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Employee-driven relations and geographical proximity

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Exploring determinants of firms' collaboration with specific universities: Employee-driven relations and geographical proximity

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ABSTRACT

This analysis of determinants of firms' collaboration on innovation with specific universities assesses both the separate and overlapping importance of geographical proximity and employee-driven relations for collaboration. It is argued that social, cognitive and functional dimensions of employee-driven relations can help firms to overcome geographical distance. Based on a sample of 2,301 innovative firms in Denmark, the study demonstrates that employee-driven relations (measured by employees' and top-managers' place of education and scientific discipline) strongly influence the likelihood that firms will collaborate with specific universities. The study confirms the existence of separate and overlapping effects of employee-driven relations and geographical proximity.

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1. INTRODUCTION

A growing literature emphasizes the importance of university collaboration for firms' innovation activities (Lööf & Broström, 2008; D'Este, Guy, & Iammarino, 2013). However, most innovative firms do not draw directly on knowledge from universities for their innovation activities (Laursen & Salter, 2004). Universities may therefore be perceived as under-utilized actors in the innovation system (Huggins & Kitagawa, 2012). Barriers for university-industry collaboration may relate to differences in incentives and orientation in relation to openness between universities and industry, as well as to potential conflicts regarding intellectual property (Bruneel, D'Este, & Salter, 2010). Lack of absorptive capacity can also be a significant barrier, as it is mainly firms with highly educated employees that collaborate with universities (Bruneel et al., 2010; Laursen et al., 2011).

Although firms often rely on a combination of local and global relations in their development activities, recent studies indicate that geographical proximity plays a role in university-industry collaboration (Broström, 2010; D'Este et al., 2013). However, Breschi and Lissoni (2001) argued that a range of different mechanisms support knowledge flows and, accordingly, that geographical proximity is not necessarily a requirement for knowledge exchanges. Similarly, Boschma (2005) argued that geographical proximity is neither a precondition nor a sufficient factor in fostering collaboration unless it coincides with other types of proximity.[i] According to Boschma and Frenken (2011), 'cognitive, social and geographical distances need to be overcome to connect firms, and to enable interactive learning' (p. 65). It is well established that personal relationships are crucial for inter-organisational collaboration, and that social capital affects firms' inclination and ability to innovate (Landry, Amara, & Lamari, 2002; Laursen, Masciarelli, & Prencipe, 2012). Østergaard (2009) has demonstrated that this is also the case for university-industry collaborations.

The purpose of the present study, then, is to explore the role of employee-driven relations in firms' collaboration with specific universities on innovation. The innovation literature stresses the role of both personal relationships and geographical proximity for collaboration. This paper attempts to combine these two views by analysing both the separate importance of geographical proximity and personal employee-driven relations for university-industry collaboration and the extent to which geographical proximity and personal employee-driven relations overlap.

Most existing studies of university-industry collaboration are based on small samples or include limited information about which firms actually collaborate with particular universities in various regions. In contrast, the present analysis is based on a large-scale sample of innovative firms in a wide range of industries, focusing on collaboration with specific universities. Previous studies of firms' collaboration on innovation with universities using innovation survey data have also tended to investigate the topic in terms of collaboration with a single university, or treat the university as a uniform identity (see e.g. Laursen & Salter, 2004; Lööf & Broström, 2008; Laursen, Reichstein, & Salter, 2011). In the present study, detailed firm-level data are matched with recent innovation survey data for 2,301 innovative firms in Denmark. These are used in logistic regression analyses of factors that influence the likelihood of firms collaborating on innovation with specific national universities. The analyses are based on information about geographical proximity, the educational background of firms' employees (including top-managers), different types of innovation, and the firms' collaboration on innovation with other partners.

The paper contributes to the existing literature on university-industry collaboration in a number of ways. First, it describes the significant role of university education in building relations between firms and specific universities. Second, the paper provides detailed analyses of the extent to which different types of employee-driven relations (social, cognitive and functional) influence university-industry collaboration. This is relevant from the perspective of innovation policy, as it may pave the way for more targeted policies. Third, geographical proximity and employee-driven relations are shown to be two separate but partly overlapping factors supporting collaboration.

The paper is structured as follows: The second section presents an overview of previous studies and outlines the hypotheses to be tested. The third and fourth sections describe data and method and presents the findings respectively. Finally, conclusions are presented.

2. UNIVERSITY-INDUSTRY COLLABORATION ON INNOVATION

Several studies have found that geographical proximity to public knowledge institutions influences the likelihood of firms' collaboration with these institutions (Broström, 2010; Johnston & Huggins, 2016), suggesting that geographical proximity is an important factor in facilitating university-industry collaboration on innovation. Petruzzelli (2011) found an average travel distance between

partners of approximately 50 kilometers in an analysis of R&D university–industry collaborations in 12 European countries. Fitjar (2014) argued that firms should ideally collaborate on innovation with the most relevant university, but that they often collaborate with the local university, for three reasons: i) that geographical proximity facilitates spillovers; ii) that bounded rationality limits firms' search processes to satisfy knowledge requirements rather than to maximise knowledge spillovers; and iii) that social responsibility orients firms more towards the local university. These motives affect firms' search processes and increase the impact of geographical proximity. The local university is often an important and very visible part of a region's identity, building networks and educating students and appearing in the local news. On that basis, the following hypothesis can be advanced:

Hypothesis 1: Firms are more likely to collaborate on innovation with a university that is geographically proximate.

