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Substitution or overlap? The relations between geographical and non-spatial proximity dimensions in collaborative innovation projects

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Abstract

Traditionally, economic geographers stress geographical proximity's positive impact on collaboration processes. Recently, effects of cognitive, organisational, social and institutional proximity dimensions have been emphasised. This paper examines the relations between geography and these non-spatial dimensions by distinguishing two mechanisms: *the substitution mechanism*, where non-spatial forms of proximity substitute for geographical proximity, and *the overlap mechanism*, where geographical proximity facilitates non-spatial proximity.

The two mechanisms' importance is analysed in collaborative innovation projects in the Danish cleantech industry. Regression models are complemented by a qualitative analysis of the relationship between the geographical and institutional dimensions, which is the only relation where the substitution mechanism is of little importance.

Keywords

Proximity, cleantech, collaboration, knowledge linkages, innovation

JEL codes

L69, O31, R11

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1. Introduction

This paper is concerned with the relations between geographical proximity and non-spatial forms of proximity – social, institutional, organisational, and cognitive proximity – in collaborative innovation projects. It is now generally accepted in the literature on innovation processes that external knowledge linkages are of significant importance for the innovative capacity of firms, but the effect of geographical proximity on the creation of such relations is widely discussed. Traditionally, economic geographers have stressed the effect of geographical proximity and agglomeration economies in stimulating innovative activity (MASKELL and MALMBERG, 1999; STORPER, 1997). According to this view, geographical proximity is not a necessity in collaborations between actors, but it is maintained that geographical proximity has a positive impact on developing non-spatial forms of proximity (MALMBERG and MASKELL, 2006). Thus, it is argued that there is a significant *overlap* between geographical and non-spatial forms of proximity.

The weight given to geographical proximity has not avoided criticism (e.g. BUNNELL and COE, 2001). Instead of viewing geography as the predominant dimension shaping collaborative innovation activities, it is suggested that, e.g. social networks can be at least as important for the formation of partnerships as the spatial context where these relations take place (AMIN and ROBERTS, 2008). It has been empirically shown that some types of knowledge linkages are primarily of global rather than local character (e.g. COENEN et al., 2004). Consequently, it is proposed that more attention should be given to non-physical dimensions of proximity (TORRE and GILLY, 2000), with the work of BOSCHMA (2005) separating between geographical, cognitive, organisational, social and institutional proximity being particularly influential (see e.g. MATTES, 2012; MOODYSSON and JONSSON, 2007). In BOSCHMA (2005), the importance of geographical proximity is downplayed and it is stressed that proximity along other dimensions may reduce coordination costs. Thus, the possibility of *substituting* the non-spatial proximity dimensions for geographical proximity is emphasised.

Accordingly, in the debate on the impact of geographical proximity on partnership formation, the fundamental issue separating these two positions is the relative importance of two mechanisms: *the substitution mechanism*, where non-spatial forms of proximity substitute for geographical proximity, and *the overlap mechanism*, where geographical proximity facilitates non-spatial forms of proximity. The aim of this paper is to empirically assess the importance of these two mechanisms for the formation of partnerships. The unit of analysis is collaborative product development projects in the Danish cleantech industry. Ordered logit models are applied to data on 180 inter-firm collaborations compiled through in-depth interviews with cleantech firms. Further, qualitative data from the interviews is analysed to elaborate on the findings from the regression analysis.

The structure of the paper is as follows. The second section reviews the debate on the importance of geography for collaboration. The third section introduces the theoretical concept of proximity, and the fourth section focuses on the *substitution* and *overlap mechanisms*. The fifth section presents the data and methodology, and the sixth section contains the analysis. The final section concludes and suggestions for further research are provided.

2. Geography and collaboration

The increasing economic importance of innovation is associated with a growing significance of knowledge linkages. Intra-firm knowledge is generally an insufficient source of innovation, as firms increasingly concentrate on core competences. Learning processes are often highly complex, crossing various communities (AMIN and COHENDET, 2004) and fuelled by knowledge inputs adopted from a number of different sources.

It is often argued that geographical proximity has a positive effect on collaborative knowledge creation (e.g. HOWELLS, 2002; MORGAN, 2004). The social character of these processes implies that easy communication and interaction between partners are important to the success of collaborations. It is suggested that these features are stimulated by geographical proximity which

allows easy face-to-face contact, resulting in trust creation and efficient information transfer (STORPER and VENABLES, 2004). Knowledge creation in geographically delimited networks is an important element in recent theories on endogenous development, from the concept of the innovative milieux to innovation systems and industrial districts. To a greater or lesser extent, these contributions stress how localised institutions and routines are critical for promoting innovation through their ability to generate collaborative learning (AYDALOT, 1988; COOKE, 2001; PIORE and SABEL, 1984).

