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Proximity and Innovation: From Statics to Dynamics

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Abstract

Despite theoretical and empirical advances, the proximity framework has remained essentially static in that the given proximity between actors explains the extent to which they interact in knowledge networks and profit from such interactions. We propose a dynamic extension of the proximity framework of Boschma in which we account for co-evolutionary dynamics between knowledge networking and proximity. For each proximity dimension, we describe how proximities might increase over time as a result of past knowledge ties. We capture these dynamics through the processes of learning (cognitive proximity), integration (organizational proximity), decoupling (social proximity), institutionalization (institutional proximity), and agglomeration (geographical proximity). We end with discussing several avenues for future research on the dynamics of knowledge networking and proximity

Key words: proximity, innovation, knowledge networks, proximity dynamics, geographical proximity

JEL: R10, R11, B52

1. Introduction

It has now been 20 years since the proximity school started to develop a theoretical framework to understand the coordination of economic activities (Bellet et al. 1993; Rallet and Torre 1999; Pecqueur and Zimmermann 2004; Boschma 2005; Torre and Rallet 2005; Lagendijk and Oinas 2005; Knoben and Oerlemans 2006; Bouba-Olga and Grossetti 2008). Notwithstanding the varieties in approaches in proximity research[i], a lot of progress has been made on both theoretical and empirical grounds. This includes the thesis of optimal proximity (Nooteboom 2000; Boschma 2005), the disentanglement of various dimensions of proximity including geographical and non-geographical proximity dimensions (Rallet and Torre 1999; Boschma 2005; Balland 2012), the notion of temporary proximity (Torre and Rallet 2005; Rychen and Zimmermann 2008; Torre 2008) and the proximity paradox (Boschma and Frenken 2010; Broekel and Boschma 2012; Cassi and Plunket 2013). Empirically, we have not only witnessed a surge in empirical studies of knowledge networks (Balland 2012; Broekel and Boschma 2012; Marrocu et al., 2013), but also the application of the proximity framework to domains other than innovation including labour mobility (Boschma et al. 2009), scientific knowledge production (Frenken 2010), land use (Torre and Zuindeau 2009) and mergers and acquisitions activities (Ellwanger and Boschma 2012).

A recent development has been the integration of network theory into the proximity framework. As such, the proximity framework can benefit from ongoing network-theoretical developments taking place in various disciplines including sociology (Rivera et al. 2010), management (Ahuja et al. 2012) and economics (Schweitzer et al. 2009; Jackson 2008). The interest has been to explain the collaboration patterns from the proximity between nodes in what has become known as 'knowledge networks', referring to any kind of relation between economic actors through which knowledge is transmitted or jointly generated. The understanding of such networks is crucial as innovation increasingly depends on access to knowledge resources held by other actors in a globalized and specialized economy.

An advantage of network analysis is that it can be applied to any kind of data indicating a relation between two actors (Ter Wal and Boschma 2009). Accordingly, various kinds of data have been used

to indicate knowledge networks, including knowledge sharing relations (Giuliani and Bell 2005; Boschma and Ter Wal 2007; Giuliani 2007; Morrison 2008; Broekel and Boschma 2012), patent citations (Agrawal et al. 2006; Breschi and Lissoni 2009), joint patents (Cantner and Graf 2006; Hoekman et al. 2009; Cassi and Plunket 2012; Ter Wal 2013b), joint publications (Ponds et al. 2007, 2010; Frenken et al. 2009; Scherngell and Hu 2011; Hardeman et al. 2012) and joint participation in R&D projects (Hagedoorn 2002, Autant-Bernard et al. 2007; Maggioni et al. 2007; Scherngell and Barber 2009; Balland 2012). What is more, network analysis lends itself to the analysis of knowledge relationships at various levels of aggregation. Hitherto, there have been empirical studies at the level of individuals (Agrawal et al. 2006; Breschi and Lissoni 2009; Cassi and Plunket 2012; Huber 2012; Ter Wal 2013b), organizations (Giuliani and Bell 2005; Boschma and Ter Wal 2007; Giuliani 2007; Cantner and Graf 2006; Autant-Bernard et al. 2007; Morrison 2008; Balland 2012; Broekel and Boschma 2012; Hardeman et al. 2012), regions (Ponds et al. 2007; Hoekman et al. 2009; Maggioni et al. 2007; Scherngell and Barber 2009; Scherngell and Hu 2011) and nations (Cassi et al. 2012). But despite the recent empirical advances and theoretical extensions of the proximity framework, we argue that we still lack a fully-fledged dynamic theory of proximity and knowledge networks in the context of innovation.

