lissoni, 2001; Boschma, 2005).

The existing literature on university-industry collaboration focuses on firm's searching for collaboration partners for innovation. However, universities are also active in the search for collaboration projects. Universities search for collaboration partners as a part of their third mission activities, but also as partners in research projects and as partners in applications to various funding bodies that often require industrial participation. Ideally, university researchers should search for the most appropriate firms, but they are also influenced by bounded rationality, maintaining networks, and responsibilities related to keeping a strong regional identity. Therefore, researchers at the universities might use their social network to recruit former collaboration partners or former students.

A certain similarity in cognitive bases between interacting organisations, which is prerequisite of absorptive capacity (Boschma, 2005; Cohen and Levinthal, 1990), is necessary for acquiring and applying external knowledge across organisational boundaries. Therefore, firms that collaborate with universities often have internal research and development capabilities (Laursen and Salter, 2004) including highly educated employees among their staff (Bruneel et al., 2010; Laursen et al., 2011). However, the knowledge that a university graduate acquires through his or her study is broader than professional knowledge; it also includes an institutional training in the norms and values of a university. Thereby the graduate builds up what may be labelled as an institutional proximity to the university sector in general, and to his or her alma mater university in particular. Social proximity may also evolve between graduates and university staff. But social proximity might not be reciprocal in the sense that the proximity might be perceived differently by the graduate and the university researcher: The graduate might perceive the social proximity as closer to the former lecturer than vice-versa. This means that social proximity can be highly subjective.

Social ties can impact firms' likelihood of collaborating with a university, because social proximity increases mutual trust which is an important factor in facilitating collaboration (Breschi and Lissoni, 2001; Boschma, 2005; Fleming and Frenken, 2007; Østergaard, 2009). Furthermore, universities are often very large and

² Boschma (2005) introduces five types of proximity: geographical, cognitive, organizational, social, and institutional proximity.

complex entities that are active in a very diverse set of research areas and they tend to focus more on educating students and on research than on collaborating with industry. Therefore, it can be difficult for firms to find the relevant university-researchers to collaborate with. An analysis of the wireless communications cluster of the North Denmark Region shows that engineers who graduated from the local Aalborg University are more likely to have relationships with researchers at Aalborg University than engineers who graduated from other universities in the country. This may signify that the locally educated engineers have an understanding of 'who knows what' at the local university and therefore meet with fewer obstacles when contacting university researchers, or that the engineers developed social networks during their years as students that they maintain even after graduation (Østergaard, 2009). Similarly, Fleming and Frenken (2007) find that co-inventor networks among different firms in Silicon Valley often were based on employees sharing a similar organizational background and in many instances this was related to university education.

The national system of innovation literature places great emphasis on the importance of the formal as well as informal institutional set-up for the actions of and interactions between the actors of the system (Lundvall, 1992; Johnson, 1992). Firms' inclination towards collaborating more often with national rather than international universities, regardless of geographical distance, can be perceived as an expression of the importance of institutional proximity (Boschma, 2005).

Most studies assume that firms' collaborate with one university only. An exception is Guerini et al. (2013), who, in a survey of 79 young high-tech firms in Italy during 2004-8, find that the 79 firms are engaged in 96 collaborations with universities, thereby implying that some firms collaborate with more than one university. Furthermore, firms that are collaborating with a university are likely to learn how to collaborate with universities in general, which may affect their search and increase their inclination to engage in collaborations with other universities.

Based on the above we hypothesize that:

H1: Geographical distance is less important for a firm's collaboration with a specific university than employee-driven relations.

H2: Geographical distance is less important for a firm's collaboration with a specific university than the firm's general experience with university collaboration.

3. Data and method

The present analysis of firms' collaboration on innovation with universities is based on a combination of register-data and survey data. Information on characteristics of firms – including location, information on employees etc. - is extracted from the Danish Integrated Database for Labour Market Research (the IDA database), which is a linked employer-employee database of the entire Danish population. Drawing on different national registers, the database contains information on the personal, employee and establishment level. The information is obtained at one point of time at any given year. In the present case we use information from November 2009. For a further description of the IDA database see Timmermans (2010). Information on firms' collaboration on innovation is based on survey data from Statistics Denmark on the innovation activity of Danish firms. The statistics are derived from responses from 4,698 randomly

selected firms from a population of 22,000 firms. The survey was mandatory resulting in very few non-responses. The firms are selected based on their number of employees and industry – the higher the number of employees, the higher the chance of being selected – giving the largest firms a 100 per cent chance of selection. Industries with a high research and development intensity have broader coverage than less research and development intensive industries. The present analysis uses the preliminary data covering the period from 2010 to 2012.