While studies have demonstrated the significant and increasing importance of local knowledge sources for knowledge production (e.g. AUDRETSCH and STEPHAN, 1996; SONN and STORPER, 2008), knowledge does not flow freely and evenly between firms in agglomerations. Analysing collaboration patterns in an agglomeration, GIULIANI (2007) finds that knowledge transfer is a highly uneven and selective process, depending on inter-organisational collaboration patterns. Thus, geographical proximity does not in itself ensure pervasive circulation of knowledge. This draws attention to the social and cognitive relations between firms' employees as well as the indirect role of geography in influencing the conventions that shape interactions between economic agents (GERTLER, 2003; STORPER, 1997). However, it also highlights how social networks are often more important for inter-organisational partnerships than geographical proximity, and can facilitate collaboration between partners which are geographically distant (ALLEN, 2000; SAXENIAN and HSU, 2001). The importance of such distanciated collaboration is now frequently emphasised (AMIN and COHENDET, 2004; BELL and ZAHEER, 2007; FLEMING et al., 2007) and it is suggested that it is inadequate to view interactions at a particular spatial scale as the key determinant of innovativeness (BUNNELL and COE, 2001). Thus, it is exactly the ability of firms to create, maintain and exploit networks at various scales which is central to innovative capacity (BATHELT et al., 2004; MOODYSSON, 2008). The proximity dimensions approach proposes a framework for understanding this issue.

3. The proximity framework

The analytical concept of proximity is currently widely applied by scholars seeking to understand the formation and effect of linkages between actors (see KNOBEN and OERLEMANS (2006) for a review). The central idea is that different forms of proximity reduce coordination costs in interactive knowledge creation. While the economic geography literature has traditionally focused on proximity in purely physical terms, LUNDVALL (1992) already noted the possibility of substituting organisational proximity for geographical and cultural proximity. The position is further developed in the work of French scholars from the *Proximity Dynamics group* (TORRE and GILLY, 2000; TORRE and RALLETT, 2005), but the model suggested by BOSCHMA (2005) gives the most detailed and thorough account of the relationship between proximity and innovation. Boschma's model contains five dimensions: geographical, cognitive, organisational, social and institutional proximity.

Geographical proximity is defined as both absolute and relative distance. *Cognitive proximity* is associated with differences and similarities in capabilities of economic agents. Capabilities at the firm level derives from learning processes by which additional technical and non-technical skills are acquired by individuals and through them, by the organisation. Differences in the cognitive capabilities of actors can make it difficult to learn from each other as the ability to absorb the diffused knowledge is simply not available (COHEN and LEVINTHAL, 1990). *Organisational proximity* is expressed through the extent of control of relations through intra- or inter-organisational arrangements. The degree of hierarchy has a great impact on the ability to coordinate economic activity and avoid uncertainty and opportunism. *Social proximity* refers to the strength of social ties between agents at the micro-level resulting from friendship, family relations or previous work related interactions. Again, this proximity influences the risk of opportunism, however, here through mechanisms of trust. Finally, *institutional proximity* describes the extent of shared norms, habits, rules and laws between economic agents. Thus, it depends on both the formal and informal *"humanly devised constraints that shape human interaction"* (NORTH, 1992, p. 477). A number of

recent studies take up the empirical challenge of measuring non-spatial forms of proximity. These contributions underline the relevance of such a multi-dimensional proximity framework for the analysis of collaborative innovation processes (AGUILÉRA et al., 2012; BALLAND, 2012; BROEKEL and BOSCHMA, 2012; PONDS et al., 2007).

4. Substitution or overlap?

A key question following from the work of Boschma concerns the role of geography in collaborations between actors. While Boschma notes that geography has an indirect effect, through the facilitation of non-spatial forms of proximity, he stresses the possibility of substituting these proximity forms for geographical proximity. Thus, *"geographical proximity per se is neither a necessary nor a sufficient condition for learning to take place"* (BOSCHMA, 2005, p. 62), as proximity along other dimensions may reduce coordination costs. Further, some degree of cognitive proximity is the only type of proximity which is considered a prerequisite for interactive learning.

In a response to BOSCHMA's (2005) paper, MALMBERG and MASKELL (2006) acknowledge that collaborations between actors do not necessarily require geographical proximity. However, they maintain that the significant attention given to the effect of geography is exactly due to the indirect impact on *"developing a common institutional, social and cultural setting"* (MALMBERG and MASKELL, 2006, p. 9). Further, they emphasise that *"['neighborhood effects' will], ceteris paribus, [...] always, in an almost automatic way, tend to create a degree of overlap between spatial and other forms of proximity"* (MALMBERG and MASKELL, 2006, p. 11).

It follows that the fundamental issue separating the positions of BOSCHMA (2005) and MALMBERG and MASKELL (2006) concerning the role of geography is the relative importance of two mechanisms: *the substitution mechanism*, where non-spatial forms of proximity substitute for geographical proximity, and *the overlap mechanism*, where geographical proximity facilitates non-spatial forms of proximity. As mentioned in the introduction, the aim of this paper is to empirically assess the

importance of these two mechanisms for the formation of partnerships. Before proceeding to the analysis, however, it is worth discussing the expectations on the relations between geography and each of the other four proximity dimensions, based on previous studies.