Without doubt, all these empirical studies have contributed to establish firmly the fact that actors who exchange knowledge also tend to be similar in terms of proximity. But since most of these studies have adopted a static approach, or have analyzed a short period of time, little is known about the emergence of this observed association between proximity and knowledge ties. Do actors choose others based on proximity characteristics, or do they become more proximate because they exchange knowledge? The privileged causal arrow in proximity studies has always been to explain knowledge networking from proximity. Put simply, the basic hypothesis holds that actors that are more proximate will be more prone to collaborate and more effective in doing so, since proximity reduces costs and facilitate the coordination of joint innovative activities. Though we certainly do not wish to depart from the basic hypothesis, we argue in this paper that the uni-causal logic does not always apply, and that the dynamics of proximities is an important issue in itself, which has not been sufficiently addressed.[ii] To fully understand the underlying processes that associates proximity and knowledge ties,

we argue that one should shift from a static to a dynamic perspective. Such a dynamic approach allows to understand whether proximity and networks come together because of a selection process based on organizations' decisions, or whether proximity is a social construct inherited from joint knowledge ties.[iii] We argue that time plays a crucial role in the co-evolution of proximity and knowledge ties, and we follow Padgett and Powell's recent statement that: "*in the short run, actors create relations; in the long run, relations create actor*" (Padgett and Powell 2012, p. 3).

In this contribution, we take stock of the current state of the proximity framework with reference to the analysis of knowledge networks and innovation (section 2). We propose a dynamic extension of the proximity framework where proximity drives knowledge networking, and knowledge networking in turn affects proximity (section 3). We do so for all five proximity dimensions proposed by Boschma (2005), as to extend this framework to include the co-evolutionary dynamics between proximity and knowledge networks in the context of innovation. We conclude with a number of research avenues for a dynamic approach to knowledge networks and proximity (section 4).

2. Proximity and knowledge networks

Probably the most important tenet of the proximity school in economic geography is the thesis that geographical proximity between organizations is neither a sufficient nor a necessary condition for learning and interactive innovation to take place (Boschma 2005). Here, geographical proximity refers to the spatial vicinity of the organizations' physical locations. This tenet was well illustrated by the seminal study by Giuliani and Bell (2005) who showed that firms within the same cluster, all equally characterized by geographical proximity, displayed very different interaction patterns when it comes to knowledge sharing. Some firms had ties with many other firms, while other firms had hardly any ties to other firms. What is more, some firms interacted with firms outside the cluster while others did not. Hence, as Giuliani's (2007) later aptly phrased it, knowledge networks within clusters are *"uneven and selective, not pervasive and collective"*, underlining that geographical co-location is neither sufficient nor necessary for knowledge to be transmitted between actors. This key insight posed two fundamental challenges for economic geography research.

First, it was argued that geographical proximity has no privileged role to play over other drivers of network formation. Rather, in many instances other forms of proximity may turn out to be more important. Accordingly, the quest for a comprehensive list of possible forms of proximity facilitating interactive innovation motivated Boschma's (2005) fivefold classification of geographical, cognitive, social, institutional and organizational proximity. Cognitive proximity refers to the extent to which two actors share the same knowledge base (Nooteboom 1999). Social proximity is generally associated with personal relationships between actors (Uzzi 1996), for example, resulting from past collaboration (Breschi and Lissoni 2009). Institutional proximity is high when actors operate under the same set of norms and incentives, for example, when co-located in the same country (Gertler 1995, Hoekman et al. 2009), or operating in the same social subsystem in particular within academia, industry, or government (Etzkowitz and Leydesdorff 2000; Ponds et al. 2007). Finally, organizational proximity refers to the membership to the same organizational entity, as it is the case, for example, for two subsidiaries of the same parent company (Balland 2012).

Second, the uneven and selective pattern of networking within and outside clusters spurred studies of knowledge networks at a much wider scale comprising multiple locations rather than zooming in on particular locations only. Only by taking into account all short and long distance relations, one can understand the determinants of knowledge networking and the specific role geographical proximity may have. Indeed, in the last five years or so, we have witnessed a surge of studies covering knowledge networks at national levels (Ponds et al. 2007; Breschi and Lissoni 2009; Cassi and Plunket 2012; Broekel and Boschma 2012; Scherngell and Hu 2011; D'Este et al. 2012; Bouba-Olga et al. 2012), European level (Autant-Bernard et al. 2007; Hoekman et al. 2009; Maggioni et al. 2007; Scherngell and Barber 2009; Balland 2012; Marrocu et al. 2011) and even at a global scale (Balland et al. 2013; Cassi et al. 2012; Hardeman et al. 2012).

