On the role and interrelationship of spatial, social and cognitive proximity: personal knowledge relationships of R&D workers in the Cambridge Information Technology Cluster

Dr Franz Huber

The Open University Business School, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom

E-mail: f.huber@gatesscholar.org

Final draft version. Forthcoming in *Regional Studies*.
DOI: 10.1080/00343404.2011.569539

ABSTRACT

Although the importance of proximity has been highlighted, it remains an open question which types and levels of proximity are critical for knowledge networks. This paper addresses this issue by examining the role of spatial, social and cognitive proximity of personal knowledge relationships in the Cambridge IT Cluster. It is shown that distinguishing between sub-dimensions of cognitive proximity can clarify the 'proximity paradox'. Moreover, the results highlight that local relationships enable access to cognitively more diverse knowledge than non-local ones. Finally, the paper provides empirical evidence of a compensation mechanism: distance in one dimension is compensated by proximity in at least one other dimension. However, similarity in terms of technical language cannot be easily substituted.

Proximity, cognitive proximity, social proximity, social networks, knowledge networks

1. INTRODUCTION

The role of spatial proximity for knowledge networks and innovation has been widely emphasised in economic geography and regional studies. However, increasingly the literature has been critical of the focus on spatial proximity in two respects: first, non-local knowledge networks have been claimed and shown to be important. And second, recent literature has argued for a wider perspective to explore the significance of alternative types of proximity such as social or cognitive proximity (e.g. BOSCHMA, 2005; LAGENDIJK and LORENTZEN, 2007; LAGENDIJK and OINAS, 2005; TORRE and RALLET, 2005).

However, there is a lack of empirical investigations on these issues. First, it remains an unresolved question which types and levels of proximity are critical for knowledge networks. Whilst proximity of some sort is generally regarded as being essential, it has been asserted that too much proximity can be detrimental for innovation (BOSCHMA and FRENKEN (2010) called this the 'proximity paradox'). However, there is a dearth of empirical investigations to examine these arguments in detail. Second, there is a lack of understanding on how the different types of proximity are related to one another. In particular, whether distance in one dimension (for instance, cognitive distance) can be compensated by proximity in another dimension (for instance, spatial proximity) remains an open question.

This paper aims to address these gaps by examining spatial, social and cognitive proximity of personal knowledge relationships in the Cambridge Information Technology (IT) Cluster. The analysis is based on a survey and interviews with 105 R&D workers in 46 companies and focuses on personal relationships which were regarded as most important for gaining work-related knowledge in the past year. The objectives of the paper are to show (i) which types and levels of proximity are critical for personal knowledge relationships, (ii) how the R&D workers deal with the

‘proximity paradox’, and (iii) how spatial, social and cognitive proximity are interrelated.

The results suggest that social proximity in terms of feelings of personal obligations and emotional closeness is very high, whereas knowing each other in terms of private life is significantly less important. Furthermore, this paper argues that distinguishing between sub-dimensions of cognitive proximity is fruitful: whereas high levels of similarity in terms of technical language is essential, a certain degree of dissimilarity in terms of know-how, know-what and the way of thinking can be beneficial for the R&D workers. This seems to be a viable strategy of the individuals to deal with the ‘proximity paradox’. Moreover, this paper highlights the effects of spatial proximity: contrary to widespread views, local contacts are not socially more proximate than non-local ones, and, interestingly, local contacts are cognitively more diverse than non-local ones. The latter suggests that an important benefit of spatial proximity is that it enables knowledge flows with cognitively different actors. Finally, this paper provides empirical evidence of a compensation mechanism: for knowledge relationships that are regarded as important, distance in one dimension (spatial, social or cognitive) is compensated by proximity in at least one other dimension. However, there is one dimension of proximity that can hardly be substituted: similarity in terms of technical language is very high for nearly all relationships and can be regarded as essential.

This paper is organised as follows. Section 2 critically discusses the literature on different types of proximity and knowledge networks, highlights open questions and links it to the research questions of this paper. Section 3 presents the research design and the methods used in this study. Afterwards, section 4 analyses the data to examine which types of proximity are important for personal knowledge relationships. By differentiating various dimensions of cognitive proximity, the ‘proximity paradox’ is critically reflected upon. Finally, section 5 explores the interrelationships between

spatial, social and cognitive proximity and investigates several hypotheses. In particular, the question of whether distances in one type can be compensated by proximity in other types will be examined. Section 6 concludes.

2. TYPES OF PROXIMITY AND KNOWLEDGE NETWORKS

The question of how spatial proximity impacts on learning and knowledge networks has been one of the most prominent topics in economic geography and regional studies. It has been widely assumed that co-located actors benefit from local knowledge flows enabled by regular face-to-face contacts and tacit knowledge transfers (GERTLER, 2003). In particular, an extensive body of *territorial innovation models* (MOULAERT and SEKIA, 2003) has been developed, which has highlighted the geographical dimension of the knowledge-economy. This literature has focused on the significance of spatial proximity and territorially defined cultural, social and institutional assets that lead to regional knowledge interactions, which shape regional competitiveness (see e.g. BRESCHI and LISSONI, 2001; CAMAGNI, 1991; CAPELLO and FAGGIAN, 2005; COOKE et al., 2005; HAUSER et al., 2007; HUBER, 2009; LAWSON and LORENZ, 1999; MALMBERG and MASKELL, 2002; STORPER, 1997).

Despite the voluminous literature on the role of space/spatial proximity for knowledge networks, the role of geographical distance in knowledge transmissions is still unclear (DÖRING and SCHNELLENBACH, 2006, 388-9). Recent literature has rightly questioned the academic focus on the local level and called for a wider spatial focus integrating extra-local networks and structures (e.g. AMIN and COHENDET, 2004; BATHELT et al., 2004; BUNNELL and COE, 2001; GIULIANI et al., 2005; MACKINNON et al., 2002; YEUNG, 2005). However, the debate about the spatial dimension of knowledge relations "[…] has been handicapped by a high degree of

abstraction coupled with a scarcity of fine-grained empirical analysis on which to support sound conceptual advancement" (GERTLER, 2004, 4). The generally accepted view is that first, local *and* global relations are important for learning and knowledge networks, and second 'proximity matters'. However, there is a lack of empirical work to substantiate these claims. Rather than stating over and over again that we have to consider local *and* global links, more empirical studies are needed to investigate which specific types of knowledge activity actually operate in which spatiality (MALECKI and OINAS, 1999, 2).

Furthermore, rather than simply stating 'proximity matters', there is a great need to substantiate how and why which type of proximity matters. As Gertler points out, a careful analysis

> "[…] would examine the strength and type of local relationships, but set this within a comparative analysis of the strength and type of non-local relationships as well. It would also inquire into the reasons why proximity matters, what particular aspects of distance are responsible for attenuating economic interaction […]" (GERTLER, 2004, 15).