4.1. Geographical and social proximity

The literature suggests that geographical proximity facilitates social proximity. Spatial co-location increases the likelihood of accidental encounters and reduces communication costs. In this way, geographical proximity can stimulate the emergence of trustful relations through repeated exchanges, the possibility of observation and a loss of anonymity (GÖSSLING, 2004; MORGAN, 2004; STORPER and VENABLES, 2004). In fact, geographical proximity may be a necessity for some collaborations, as it allows the creation of specific social relations and social proximity (ZELLER, 2004). Thus, a strong overlap effect between geographical and social proximity is expected.

Other studies emphasise that social proximity may also substitute for geographical proximity. Collaboration over distance is significantly more likely between individuals with established social relationships (HANSEN and LØVÅS, 2004). Such effects have been identified at both the regional (AGRAWAL et al., 2006) and the firm level (CORREDOIRA and ROSENKOPF, 2010). Practices that strengthen social relations between distanciated partners therefore facilitate collaboration (FROST and ZHOU, 2005). Consequently, in addition to an overlap effect, a substitution effect between social and geographical proximity is also expected.

4.2. Geographical and institutional proximity

It is argued that a main effect of geographical proximity on collaborations is through the impact of localised institutions (GERTLER, 2010). Conventions tied to specific territories function as coordination principles in interactions between economic agents (STORPER, 1997). Institutions underpin collective learning processes and geographical proximity plays an important role in creation and modification of institutions (KIRAT and LUNG, 1999). Therefore, an overlap between geographical and institutional proximity is expected.

Regarding the substitution effect, some ambiguity is found in the literature. On the one hand, KIRAT and LUNG (1999) argue that, while institutions are created by actors in geographical proximity, they can subsequently be disseminated, opening up for collaboration over distance. Such collaborations are facilitated by similarities in management culture, attitudes to hierarchy and opinions towards the functioning of partnerships (BRADSHAW, 2001; SAXENIAN and HSU, 2001). On the other hand, GERTLER (2003) suggests that the institutional environment acts as the most important barrier to long-distance collaborations. A case study by LAM (1997) demonstrates how low institutional proximity, resulting from low geographical proximity, cannot be overcome despite long periods of temporary proximity, i.e. face-to-face meetings and visits of a non-permanent duration (TORRE and RALLETT, 2005). This suggests that institutional proximity in particular depends on frequent and enduring interactions, thus, geographical proximity is important to maintain institutional proximity over time. Therefore, while it may be possible to substitute institutional for geographical proximity, less of a substitution effect is expected than with social proximity.

4.3. Geographical and organisational proximity

Theoretically, there might be some overlap effect between geographical and organisational proximity: firms may for instance primarily set up subsidiaries close to the headquarters to ease monitoring. However, the importance of this effect can be questioned, and it can furthermore be argued that firms often set up subsidiaries in distant locations to access local markets and knowledge (JOHANSON and WIEDERSHEIM-PAUL, 1975; MOOSLECHNER, 2007). Thus, no overlap effect between geographical and organisational proximity is expected.

Concerning the substitution effect, it is argued that knowledge flows more easily between individuals within the same firm (KOGUT and ZANDER, 1992). Thus, large corporations can establish internal networks which facilitate collaboration between distant partners (ZELLER, 2004). Consequently, even though organisational proximity does not ensure flawless collaboration (BLANC and SIERRA, 1999; STENSHEIM, 2012), straightforward communication channels and low uncertainty facilitate long-

distance intra-organisational collaborations (BRADSHAW, 2001). A substitution effect between organisational and geographical proximity is therefore expected.

4.4. Geographical and cognitive proximity

The overlap effect between geographical and cognitive proximity is shaped by the degree of territorial specialisation. It can be assumed that people working within the same industry generally have greater cognitive proximity than people working in different industries, as the needed capabilities and expertises vary significantly between industries. Thus, members of firm clusters often have similar capabilities, as long as the degree of internal specialisation in the cluster is not too high (MASKELL, 2001). Therefore, in the case of industries depending on localisation economies, defined as agglomeration effects internal to the individual industry, an overlap effect is expected.

With regard to the substitution effect, work on epistemic communities highlight the possibility of distanciated collaboration within such communities (AMIN and COHENDET, 2004; KNORR CETINA, 1999). While temporary geographical proximity in the form of occasional meetings is necessary, the cognitive proximity between members resulting from shared expertise within a specific field allows collaboration between community members separated by a great distance in their everyday life (GERTLER, 2008; MOODYSSON, 2008). Thus, it is expected that cognitive proximity may substitute for geographical proximity.

5. Data and method

The data for the analysis has been collected through structured interviews with representatives from Danish cleantech firms. While other studies of proximity and innovation are based on data on scientific co-publications (PONDS et al., 2007) or EU-funded projects (BALLAND, 2012), the interview approach allows an operationalisation of the proximity categories which is closer to BOSCHMA's (2005) framework (see BROEKEL and BOSCHMA, 2012 for a second study of proximities based on interviews). For instance, contrary to studies that measure institutional proximity according to

whether actors belong to the same or different organisational form (industry, academia or government), the method applied in this paper takes the informal side of institutions into consideration. Structured interviews have been chosen over questionnaires as much of the gathered information is considered confidential by the interview persons, and several interviewees noted that they were transmitting information which they would not have provided without the trust created by a conversation. Naturally, interviews also allow a greater depth in the data collection process, which the qualitative part of the analysis draws on.