From empirical studies, we have learnt that controlling for non-geographical forms of proximity, the effect of geographical proximity on actors being linked in a knowledge network tends to decrease (Singh 2005; Breschi and Lissoni 2009). That is, geographical and non-geographical proximities tend to be positively correlated, probably reflecting that geographical proximity facilitates the establishment of other forms of proximity. Yet, while all studies show that geographical proximity

turns out to be less important than previously assumed once non-geographical proximities are included, it is worth noting that those studies that included *all* five forms of proximity still found that geographical proximity positively affects tie formation in knowledge networks (Balland 2012; Hardeman et al. 2012; Balland et al. 2013).

Some studies also looked at whether geographical and non-geographical proximities can be substitutes, that is, whether the lack of one proximity can be compensated by the presence of another form of proximity. For example, some claim that in high-tech clusters, geographical proximity may help to overcome institutional differences between university, industry and government. Such an effect was indeed found in a study by Ponds et al. (2007) comparing regional and national co-publications in science-based industries. Another example of substitutive effects was pointed out by Singh (2005) who found that geographical proximity is especially important in the establishment of interdisciplinary research collaborations, when cognitive proximity between organizations is low. Cassi and Plunket (2012) showed that organizational, social and geographical proximity perform similar roles and therefore act as substitutes in the establishment of co-inventor collaborations. Another example is Saxenian (2006) who described how re-migrating entrepreneurs from Silicon Valley make use of their personal networks created in Silicon Valley to set up high-tech ventures in their home countries trading with Silicon Valley companies.

Quite some studies have investigated whether one can speak of an optimal level of proximity between actors, as too little and too much proximity may both harm performance (Boschma 2005). Some geographers have suggested that a combination of local and non-local linkages might work out best for firms, because it provides access to local buzz and global knowledge (Asheim and Isaksen 2002; Bathelt et al. 2004). Nooteboom (1999) claimed that agents should have optimal cognitive distance to innovate more efficiently. For instance, Nooteboom et al. (2007) found evidence of an inverted U-shaped relationship between technological distance and innovative performance of firms in high-tech alliance networks. Other scholars pointed out that optimal social proximity may be a prerequisite, as embodied, for instance, in a balance between embedded relationships within cliques and strategic 'structural hole' relationships among cliques (Rowley et al. 2000; Fleming et al. 2007). Empirical

studies have indeed found evidence for the existence of such an optimum for various proximity dimensions.

A more recent finding has been that while higher levels of proximity lead to ties being more likely, such high levels of proximity may actually turn out to sub-optimal in terms of the extent to which actors profit from such ties. Boschma and Frenken (2010) refer to differential effects of proximity on tie formation and node performance as the proximity paradox. In an empirical study on knowledge networks in the Dutch aviation industry, Broekel and Boschma (2012) found that the proximity paradox hold for the cognitive and the organizational dimension: while cognitive and organizational proximity were important drivers of knowledge tie formation, these did not yield superior innovative performance for the firms concerned. However, they did not find evidence for this proximity paradox in the case of geographical and social proximity: these increased the likelihood of knowledge networking as well as the innovative performance of firms. Cassi and Plunket (2013) also found some evidence for the proximity paradox when analyzing European co-inventor networks in genomics, as geographical and organizational proximity did increase collaboration and knowledge sharing, but these did not act as a catalyst for innovative performance. In contrast, technical proximity had a positive effect on both knowledge networking and performance.

The proximity framework also lends itself for comparative analysis between territories. Hardeman et al. (2012) compared the extent to which different proximity dimensions played a role in scientific collaboration within Europe and within North-America. Including all five proximity dimensions, they found that geographical, organizational, and social proximity play less of a role in Europe than in North-America, while cognitive and institutional proximity are equally important in both parts of the world. The latter result is remarkable, as it is often argued that the institutional boundaries between university, industry and government are more blurred in North-America than in Europe.

3. From statics to dynamics

What is clear from this short review on progress made within the proximity framework is that proximity is taken as a static concept. The privileged causal arrow in proximity studies has always

been to explain collaboration from proximity, that is, that more proximate actors will be more prone to collaborate and more effective in doing so.