Importantly, recent literature suggests that the discussion about proximity needs to be extended beyond *spatial proximity* to investigate the role of other forms of proximity such as organisational, social, cultural or cognitive proximity (BOSCHMA, 2005; GERTLER, 2004; KNOBEN and OERLEMANS, 2006; LAGENDIJK and LORENTZEN, 2007; LAGENDIJK and OINAS, 2005; TORRE and RALLET, 2005; ZELLER, 2004). The starting point of such an endeavour is the idea that successful knowledge flows and interactions require a certain form of proximity as a pre-condition to be successful (BOSCHMA, 2005). Generally, proximity is a relational concept referring to the degree of closeness of actors. But it remains an empirical question which type and which degree of proximity is vital for knowledge networks.

In addition to spatial proximity, this paper focuses on the critical concepts of social and cognitive proximity.[1]

Social proximity refers to the issue of the strength of interpersonal links, in particular to what extent people know each other and interact in private or professional contexts. The traditional argument is that strong, trust-based ties facilitate knowledge interaction (GERTLER, 2004, 156). However, the existing literature on social proximity (sometimes also referred to as relational proximity or personal proximity)[2] is dominated by a rather loose usage of this idea (see e.g. AMIN and COHENDET, 2004). To clarify and operationalise the notion of social proximity, more specific concepts and measures of strengths of relationships are needed.

Cognitive proximity, broadly understood, denominates similarity in the way people perceive, interpret, understand and evaluate the world (WUYTS et al., 2005). Here the argument is that cognitive proximity is required to understand each other and to communicate with each other effectively. Also here empirical research that clarifies which quality of cognitive proximity is important for valuable knowledge flows is needed. Empirical studies which use crude proxies such as technological profiles derived from patent data (e.g. NOOTEBOOM et al., 2007) seem limited in this respect. In particular, the existing empirical studies do not differentiate between sub-dimensions of cognitive proximity, which seems important to grasp the complexity of the broad concept of cognitive proximity.

However, the emphasis on the importance of proximity involves an intricate problem: whilst on the one hand there is the argument that proximity is vital, on the other hand there is an increasing awareness that resource heterogeneity and access to diverse knowledge is beneficial for innovation (NOOTEBOOM, 2000). This leads to a *'proximity paradox'*[3] (BOSCHMA and FRENKEN, 2010): too much proximity can be in fact problematic because there is the risk of not learning any new knowledge, but too much distance is also problematic because the actors might not understand

each other any more when they are too different (NOOTEBOOM et al., 2007). More empirical research is needed to clarify this dilemma. The empirical results by BROEKEL and BOSCHMA (2011) show that cognitive proximity reduces firms' innovative performance but geographical and social proximity does not reduce it. This suggests that the proximity paradox is particularly relevant for cognitive proximity. Also analytically one can argue that cognitive proximity is the type of proximity that is most closely linked to knowledge and innovation as also discussed by NOOTEBOOM (2000). Therefore, the discussion of the proximity paradox in this paper will focus on cognitive proximity.

Furthermore, there is the important question of *how the various types of proximity are related to one another*. Whilst this issue has been discussed as being critical, there is a dearth of empirical exploration of it as indicated by BOSCHMA (2005, 72). Traditionally it tends to be explicitly or implicitly assumed in the literature that spatial proximity also leads to other forms of proximity. However, new theoretical views have emerged. In particular, it has been argued that other forms of proximity may be a substitute for spatial proximity (BOSCHMA, 2005). MENZEL (2008) made a more general claim that distance in one type can be bridged by proximity in other types. However, these are all conjectures which need to be empirically tested.

To conclude, there is an empirical void of studies that explore which types and aspects of proximity actually matter for knowledge interactions and how these types of proximity are interrelated.

This paper aims to address these open questions by examining the following research questions:

(a) Which type and which level of proximity is critical for personal knowledge relationships that are regarded as important?

(b) How do the R&D workers deal with the proximity paradox?

(c) What is the relationship between spatial, social and cognitive proximity?

3. RESEARCH DESIGN AND METHODS

Since the question of proximity and knowledge networks has been mainly discussed in the context of knowledge-intensive industries, this study focuses on R&D workers in one of the most prominent high-tech clusters in Europe, the Cambridge Information Technology (IT) Cluster. IT is the largest sector in terms of the number of innovation-based businesses in the Cambridge region (LIBRARYHOUSE, 2004) and therefore constitutes the dominant sector of the 'Cambridge phenomenon'. Within the Cambridge IT Cluster, innovation-based firms (excluding purely service-based firms) of the dominant sub-sectors hardware and software were randomly selected. In each firm individual R&D workers were chosen as the embedded unit of analysis.

The list of the firms in the target population was constructed by using the data of the 'Library House', a research and (now dissolved) data service company, merged with the data available from the research and consultancy company 'Cambridge Investment Research Ltd.'. The target population (sampling frame) at firm-level consists of 220 firms in the Greater Cambridge Region, 156 in software and 68 in hardware. The sample is constituted by first taking a random sample of 100 firms (70 in software, 30 in hardware).[4] Within those the firms were asked to select R&D workers in various job positions from junior engineers, technology managers to managing directors (if s/he is actively involved in research or development).

It has to be emphasized that getting access to the firm was incredibly difficult. After 11 months (January-November 2008), data from 105 individuals in 46 firms were collected, which represents a response rate of 46% of the firms in the sample. In terms of the *sub-sector* 58 individuals in 25 firms are in software, and 47 individuals in 21 firms in hardware. The average *firm size* in terms of the number of employees (full-time head count) is 35 for the Cambridge sites (median 20) and 81 for all locations world-wide (median 30). On average there are 17 R&D workers in each firm

site in Cambridge (median 9). In terms of the *job position* in the sample there are 14 Managing Directors, 33 Directors of Research/Development or Chief Technology Officers, 34 senior engineers/developers, 16 mid-level engineers/developers, 6 junior engineers/developers and 2 in other positions.

Taking a *multi-method approach*, face-to-face meetings with the R&D workers were arranged to go through structured questionnaires and conducted semi-structured interviews. Overall, the meetings lasted from 20 to 120 minutes (mean 45 minutes).

The paper is based on an ego-network analysis of the following kind: the interviewees were asked to nominate the most important personal contact outside of their firm for gaining work-related knowledge in the past year.[5] Subsequently, data about this contact and the relationship were collected and analysed. The data discussed in this paper were collected using a self-administered questionnaire. Interestingly, 18 interviewees could not think of any contact;[6] thus, the analysis is based on 87 nominated relationships. It needs to be highlighted that the 'importance' of personal contacts is assessed subjectively by the respondents, but no 'objective' performance indicator is used.[7]

4. WHICH TYPE OF PROXIMITY IS CRITICAL FOR PERSONAL KNOWLEDGE RELATIONSHIPS?

Let us first examine the role of social proximity (section 4.1) and cognitive proximity as well as the proximity paradox (4.2).