A further reason for the need to build a dataset is the focus on the cleantech sector. This paper follows the definition of the cleantech sector proposed by FORA (2009)[i] as firms that develop and sell products, solutions or technologies that improve the environment – either directly or through a more efficient utilisation of resources. Consequently, firms from all industries can be part of the cleantech sector, but the majority is made up of firms from industries such as renewable energy and green construction. The lack of a cleantech-code in industrial classifications makes it necessary to demarcate the sector in different ways. Used methods are snowball analysis, search for keywords on internet databases and creation of tailor-made software for scanning of firm web pages (FORA, 2009; THE PEW CHARITABLE TRUSTS, 2009). These methods are all labour intensive, resulting in a lack of academic attention to the cleantech sector as a whole in economic geography.[ii] Accordingly, there is a need for studies focusing on the opportunities and challenges posed by the emerging green economy (ECONOMIC GEOGRAPHY, 2011). Further, the cleantech industry is an interesting case for studying relations between proximity dimensions, as it is characterised by a great heterogeneity, encompassing both high- and low-tech firms. Often, partnerships bring together cleantech firms specialised in sustainable technologies with producers of traditional, non-environmentally conscious products.

The population of Danish cleantech firms in this analysis is constructed with the snowball method, supplemented with firm lists from industrial organisations and export promotion agencies, resulting

in a total number of 279 cleantech firms which undertake product development. 50 interviews have been carried out with firm representatives (CEOs in small firms; CTOs, CSOs and Development Managers in larger firms) in the period September 2010 to January 2011, equal to a sample size of 17.9 %. The sample reflects the composition of the Danish cleantech industry in terms of firm size (see table 1) and geographical distribution. Following recent interest in projects, as a flexible and adaptive organisational practice (GRABHER, 2002b), the main theme of the interviews was the firms' most recently completed product development projects with external partners. Importantly, projects which took the form of knowledge transfer from one partner to another are not included in the analysis, thus, all collaborations are characterised by a collective learning effort.[iii] On average, each interviewee described collaborations with between three and four collaborators and the total dataset consists of 180 inter-firm linkages.

Table 1. Employment size distribution

	Interviewed firms (50)	Population (279)
<10 employees	40%	36%
10-49 employees	30%	27%
50-199 employees	16%	19%
>199 employees	14%	18%
Total	100%	100%

The key data used in this paper describes the distance between the partners according to the proximity dimensions (mean and standard deviations are reported in appendix A). As the interest of the paper is the role of the *substitution* and *overlap* mechanisms in the relations between the geographical and the four non-spatial dimensions, the geographical dimension is the central independent variable, while the remaining four proximity dimensions are the dependent variables.

Taking the location of the respondent's firm as the outset, the *geographical dimension* variable describes the location of the partner separating between the same Danish region, other parts of Denmark, neighbouring countries (Germany, Norway and Sweden), other European countries, and outside of Europe. Thus, rather than measuring geographical distance in a linear way, this paper

follows SONN and STORPER's (2008) suggestion to treat geography as a discontinuous variable, as there are certain threshold values after which the costs of interacting increase significantly, e.g. when an overnight stay is required.

As a proxy for the *social dimension*, the interviewees were asked to describe how contact between the partners was initiated (did the partners have 'personal relations' or 'acquaintances' across the project team, a 'mutual acquaintance' outside of the project team or had there been 'no previous contact' prior to the project start). In this way, social proximity is not assessed at the aggregate level as by, e.g. BALLAND (2012) who measure whether organisations have partners in common, but at the level of the people collaborating in the project. This follows GRABHER's (2002a) emphasis on inter-personal relations rather than inter-firm relations in the analysis of project collaborations.

In order to measure the *institutional dimension*, the interviewees were requested to indicate the similarity of the partner's firm culture in terms of norms and habits compared to their own (on a five-point Likert scale ranging from 'very large differences' to 'no differences'). This operationalisation allows the respondents to take the various aspects of the institutional dimension, ranging from formal to informal institutions, into consideration. While alternative measures have considered if partners are located in the same country (BALLAND et al., 2013), or are of the same organisational type (PONDS et al., 2007), this open way of assessing institutional proximity allows the interview persons to take different aspects such as dissimilar types of incentive structures and distinctive national cultures into account.

The variable for the *organisational dimension* takes a binary form depending on whether the partners are part of the same legal entity or not. While the majority of studies in the proximity literature uses this operationalisation of the organisational dimension, BROEKEL and BOSCHMA (2012) measure whether collaborators are of the same organisational type, however, this would create a significant overlap with the institutional dimension in this study.

Finally, as a proxy for the *cognitive dimension*, respondents were asked to compare the educational backgrounds of their own and the partner's key employees in the project, separating between 'same educational backgrounds (e.g. engineers with common specialisation)', 'related educational backgrounds (e.g. engineers with different specialisation)' and 'different educational backgrounds'. While cognitive frameworks depend on more than educational background, this is still a crucial aspect of the cognitive capabilities of actors, in particular in professional activities. Furthermore, as with the social dimension, this measure considers the relations between the people where the actual collaboration takes place, rather than relations at the aggregate level such as firm specialisation in product segments (used by e.g. BALLAND, 2012).