A first step to adopt a dynamic approach is to analyze how the influence of proximity changes over time. Following the contribution of Powell et al. (2005), empirical studies have started to explore the dynamics of network ties in the context of evolving technologies and markets. Ter Wal (2013a) found evidence that geographical proximity became less important as a driver of co-inventor networks in German biotechnologies as time passed by, which he explained by the increasing codification of knowledge in this technological field. At a European level, Scherngell and Lata (2012) also found that knowledge networks funded by the European Commission became less sensitive to geographical proximity over time. But for other types of knowledge networks, the observed trend is different. Hoekman et al. (2010) show that, if anything, geographical proximity plays a *growing* role in the formation of scientific networks, controlled for institutional proximity as defined by national borders.[iv] Similarly, Balland et al. (2013) showed for the video game industry that geographical proximity became a more important driver of tie formation as the industry evolved, which they explained from the increasing technological complexity of new video game development (cf. Sorenson et al. 2006). But even though these works make an important step by looking at whether the type of proximity explaining collaboration changes over time, the static logic in proximity approaches is essentially maintained, as proximity remains the driver of tie formation, and no attention is paid to the question whether the latter affects the former.

In all, theoretical tenets and empirical research designs based on the proximity concepts have remained essentially static, in that the given proximity between actors explains the extent to which actors interact in knowledge networks and profit from such interactions. An understanding of the long-run dynamics of knowledge networks, however, will have to start from the observation that proximities themselves, are subject to change. The evolution of proximities is not only due to external influences, but also, and more importantly, as a result from participation in knowledge networks. The co-evolution of proximity and network ties stems from the fact that interacting actors also tend to become more similar over time. This phenomenon is known as ‘social influence’ in sociology (Friedkin 1998). Social influence expresses the idea that social networks tend to diffuse behavioral norms and shape

individual's characteristics as diverse as happiness (Cacioppo et al. 2009), smoking (Mercken et al. 2010**)**, drinking (Steglich et al. 2010), criminality (Dijkstra et al. 2010) or obesity (Christakis and Fowler 2007).

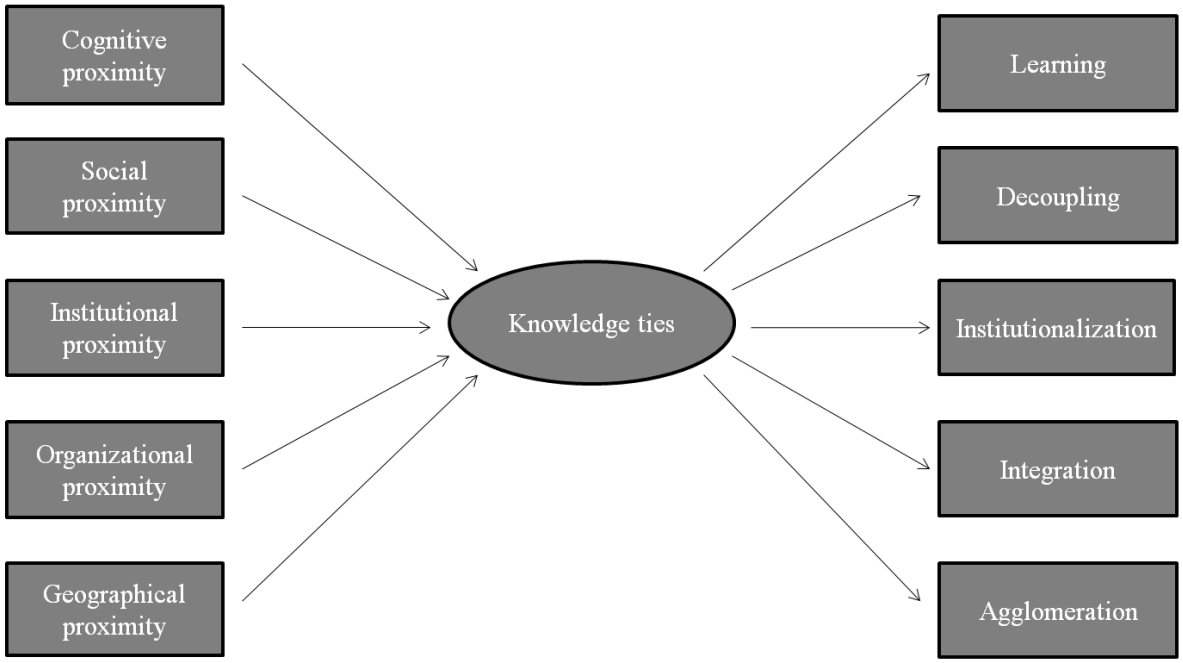
Here, we aim to explore the co-evolutionary dynamic between proximity and knowledge networking at the level of organizations. We go into the processes that lead to changing proximities as a result of inter-organizational knowledge networks, and discuss the likely effects on the costs and benefits of knowledge networking over time. As argued, the key issue for the development of a fully dynamic proximity framework is to avoid taking proximity between actors as fixed but as co-evolving with network activities over time. Indeed, not only relations, but also the attributes of actors, defining their mutual degree of proximity, are likely to change over time.