However, co-location with a university does not, in itself, bring a firm into regional networks; cognitive and/or social proximity also influence the likelihood of collaboration (Breschi & Lissoni, 2001; Boschma, 2005). Ponds, Van Oort, and Frenken (2010) confirmed that there are some localized knowledge spillovers from universities as a result of spinoffs and labour mobility, but knowledge spillovers from research collaborations can also occur over long geographical distances. Johnston and Huggins (2016) proposed that proximity may, in reality, be a relatively fluid concept, depending on the type of location: actors in urban areas may have a different perception of proximity than those in rural areas, where geographical distances between actors are generally larger. Additionally, firms and universities tend to co-locate, resulting in a large proportion of firms with at least one university within a short distance (Laursen et al., 2011). Finally, a considerable proportion of firms that engage in university collaboration do so with multiple universities (e.g., Guerini, Bonaccorsi, Colombo, & Lamastra, 2013), again underlining that factors other than geographical proximity influence firms' choices of specific universities as collaboration partners.

During their time at university, students build up social capital at the institution in question. Analysing social capital from a regional perspective, Laursen et al. (2012) found that firms in Italian regions with a high level of structural social capital are more likely to innovate. This can be explained in terms of two effects: i) localised connectivity between organisations, facilitated by shared norms and networks, and ii) localised trust, which diminishes potential problems of moral hazard. Similarly,

Landry et al. (2002) found that social capital, including trust and different types of network, is positively associated with intention to innovate.

Accordingly, the knowledge that a university graduate acquires through his or her study is broader than professional knowledge; it also includes institutional training in the norms and values of a specific university (and of the university sector in general), implying that the role of employees in industry-university collaboration may extend beyond building up firms' absorptive capacity. Social ties may also evolve between graduates and the university staff. Social ties can influence the likelihood of a firm's collaboration with a university by increasing mutual trust and therefore social capital (Breschi & Lissoni, 2001; Boschma, 2005; Østergaard, 2009).

An analysis of the wireless communications cluster around Aalborg showed that engineers who graduated from the local university were more likely than engineers who graduated from other universities to have informal contacts to researchers at Aalborg University. This may indicate that the locally educated engineers have an understanding of 'who knows what' at the local university, and that they develop social networks during their student years that they maintain even after graduation (Østergaard, 2009). In summary, attending a specific university builds up social capital that the graduate brings to their employing firm, so facilitating future collaboration between university and firm.

Hypothesis 2: The higher the share of graduates from a specific university among a firm's employees, the higher is the likelihood that the firm will collaborate on innovation with that university.

Universities are also active in the search for collaboration partners as part of their research and third mission activities. Meyer-Krahmer and Schmoch (1998) argued that because firms conduct a lot of R&D, they are a source of new knowledge for university researchers. Just like firms, researchers are influenced by bounded rationality and existing networks, and universities are often mandated to preserve a strong regional identity. In addition, as university technology transfer offices search actively for potential industry collaboration partners, often with a particular focus on establishing local/regional industry links (Slavtchev, 2013), university employees are likely to use their personal social relationships to recruit collaboration partners. People's limited geographical mobility means that personal relationships often coincide with geographical proximity—that is, employee-driven relations may help firms to overcome geographical distance, but geographical proximity also

overlaps with employee-driven relations by virtue of limited mobility. Based on this argument, Figure 1 illustrates how collaboration between a firm and a university is facilitated when there is either i) geographical proximity but no employee-driven relations, ii) no geographical proximity but employee-driven relations or iii) geographical proximity and employee-driven relations. It follows that employee-driven relations contribute to explaining why some firms collaborate on innovation with universities regardless of geographical proximity.

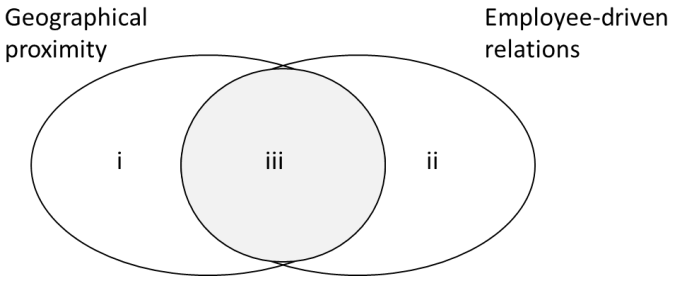

Figure 1. Geographical proximity and employee-driven relations (separate and overlapping).

Hypothesis 2 introduced employee-driven relations in the form of social ties to the specific universities from which firms' highly educated employees graduated. If such relations matter for collaboration then, given the limited mobility of people, introducing employee-driven relations as an explanatory factor is likely to reduce the relevance of geographical proximity (cf. Breschi & Lissoni, 2009). Given the overlap between employee-driven relations and geographical proximity, the following hypothesis is therefore advanced:

Hypothesis 3: Including employee-driven relations as an explanatory factor for collaboration on innovation between a firm and a specific university reduces the importance of geographical proximity for such collaboration.

However, there may also be a functional aspect to the role of employee-driven relations in firms' collaboration with specific universities. Even if a firm's employees have a relationship with a specific university, these employees are not necessarily in a position to influence who the firm collaborates with. For that reason, a separate hypothesis is proposed, singling out those graduates who are top-managers, in order to test whether an employee's functional role in the firm influences collaboration.

Hypothesis 4: Including top-manager-driven relations as an explanatory factor for collaboration on innovation between a firm and a specific university reduces the importance of geographical proximity for such collaboration.

Previous studies have shown that firms collaborating with universities often have internal research and development capabilities (Laursen & Salter, 2004), including highly educated employees among their staff (Bruneel et al., 2010; Laursen et al., 2011). This reflects the need for some similarity in cognitive bases between organisations that acquire and apply knowledge across boundaries (Cohen & Levinthal, 1990; Boschma, 2005). However, viewing highly educated staff as a uniform entity without considering their field of study ignores the fact that absorptive capacity is based on knowledge that matches the type of knowledge to be acquired. More detailed analyses of employees' educational background are therefore needed, reaching beyond relations to universities as mere social ties to encompass scientific field-specific cognitive relations. In other words, employee-driven relations are likely to be based on a common knowledge base in combination with social ties. Hypothesis 5 introduces employees' scientific discipline as a determining factor in collaboration with specific universities.

Hypothesis 5: Including scientific discipline-related employee-driven relations as an explanatory factor in collaboration on innovation between a firm and a specific university reduces the importance of geographical proximity for such collaboration.