4.1. Social proximity

Social proximity "is defined here in terms of socially embedded relations between agents at the micro-level" (BOSCHMA, 2005, 66). This idea seems equivalent to the

popular concept of the strength of ties (GRANOVETTER, 1973). However, although tie strength seems to be a clear, intuitive concept, its conceptualisation and operationalisation usually remains fuzzy and unspecific. The widespread dichotomy between strong and weak ties often seems too simplistic. A more careful reflection on the pre-theoretic idea of tie strength reveals that it is more complicated and cannot be easily captured by one indicator (see e.g. MARSDEN and CAMPBELL, 1984). For the purposes in this study, the following dimensions of social proximity are examined:

(a) *Knowing each other*: the degree to which one knows each other in terms of the private life on the basis of previous interaction.

(b) *Emotional closeness*: how emotionally close one feels to the contact in terms of caring about his/her personal well-being.

(c) Feeling of *personal obligation*: how much one feels personally obliged to help the contact if he/she asks for help but it would require a significant amount of time.

These three dimensions of social proximity were measured by asking the respondents to rate on a Likert scale from 1 (= very proximate) to 7 (= very distant). As an overall indicator, the social proximity index represents the mean of the three dimensions.

Overall, 53.1% of the nominated personal knowledge contacts are purely private (in the sense of not involving any official professional relationship)[8], whereas 33.6% are professional relationships (clients, collaborators or suppliers) and 13.3% a mixture of private and professional relationships. This confirms the results by TRIPPL et al. (2009) that informal channels of knowledge transfer are very important in software. On which levels of social proximity are these relationships based?

The empirical results show that the social proximity in terms of the level of *emotional closeness* (caring about personal well-being) is very high with 77.9%

stating closeness (rating 1-3), the mean being 2.55 and the median 2 (see Table 1 for all details)[9].

Table 1. Indicators of social proximity (N = 86). Likert scale from 1 (= very proximate) to 7 (= very distant)

	How much do you care about personal well-being?	**Ho well do you know each other personally in terms of your private life?**	**How much obliged to help if three hours of work?**	**Social proximity index**
Mean	2.55	3.58	1.94	2.69
Median	2	3	2	2.33
Mode	1	1	1	1
Std. Deviation	1.72	2.13	1.20	1.43
Rating 1-3	77.9%	55.8%	89.5%	69.8%

The highest level of social proximity is in terms of a feeling of *personal obligation* to help: 89.5% rated the question with 1-3, which explicitly means obliged to help, the mean is 1.94 and the median 2. This underscores the importance of reciprocity.[10] Yet, a few interviewees highlighted that they would even help people whom they do not know so well, if it concerns a technical issue they are interested in.

Knowing each other in terms of their *private life* is also rated rather highly, but the proximity is statistically significantly lower (paired samples t-tests, p = 0.000) than the other indicators: the mean is 3.58, the median 3, and only 55.8% rated 1-3. This suggests that, many personal knowledge relationships that are regarded as important are of a more work-centred, strategic nature.

Overall, we can conclude that the social proximity of the nominated most important knowledge relationships is high in various dimensions. In particular, the feeling of personal obligation and emotional closeness is very high, whereas knowing each other in terms of private life is lower.

4.2. Cognitive proximity

The notion of *cognitive proximity* can be broadly understood as similarity in the way actors perceive, interpret, understand and evaluate the world (WUYTS et al.,

2005). The 'proximity paradox' (BOSCHMA and FRENKEN, 2010) seems most relevant in the context of cognitive proximity as also the study of BROEKEL and BOSCHMA (2011) suggests. However, this paper aims to show that to clarify this paradox, rather than speaking about cognitive proximity in general terms, it is fruitful to analyse the importance of various sub-dimensions. In particular, the analysis differentiates between (i) proximity regarding a common technical language, (ii) similarity of the way of thinking about the technology or product, (iii) similarity in terms of work-related technical details/facts (know-what), and (iv) similarity in terms of work-related know-how (how to do things or to solve a problem). Again, a 7-point Likert scale was used.[11]

The results illustrate that similarity in terms of technical language is the most critical form of cognitive proximity (mean: 2.28, median: 2; 92% rated 1-3). The cognitive proximity in other dimensions is not as high (means: 3.31, 3.90 and 3.52; medians: 3, 4 and 3 – see Table 2); their levels of proximity are statistically significantly lower (paired samples t-tests, p = 0.000).

Table 2. Various dimensions of cognitive proximity (N = 87)

	To what extent share common technical language	**How similar in terms of way of thinking about technology or product**	**How similar in terms of work-related technical details**	**How similar in terms of work-related know-how**
Mean	2.28	3.31	3.90	3.52
Median	2	3	4	3
Mode	2	2	3	3
Std. Deviation	1.29	1.37	1.60	1.40
Rating 1-3	92.0%	64.7%	46.0%	56.3%

Only four respondents rated very high levels (answers 6 or 7) of dissimilarity in terms of technical language and two rated undecided (4). Why is this lack of cognitive proximity not problematic for those six relationships? The interview material suggests that, first, for several respondents very strong personal bonds (very high levels of social proximity) can overcome language differences (see section 5.2.1 for a further examination of this issue). For example, in one case a Managing Director receives

confidential advice on how to manage people from his wife who does not know anything about the technology. Related to this, second, for a few people a certain degree of dissimilarity does not matter because they are discussing business knowledge and not technological knowledge.[12] Third, one respondent developed a technical 'half-jargon' to be able to communicate with his friend.

However, let us reiterate that these are exceptions. 92% of the nominated most important knowledge contacts are similar (rating 1-3) in terms of the technical language.

Whilst most of the respondents highlighted that a common language is critical, many emphasised that a certain degree of dissimilarity in *other* dimensions of cognitive proximity is useful. The plausible reason for this put forward by many interviewees is that otherwise they would not be able to learn anything new from them:

> "If we were completely similar in terms of work-related details, there wouldn't be much point talking to him, I suppose, haha" (Senior developer, large software company).