Since the focus is on collaboration on innovation, only innovative firms are included in the analysis. Firms are characterised as innovative if they have introduced new or significantly improved products, manufacturing processes, operations, organisational structures, or methods of marketing between 2010 and 2012. Novelty is determined from the perspective of the individual firm, i.e. whether products, processes etc. are new to the firm. A total of 2,183 innovative firms are included in the analysis. The analysis is carried out on un-weighted data, which implies that the data are not representative of the entire Danish population of firms in terms of size and industry distribution.

The effects of geographical distance, employee-driven relations, human capital and general experience with collaborating with universities on the likelihood of firm collaboration with specific universities are estimated with logistic regression. For six of the eight universities³ included in the analysis there was a possible issue of a quasi-complete separation of data points in the model. This issue occurs when one or more parameters in the model become theoretically infinite. This phenomenon may occur if the model perfectly predicts the response or if there are more parameters in the model than can be estimated because the data are sparse (Webb et al., 2002). We have used Firth correction to modify the score functions of the logistic regression models through penalized likelihood estimation where quasi-complete separation of data points appeared to be an issue (Heinze and Schemper, 2002).

3.1. Dependent variable

The dependent variable is a dummy variable indicating whether firms have collaborated on innovation with a specific Danish university within the 3-year period 2010-2012. This information is extracted from the above-mentioned innovation survey, where firms were asked whether they have collaborated with each of the eight Danish universities on innovation. In order to take into account differences between different types of universities we run regression models for each of the eight universities separately.

Collaboration on innovation is defined as “The firm’s active participation in innovation activities with other firms, universities and other research institutions” (Statistics Denmark, 2012). A pure contracting out of innovation activities which does not imply active collaboration is not regarded as collaboration on innovation.

3.2. Explanatory variables

We measure geographical distance to a university by travel distance following the method of Boschma et al. (2014). First we take the logarithm to the road travel time between the firm’s and the university’s postal

³ Aarhus University, Roskilde University, Copenhagen University, University of Southern Denmark, Copenhagen Business School and IT University of Copenhagen. In the cases of Roskilde University, Copenhagen Business School and IT University of Copenhagen the problem may be due to a very low number of firm collaborations: only 21, 51 and 13 innovative firms respectively have cooperation with each of these universities.

code and then we subtract this value from the highest value in the data set. Thus, the value is zero for firms that are located farthest away. The information on firm location is extracted from the IDA Database.

There are four universities located in the Capital Region around Copenhagen in the eastern part of Denmark, and one university in each of the four other administrative regions (see Figure 1).