3. DATA AND METHOD

The present analysis is based on a combination of register and survey data. Information on the characteristics of the firms is extracted from the Danish Integrated Database for Labour Market Research, which is a linked employer-employee database of the entire Danish population. The database contains information at personal, employee and establishment level. Information on firms' innovation activities is based on survey data from Statistics Denmark. The statistics are derived from the responses of 4,788 randomly selected firms within a population of 22,000 firms. Participating firms are selected on the basis of number of employees and industry affiliation. The survey is mandatory, resulting in very few non-responses.

Only innovative firms were included in the analysis. Firms were characterised as innovative if they introduced new or significantly improved products, manufacturing processes, operations, organisational structures or methods of marketing between 2011 and 2013. In total, the analysis includes 2,301 innovative firms.

The effects of employee-driven relations and geographical proximity on the likelihood of a firm's collaboration with specific universities were estimated using logistic regression.

A variance inflation factor (VIF) test for multicollinearity revealed no potential problems, as all variance inflation factors in all regression models are below 2. The correlation matrix of explanatory and control variables for Aalborg University is available in appendix.[ii]

3.1. DEPENDENT VARIABLE

A dummy variable indicates whether firms had collaborated on innovation with a specific university within the period 2011–2013. Firms were asked whether they collaborated on innovation with each of the eight Danish universities; because very few have collaborated with Roskilde University or the IT University of Copenhagen, these were excluded from the analyses. Collaboration on innovation has been defined as 'The firm's active participation in innovation activities with other firms, universities and other research institutions'.

There are four universities in the Capital Region around Copenhagen, and one university in each of the country's other four administrative regions. The universities differ in age, size, ranking and scope. While Copenhagen Business School and the Technical University of Denmark specialise in business and engineering, respectively, the other universities included in the analyses are multi-faculty (see Table 1). In the period covered by this analysis, none of Denmark's universities featured among the World's Top 100 in the Times Higher Education World University Rankings. However, the Technical University of Denmark, Aarhus University and Copenhagen University all appear in the Top 200. The University of Southern Denmark and Aalborg University rank between 300 and 400.

The Technical University of Denmark and Aalborg University are the largest engineering universities in Denmark; the University of Southern Denmark also offers some engineering degrees but at a much smaller scale. Engineering represents a very small element of teaching and research activities at Aarhus University. The remaining universities do not offer engineering degrees.

Table 1. Overview of Danish universities

Source: Universities Denmark: 'Statistical resources', and individual university webpages

	Est.	Ranking* 2014-2015	Student population 2014					Region
			Social sciences	Humanities	Technical and natural sciences**	Health sciences	Total	
Aalborg University	1974	351-400	5,782	5,040	8,022	1,387	20,411	North Denmark
Aarhus University	1928	153	14,341	12,290	7,176	4,313	38,120	Central Denmark
University of Southern Denmark	1966	301-350	8,305	7,249	4,515	4,257	24,326	Southern Denmark
Copenhagen University	1479	160	11,147	12,297	9,539	7,899	40,882	Capital
Copenhagen Business School	1917	n.a.	15,461	2,216	-	-	17,677	Capital
Technical University of Denmark	1829	121	-	-	10,311	-	10,311	Capital
Roskilde University	1972	n.a.	3,202	3,519	925	-	8,045	Zealand
IT University of Denmark	1999	n.a.	-	-	1,915	-	1,915	Capital

* Times Higher Education World University Rankings

** Universities generally report the student population within technical and natural sciences as one.

Most studies assume that firms collaborate with only one university (e.g. Laursen et al., 2011). However, 54 percent of university-collaborating firms included in the present analysis have collaborated with more than one national university.

3.2. EXPLANATORY VARIABLES

GEOGRAPHICAL PROXIMITY

Geographical proximity between a firm and a university was measured by travel distance, following the method of Boschma et al. (2014). First, the logarithm of road travel time between firm and university postcode areas was calculated. In applying postcodes areas, as in D'Este et al. (2013), travel time between firms and universities located within the same postcode area was set to zero (redefined to 1 for calculating logarithms), which slightly underestimates actual travel time.[iii]

Second, the value of the logarithm of road travel time was subtracted from the highest value in the data set, yielding a value of zero for firms farthest away from the university in question.

Earlier studies of the importance of co-location for university-industry collaboration have used broad measures, defining 'local' as within a 100-mile radius (Laursen et al., 2011), within the same county (Broström, 2010) or even within the same nation (Arundel & Geuna, 2004). Using a discrete variable to express proximity or co-location may lead to border problems, and the fact that a large proportion of firms included in the present analyses had at least one university within a relatively short travel distance underlines the importance of using a continuous measure of distance. The average minimum travel time between a firm in the sample and the nearest university is 28 minutes, and 36 percent of the firms had at least one university within a 10-minute travel distance. If travel time was increased to 30 minutes, 66 percent of firms would have access to at least one university. Such short distances to a university are not unique to Denmark; in their study of the UK, Laursen et al. (2011) reported an average minimum distance of 11.1 miles between sampled firms and the nearest university. Nine percent of firms in the UK study had a university within a one-mile radius, while more than 60 percent had at least one university within a 10-mile radius.

EMPLOYEE-DRIVEN RELATIONS

Employee-driven relations are measured as share of employees who graduated with at least a Bachelor's degree from a specific university. The analyses included only graduates of that university who were employees in the firms in the year *prior* to the three-year period covered by the innovation survey. 74 percent of the innovative firms with university graduates in their workforce employ graduates from a university in the firm's home region.

Employee-driven relations include social, cognitive and functional dimensions. To explore these, place of education is supplemented by information about field of study—that is, whether employees graduated in social sciences, humanities, technical sciences, natural sciences or health sciences—as well as information about whether any of the firm's top-level managers are graduates of a particular university.