That is, although very rarely the contacts are very dissimilar and the means of the ratings are still pointing towards similarity rather than dissimilarity (see Table 2), a certain degree of dissimilarity is considered to be useful for acquiring new knowledge. One could argue that the optimal situation to deal with the proximity paradox would be to have a highly similar technical language but to be different in other dimensions of proximity. A similar language would ensure smooth communication, and yet one would be able to learn a lot of new things. Why is this not the case? As we can see later in Table 4, the way of thinking, know-what and know-why are moderately correlated with similarity regarding technical language (0.30-0.38). That is, it seems that, in order to ensure similarity in terms of technical language and therefore smooth communication, the other dimensions also have to

show a certain level of proximity and cannot be fully different. A plausible reason for this seems to be that the processes of learning a technical language usually go hand in hand with learning theories about the world, know-how or know-what (in particular, in contexts of professional socialisation at universities or official work-contexts). Indeed, the vast majority of the respondents have initially formed their relationships with the knowledge contacts in either work-related contexts or in taking the same course at university.

To sum it up, the results suggest that a differentiation of sub-dimensions of cognitive proximity can clarify an important aspect of the innovation paradox: high levels of similarity in terms of technical language seems vital for effective communication, but in order to learn new things other forms of cognitive proximity (the way of thinking, know how and know what) benefit from not being too high. However, given that these dimensions are correlated with similarity concerning technical language, it seems that these dimensions cannot show high levels of difference because this would undermine similarity in terms of language (which tends to be an essential requirement for knowledge contacts that are regarded as important).

5. INTERRELATIONSHIPS BETWEEN TYPES OF PROXIMITY: BRIDGING DISTANCE THROUGH PROXIMITY?

Let us now turn to the question of how the types of proximity (including spatial proximity) are related to each other. Let us discuss the theoretical expectations which can be derived from the literature.

It has been argued, for instance by BOSCHMA (2005), that spatial proximity is likely to be effective through influencing other types of proximity. First, the traditional view of territorial innovation models is that spatial proximity is highly

interrelated with social proximity in the sense that the former facilitates the latter. The territorial interpretations of the 'embeddedness' of economic activity reinforced this view (for a critical review see HESS, 2004). That is, explicitly or implicitly, it tends to be assumed that spatial proximity quasi-automatically leads to social proximity, at least in the sense that co-located individuals benefit from strong, trust-based ties (GRABHER, 2006, 165). According to this view, the possibility of frequent face-to-face interaction in contexts of co-location increases the chances that stronger social bonds develop as highlighted by several territorial innovation models (CAMAGNI, 1991; CAPELLO and FAGGIAN, 2005; e.g. LAWSON and LORENZ, 1999; STORPER, 1997).

Hypothesis 1: Important local knowledge contacts tend to be more socially proximate than non-local ones.

Furthermore, it is usually assumed that, based on a shared regional culture, frequent face-to-face interaction and collective learning, it is likely that co-located actors also share a common knowledge base (LAWSON and LORENZ, 1999). Based on common interpretative schemes, local actors can understand and benefit from local 'buzz' or 'noise' (BATHELT et al., 2004, 39; GRABHER, 2002, 254). And, as argued by Boschma (2004, 2005), due to local practices of imitation and selection, competences and routines converge within regions rather than between regions.

Hypothesis 2: Important local knowledge contacts tend to be more cognitively proximate than non-local ones.

However, although hypothesis 2 above seems to be the prevalent view in the literature, also an alternative argument of an inverse relationship between spatial proximity and cognitive proximity could be put forward: as hypothesised by FREEL (2003), the more cognitively distant the knowledge, the more important is spatial proximity (see also MENZEL, 2008). This is, one could maintain, because the

possibility of regular face-to-face contacts among co-located actors facilitates the more complex communication processes in the case of cognitive distance. In other words, co-location represents an advantage to access diverse knowledge.

Hypothesis 2A: Important local knowledge contacts tend to be more cognitively diverse than non-local ones.

Also in terms of the interrelationship between social and cognitive proximity one can develop theoretical expectations. As we have seen above in section 4.2, a few interviews suggest that large cognitive distances go hand in hand with strong social relationships (such as being a spouse or a close friend). One could generalise this and argue that cognitively distant relations require a higher level of social proximity in order to function.

Hypothesis 3: Cognitively distant knowledge contacts tend to be more socially proximate than cognitively close ones.

Similarly, conversely, one could argue that the governance of socially distant contacts is based on being cognitively close.[13] If people are socially distant, one could maintain, what makes the relationship work is a higher level of cognitive proximity.

Hypothesis 4: Socially distant knowledge contacts tend to be more cognitively proximate than socially close ones.

Furthermore, one can explore a more general theory of the interrelationship between the various types of proximity: one could argue that distance in one type of proximity can be compensated by proximity in at least one other type. In other words, at least one type of proximity needs to be present for important knowledge relationships but the other types can be distant. That is, social or cognitive proximity can offset spatial distance, spatial or cognitive proximity can compensate social distance, and spatial or social proximity can compensate cognitive distance.

The few discussions on the issue of compensation that exist in the literature have focused on spatial proximity. As, in particular, BOSCHMA (2005) has argued, other forms of proximity may be a substitute for spatial proximity. The most general thoughts on the topic of compensation have been recently put forward by MENZEL (2008) who hypothesised that bridging distance in one dimension requires proximity in other dimensions. But no empirical studies exist which explore this thesis and which specific dimensions matter for bridging distance.

Compensation hypothesis: for important knowledge relationships, distance in one dimension is compensated by proximity in at least one other dimension.

In this context, the following question emerges: *is there a type of proximity which is a requirement for knowledge relationships and cannot easily be substituted by another form of proximity?*

Let us investigate these issues in the following subsections.

5.1. The relationship between spatial proximity and social/cognitive proximity

Let us first contrast local versus non-local[14] knowledge contacts in terms of social and cognitive proximity to investigate hypotheses 1 and 2.

Table 3. Social and cognitive proximity for local versus non-local contacts (N = 86)

	Local?	Mean
How much do you care about personal well-being?	Local Non-local	2.3 2.7
Ho well do you know each other personally in terms of your private life?	Local Non-local	3.1 3.8
How much obliged to help if three hours of work?	Local Non-local	1.9 2.0
Social proximity index	Local Non-local	2.5 2.8
To what extent share a common technical language?	Local Non-local	2.9 2.0*
How similar in terms of way of thinking?	Local Non-local	3.5 3.2
How similar in terms of work-related technical details?	Local Non-local	4.4 3.7*
How similar in terms of work-related know-how?	Local Non-local	3.8 3.4
Cognitive proximity index	Local Non-local	3.6 3.0*

* Statistically significant difference at the 5% level (independent samples t-test)

We can see that, whilst local contacts show a slightly higher level of social proximity, these differences are not statistically significant (at the 5% level, independent samples t-test). Hence, we cannot confirm hypothesis 1; important local knowledge contacts are not more socially proximate than non-local ones.