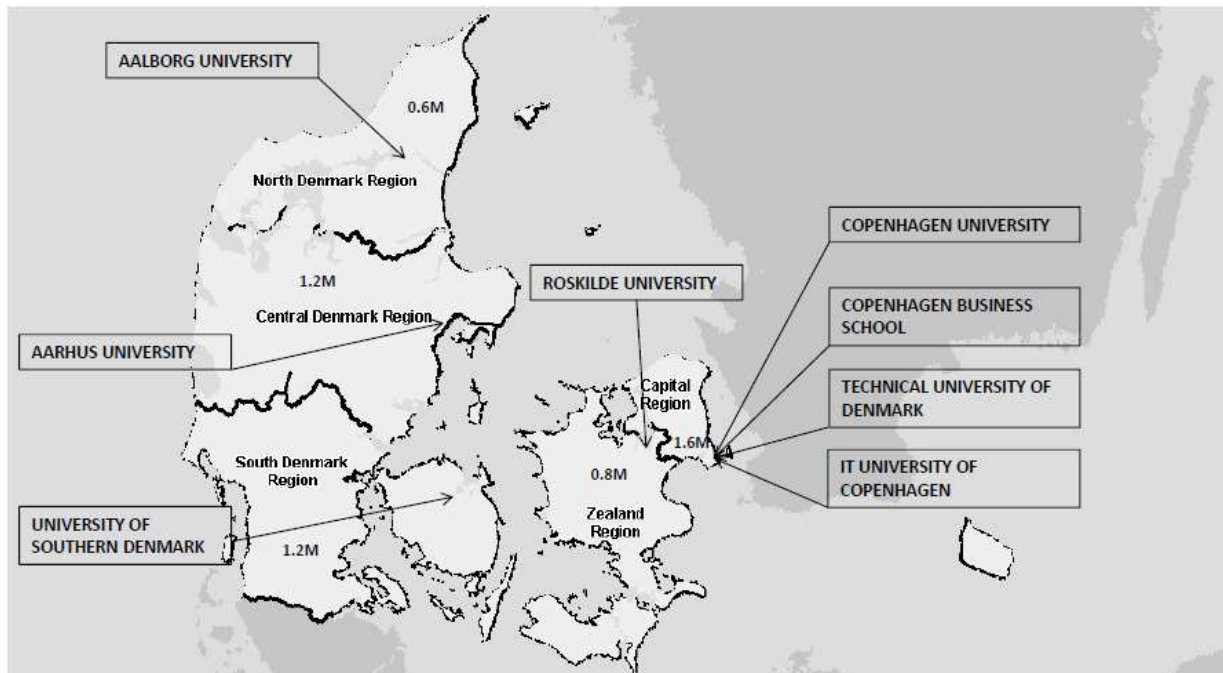


Figure 1. The five administrative regions in Denmark (numbers indicate regional population in millions).

The universities differ in age, size and scope. Copenhagen Business School, the Technical University of Denmark and the IT University of Copenhagen are specialized universities in business, engineering and information and communication technologies (ICT) respectively, whereas the remaining five universities are ‘complete’, multi-faculty universities (see Table 1).

Table 1. Overview of the Danish universities

Source: Universities Denmark’s statistical resources and individual university webpages

	Established	Student population 2013	Type	Region
Aalborg University	1974	19,064	Multi-faculty	North Denmark
Aarhus University	1928	38,169	Multi-faculty	Central Denmark
University of Southern Denmark	1966	22,224	Multi-faculty	Southern Denmark
Roskilde University	1972	7,588	Multi-faculty	Zealand
Copenhagen University	1479	40,866	Multi-faculty	Capital
Copenhagen Business School	1917	16,659	Specialised	Capital
Technical University of Denmark	1829	10,196	Specialised	Capital
IT University of Denmark	1999	1,894	Specialised	Capital

Table 2 reveals that geographical distance in terms of spatial co-location within the same region seems to matter for firms' collaboration on innovation with universities. With the exception of firms located in the Zealand Region⁴, the majority of the innovative firms that collaborate with a Danish university do so with a university located in the same region as the firm. Table 2 also reveals that several innovative firms collaborate with more than one Danish university. A total of 44 per cent of the firms that collaborate with Danish universities on innovation, collaborate with more than one national university.

Co-location is, however, a relatively crude measure of distance. In the regression analyses we use travel distance in time as a more precise measure of geographical distance in order to avoid border problems. Most other studies of the importance of co-location use a broader measure, e.g. defining local as within a 100 miles radius (Laursen et al., 2011) or within the same nation (Arundel and Geuna, 2004). In a Danish context using a 100 miles radius to define local would imply that seven out of the eight universities would be defined as local for a firm located in the middle of Denmark.

Table 2. Share of innovative firms in each region which have collaborated with each of the Danish universities on innovation

	Aalborg University (North Denmark Region)	Aarhus University (Central Denmark Region)	University of Southern Denmark	Roskilde University (Zealand Region)	Copenhagen University (Capital)	Copenhagen Business School (Capital Region)	Technical University of Denmark (Capital Region)	IT University of Denmark (Capital Region)	Any Danish university
Capital Region	4.8%	4.0%	4.4%	1.9%	7.9%	5.0%	10.4%	1.3%	15.9%
Zealand Region	1.5%	2.6%	1.5%	1.0%	4.6%	0.0%	5.6%	0.0%	11.2%
Southern Denmark Region	4.8%	3.4%	7.5%	0.0%	2.2%	0.2%	5.8%	0.0%	13.7%
Central Denmark Region	4.5%	6.9%	2.8%	0.4%	3.2%	0.9%	4.7%	0.2%	11.8%
North Denmark Region	12.3%	2.5%	1.0%	0.0%	0.5%	0.5%	2.9%	0.0%	14.7%
Any Danish region	5.2%	4.6%	4.0%	1.0%	4.8%	2.3%	7.7%	0.6%	

Numbers in bold indicate within-region collaboration.

Previous studies find that firms are more likely to collaborate with a university if they have university graduates among their employees (Bruneel et al., 2010; Laursen et al., 2011); therefore firms' share of employees with a higher education is included as an explanatory variable. Higher education is here defined as having at least a university bachelor's degree. The information on level of education of the employees is based on the IDA database. We measure whether the firms have employees with a higher education *prior* to the 3-year period where collaboration is measured. If a firm has no employees with a higher education prior to the 3-year period, but hires such people during the 3-year period, these are not included in the analysis. This means that we might under-estimate the importance of having employees with higher education.

⁴ Zealand Region is the neighbouring region to the Capital Region of Denmark, and Zealand's regional university – Roskilde University – is located only 30 kilometres from the centre of Copenhagen.