3.3. CONTROL VARIABLES

Firms are more likely to collaborate with universities if their employees include university graduates (Bruneel et al., 2010; Laursen et al., 2011). For that reason, share of employees with at least a university bachelor's degree is included as a control variable expressing general absorptive capacity.

Firms collaborating with any university are likely to learn how to collaborate with universities in general. This may affect their search processes and increase their tendency to engage in collaborations with other universities (Johnston & Huggins, 2016). Therefore, two dummy variables related to collaboration on innovation with either other national or foreign universities were included as controls.

Firms might choose to collaborate with a university simply because of a greater openness in their innovation processes. Following Laursen and Salter (2004), the analysis therefore also controls for this by including an openness variable, ranging from 0 to 10 according to the number of different types of partners the firm has collaborated with on innovation.

Different types of innovation may lead to different spatial configurations of university-industry collaboration—that is, the choice of collaborating university may differ if, for instance, a firm is trying to develop a new product or to introduce organisational change. For this reason, types of innovation are included as control variables (dummies). The analysis also controls for firm size and industry affiliation.

See appendix for summary statistics of variables.

4. RESULTS

Logistic regression models are run separately for each of the universities in order to take different characteristics of the included universities into account.[iv] The results of the regressions are summarised in Tables 2 and 3.[v]

Model 1 (the base model) tests Hypothesis 1. This model includes travel distance to the specific university as an explanatory variable. Control variables include general absorptive capacity expressed as share of employees with higher education, collaboration with other national and foreign universities, openness, innovation type, industry and firm size. The model shows that travel

distance influences collaboration for five of the six analysed universities. The only exception is collaboration with Copenhagen Business School, where proximity is not a significant factor. In the case of collaboration with Copenhagen University, the proximity variable is only significant at the 10 percent level. This finding tends to support Hypothesis 1, although there are indications that proximity is of less importance for collaboration with universities located in the capital region.

With regard to the control variables, general absorptive capacity is highly significant for four of the six universities. General experience of collaboration with other national universities is highly significant for all six universities. Collaboration with foreign universities is significant for Copenhagen University, Aarhus University and the Technical University of Denmark only. Openness is highly significant for all universities.

There are no highly significant results regarding differences in spatial collaboration patterns for different types of innovation, but there is evidence of some weak effects. Aarhus is the only university where product innovation is positively significant; service innovation is positively significant for Aalborg University and Copenhagen Business School but negatively significant for the Technical University of Denmark. Process and organisational innovation are positively significant only for Copenhagen Business School.

Table 2. Summary of regression results: Models 1–4

	Aalborg University	Aarhus University	University of Southern Denmark	Copenhagen University	Copenhagen Business School	Technical University of Denmark
Model 1 (max rescaled R^2)	0.48	0.53	0.44	0.54	0.55	0.52
Geographical proximity (travel distance, inverse log)	0.80**	0.39**	0.73**	0.14	-	0.45*
Share of employees with higher education	1.73**	-	-	3.39**	2.44**	2.00*
Collaboration with other Danish universities	0.99**	1.40**	0.94**	1.22**	1.04**	1.00*
Collaboration with foreign universities	-	0.31*	-	0.55**	-	0.65*
Openness	0.32**	0.28**	0.38**	0.22**	0.30**	0.32*
Product innovation	-	0.28*	-	-	-	-
Service innovation	0.23	-	-	-	0.39*	-0.27*
Process innovation	-	-	-	-	0.36	-
Organisational innovation	-	-	-	-	0.53	-
Size and industry controls	Yes					
Model 2 (max rescaled R^2)	0.45	0.54	0.43	0.61	0.55	0.55
Employees from same university (share)	5.48**	4.24**	8.23**	7.22**	6.84**	8.60**
Share employees from other Danish universities	-	-	-	-	1.96*	-
Collaboration with other Danish universities	0.93**	1.41**	0.89**	1.35**	1.12**	1.03**
Collaboration with foreign universities	-	0.32*	-	0.59**	-	0.53**
Openness	0.31**	0.29**	0.40**	0.20**	0.30**	0.34**
Product innovation	-	0.25	-	0.24	-	-
Service innovation	-	-	-	-	0.36*	-
Process innovation	-	-	-	-	0.38	-
Organisational innovation	-	-	-	-	0.48	-
Size and industry controls	Yes					
Model 3 (max rescaled R^2)	0.48	0.54	0.44	0.61	0.56	0.56
Geographical proximity (travel distance, inverse log)	0.68**	0.26*	0.56**	-	-	0.33*
Employees from same university (share)	3.44**	3.52**	5.84**	7.14**	6.74**	7.34*
Share employees from other Danish universities	1.35	-	-	-	1.91*	-
Collaboration with other Danish universities	1.01**	1.44**	0.95**	1.35**	1.12**	1.08*
Collaboration with foreign universities	-	0.32*	-	0.59**	-	0.54*
Openness	0.32**	0.29**	0.39**	0.20**	0.29**	0.35*
Product innovation	-	0.26	-	0.24	-	-
Service innovation	0.23	-	-	-	0.35*	-
Process innovation	-	-	-	-	0.38	-
Organisational innovation	-	-	-	-	0.49	-
Size and industry controls	Yes					
Model 4 (max rescaled R^2)	0.48	0.54	0.45	0.63	0.56	0.57
Geographical proximity (travel distance, inverse log)	0.60**	0.26*	0.49**	-	-	0.28*
Top-manager from same university (dummy)	0.32*	-	0.31*	0.53**	-	0.54*
Employees from same university (share)	3.04*	3.53**	5.53**	6.38**	6.26**	6.52*
Share employees from other Danish universities	1.25	-	-	-	1.94*	-
Collaboration with other Danish universities	1.03**	1.44**	0.96**	1.33**	1.14**	1.08*
Collaboration with foreign universities	-	0.32*	-	0.56**	-	0.50*
Openness	0.31**	0.29**	0.38**	0.21**	0.29**	0.35*
Innovation type, industry and firm size controls	Yes					
Number of observations	2,301					

Only significant parameters are included. ** indicates significance at the 1% level. * indicates significance at the 5% level. Remaining parameters are significant at the 10% level.