However, there is a statistically significant difference in terms of cognitive proximity: non-local contacts show a higher level of proximity in terms of a common technical language (nearly one point on the Likert-scale), in terms of work-related technical details and in terms of the overall cognitive proximity index. In the light of this, hypothesis 2 is rejected but hypothesis 2A is confirmed: important local knowledge contacts tend to be more cognitively diverse than non-local ones.

5.2. How is social and cognitive distance compensated?

Let us now turn to the interrelationship between social and cognitive proximity. As a first starting point, let us first look at the correlation between social and cognitive indicators. As Table 4 shows, the sub-indicators of social proximity are significantly positively correlated with one another; the same applies to the sub-indicators of cognitive proximity. However, there is no significant correlation between indicators of social proximity and cognitive proximity. The only exception is a significant weakly positive correlation (5%-level) of knowing each other in terms of private life and cognitive proximity (0.214) as well as similarity in terms of know-how (0.222).

Overall, this suggests that there is no negative correlation between social proximity and cognitive proximity. That is, there is no strong version of a compensation mechanism going in the sense of the higher social distance the higher cognitive proximity, and conversely.

Table 4. Correlation between all indicators of social and cognitive proximity (Spearman's rho correlation coefficients, N = 86)

	How much do you care about personal well-being	How well do you know each other personally in terms of your private life	How much obliged to help if three hours of work	Tie strength: average of 3 variables	To what extent share common technical language	How similar in terms of way of thinking about technology or product	How similar in terms of work-related technical details	How similar in terms of work-related know-how
How much do you care about personal well-being								
How well do you know each other personally in terms of your private life	.719**							
How much obliged to help if three hours of work	.407**	.441**						
Tie strength: average of 3 variables	.855**	.942**	.619**					
To what extent share common technical language	.022	.046	.179	.071				
How similar in terms of way of thinking about technology or product	-.005	.085	-.060	.030	.306**			
How similar in terms of work-related technical details	.043	.141	-.032	.091	.296**	.332**		
How similar in terms of work-related know-how	.058	.222*	.011	.155	.384**	.280**	.487**	
CognitiveProximity: average of 4 variables	.080	.214*	.056	.161	.636**	.645**	.779**	.742**

** = Correlation is significant at the 1% level (2-tailed)
* = Correlation is significant at the 5% level (2-tailed)

Let us now explore the cases of social distance and cognitive distance in more detail to investigate our hypotheses.

5.2.1. Does social or spatial proximity compensate cognitive distance?

Let us first contrast the instances of cognitively distant and cognitively close contacts in terms of technical language.[15] The results show that there is no statistically significant difference in terms of indicators of social proximity (see Table 5). That is, hypothesis 3 is rejected, since cognitively distant knowledge contacts tend not to be more socially proximate than cognitively close ones.

Table 5. Distance versus proximity in terms of technical language (distant (rating > 4): N = 5, not distant (rating < 5): N = 81).

	Distant in terms of language?	**Mean**
How much do you care about personal well-being?	Distant Not distant	2.4 2.6
Ho well do you know each other personally in terms of your private life?	Distant Not distant	3.4 3.6
How much obliged to help if three hours of work?	Distant Not distant	2.4 1.9
Social proximity index	Distant Not distant	2.7 2.7
Percentage of contacts located within the Greater Cambridge region	Distant Not distant	80% 32%*

* Statistically significant difference at the 5% level (independent samples t-test)

For the other indicators of cognitive distance, there is also no statistically significant difference, the only exception being distance regarding work-related know-how: cognitively distant contacts in terms of know-how are more distant in terms of knowing each other privately than cognitively close ones. This also impacts on the overall social proximity index (see Table 6).

That is, contrary to hypothesis 3, also here one can observe that cognitively distant contacts are not socially closer than cognitively close ones.

Table 6. Distance versus proximity in terms of know-how (distant (rating > 4): N = 19, not distant (rating < 5): N = 67).

	Distant in terms of language?	Mean
How much do you care about personal well-being?	Distant Not distant	3.1 2.4
Ho well do you know each other personally in terms of your private life?	Distant Not distant	4.7 3.3*
How much obliged to help if three hours of work?	Distant Not distant	2.1 1.9
Social proximity index	Distant Not distant	3.3 2.5*
Percentage of contacts located within the Greater Cambridge region	Distant Not distant	47% 31%

* Statistically significant difference at the 5% level (independent samples t-test)

In terms of the spatial dimension, one can see a tendency that cognitively distant contacts tend to be more localised. Whilst there is no statistically significant difference regarding proximity in terms of know-how[16], relationships with a different technical language tend to be co-localised: 80% of those five who have a different language are located within the Greater Cambridge region. That is, this suggests that cognitive distance (in particular regarding technical language) is compensated by spatial proximity.

5.2.2. Does cognitive or spatial proximity compensate social distance?

Let us now contrast the cases of social distance with social proximity using the indicator of knowing each other in terms of private life.[17] As shown in Table 7, cognitive proximity tends to be lower for socially distant relationships. In particular, similarity in terms of work-related technical details, similarity in terms of work-related know-how and the overall cognitive proximity index exhibit statistically significant differences: socially close ('not distant') contacts are also cognitively closer.

Table 7. Social distance versus proximity (distant (rating > 4): N = 30, not distant (rating < 5): N = 56).

	Distant private life?	Mean
To what extent share a common technical language?	Distant Not distant	2.6 2.1
How similar in terms of way of thinking?	Distant Not distant	3.7 3.1
How similar in terms of work-related technical details?	Distant Not distant	4.4 3.6*
How similar in terms of work-related know-how?	Distant Not distant	4.0 3.3*
Cognitive proximity index	Distant Not distant	3.7 3.0*
Percentage of contacts located within the Greater Cambridge region	Distant Not distant	30% 38%

* Statistically significant difference at the 5% level (independent samples t-test)

Hence, hypothesis 4 is rejected: socially distant knowledge contacts tend not to be more cognitively proximate than socially close ones.

What about the spatial dimension? There is no statistically significant difference between socially distant versus not distant ties; thus, in this sense, social distance is not compensated by spatial proximity.

5.3. Are there critical types of proximity that cannot easily be substituted?

Are there any indicators which are consistently rated very highly regardless of the level of spatial, social or cognitive proximity?

First, the contacts tend to feel very obliged to help and care very much about the personal well-being regardless of the level of spatial and cognitive proximity (see Table 3, Table 5 and Table 6). That is, in this weaker sense, one could say that spatial and cognitive distance is ‘compensated’ by these forms of social proximity. However, as noted earlier, caring about the personal well-being seems not very relationship-specific (but, as gleaned from the interviews, often reflects the tendency to wish every human being on earth all the best); and feeling obliged to help can also be seen as an effect of receiving important knowledge rather than a necessary prerequisite.