According to hypothesis 2, firms that are collaborating with one university are likely to learn how to collaborate with universities in general. Since this may increase their inclination to engage in collaborations with another university, we include two variables on collaboration on innovation with other universities. We distinguish between collaboration with Danish and foreign universities. Since the dependent variable is collaboration with a specific Danish university, the variable expressing collaboration with other Danish universities in general compresses the other seven universities. Information on collaboration with Danish and foreign universities is taken from the innovation survey. Both university collaboration variables are dummy variables.

In order to test hypothesis 1 that employee-driven relations are more important than geographical distance for a firm's collaboration with a specific university, we include information on whether at least one of a firm's employees is a graduate from that particular university. This variable is a dummy variable based on information from the IDA database. We only include graduates from the particular university who are employed by the collaborating firms *prior* to the 3-year period where collaboration is measured in the analysis.⁵

We assume that recent graduates have the same degree of proximity to their alma mater university as people who have graduated decades ago. Therefore we do not take time of graduation into account. Potential previous employment at a university is not included either. We assume that just one employee from a particular university is sufficient to establish an employee-driven relation between a firm and a university, regardless of the size of firm.

Table 3 illustrates that - with the exception of firms located in Zealand Region - the majority of the innovative firms with university graduates among their employees have graduates from a university in the firm's home region. 75 per cent of the innovative firms have graduates from a Danish university among their employees. This indicates that geographical distance is a proxy for employee-driven relations.

⁵ We assume that the causality is from having graduates amongst employees to collaboration with university. It may however be relevant to analyze the extent to which the reverse causality may also be present so that firms that collaborate with a university are more likely to hire graduates from that university. This is a subject for future analyses.

Table 3. Share of innovative firms in each region with employees that are graduates from each of the Danish universities

	Aalborg University (North Denmark Region)	Aarhus University (Central Denmark Region)	University of Southern Denmark	Roskilde University (Zealand Region)	Copenhagen University (Capital)	Copenhagen Business School (Capital Region)	Technical University of Denmark (Capital Region)	IT University of Denmark (Capital Region)	Any Danish university
Capital Region	33.6%	43.7%	34.1%	33.6%	55.2%	63.8%	41.4%	12.7%	83.9%
Zealand Region	11.2%	19.9%	16.3%	13.8%	29.1%	38.3%	32.1%	1.5%	62.2%
Southern Denmark Region	26.9%	36.5%	56.7%	2.4%	17.3%	14.4%	17.8%	1.2%	70.4%
Central Denmark Region	36.6%	58.7%	27.7%	4.1%	17.4%	10.5%	14.0%	1.3%	71.0%
North Denmark Region	62.3%	34.3%	10.3%	0.0%	5.9%	6.4%	12.8%	0.5%	71.6%
Any Danish region	33.7%	42.5%	33.2%	16.4%	32.9%	35.3%	27.5%	5.9%	75.5%

Numbers in bold indicate employment in region of education.

3.2. Control variables

We apply several control variables in the regression. We control for firm size and industry affiliation in our analysis, since larger firms and firms in particular industries are more likely to collaborate with universities (Pavitt, 1984; Laursen et al., 2011).

Firms might choose to collaborate with a university simply because they are more open in their innovation process. Therefore, we have also controlled for collaboration on innovation with suppliers in order to control for the firms' general likelihood to collaborate on innovation. Information on firm size and industry affiliation is based on the IDA database, whereas information on collaboration with suppliers is taken from the innovation survey. See Table 4 for an overview of all variables included in the regression analyses.

Table 4. Summary statistics of regression variables

Fraction of innovative firms that collaborate with	Aalborg University	5.13%
	Aarhus University	4.58%
	University of Southern Denmark	4.03%
	Roskilde University	0.96%
	Copenhagen University	4.86%
	Copenhagen Business School	2.34%
	Technical University of Denmark	7.19%
	IT University of Copenhagen	0.60%
	Other DK uni. than Aalborg University	12.23%
	Other DK uni. than Aarhus University	12.41%
	Other DK uni. than Uni. of Southern Denmark	12.64%
	Other DK uni. than Roskilde University	13.42%
	Other DK uni. than Copenhagen University	12.87%
	Other DK uni. than Copenhagen Business Sch.	13.33%
	Other DK uni. than Technical University	11.54%
	Other DK uni. than IT University	13.51%
	Suppliers	30.87%
Foreign universities	5.22%	