In relation to Hypothesis 2, Model 2 returns positive, highly significant results for all six universities regarding share of employees from a specific university: the higher the share of employees who are graduates of a specific university, the higher is the likelihood of firms collaborating on innovation with that university. Otherwise, the results are very similar to those for Model 1.

Model 3 supports Hypothesis 3 because expanding the base model with employee-driven relations as an explanatory factor reduces the importance of geographical proximity for collaboration on innovation between a firm and a specific university. In the case of Copenhagen University, the coefficient for the proximity variable is no longer significant, and for the four universities where the coefficient remains positive and statistically significant, its size is reduced as compared to the base model. This finding is in line with Boschma and Frenken (2011), who argued that types of proximity other than geographical are necessary for inter-organisational collaboration. The overall explanatory power of the model increases slightly for most universities as compared to Models 1 and 2. The very similar findings for Models 1 and 2, combined with only minor effects when including both geographical proximity and employee-driven relations in Model 3, suggest that although the two factors have separate effects, there is also a considerable overlap between these.

The variable of general human capital, now defined as share of employees from other national universities, is only weakly significant for Aalborg University and Copenhagen Business School. Coefficients for the remaining control variables are largely unchanged; the exception is for innovation type, where product innovation is now statistically significant for Copenhagen University, and service innovation is no longer statistically significant for the Technical University of Denmark. On that basis, there seem to be very few differences in spatial collaboration patterns for the different types of innovation.

Not all company employees are necessarily in a position to make decisions that will initiate collaboration on innovation with a specific university. In Model 4, testing Hypothesis 4, the dummy variable for a top-manager educated at the collaborating university is positive and significant for four of the six universities. Additionally, in three of the four cases where travel distance was statistically significant in Model 3, coefficient sizes are considerably reduced. Clearly, then, top-managers' social relations influence the decision to collaborate with a specific university, implying that the functional aspect of employee-driven relations is of relevance to university-industry

collaboration. In particular, the effect is non-negligible for firms with a top-manager educated at the Technical University of Denmark or at Copenhagen University, where the effects are highest; these firms are three times more likely to collaborate with these universities than firms with top-managers from other educational backgrounds. Furthermore, the effect of travel distance diminishes for the Technical University of Denmark while there continues to be no significant effect for Copenhagen University. These findings support Hypothesis 4.

Table 3. Summary of regression results: Models 5 and 6

	Aalborg University	Aarhus University	University of Southern Denmark	University of Southern Denmark	Copenhagen University	Copenhagen Business School	Copenhagen Business School	Technical University of Denmark
Model 5 (max rescaled R^2)	0.49	0.54	0.46		0.64		0.56	0.57
Geographical proximity (travel distance, inverse	0.55**	0.32**	0.47**		-		-	0.28**
Top-manager from same university (dummy)	0.33*	-	0.29		0.56**		-	0.54**
Share employees same uni., social sciences	-	4.64**	-		4.14**		5.30*	n.a.
Share employees same uni., humanities	-	-	-		-		12.52	n.a.
Share employees same uni., tech. sciences	4.45**	n.a.	25.75**		n.a.		n.a.	6.52**
Share employees same uni., nat. sciences	-	-	-		8.12**		n.a.	n.a.
Share employees same uni., health sciences	-	-	-		7.82**		n.a.	n.a.
Share employees, other Danish universities	1.26	-	-		-		1.84	-
Collaboration with other Danish universities	1.07**	1.47**	0.97**		1.37**		1.14**	1.08**
Collaboration with foreign universities	-	0.33*	-		0.53**		-	0.50**
Openness	0.30**	0.29**	0.39**		0.21**		0.29**	0.35**
Inno. type, industry and firm size controls	Yes							
Model 6 (max rescaled R^2)	0.49	0.55	0.46	0.46	0.65	0.55	0.54	0.58
Geographical proximity (travel distance, inverse	0.63**	0.31*	0.49**	0.55**				0.22*
Top-manager from same university (dummy)	0.32*		0.28	0.28	0.55**			0.57**
Share employ., tech.sciences, Aalborg Uni.	3.74*							
Share employ., tech.sciences, Southern DK Uni.			26.44**					
Share employ., tech.sciences, Technical Uni.	2.56*							6.86**
Share employ., soc.sciences, Aarhus Uni.		4.47**						
Share employ., soc.sciences, Roskilde Uni.						6.39		
Share employ., soc.sciences, Cph. Uni.		3.80**						
Share employ., soc.sciences, CBS						4.66		
Share employ., humanities, Roskilde Uni.							16.82	
Share employ., humanities, CBS							12.52	
Share employ., nat.sciences, Aalborg Uni.					5.41*			
Share employ., nat.sciences, Aarhus Uni.					6.82**			
Share employ., nat.sciences, Southern DK					9.39**			
Share employ., nat.sciences, Roskilde Uni.					11.64**			
Share employ., nat.sciences, Cph. Uni.					8.49**			
Share employ., health sciences, Cph. Uni.				5.79**				
Share employ. same uni., other scientific disciplines				5.43*	4.81**	11.78	4.93	
Share employ. other uni., other scientific disciplines						1.76	1.84	
Collaboration with other Danish universities	1.01**	1.47**	0.98**	0.96**	1.39**	1.11	1.09	1.10**
Collaboration with foreign universities		0.36*		0.30	0.57**			0.52**
Openness	0.31**	0.29**	0.39**	0.38**	0.21**	0.30	0.30	0.35**
Innovation type, industry and firm size controls	Yes							
Number of observations	2,301							

Only significant parameters are included. ** indicates significance at the 1% level. * indicates significance at the 5% level. Remaining parameters are significant at the 10% level.