Therefore, these two variables rather should not be interpreted as causally active 'ingredients' of a compensation mechanism. In other words, it seems that they cannot be regarded as a necessary requirement for bridging distances in other dimensions. Second, it is important to note that the absolute level of similarity in terms of a common technical language is very high regardless of the levels of spatial and social proximity (see Table 3 and Table 7). This underscores the importance of being close concerning technical language *regardless* of whether you are spatially or socially close or not. Since the interviewees consistently mentioned that a similar language is critical, and since similarity of language is usually not an effect of receiving knowledge, similarity of language can be seen as a prerequisite for important personal knowledge relationships in nearly all cases.

5.4. Conclusion: is there an overall compensation mechanism?

Let us reflect on these results and discuss their theoretical implications in the light of the hypotheses put forward at the beginning of this section.

As we have seen in section 5.1, local versus non-local relationships do not differ in terms of social proximity but differ in terms of cognitive proximity: local contacts tend to be more cognitively distant than non-local ones. These results question widespread views that co-located actors in innovative clusters benefit from a shared regional cognitive culture and social contexts: contrary to hypothesis 1, important local knowledge contacts are not more socially proximate than non-local ones. This underscores that social proximity can be maintained over long distances and does not require permanent spatial proximity. And contrary to hypothesis 2, important local knowledge contacts do not tend to be more cognitively proximate than non-local ones. Instead, the results support the alternative view (hypothesised by only very few authors, in particular by FREEL, 2003; MENZEL, 2008) that co-location makes it

possible to benefit from cognitively diverse contacts (hypothesis 2A).[18] Indeed, the reason for this might be the possibility of regular face-to-face contacts which makes it easier to communicate about knowledge which is cognitively more distant and therefore harder to grasp.[19]

Afterwards, in section 5.2 we have explored the compensation of social and cognitive distance. Contrary to hypothesis 3, we have seen that cognitively distant contacts are not socially closer than non-distant ones (but rather the contrary); and the results show that, contrary to hypothesis 4, socially distant contacts are not cognitively closer than non-distant ones (rather the contrary). That is, social and cognitive proximity are not forming a general compensation mechanism.

Can we confirm our overall compensation hypothesis? Let us look at the overview picture of the interrelationships between spatial, social and cognitive proximity/distance (see Table 8). As we can see, not a single case exists for the combination of spatial, social and cognitive distance. This suggests that a general compensation mechanism operates: for important knowledge relationships, distance in one dimension is compensated by proximity in at least one other dimension. More specifically, more than 50% of the cases are in contexts of spatial distance but social and cognitive proximity. The second most frequent combination is where all three types (spatial, social and cognitive) are proximate (25.9%). Moreover, 11.8% of the relationships are in a context of spatial and social distance but cognitive proximity. And 4.7% are cognitively distant but spatially and socially proximate.

Table 8. Interrelationships between spatial, social and cognitive proximity/distance (N = 85).

		Cognitive proximity (index)	**Cognitive distance (index)**
Spatial proximity	**Social proximity (index)**	25.9%	4.7%
	Social distance (index)	2.4%	1.2%
Spatial distance	**Social proximity (index)**	52.9%	1.2%
	Social distance (index)	11.8%	0

Since the overall indices in the table above are leaning towards social and cognitive proximity (rather than distance), let us also look at the sub-indicators which are most diversely distributed: know-what and knowing each other in terms of private life (Table 9).

Table 9. Interrelationships between spatial proximity, private proximity and proximity in terms of know-what (N = 86).

		Know-what proximity	**Know-what distance**
Spatial proximity	**Private proximity**	15.1%	9.3%
	Private distance	2.3%	8.1%
Spatial distance	**Private proximity**	33.7%	7.0%
	Private distance	12.8%	11.6%

We can observe a similar pattern as in Table 8 but with one exception: distance regarding know-what is more frequent, and it is more often combined with other types of distances. Interestingly, 11.6% of the relationships exhibit spatial, private and know-what distance, which one could interpret as undermining the compensation hypothesis. However, let us recall that similarity in terms of language tends to be very high in all cases, also in the cases of distance regarding know-what.[20] This, again, highlights the importance of differentiating the sub-dimensions of cognitive proximity; difference in know-what, know-how or the way of thinking can be compensated through a similar technical language. Overall, we can confirm the general compensation hypothesis but only with one critical qualification: similarity in terms of technical language is a prerequisite for nearly all knowledge relationships; only very few are able to compensate a different language by other proximities.

6. CONCLUDING REMARKS

This paper aimed to address the dearth of empirical research on the role of proximities for knowledge networks. I investigated which *kinds of proximity* are critical for the most important personal knowledge contacts in the past year.

In terms of *social proximity* we have seen that the most important knowledge relations are based on high levels of feelings of personal obligations and emotional closeness, whereas knowing each other in terms of private life is significantly less proximate.

Furthermore, we have seen that a distinction between *sub-dimensions of cognitive proximity* clarifies the significance of cognitive proximity. This shows that high levels of similarity in terms of sharing a technical language are very important, but a certain degree of dissimilarity in terms of know-how, know-what and the way of thinking can be fruitful for the R&D workers. Importantly, this contributes to understanding the 'proximity paradox' (BOSCHMA and FRENKEN, 2010): the results suggest that knowledge workers deal with this problem by ensuring that they share a common technical language and allowing a certain degree of difference in the other dimensions of cognitive proximity. However, as we have argued, the difference in terms of the way of thinking, know-how and know-what cannot be very high because this would undermine similarity in terms of technical language.

Finally, we investigated the *interrelationships between spatial, social and cognitive proximity*. We have seen that, contrary to widespread views, local contacts are not socially and cognitively closer than non-local contacts. This highlights that social proximity can be maintained over spatial distances, and it does not indicate that there is a homogeneous regional cognitive milieu (see also HUBER, 2011). It is usually argued that non-local connections are critical for sourcing new knowledge because local relationships tend to be cognitively homogeneous, which represents a danger for spatial lock-in processes (BOSCHMA, 2005, 70). However, the empirical results suggest that, in particular if there is a variety of organisations in the local region such as in Cambridge, local contacts are even more likely to act as cognitive 'bridges' to diverse knowledge than non-local ones. This is compatible with the results of the study by BROEKEL and BOSCHMA (2011) which show that

relationships to geographically close actors with different knowledge bases is likely to positively influence firms' innovative performance. The results support the minority view (in particular, expressed by FREEL, 2003; MENZEL, 2008) that the advantage of co-location is to gain access to cognitively different knowledge. A plausible explanation for this is that the possibility of regular face-to-face contacts makes it more likely to understand and benefit from cognitive distance.