Additionally, a number of control variables are included in the study. *Location* separates between firms from urban and peripheral parts[iv] of Denmark, as the development of Danish industries has followed different trajectories, depending on their location since the mid-1990s (HANSEN et al., 2013). *Regional human capital* measures the share of employees with at least bachelor degree at the regional level, as there are considerable differences between the human capital levels at the regional scale in Denmark. *Knowledge base* reflects the critical knowledge base of the firm (see ASHEIM (2007) for a detailed description of the typology of knowledge bases), as this affects the impact of the different proximity dimensions and the geographical reach of knowledge linkages (MARTIN and MOODYSSON, 2013; MATTES, 2012).[v] Firms combine the analytic and synthetic knowledge bases, but in most cases they draw primarily on one of them. In this analysis, firms are assigned a principal knowledge base on the basis of the interviews and the importance the interviewees gave to, e.g. science- and engineering-based innovations as well as the degree of formal education and university training of employees. *Start-up* expresses if a firm is a start-up, here defined as having been established in the period 2005-2010, as the age of firms has been found to influence the formation of knowledge linkages (COHEN et al., 2002). *Firm size* is included as multiple studies find that this variable influences collaboration patterns (e.g. ROSENKOPF et al., 2001). It is measured as the number of employees expressed in logarithms. *Subsector* separates between five sub-sectors of the

cleantech industry: renewable energy, smart grid, green construction, waste and water, and transportation. *Technological complexity* accounts for the expected technological complexity of the project prior to initiation, as estimated by the respondents on a five-point Likert scale ranging from 'very large' to 'very limited'. Finally, *Firm* controls for potential effects of having more than one observation for each firm.

As the dependent variables are ordinal, the quantitative analysis is carried out using the polytomous logit universal model (PLUM) in IBM SPSS Statistics version 19. Models are estimated for each of the four dependent variables in order to assess the importance of *the substitution mechanism* (evident when geographically distant collaborations are found to be close in non-spatial terms) and *the overlap mechanism* (evident when geographically proximate collaborations are found to be close in non-spatial terms) in the relation between geography and the other four proximity dimensions. Odds ratios are calculated on the basis of parameter estimates and reported with significance levels and 95 % confidence intervals. A pseudo R^2 measure (Nagelkerke R^2) is reported along with the -2 log-likelihood for the intercept and the final model.

6. Analysis and results

Initially, an overview of the data is provided (table 2). The focal independent variable, *Geographical dimension*, highlights that collaboration processes are subject to strong distance decay effects. The propensity to collaborate with domestic partners is high, while very few partners are found outside of Europe. Concerning the *Social dimension*, a majority of partners have personal relations or are acquaintances, but still nearly one out of four collaborations is between partners that do not know each other and have no mutual acquaintances. On the *Institutional dimension*, it is worth noticing that more than 40 % of the collaborations are characterised by either large or very large cultural differences. Thus, relatively few collaborations are between partners with similar firm cultures. Regarding the *Organisational dimension*, most collaborations are between different organisations, and intra-organisational collaborations are relatively rare. Finally, concerning the *Cognitive*

dimension, most of the collaborators have related educational backgrounds, while it is less common to collaborate with partners that have the same educational background.

Table 2. Main variables

	Number	Percentage
Geographical dimension		
0. Outside Europe	10	5.6
1. Rest of Europe	25	13.9
2. Neighbouring country	22	12.2
3. Other Danish region	76	42.2
4. Same region	47	26.1
Social dimension		
0. No previous contact	42	23.3
1. Mutual acquaintance	26	14.4
2. Acquaintance	50	27.8
3. Personal relation	62	34.4
Institutional dimension		
0. Very large differences	14	7.8
1. Large differences	61	33.9
2. Some differences	48	26.7
3. Minor differences	39	21.7
4. No difference	18	10.0
Organisational dimension		
0. Different group	167	92.8
1. Same group	13	7.2
Cognitive dimension		
0. Different educational backgrounds	66	36.7
1. Related educational backgrounds	72	40.0
2. Same educational backgrounds	42	23.3

Appendix table A1 gives the descriptive statistics and correlation coefficients of the variables. The coefficients show that geography is significantly correlated to the other four dimensions: geographical proximity is associated with closer social relations to partners and smaller cultural differences. However, geographical proximity is negatively correlated with organisational and cognitive proximity.