In Model 5, testing Hypothesis 5, variables expressing the share of employees with degrees within each of the five scientific disciplines from the specific university are added. The results show that,

compared to Model 4, there are mixed effects regarding the importance of travel distance. Coefficients are reduced for Aalborg University and University of Southern Denmark, remaining the same for the Technical University of Denmark and increasing for Aarhus University. Overall, however, the coefficients for travel distance are considerably lower than for Model 1. The results suggest that the effects of employee-driven relations found in the previous models are driven to some extent by underlying scientific discipline-specific relations. Looking at the detailed findings regarding scientific discipline, the variables for share of employees in natural sciences and health sciences are significant only for Copenhagen University. This can be explained by the university's profile and by the fact that more of their health science graduates are employed in private firms as compared to Aarhus University and the University of Southern Denmark. In technical sciences, share of employees from the specific university is statistically significant and positive for the three universities with sizeable engineering programmes while no other disciplines for these universities are statistically significant. Furthermore, proximity is still important for collaborating with Aalborg University and the Technical University of Denmark. This is remarkable, as their dominance in engineering might suggest that they have more geographical reach. The results may indicate a geographical division of labour between the two universities, which is an issue that invites further investigation.

The share of employees in social sciences from a particular university is positive and significantly associated with collaboration on innovation for Aarhus University, Copenhagen University and Copenhagen Business School. Graduates in humanities are of relevance only for collaboration with Copenhagen Business School. The general absorptive capacity measured by share of highly educated employees from other universities is still only weakly significant for two universities. Collaboration with other Danish universities and openness remain highly significant and positive for all. In summary, the results of Model 5 confirm Hypothesis 5, as the importance of geographical proximity is reduced as compared to the base Model 1.

The results of Model 5 indicate that, in addition to social ties, universities' competencies in different scientific disciplines influence collaboration. Firms with particular technological needs presumably seek to collaborate with a university with those research competencies, which means that firms employing a large share of engineers seem likely to seek collaboration with universities that conduct

engineering research and educate engineers. If scientific discipline is the dominant explanatory factor, it may be assumed that, regardless of university of graduation, share of employees in technical sciences would be the driving force. Model 6 therefore tests the robustness of findings from Model 5 by combining scientific discipline with university of graduation. Only positive, significant results for employee share are included in Table 3.

Model 6 largely confirms the findings of Model 5, although there are notable differences between scientific disciplines. The results are most clear for universities specialising in technical sciences. Only the share of graduates within technical sciences from the Technical University of Denmark creates a statistically significant and positive likelihood of collaboration with the Technical University of Denmark, and the same applies for the University of Southern Denmark: only their own graduates within this specific discipline affect the likelihood of collaboration. Collaboration with Aalborg University is, however, positively related to shares of graduates within technical sciences from Aalborg University, as well as from the Technical University of Denmark.

In natural sciences, collaboration appears to be driven more by scientific discipline than by place of education, with Copenhagen University the preferred collaboration partner, regardless of where graduate employees are educated. This probably reflects Copenhagen University's status as the largest natural science university in Denmark.

In social sciences, employee-driven social relations seem to influence collaboration with Aarhus University and Copenhagen Business School. However, employees with a social sciences degree from Copenhagen University are also positively associated with collaboration with Aarhus University, and employees with a degree from Roskilde University are positively associated with collaboration with Copenhagen Business School. Finally, in humanities, employees who have graduated from Copenhagen Business School and graduates from Roskilde University are positively associated with collaboration with Copenhagen Business School.

Geographical proximity is still significant and positive for most universities. However, the coefficients have increased compared to Model 5. The results of Models 2 to 6 demonstrate that graduates' geographical mobility can enhance university-industry collaboration over a distance. Hiring graduates from a university establishes an employee-driven social (as well as a specific cognitive) relation between the firm and the university that facilitates collaboration. It should be

noted that many graduates remain in their university region after graduation. This is true for all Danish universities, as well as in the UK (Faggian & McCann, 2009), the Netherlands (Venhorst, van Dijk & van Wissen, 2010) and Germany (Krabel & Flöther, 2014). This may reflect how universities specialize to meet the needs of the local labour market, or that universities shape the local industry structure over time, and in turn imply that geography matters to the extent that relevant collaboration partners are not randomly distributed in geographical space (Knoben & Oerlemans, 2012), and firms may be attracted to locate close to universities to gain access to graduates within a specific discipline.

Laursen et al. (2011) argued that firms prioritise the university's quality rather than geographical proximity. The present results indicate that geographical proximity is positive and significant for higher as well as lower ranked universities, and it seems that geographical proximity to a certain extent matters for collaboration with universities regardless of quality, at least for universities outside Top 100.

5. CONCLUDING DISCUSSION

This paper contributes to the literature by demonstrating how the social, cognitive and functional dimensions of employee-driven relations influence university-industry collaboration on innovation. The finding that having employees who are graduates from a specific university in most cases is positively associated with a firm's likelihood to collaborate with that specific university illustrates the social dimension. These findings align with studies positing the importance of social ties between a firm's employees and university researchers in facilitating university-industry collaboration over geographical distances (Breschi & Lissoni, 2001; Boschma, 2005; Østergaard, 2009). Alternatively, the findings might be interpreted in terms of a bounded search for collaboration partners by former graduates of the collaborating university, and vice versa. Most graduates find employment in their region of education, which may explain why the importance of geographical proximity diminishes when social ties are added to the models. At a theoretical level, these findings suggest that i) employee-driven relations can help firms to overcome geographical distance and ii) geographical proximity partly overlaps with employee-driven relations as an effect of limited mobility.