Furthermore, we have seen that cognitively distant contacts are not socially closer than non-distant ones, and that socially distant contacts are not cognitively closer than socially close ones. Hence, social proximity/distance and cognitive proximity/distance do not form a mutual compensation mechanism.

However, overall, including spatial proximity, the results confirm a general compensation mechanism for spatial, social and cognitive proximity: for important knowledge relationships, distance in one dimension is compensated by proximity in at least one other dimension. There is no case where the most important knowledge relationships were based on spatial, social and cognitive distance (at least cognitive distance regarding technical language). However, there is a critical qualification to the compensation mechanism: similarity in terms of technical language is consistently very high, and distance in this respect seems very hard to be compensated by other dimensions.

In terms of the generalisability of the findings, one can make the following arguments. One can argue that there are general implications for theorising the role of proximity for personal knowledge relationships in innovative industries. The existing literature on proximity to which this study contributes—cf. section 2 and the hypotheses discussed in section 5—tends to apply to innovative practices in general, regardless of the industry. However, more empirical research in different places and industries is needed to clarify whether the results (e.g. the compensation mechanism

or the critical role of sharing a technical language) really hold in other industries. That is, it remains to be seen whether certain results might be specific to regions or industries with certain characteristics. In particular, it needs to be investigated whether, for instance, the effect that local contacts tend to be cognitively more diverse than non-local ones requires a significant regional agglomeration of (perhaps diverse) high-technology companies.

There are several aspects that have not been investigated by this study. First, this study did not aim to link various forms of proximity to a dependent variable of innovative success; thus, this analysis is not able to calculate 'objective' optimal forms and levels of proximity for successful knowledge sourcing and innovation. Instead, this research looks at the phenomenon from the R&D workers' perspective to understand the characteristics and functioning of important knowledge relationships as perceived by the individuals.

Second, this study is based on data at a specific point in time, and potential evolutionary changes of proximities over time (BOSCHMA, 2005; BOSCHMA and FRENKEN, 2010; TORRE and RALLET, 2005) were not investigated.

Third, this study did not examine other forms of proximity, notably organisational and institutional proximity.

Fourth, this paper focused on inter-organisational relations (through the lens of people) and did not investigate knowledge relationships within companies, which can involve globally distributed firm sites. This would add additional dimensions to the question of proximity.

Regardless of this, this study suggests that *knowledge management and R&D policies* need to be more sensitive towards the importance of a shared language as a precondition for personal knowledge relationships that are regarded as important by R&D workers. Furthermore, the results suggest that that scope of local networking

initiatives might be greatest when aiming to link cognitively diverse actors, perhaps ideally in contexts of related variety (BOSCHMA and IAMMARINO, 2009; FRENKEN et al., 2007).

Acknowledgements

This research has been funded by a Gates Cambridge Scholarship. I would like to thank Bob Bennett, Mia Gray and two anonymous referees for helpful comments on earlier versions of this manuscript.

NOTES

[1] There is some conceptual confusion in the literature on different forms of proximity (KNOBEN and OERLEMANS, 2006). This paper focuses on concepts and definitions which seem to grasp some of the main ideas in the literature. But it does not discuss the notions of organisational, institutional or cultural proximity based on national characteristics. A principal reason for this was that the respondents had only very limited time; therefore the study pragmatically needed to concentrate on some of the major dimensions. Furthermore, a detailed analysis of proximity regarding regional/national characteristics would require an alternative focus of the study in different places (such as in GERTLER, 2004).

[2] Schamp et al. (2004) used the term 'personal proximity' and Coenen et al. (2004) 'relational proximity'.

[3] Strictly speaking, it does not seem to be a 'paradox' but rather a 'dilemma'.

[4] That is, the distribution of hardware versus software firms in the sample is (roughly) the same as in the population. Because of a lack of data on the firms and individuals in the population, the sample cannot be compared with the population in greater detail.

[5] Whilst the sample focuses on firms, the ego-network analysis is open towards nominated non-firm actors and potentially includes, for instance, universities.

[6] Those individuals use alternative sources of knowledge—in particular local colleagues within the firm and the Internet—which is regarded as sufficient to do their job successfully. That is, those R&D workers are not insular nerds but tend to use personal knowledge networks *within* the company extensively. All of them are working in firms with more than four R&D workers.

[7] That is, the term 'important personal knowledge relationships' throughough this paper is based on the subjective assessments of the respondents but not on an 'objective' indicator of importance/performance.

[8] However, the majority initially got to know each other in official work-contexts or at university.

[9] However, the interview material suggests that there is a potential bias towards closeness, since several interviewees seem to have a tendency to wish every human being in the world well-being.

[10] Obligation can also be seen as a result of receiving valuable knowledge.

[11] The questionnaire included statements which aimed to clarify the meaning of these sub-dimensions for the interviewees. However, standardisation of such complex concepts always involve a certain amount of uncertainty in terms of validity.

[12] However, overall in terms of the cognitive proximity ratings there is no statistically significant difference between senior managers and non-managerial technical workers.

[13] Since no correlation between the two variables is hypothesised, hypothesis 4 does not automatically follow from hypothesis 3.

[14] Local means that the personal contact is located within the Greater Cambridge region (but outside of ones own company). Non-local refers to personal contacts located anywhere outside the Greater Cambridge region.

[15] Note that there are only five cases of distance in terms of technical language.

[16] However, also here 47% of those with different know-how are located within the Greater Cambridge region; a reason why there is no statistically significant difference is the low number of distant cases (N = 19).

[17] The overall index of social proximity involves several quite different sub-dimensions. 'Knowing each other in terms of private life' seems to be the sub-indicator which reflects the theoretical arguments cognitive distance goes hand in hand with strong *private* bonds best.

[18] However, recall that although non-local contacts are *relatively* more diverse, the *absolute* ratings still indicate proximity (e.g. cognitive proximity index: 3.6).

[19] Since this study measures the frequency of communication but not of face-to-face communication, this plausible explanation could not be investigated.

[20] This is the reason why in Table 8 there is no case of cognitive distance in combination with spatial and social distance.

REFERENCES

AMIN A. and COHENDET P. (2004) *Architectures of knowledge: firms, capabilities, and communities*. Oxford University Press, Oxford.

BATHELT H., MALMBERG A. and MASKELL P. (2004) Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* 28, 31-56.

BOSCHMA R. A. (2004) Competitiveness of regions from an evolutionary perspective, *Regional Studies* 38, 1001-14.

BOSCHMA R. A. (2005) Proximity and innovation: a critical assessment, *Regional Studies* 39, 61-74.

BOSCHMA R. A. and FRENKEN K. (2010) The spatial evolution of innovation networks. A proximity perspective, in BOSCHMA R. A. and MARTIN R. (Eds) *Handbook of evolutionary economic geography*, pp. 120-35. Edward Elgar, Cheltenham.