Table 3. Regression results

High odds ratios indicate high possibilities of being distant in terms of the dependent variable

Proximity dimension	Social dimension		Institutional dimension		Organisational dimension		Cognitive dimension	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Geographical dimension (reference = same region)								
Other Danish region	0.85	0.42-1.72	1.19	0.76-1.84	1.68	0.54-5.23	0.82	0.32-2.12
Neighbouring country	2.63*	1.02-6.77	2.46**	1.34-4.52	0.68	0.18-2.55	0.16**	0.04-0.64
Rest of Europe	1.72	0.68-4.37	1.62	0.90-2.90	0.86	0.26-2.89	0.20*	0.06-0.70
Outside Europe	0.13†	0.01-1.19	6.52***	2.75-15.49	0.20*	0.04-0.93	0.29	0.05-1.59
Location (reference = urban)								
Peripheral	4.37**	1.66-11.50	1.35	0.79-2.32	5.50*	1.14-26.38	3.13†	0.89-11.06
Knowledge base (reference = synthetic)								
Analytical	0.63	0.30-1.33	0.51**	0.32-0.81	2.80	0.68-11.53	0.40†	0.15-1.05
Start-up (reference = start-up)								
No start-up	0.68	0.31-1.48	1.77*	1.06-2.95	2.47	0.44-13.88	5.67**	1.69-19.08
Log regional human capital	14.16*	1.77-113.59	2.19	0.70-6.82	23.42*	1.52-360.26	5.46	0.42-71.37
Log firm size	0.54*	0.32-0.91	0.81	0.60-1.10	0.35†	0.12-1.03	0.23***	0.10-0.52
Subsector					***		**	
Technological complexity	†		*				*	
Firm			*				**	
Nagelkerke R^2	0.262		0.266		0.515		0.421	
-2 log-likelihood intercept	440.817		478.976		87.010		359.004	
-2 log-likelihood final	390.361		426.557		44.944		275.429	

† p<0,10; * p<0,05; ** p<0,01; *** p<0,001

6.1. PLUM

Turning to the regression analyses, table 3 contains the odds ratios[vi] of the four models that allow us to assess the importance of the substitution and overlap mechanisms in collaborations between actors.

The first model, *Social dimension*, shows that there is no significant difference between intra-regional partnerships and collaborations across the Danish regions. However, collaborations with partners in neighbouring countries are characterised by high social distance compared to domestic partnerships, confirming the expectation of an overlap effect between geographical and social proximity.

Further, concerning the international partnerships, the odds ratios show that social relations are less close to firms in neighbouring countries compared to those over longer distances: the odds ratio of partnerships outside of Europe indicates that these partnerships are characterised by a high social proximity. Thus, the results confirm the expectation of a substitution effect between social and geographical proximity: while firms have relatively few hesitations about partnering with unknown actors in the neighbouring countries, long-distance collaborations are significantly more likely between partners with established social relationships.

The second model, *Institutional dimension*, suggests that collaborations within the Danish regions are more likely to be between culturally similar partners than partnerships with actors in the neighbouring countries. Collaborations with partners outside of Europe have by far the greatest chance of being characterised by large differences in firm culture. This confirms the importance of the overlap mechanism between geographical and institutional proximity: territorially bound conventions function as coordination principles in collaborations between actors.

Conversely, as the significant odds ratios show that cultural differences increase with distance, the results do not fulfil the expectation of a substitution effect. This questions the suggestion by KIRAT and LUNG (1999) that the diffusion of institutions can facilitate collaboration over distance. The

present analysis of actual collaborations finds little evidence of this effect, thus, the results lend support to the proposal by GERTLER (2003) that the main challenge of long-distance collaborations is to overcome institutional differences.

The third model, *Organisational dimension*, highlights that collaborations with partners outside Europe have the greatest chance of being within the same group, while no significant differences can be found between intra-regional partnerships and the remaining three spatial categories. Thus, as expected, there is no overlap effect between geographical and organisational proximity, but a strong substitution effect. While there are no significant differences between the short-distance categories, internal networks can facilitate collaboration between distant partners, and organisational proximity appears to be indispensable for partnerships reaching beyond the boundaries of Europe.

The fourth model, *Cognitive dimension*, shows that intra-regional partnerships are relatively unlikely to be between partners with similar educational backgrounds. In fact, intra-regional collaborations are the least likely to have a high cognitive proximity. Thus, there is no overlap effect between geographical and cognitive proximity, indicating that the Danish cleantech sector is not depending on localisation economies in the form of specialised networks.[vii]

On the contrary, the results indicate that shared capabilities and expertise facilitate long-distance collaborations: the international collaborations are far more likely to have a high degree of cognitive proximity than the intra-regional collaborations. This confirms that cognitive proximity may substitute for geographical proximity.

Concerning the control variables, it is worth noticing that high levels of regional human capital are strongly associated with collaborations characterised by low social and organisational proximity. Further, the partners of large firms are generally proximate along the different non-spatial dimensions. Finally, firms with a synthetic knowledge base are more likely to engage in partnerships with significant cultural differences. This shows how the ability to collaborate despite different norms

and habits is important for firms that innovate through the ability to synthesise different forms of knowledge.

Summing up, table 4 gives an overview of the importance of the substitution and overlap mechanisms. While the results generally correspond to our expectations, the apparent inability to substitute institutional proximity for geographical proximity remains an interesting point. The analysis of this issue is elaborated in the following section based on qualitative data from the interviews, which give us a more detailed understanding of the relationship between the geographical and institutional dimensions.