By including scientific disciplines, the social dimension is supplemented by a cognitive aspect. The results confirm that highly educated employees are important for university-industry collaboration (Bruneel et al., 2010; Laursen et al., 2011). However, although share of employees with a higher education affects the likelihood of collaboration, it is to a large extent the educational background of employees that determines which specific universities firms collaborate with. In other words, collaboration is not only influenced by having employees with university degrees but by the fact that those degrees are from a specific university and a specific field of study. For three of the six universities in these analyses, graduates with a degree in technical sciences from a specific university drove the collaboration. This is not surprising, as technical engineering is more application-oriented than other scientific disciplines. These results confirm that absorptive capacity still matters for university-industry collaboration while highlighting how absorptive capacity depends on employee knowledge that is of relevance to that collaboration.

The functional aspect refers to whether employees' position in the firm influences collaboration. For most universities, we found that top-managers' social relations with a university relate positively to collaboration on innovation with that university.

With regard to the specific role of geographical proximity, the analyses show that even when taking account of employee-driven relations, geographical proximity does affect university-industry collaboration, although its importance diminishes when employee-driven relations are included.

In terms of innovation policy, the results support the view that building up firms' absorptive capacity is still important for university-industry collaboration. However, policies should be targeted to match the needs of firms with the scientific specialisations of the different universities. The results show that employee-driven social and scientific discipline-specific relations can be utilized to link firms and universities across geographical distances. This suggests that regional innovation policy should focus not only on supporting local or regional relations but also on promoting university graduate mobility across regional boundaries as a means of establishing and sustaining inter-regional networks and knowledge collaboration between firms and relevant universities, regardless of geographical proximity.

These analyses have some limitations. First, the nature of collaboration, including the issue of which individuals are actually involved and the scale and scope of the collaborative arrangements, is not

specified. This information would be of relevance for further exploration of the role of social relations. Second, the measure of employee-driven relations says nothing about the quality of those relations. Third, panel data would have enabled analysis of the importance of developing relations and collaborative experience over time, and whether previous collaboration with a particular university influences the likelihood of subsequent collaboration. Fourth, as no information is included on any previous collaboration between a firm and a specific university, the analyses cannot assess whether collaboration with a particular university influences the likelihood of hiring graduates from that university (provided the firm does not already have graduates from that university among its employees). Fifth, these analyses are based on a single country, which precludes identifying the extent to which the specific national context affects the findings. These are issues for future research.

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APPENDIX

Figure A1. Denmark's five administrative regions (numbers indicate regional populations in millions).

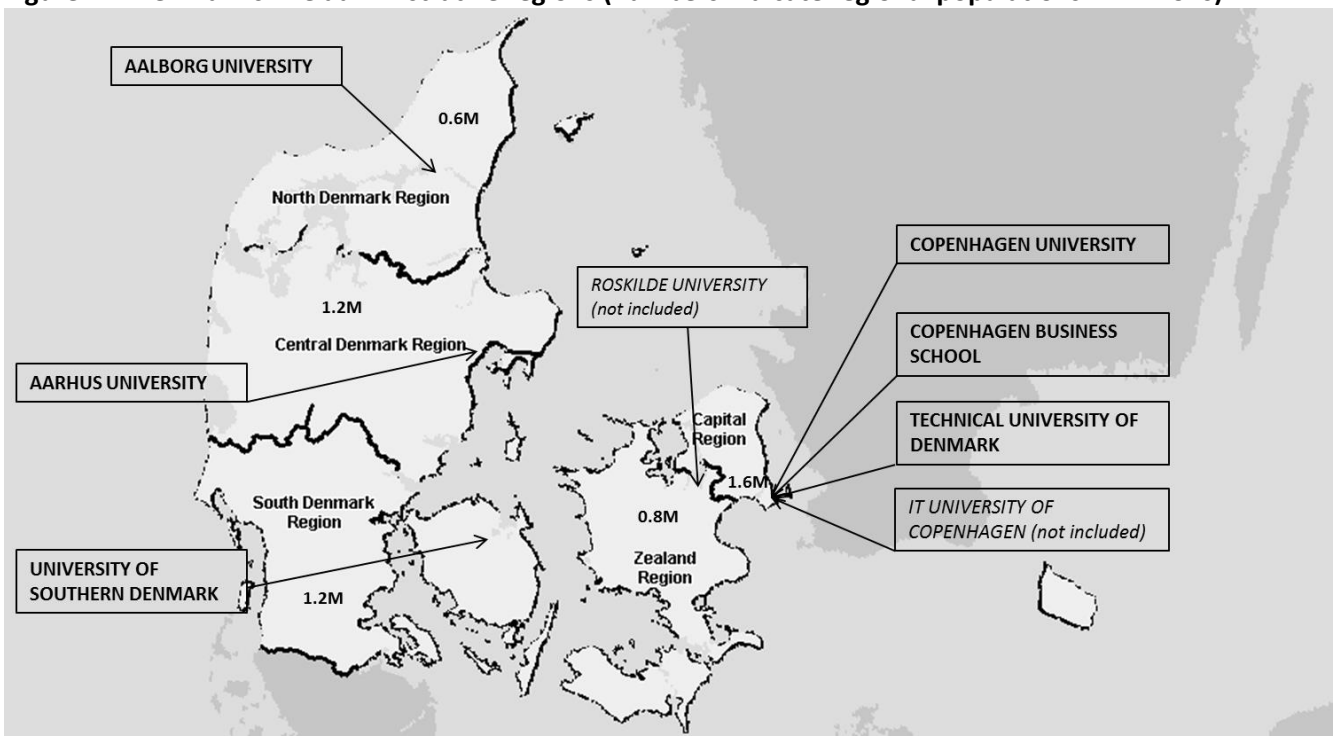

Table A1. Innovative firms in each region that have collaborated with Danish universities and employees graduating from those universities (%)