Fraction of innovative firms with employees who are graduates from	Aalborg University	33.81%
	Aarhus University	42.51%
	University of Southern Denmark	33.21%
	Roskilde University	16.45%
	Copenhagen University	32.89%
	Copenhagen Business School	35.23%
	Technical University of Denmark	27.49%
	IT University of Copenhagen	5.91%
Distribution of innovative firms by region	Capital Region	41.13%
	Zealand Region	9.01%
	Southern Denmark Region	19.12%
	Central Denmark Region	21.37%
	North Denmark Region	9.38%
Distribution of firms by size	Below 10 employees	15.25%
	10-49	36.51%
	50-99	17.41%
	100-249	19.84%
	250+	10.99%
Distribution of firms by industry group (se appendix for industry classifications)	Primary sector	1.01%
	High-tech manufacturing	4.99%
	Medium-high-tech manuf.	9.67%
	Medium-low-tech manuf.	7.79%
	Low-tech manufacturing	9.34%
	Knowledge Intensive Services (KIS)	34.68%
	Less Knowledge Intensive Services	28.91%
	Utilities	1.28%
	Construction	2.34%
Share of employees with higher education	Mean	0.1480
	Standard Error	0.1963
	Min	0
	Max	1

4. Results

The results of the regressions are summarised in Table 5.⁶ Model 1, which is the base model, shows that, despite the short distances in Denmark, distance matters for collaboration with four of the eight universities. However, firms' share of employees with higher education, i.e. human capital, as well as collaboration with suppliers is highly significant for all universities.

Model 2 tests hypothesis 1 stating that geographical distance is less important for a firm's collaboration with a specific university than employee-driven relations by adding firm employees from the collaborating university as an explanatory variable. The model shows that for seven of the eight universities, employees from the collaborating university are highly significant. Distance to university is now only significant at a 1 per cent level for one university, and significant at a 5 and 10 per cent level respective for two additional universities. Furthermore the sizes of the coefficients have dropped compared to model 1. These results

⁶ See appendix for detailed results of the total model (model 4). Detailed results for models 1-3 are available upon request.

thus confirm hypothesis 1. This is in line with Breschi and Lissoni (2001) and Boschma (2005) who argue that location in a region does not make a firm a part of the regional networks.

The share of employees with higher education is still significant for all universities, but the sizes of the coefficients generally decrease compared to model 1. There are literally no differences in the importance of collaboration with suppliers between model 1 and model 2.

Model 3 tests hypothesis 2 by exploring whether geographical distance is less important for a firm's collaboration with a specific university than the firm's general experience with university collaboration. These are somewhat surprising since including the collaboration with other Danish and foreign universities increase the importance of distance for collaborating with a specific university. Distance is now significant for six of the eight universities, although at mixed levels of significance. This could indicate that firms that collaborate with several universities are also inclined to collaborate with the local university. Therefore we are not able to confirm hypothesis 2.

The results from model 3 do not reveal whether it is the broad collaboration – which could indicate a cognitive proximity to the university sector – that spurs local collaboration, or whether the causality is the reverse. Collaboration with other Danish universities is highly significant for all eight universities, whereas this is only the case for four of the eight with respect to collaboration with foreign universities. Share of employees with higher education loses importance when collaboration with other universities is included, just as is the case with collaboration with suppliers.

Finally, model 4 includes all variables. This model has the highest explanatory power for all universities compared to the other models. In this model distance is only significant for three universities: Aalborg University and Technical University of Denmark (significant at 1 per cent level), and Aarhus University (significant at 5 per cent level). That distance is highly important for collaborating with Aalborg University and the Technical University is remarkable, given that these two universities are also the most collaborating universities in Denmark. They are also the two major engineering universities in Denmark, which could lead to the assumption that they have a broader geographical reach. The results could indicate that there is a geographical division of labour between the two universities. This is an issue that calls for further investigation. The share of employees with higher education is only significant for Aarhus University and Copenhagen Business School. This indicates that it is not the level of human capital that determines firms' collaboration with specific universities, but that this measure may be a proxy for more specific employee-driven relations.

Looking explicitly at employee-driven relations between the collaborating firm and university, as expressed by firm employees that are graduates from the collaborating university, model 4 shows that such employee-driven relations matter for collaboration with seven out of the eight universities. This means that firms are more likely to collaborate with a university if they have employees who have graduated from that specific university, even when controlling for location. This indicates that geographical mobility of graduates enhances university-industry collaboration over geographical distance. Thus, hiring graduates from a university establishes an employee-driven relation between the firm and the university which facilitates collaboration. However, it should be noted that many graduates' stay in the region after graduation which is true for all Danish universities (Drejer, 2014). This may reflect that universities

specialize according to the needs of local labor market, or that universities over time shape the local industry structure (Best, 2001).