Table 4. Overview – substitution and overlap

	Substitute for geographical proximity	Overlap with geographical proximity
Social proximity	Yes	Yes
Institutional proximity	No	Yes
Organisational proximity	Yes	No
Cognitive proximity	Yes	No

6.2. The geographical and institutional dimensions

Returning to the argument of KIRAT and LUNG (1999), they propose that institutions created by actors in geographical proximity can subsequently be disseminated, opening up for collaboration over distance. The channels of dissemination are of particular importance here, and KIRAT and LUNG (1999) emphasise the links between producers and suppliers as a key relation in this process. Further, they consider that these relations are characterised by learning between the diffusing and adopting actors. In this way, the diffusion of institutions is considered to be depending on social interaction. This raises the question of the role of social proximity in facilitating institutional proximity in geographically distanciated relations.

The interviews show that the relatively few collaborations with both a high institutional proximity and a low geographical proximity are in fact most often between partners with a high social proximity. The partnership between a Danish green construction firm and a Swiss research institution

exemplifies this point. The two partners have collaborated over a number of years on different projects. According to the Technical Manager, the relation was initially complicated due to cultural differences and language barriers. Therefore, a targeted effort was made to build strong social relations, particularly between the project managers, through frequent and regular telephone and physical meetings. As a result, while there are still considerable cultural differences between the two organisations in general, then there are now hardly any differences in the way the team members are working. The relation between a Danish engineering firm within renewable energy and an Irish energy provider has similar characteristics: Again, a number of previous collaborations preceded this project, and personal relations were established. The Chairman of the Board of the Danish firm describes the cultural similarities in the following way: *"We have very similar cultures... [T]hey are very large, they build fossil fuelled power plants in [lists several countries], but the engineering group we work with has with time become interested in our niche technology and our way of working."* Finally, social proximity can even promote institutional proximity between partners located on different continents. A Danish specialised supplier to the wind turbine industry explains how trust following from a close social relation to an Asian producer of wind turbines has allowed the persons involved in the collaboration to go beyond a formal relationship. This has resulted in a better understanding of the collaborators business culture.

These cases highlight the impact of social proximity in dissemination of institutions, and it is important to note the order of events: the initial development of social proximity allows the construction of institutional proximity – not vice versa. In both examples, the diffusion and adoption of institutions are facilitated by close social relations between the partners. According to the interview person in the second example, the roles of diffuser (the engineering firm) and adopter (the energy provider) are clearly identifiable in this case; however, this distinction is often less clear. This is illustrated by a relationship between two collaborators from the wind turbine industry in respectively Denmark and the United States which goes more than a decade back. According to the Danish Research Engineer, the Americans have traditionally had a greater focus on compliance to

rules and anticipation of new regulatory demands. He explains: *"That's probably where the greatest difference was… Of course we have to care about the safety factors.*[viii] *We were used to take the safety factors from the certification authority without considering the final needs of the customer – and of other potential customers... [T]hen we had to deal with those problems later."* On the other hand, he also notes how the greater creativity and flexibility on the Danish side has influenced the work habits of the Americans. Thus, in this case, the increasing institutional proximity is not a result of a diffusion of firm culture from one partner to the other, but rather a process where the actors take on the roles of diffuser and adopter simultaneously. Still, in this case, initial social proximity is a prerequisite for the institutional alignment to take place.

Finally, it is worth emphasising that the high institutional proximity in these cases of long-distance collaboration is highly valuable for the outcomes of the projects. This is evident in the previous case, and it is also obvious in the collaboration between a Danish supplier from the wind turbine industry and a British research group. The Danish CEO explains that *"[the work cultures] are extremely similar... [I]f someone has an idea, then it's being tested. Things go very fast and it is highly experimental... I can't imagine a better collaboration."* Similarly, the institutional proximity in a relation between two firms from the biomass industry located in Denmark and Holland is highly valued by the Danish CEO. He describes that *"it makes it much easier to deal with challenges that are outside their comfort zone"* in comparison to another collaborator with lower institutional proximity, located in a neighbouring country. Naturally, the ability to collaborate quickly and smoothly is often considered an advantage of partnerships between collaborators located in geographical proximity, thus, the present examples indicate that institutional proximity may substitute for geographical proximity.

Summing up, the findings of the PLUM analysis are modified on the basis of the qualitative analysis. There is indeed a substitution effect between institutional and geographical proximity, however, social proximity is an essential intermediate in this relation. Further, the instances where institutional

proximity substitutes for geographical proximity are few and far between, thus, the substitution mechanism is of relatively low importance in the relation between the geographical and institutional dimensions.

7. Conclusion

This paper sets out to analyse empirically the relationship between geographical and non-spatial forms of proximity in collaborative innovation processes. The theoretical outset is taken in the different conceptions of the importance of geographical proximity for such relations. It is argued that the differences rest on divergent opinions concerning the relative importance of two mechanisms: *the substitution mechanism*, where non-spatial forms of proximity substitute for geographical proximity, and *the overlap mechanism*, where geographical proximity facilitates non-spatial forms of proximity.