	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
	a) Share of firms in region which have collaborated with the university								
Capital Region	4.5%	6.1%	4.3%	2.0%	9.3%	3.7%	10.0%	1.1%	16.4%
Zealand Region	3.0%	3.0%	3.5%	1.0%	4.5%	1.0%	7.5%	1.0%	15.0%
Southern Denmark Region	4.0%	4.3%	9.1%	0.2%	2.1%	0.7%	5.1%	0.0%	14.0%
Central Denmark Region	5.9%	8.6%	2.6%	0.2%	4.7%	1.6%	4.9%	0.2%	14.0%
North Denmark Region	11.8%	2.4%	1.0%	0.0%	1.0%	0.5%	2.8%	0.0%	13.7%
Any Danish region	5.3%	5.7%	4.4%	1.0%	5.7%	2.1%	7.1%	0.6%	15.0%
	b) Share of firms in region which have graduates from the university								
Capital Region	30.6%	42.4%	33.6%	32.0%	55.0%	61.4%	41.8%	12.9%	82.5%
Zealand Region	14.0%	18.5%	13.0%	12.5%	23.0%	29.5%	28.0%	1.5%	56.5%
Southern Denmark Region	25.2%	32.9%	53.9%	2.6%	16.3%	11.9%	17.5%	0.9%	67.4%
Central Denmark Region	35.8%	61.3%	25.7%	2.6%	14.7%	9.2%	14.9%	0.8%	71.9%
North Denmark Region	63.0%	30.3%	9.5%	0.0%	6.2%	9.0%	14.7%	0.5%	71.1%
Any Danish region	32.3%	41.6%	31.6%	15.4%	31.6%	33.0%	27.6%	5.8%	74.0%

Grey background indicates a) within-region collaboration / b) employment in region of education.

Table A2. Summary statistics of regression variables

Fraction of innovative firms that collaborate with	At least one Danish university		15.04
	One Danish university only		6.95
	Foreign universities		5.35
	See Table A1 for specific university statistics		
Fraction of innovative firms with employees who are graduates of specific universities	See Table A1 for statistics		
Fraction of innovative firms with top managers who are graduates of	Aalborg University		14.21
	Aarhus University		24.25
	University of Southern Denmark		17.30
	Copenhagen University		14.43
	Copenhagen Business School		22.56
	Technical University of Denmark		16.95
Proportion of sampled firms with at least one university within the given travel time (minutes)	10 minutes		0.36
	30 minutes		0.66
	60 minutes		0.85
Fraction of innovative firms who carry out	Product innovation		35.98
	Service innovation		22.86
	Process innovation		45.37
	Organisational innovation		61.63
Distribution of firms by size	Below 10 employees		19.04
	10-49		35.98
	50-99		17.47
	100-249		17.99
	250+		9.52
Distribution of firms by industry group	Primary sector		1.00
	High-tech manufacturing		4.56
	Medium-high-tech manuf.		9.30
	Medium-low-tech manuf.		6.78
	Low-tech manufacturing		8.82
	Knowledge Intensive Services (KIS)		37.24
	Less Knowledge Intensive Services		28.21
	Utilities		1.83
	Construction		2.26
	Mean	Min.	Max.
Share of employees with higher education	0.17	0	1
Share of employees with higher education in social sciences	0.06	0	1
Share of employees with higher education in human sciences	0.03	0	1
Share of employees with higher education in technical sciences	0.04	0	1
Share of employees with higher education in natural sciences	0.03	0	1
Share of employees with higher education in health sciences	0.01	0	1
Number of partner types (Openness)	1.14	0	10
Distance to nearest university (travel time in minutes)*	28.05	0	173.91

* Distance/travel time is based on postcode; a travel time of zero minutes means that firm and university are located within the same postcode.

Table A3. Correlation matrix of explanatory and control variables for Aalborg University

	1. Travel distance, inverse log	2. Employees from same university (share)	3. Share of employees from other Danish universities	4. Share of employees with higher education	5. Collaboration with other Danish universities	6. Collaboration with foreign universities	7. Openness	8. Product innovation	9. Service innovation	10. Process innovation	11. Organisational innovation	12. Size (employees)	13. Industry	14.Top manager from same university
1.	1													
2.	0.34***	1												
3.	-0.21***	0.00	1											
4.	-0.09***	0.31***	0.95***	1										
5.	-0.07***	0.01	0.25***	0.24***	1									
6.	-0.03	0.04**	0.18***	0.19***	0.45***	1								
7.	-0.03*	0.04*	0.18***	0.18***	0.60***	0.45***	1							
8.	0.03	0.03	-0.01	0.00	0.19***	0.16***	0.25***	1						
9.	-0.07***	0.01	0.17***	0.16***	0.12***	0.07***	0.18***	0.13***	1					
10.	-0.03	-0.03	-0.02	-0.02	0.09***	0.08***	0.18***	0.09***	0.16***	1				
11.	-0.03	-0.03	-0.01	-0.01	0.08***	0.06***	0.13***	-0.05**	0.07***	0.18***	1			
12.	0.00	-0.07***	-0.15***	-0.16***	0.14***	0.10***	0.17***	0.15***	0.04*	0.08***	0.20***	1		
13.	-0.06***	0.01	0.08***	0.08***	-0.11***	-0.11***	-0.11***	-0.28***	0.09***	-0.04*	0.03	-0.06***	1	
14.	0.25***	0.18***	-0.06***	0.00	0.08***	0.06***	0.15***	0.15***	0.05**	0.08***	0.09***	0.36***	-0.13***	1

Note: Statistical significance: *** at 1 % level, ** at 5 % level, *at 10 % level

[i] Boschma (2005) introduces geographical, cognitive, organisational, social and institutional proximity.

[ii] Correlation matrices for all universities and are available on request.

[iii] The analyses include 439 postcode areas (small postcode areas in Copenhagen have been merged), with an average size of 98 km^2.

[iv] In a few cases, there was a possible issue of quasi-complete separation of data points in the models. This occurs when one or more parameters in the model become theoretically infinite, 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, Wilson, & Williams, 2002). In the present analyses, the issue typically occurred where relatively few firms had collaborated with a specific university. When a quasi-complete separation of data points seemed to be an issue, Firth correction was used to modify the score functions of the logistic regression models through penalized likelihood estimation (Heinze & Schemper, 2002).

[v] Detailed results are available on request.