Table 5. Summary of regression results

	Aalborg University (North Denmark Region)	Aarhus University (Central Denmark Region)	University of Southern Denmark	Roskilde University (Zealand Region)	Copenhagen University (Capital Region)	Copenhagen Business School (Capital Region)	Technical University of Denmark (Capital Region)	IT University of Copenhagen (Capital Region)
Model 1 (max rescaled R ²)	(0.35)	(0.32)	(0.29)	(0.26)	(0.37)	(0.44)	(0.39)	(0.39)
Distance, inverse log	0.51		0.43	<i>0.46</i>			0.32	
Share of employees with higher education	3.31	3.21	2.69	3.18	3.41	4.81	3.25	3.05
Collaboration with suppliers	1.26	1.11	1.19	0.77	1.19	1.44	1.29	1.33
Industry and firm size controls	Yes							
Model 2 (max rescaled R ²)	(0.37)	(0.32)	(0.32)	(0.29)	(0.43)	(0.47)	(0.44)	(0.46)
Distance (inverse log)	0.34			<i>0.34</i>			<i>0.22</i>	
Share of employees with higher education	2.73	3.17	2.16	2.62	2.23	4.26	2.52	<i>3.06</i>
Collaboration with suppliers	1.27	1.11	1.18	0.79	1.16	1.44	1.30	1.44
Employees from same university	0.60		0.67	0.72	1.06	0.80	0.90	0.99
Industry and firm size controls	Yes							
Model 3 (max rescaled R ²)	(0.46)	(0.45)	(0.41)	(0.43)	(0.56)	(0.56)	(0.52)	(0.56)
Distance (inverse log)	0.65	<i>0.27</i>	0.49	<i>0.45</i>	0.15		0.56	
Share of employees with higher education	<i>1.54</i>	<i>1.44</i>			1.20	3.16	<i>1.47</i>	
Collaboration with suppliers	0.75	0.53	0.65		<i>0.41</i>	0.75	0.82	
Collaboration with other Danish Universities	1.17	1.11	1.21	1.68	1.54	1.45	1.21	2.11
Collaboration with foreign universities	0.43	0.52			0.50		0.56	
Industry and firm size controls	Yes							
Model 4 (max rescaled R ²)	(0.48)	(0.45)	(0.44)	(0.46)	(0.61)	(0.59)	(0.55)	(0.62)
Distance (inverse log)	0.49	<i>0.26</i>					0.29	
Share of employees with higher education		<i>1.42</i>				2.64		
Employees from same university	0.67		0.64	0.79	1.09	1.00	0.72	1.14
Collaboration with other Danish Universities	1.19	1.11	1.22	1.64	1.56	1.52	1.14	2.21
Collaboration with foreign universities	0.45	0.52		<i>0.42</i>	0.48		0.47	
Collaboration with suppliers	0.76	0.53	0.65		<i>0.38</i>	0.72	0.86	
Industry and firm size controls	Yes - see appendix							
<i>Number of observations</i>	<i>2,183</i>							

Only significant parameters are included. See appendix for complete regression results (including control variables).

Estimates in **bold** indicate significance at 1% level. Estimates in *italics* indicate significance at 5 % level. Estimates in normal font indicate significance at 10% level.

5. Concluding discussion

This paper has analysed the importance geographical distance for innovation-oriented collaboration between firms and specific universities. It adds to previous literature on the subject by being able to identify the specific collaborating organisations in a broad dataset. The available data allows us to take into consideration that a relatively large proportion of the Danish firms that collaborate with a national university on innovation, collaborates with more than one university. And we do find that collaboration with other universities is an important explanatory factor behind firms' collaboration with specific universities. We interpret this as an indicator of the importance of firms' general experience from collaborating with universities. This effect has been largely overlooked in the literature that mainly focuses on collaboration with a single university.

Previous studies find that geographical distance to universities is important for firms' likelihood to collaborate with universities (Arundel and Geuna, 2004; Laursen et al., 2011; D'Este et al., 2012). In the present study we also find that geographical distance matters. However, the importance of geographical distance diminishes considerably when other factors are included. In addition to firms' collaboration with other universities, we find that employee-driven relations, measured as having employees who are graduates from the specific, collaborating university, is considerably more important than merely being located near the university. This points toward the importance of social ties between firms' employees and university researchers in facilitating university-industry collaboration over geographical distances (Breschi and Lissoni, 2001; Boschma, 2005; Fleming and Frenken, 2007; Østergaard, 2009). It could also be interpreted as an increased trust between the organisations or as a result of a bounded search for collaboration partners by former graduates of the collaborating university. In addition, having highly educated among the employees is still an important for university-industry collaboration (Bruneel et al., 2010; Laursen et al., 2011). However, it is not the share of employees with a higher education that is important, but it is employing employees from a specific university.