BOSCHMA R. A. and IAMMARINO S. (2009) Related Variety, Trade Linkages, and Regional Growth in Italy, *Economic Geography* 85, 289-311.

BRESCHI S. and LISSONI F. (2001) Knowledge spillovers and local innovation systems: a critical survey, *Industrial and Corporate Change* 10, 975-1005.

BROEKEL T. and BOSCHMA R. (2011) Knowledge networks in the Dutch aviation industry: the proximity paradox, *Journal of Economic Geography* in print.

BUNNELL T. G. and COE N. M. (2001) Spaces and scales of innovation, *Progress in Human Geography* 25, 569-89.

CAMAGNI R. (1991) Introduction: from the local 'milieu' to innovation through cooperation networks, in CAMAGNI R. (Ed) *Innovation networks: spatial perspectives*, pp. 1-9. Belhaven-Pinter, London.

CAPELLO R. and FAGGIAN A. (2005) Collective learning and relational capital in local innovation processes, *Regional Studies* 39, 75-87.

COENEN L., MOODYSSON J. and ASHEIM B. T. (2004) Nodes, networks and proximities: on the knowledge dynamics of the Medicon Valley biotech cluster, *European Planning Studies* 12, 1003-18.

COOKE P., CLIFTON N. and OLEAGA M. (2005) Social capital, firm embeddedness and regional development, *Regional Studies* 39, 1065-77.

DÖRING T. and SCHNELLENBACH J. (2006) What do we know about geographical knowledge spillovers and regional growth? A survey of the literature, *Regional Studies* 40, 375-95.

FREEL M. S. (2003) Sectoral patterns of small firm innovation, networking and proximity, *Research Policy* 32, 751-70.

FRENKEN K., VAN OORT F. and VERBURG T. (2007) Related variety, unrelated variety and regional economic growth, *Regional Studies* 41, 685-97.

GERTLER M. S. (2003) Tacit knowledge and the economic geography of context, or the undefinable tacitness of being (there), *Journal of Economic Geography* 3, 75-99.

GERTLER M. S. (2004) *Manufacturing culture: the institutional geography of industrial practice*. Oxford University Press, Oxford.

GIULIANI E., RABELLOTTI R. and VAN DIJK M. P. (2005) *Clusters facing competition: the importance of external linkages*. Ashgate, Aldershot.

GRABHER G. (2002) The project ecology of advertising: tasks, talents and teams, *Regional Studies* 36, 245-62.

GRABHER G. (2006) Trading routes, bypasses, and risky intersections: mapping the travels of 'networks' between economic sociology and economic geography, *Progress in Human Geography* 30, 163-89.

GRANOVETTER M. (1973) The strength of weak ties, *American Journal of Sociology* 78, 1360-80.

HAUSER C., TAPPEINER G. and WALDE J. (2007) The learning region: the impact of social capital and weak ties on innovation, *Regional Studies* 41, 75-88.

HESS M. (2004) 'Spatial' relationships? Towards a reconceptualization of embeddedness, *Progress in Human Geography* 28, 165-86.

HUBER F. (2009) Social capital of economic clusters: towards a network-based conception of social resources, *Tijdschrift Voor Economische En Sociale Geografie* 100, 160-70.

HUBER F. (2011) Do clusters really matter for innovation practices in Information Technology? Questioning the significance of technological knowledge spillovers, *Journal of Economic Geography* forthcoming.

KNOBEN J. and OERLEMANS L. A. G. (2006) Proximity and inter-organizational collaboration: A literature review, *International Journal of Management Reviews* 8, 71-89.

LAGENDIJK A. and LORENTZEN A. (2007) Proximity, knowledge and innovation in peripheral regions. On the intersection between geographical and organizational proximity, *European Planning Studies* 15, 457-66.

LAGENDIJK A. and OINAS P. (2005) Proximity, external relations, and local economic development, in LAGENDIJK A. and OINAS P. (Eds) *Proximity, distance and diversity. Issues on economic interaction and local development*, pp. 3-22. Ashgate, Farnham.

LAWSON C. and LORENZ E. (1999) Collective learning, tacit knowledge and regional innovative capacity, *Regional Studies* 33, 305-17.

LIBRARYHOUSE (2004) Flight to quality. The Cambridge Cluster Report 2004. The Library House, Cambridge.

MACKINNON D., CUMBERS A. and CHAPMAN K. (2002) Learning, innovation and regional development: a critical appraisal of recent debates, *Progress in Human Geography* 26, 293-311.

MALECKI E. and OINAS P. (1999) Making connections: introduction, in MALECKI E. and OINAS P. (Eds) *Making connections. Technological learning and regional economic change*, pp. 1-4. Ashgate, Aldershot.

MALMBERG A. and MASKELL P. (2002) The elusive concept of localization economies: towards a knowledge-based theory of spatial clustering, *Environment and Planning A* 34, 429-49.

MARSDEN P. V. and CAMPBELL K. E. (1984) Measuring tie strength, *Social Forces* 63, 482-501.

MENZEL M.-P. (2008) Dynamic proximities: changing relations by creating and bridging distances, *Papers in Evolutionary Economic Geography Working Paper Series* 08.16.

MOULAERT F. and SEKIA F. (2003) Territorial innovation models: a critical survey, *Regional Studies* 37, 289-302.

NOOTEBOOM B. (2000) *Learning and innovation in organizations and economies*. Oxford University Press, Oxford.

NOOTEBOOM B., VAN HAVERBEKE W., DUYSTERS G., GILSING V. and VAN DEN OORD A. (2007) Optimal cognitive distance and absorptive capacity, *Research Policy* 36, 1016-34.

SCHAMP E. W., RENTMEISTER B. and LO V. (2004) Dimensions of proximity in knowledge-based networks: the cases of investment banking and automobile design, *European Planning Studies* 12, 607-24.

STORPER M. (1997) *The regional world: territorial development in a global economy*. Guilford Press, London.

TORRE A. and RALLET A. (2005) Proximity and localization, *Regional Studies* 39, 47-59.

TRIPPL M., TÖDTLING F. and LENGAUER L. (2009) Knowledge sourcing beyond buzz and pipelines: evidence from the Vienna software cluster, *Economic Geography* 85, 443-62.

WUYTS S., COLOMB M. G., DUTTA S. and NOOTEBOOM B. (2005) Empirical tests of optimal cognitive distance, *Journal of Economic Behaviour & Organization* 58, 277-302.

YEUNG H. W. C. (2005) The firm as social networks: an organisational perspective, *Growth and Change* 36, 307-28.

ZELLER C. (2004) North Atlantic innovative relations of Swiss pharmaceuticals and the proximities with regional biotech arenas, *Economic Geography* 80, 83-111.