Based on an empirical analysis of the characteristics of collaborative innovation projects in the Danish cleantech industry, support is generally found for the expectations extracted from previous studies dealing with geographical and non-spatial proximity dimensions. The findings indicate that the relation between the geographical and social dimensions is influenced by both the substitution and overlap mechanisms. Concerning the organisational and cognitive dimensions, no evidence is found for the overlap effect, but only for the substitution effect. Conversely, the regression analysis highlights that while the geographical and institutional dimensions overlap, there is no indication of a substitution effect in this relation. However, as discussed at length in the qualitative part of the analysis, the interviews indicate that it is indeed possible to substitute institutional proximity for geographical proximity, but these instances are relatively rare, presumably partly because social proximity is an essential intermediate in these cases. Thus, while it exists, the substitution mechanism is of relatively low importance in the relation between the geographical and institutional dimensions, supporting the suggestion of GERTLER (2003) that the main challenge of long-distance collaborations is to overcome institutional differences.

A point worth stressing is the lack of significant differences in the regression analyses between intra-regional partnerships and collaborations across the Danish regions. This suggests that the overlap effect applies to collaborations with Danish actors in general, rather than specifically with actors from the same region. This inability to measure significant differences may be explained by the relatively small size of the Danish regions and the highly specialised character of most of the innovation processes, which limits the number of potential partners within the country.

In addition to the empirical findings of the paper, it also has a conceptual contribution to future research on the geography of collaborations, by explicitly distinguishing between the overlap and substitution mechanism. Often, empirical analyses within this field fail to recognise the potential simultaneous importance of these two effects. Some studies, with a point of departure in territorial analysis, tend to overemphasise the underpinning effect of geography on other forms of proximity, while other traditions, with an aspatial foundation, fail to acknowledge the distinct influence of geographical context on partnership formation. Thus, it is argued in this paper that it is necessary and important to approach research questions within this topic with an awareness of the existence of both mechanisms.

Finally, acknowledging the limitations of this paper, several challenges for future research remain. There is a need for analysing the importance of overlap and substitution mechanisms across different types of industries. While the cleantech sector is very heterogeneous in terms of, e.g. the research intensity of the firms, it is also characterised by frequent collaborations that bring together actors with knowledge on sustainable practices and traditional production techniques. Studies with a focus on inter-industrial differences are required to examine the potential impact of this characteristic. Moreover, this paper has analysed one type of interaction, namely collaborative innovation projects. A second strand of research worth pursuing is to extend this analysis to more informal types of collaborations (see e.g. TRIPPL et al., 2009), which might show different relations between geographical and non-spatial proximity dimensions. Thirdly, studies with a longitudinal approach may

analyse if there is a dynamic relation between the substitution and overlap effects, i.e. whether for instance the overlap effect is initially important in facilitating other forms of proximity which may subsequently allow for a substitution effect.[ix] Finally, an important future empirical challenge within the proximity literature, in general, is to analyse and assess the relations between different measures for the same proximity dimensions to better understand the influence that different operationalisations of the dimensions may have for the reached conclusions.

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Appendix A

Table A1. Correlation coefficients between the variables

	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Social dimension	1.73	1.17									
2. Institutional dimension	1.92	1.13	0.15*								
3. Organisational dimension	0.07	0.26	0.33***	-0.15*							
4. Cognitive dimension	0.87	0.76	0.28***	0.04	0,13†						
5. Geographical dimension	2.69	1.16	0.15*	0.16*	-0,16*	-0,15*					
6. Location firm	0.53	0.50	0.14†	-0.03	-0,04	0,05	0.12				
7. Knowledge base firm	0.61	0.49	-0.10	-0.19**	0,18*	-0,15*	-0.12	-0.31***			
8. Start-up	0.27	0.45	-0.19**	0.12	-0,07	0,06	0.02	-0.23**	-0.10		
9. Log regional human capital	-0,97	0.20	-0.05	-0.02	-0,19*	-0,03	0,10	0,59***	-0,33***	0.02	
10. Log firm size	1.07	0.73	0.10	-0.09	0,26**	0,05	-0.15*	-0.19**	0.19*	-0.30***	-0,20**

† p<0.10; * p<0.05; ** p<0.01; *** p<0.001

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[i] FORA is the Danish Enterprise and Construction Authority's division for research and analysis.
[ii] Numerous studies have dealt with subsections of the cleantech industry from wind energy (GARUD and KARNØE, 2003) to fuel cells (MADSEN and ANDERSEN, 2010), but few studies analyse the cleantech industry as a whole.
[iii] The interview methodology made it possible to only include projects where all actors were actively involved, contrary to relations where pieces of information or knowledge are transmitted from one actor to another (see also TRIPPL et al., 2009).
[iv] The urban part is defined as the Greater Copenhagen Area and the three largest cities outside the capital, Aarhus, Odense and Aalborg.
[v] Since the symbolic knowledge base is of limited importance for the majority of the firms in the cleantech industry it is left out of this analysis.
[vi] The odds ratio indicates the ratio of the odds of a particular answer compared to a reference group (with an odds ratio of 1), which in this paper is ”partners located within the same region” for the main independent variable, the geographical dimension. Thus, in this paper, high odds ratios indicate high possibilities of being distant in terms of the dependent variable.
[vii] It may rely on other forms of localised benefits, e.g. access to a shared labour pool.
[viii] The safety factor is the relation between the strength of the component and the load on the component.
[ix] The author is indebted to one of the referees for pointing out this area of future research.