In terms of innovation policy, the results point in the direction of not only focusing on supporting cognitive proximity between firms and universities by building up 'generic' absorptive capacity in firms, but also on seeking to establish and utilize very specific employee-embedded relations between firms and universities.

The analysis also has limitations. Including a time factor in terms of firms' collaboration with both a specific university and universities in general previous to the analyzed period could allow for analyzing the building up relations and collaborative experience over time. However, such analyses require panel data, and the Danish surveys on innovation are only partially overlapping.

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Appendix

Table A1. Industry classification

	NACE Rev. 2	
High-tech manuf. (High)*	21	Man. of basic pharmaceutical products and pharmaceutical preparations
	26	Man. of computer, electronic and optical products
Medium-high-tech manufacturing (Med-High)*	20	Man. of chemicals and chemical products
	27-30	Man. of electrical equipment; man. of machinery and equipment n.e.c.; man. of motor vehicles, trailers and semi-trailers; man. of other transport equipment.
Medium-low-tech manufacturing (Med-low)*	19	Man. of coke and refined petroleum products
	22-25	Man. of rubber and plastic products; man. of other non-metallic mineral products; man. of fabricated metal products, except machinery and equipment.
	33	Repair and installation of machinery and equipment
Low-tech manufacturing (Low)*	10-18	Man. of food products, beverages, tobacco products, textiles, wearing apparel, leather and related products, wood and products of wood, paper and paper products, printing and reproduction of printed media.
	31-32	Man. of furniture; other manufacturing.
Knowledge intensive services (KIS)*	50-51	Water transport; air transport
	58-63	Publishing activities; motion picture, video and television programme production; sound recording and music publishing activities; programming and broadcasting activities; information service activities.
	64-66	Financial and insurance activities.
	69-75	Legal and accounting activities; activities of head offices; management consultancy activities; architectural and engineering activities; technical testing and analysis; scientific research and development; advertising and market research; other professional, scientific and technical activities; veterinary activities.
	78	Employment activities.
	80	Security and investigation activities.
	84-93	Public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation.
Less knowledge-intensive services (LKIS)*	45-47	Wholesale and retail trade; repair of motor vehicles and motorcycles.
	49	Land transport and transportation pipelines
	52-53	Warehousing and support activities for transportation; postal and courier activities.
	55-56	Accommodation and food service activities.
	68	Real estate activities.
	77	Rental and leasing activities.
	79	Travel agency, tour operator reservation service and related activities.
	81-82	Services to building and landscape activities; office administrative, office support and other business support activities.
	94-96	Activities of membership organisations; repair of computers and personal and household goods; other personal service activities.
97-99	Activities of household as employers of domestic personnel; undifferentiated goods- and services-producing activities of private households for own use; activities of extraterritorial organisations and bodies.	
Utilities	35-39	Electricity, gas, steam and air conditioning supply; water collection, treatment and supply; sewerage; waste collection, treatment and disposal activities; materials recovery; Remediation activities and other waste management services
Construction	41-43	Construction of buildings; civil engineering; specialised construction activities

* Classification is based on Eurostat.

Table A2. Regression results for Aalborg University, Aarhus University and University of Southern Denmark

		Aalborg University (North Denmark Region)			Aarhus University (Central Denmark Region)			University of Southern Denmark		
		Estimate		SE	Estimate		SE	Estimate		SE
Constant		-2.95	***	0.33	-3.17	***	0.36	-3.41	***	0.44
Distance, travel time (inverse log)		0.49	***	0.13	0.26	**	0.12	0.30		0.18
Firm size										
<i>Benchmark: below 10 employees</i>	250+	0.14		0.26	0.95	***	0.25	-0.07		0.26
	100-249	-0.20		0.26	-0.37		0.28	-0.13		0.26
	50-99	-0.13		0.29	0.32		0.26	-0.17		0.30
	10-49	0.10		0.25	-0.54	**	0.26	0.02		0.25
Share of H.E. employees		0.95		0.73	1.42	**	0.70	0.25		0.71
Employees from same university		0.67	***	0.16	0.01		0.16	0.64	***	0.17
Collaboration with other Danish universities		1.19	***	0.15	1.11	***	0.15	1.22	***	0.16
Collaboration with foreign universities		0.45	***	0.15	0.52	***	0.15	0.19		0.16
Collaboration with suppliers		0.76	***	0.16	0.53	***	0.16	0.65	***	0.17
Industry controls										
<i>Benchmark: primary sector</i>	Construction	0.41		0.75	-1.20		1.40	-0.76		1.46
	Utilities	1.67	***	0.53	-0.18		0.75	0.42		0.63
	LKIS	-1.46	***	0.40	0.27		0.33	-0.31		0.37
	KIS	-0.27		0.29	0.09		0.33	0.28		0.33
	Low	-0.22		0.37	0.20		0.41	-0.36		0.46
	Med-low	0.08		0.40	0.17		0.46	0.19		0.48
	Med-high	-0.14		0.33	-0.61		0.43	0.09		0.38
	High	-0.42		0.43	-0.07		0.46	0.13		0.47
Number of observations		2,183			2,183			2,183		
Log-Likelihood		-250.34			-223,14			-206.59		
R ² (max-rescaled)		0.48			0.45			0.44		

*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.

Table A3. Regression results for Roskilde University, Copenhagen University and Copenhagen Business School

		Roskilde University (Zealand Region)			Copenhagen University (Capital Region)			Copenhagen Business School (Capital Region)		
		Estimate		SE	Estimate		SE	Estimate		SE
Constant		-4.85	***	0.77	-3.08	***	0.39	-4.40	***	0.92
Distance, travel time (inverse log)		0.30		0.22	0.04		0.09	-0.46		0.51
Firm size										
<i>Benchmark: below 10 employees</i>	250+	-0.14		0.47	0.04		0.26	0.86	***	0.33
	100-249	0.21		0.43	-0.01		0.27	0.23		0.37
	50-99	-0.49		0.64	0.23		0.30	-0.41		0.50
	10-49	-0.14		0.48	-0.54		0.28	-0.36	*	0.44
Share of H.E. employees		0.72		1.12	-0.08		0.77	2.64	***	0.96
Employees from same university		0.79	***	0.30	1.09	***	0.19	1.00	***	0.27
Collaboration with other Danish universities		1.64	***	0.34	1.56	***	0.18	1.52	***	0.26
Collaboration with foreign universities		0.42	*	0.24	0.48	***	0.16	0.11		0.19
Collaboration with suppliers		-0.02			0.38	**	0.17	0.72	***	0.27
Industry controls										
<i>Benchmark: primary sector</i>	Construction	0.80		1.48	-1.33		1.56	-0.78		1.64
	Utilities	-0.54		1.35	-0.29		0.68	1.28		0.87
	LKIS	0.37		0.56	-0.49		0.41	0.08		0.50
	KIS	0.19		0.52	0.66	*	0.36	0.34		0.44
	Low	-0.76		1.24	0.16		0.46	0.25		0.65
	Med-low	-0.62		1.31	-0.50		0.69	0.12		0.85
	Med-high	-0.28		0.72	-0.18		0.45	-0.74		0.60
	High	-0.52		0.85	0.85	*	0.48	-0.11		0.64
Number of observations		2,183			2,183			2,183		
Log-Likelihood		-57.95			-173,491			-95.49		
R ² (max-rescaled)		0.46			0.61			0.59		

*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.

Table A4. Regression results for Technical University of Denmark and IT University of Copenhagen

		Technical University of Denmark (Capital Region)			IT University of Copenhagen (Capital Region)		
		Estimate		SE	Estimate		SE
Constant		-2.70	***	0.32	-5.58	***	0.89
Distance, travel time (inverse log)		0.29	***	0.09	0.15		0.19
Firm size							
<i>Benchmark: below 10 employees</i>	250+	-0.07		0.24	-0.75		0.64
	100-249	-0.17		0.23	0.59		0.52
	50-99	-0.01		0.25	0.74		0.62
	10-49	-0.10		0.22	-0.61		0.67
Share of H.E. employees		0.94		0.69	0.26		1.46
Employees from same university		0.72	***	0.14	1.14	***	0.39
Collaboration with other Danish universities		1.14	***	0.13	2.21	***	0.58
Collaboration with foreign universities		0.47	***	0.15	0.14		0.29
Collaboration with suppliers		0.86	***	0.14	0.50		0.40
Industry controls							
<i>Benchmark: primary sector</i>	Construction	0.31		0.79	0.96		1.68
	Utilities	1.87	***	0.58	0.19		1.32
	LKIS	-0.40		0.32	-0.86		1.17
	KIS	-0.52		0.31	1.38	**	0.62
	Low	0.08		0.37	-0.51		1.24
	Med-low	-0.77		0.51	0.02		1.30
	Med-high	0.99	***	0.33	-1.21		1.27
	High	0.48		0.38	-0.66		1.29
Number of observations		2,183			2,183		
Log-Likelihood		-290.10			-26.61		
R ² (max-rescaled)		0.55			0.62		

*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.