A key element to understand the complex joint dynamics between proximity and networks is the time frame considered. In their latest book on the emergence of organizations and markets, Padgett and Powell (2012) make an important step into that direction by arguing that "*in the short run, actors create relations; in the long run, relations create actor*" (p. 3). This co-evolutionary idea is the corner stone of Padgett and Powell's theory, when they explain where novelty, organizational forms and network ties come from. We follow their line of reasoning and extend it to the dynamics of proximity dimensions. Paraphrasing them, we argue that *in the short run, proximity creates knowledge networks, in the long run, knowledge networks create proximity*. Indeed, it is important to note that proximity between organizations displays a certain degree of inertia, because attributes evolve less quickly than relations, which are more instable by nature (Gay and Dousset 2005). At the same time, through enduring interactions, node attributes are affected, and hence proximities change over time.

We will elaborate this idea for all of Boschma's (2005) five forms of proximity. That is, we consider the co-evolution of knowledge networking and proximity through the processes of learning (cognitive proximity dynamics), decoupling (social proximity dynamics), institutionalization (institutional proximity dynamics), integration (organizational proximity dynamics) and agglomeration (geographical proximity dynamics). For each dimension, we describe the underlying mechanism of its evolution, that is, how proximities might increase over time as a result of past knowledge interactions. As such, we argue that proximity should be analyzed as a dynamic process by itself, largely

constructed from interactions between actors, as depicted in Figure 1. Thus, our discussion is intended as a first step to a fully-fledged dynamic theory of proximity, knowledge networking and innovation.

Figure 1. Joint dynamics of knowledge networks and proximity



Learning

Arguably, a fundamental requirement for effective knowledge networking to take place is some minimum level of cognitive proximity (Nooteboom 2000, Boschma 2005). Without some of overlap in knowledge bases, meaningful interaction between members of organizations is impossible. For one thing, those involved in collaboration projects need to share some communication codes and similar knowledge bases to effectively communicate as to transfer or create knowledge. But the degree of similarity between knowledge bases of actors is not a static picture. In fact, knowledge bases of actors change continuously over time according to cumulative learning process (Dosi and Nelson 1994). As knowledge is becoming more complex (Sorenson et al. 2006) and innovation networks more ubiquitous, actors increasingly tend to rely on each other to access specific knowledge and use the experience of others (Argote et al. 2000; Hagedoorn 2002). The underlying process of cognitive

proximity dynamics, i.e. learning, is therefore a social process based on the recombination of existing knowledge available inside or outside organizations. The co-evolutionary logic between proximity and collaboration refers more in particular to the non-linear process of interactive learning (Lundvall and Johnson 1994), which will in turn reduce the cognitive distance between partners.

Cognitive proximity is likely to increase both for knowledge transmission where the knowledge base of the receiving partner expands and will come to be more alike of the knowledge base of the transmitting partner and for joint knowledge creation where both partners jointly learn something new leading to more similar knowledge bases. Thus, as they interact, exchange and produce knowledge, actors learn from each other (Argote et al. 2000, Nooteboom 2000). Through interactive learning, actors reduce their cognitive distance more or less voluntarily, eventually changing the configuration of knowledge complementarities between actors (Cowan et al. 2006). Building on the communication model developed by Denzau and North (1994), Menzel (2008) argues that knowledge ties contribute to increase cognitive proximity because of an underlying adjustment process of shared mental models during knowledge exchange. Yet, the tendency of knowledge base convergence can be counteracted by internal R&D to increase diversity and absorptive capacity (Cohen and Levinthal 1990) and by collaborative R&D with multiple partners of different backgrounds.

Decoupling

The degree of social proximity is defined by the degree of personal acquaintance between two actors. Social proximity should be understood as a dynamic process because it refers to the embeddedness of knowledge relationships in an evolving social context (Kossinets and Watts 2006). Analyzing social proximity dynamics goes back to the emergence of interpersonal relations[v] between individuals belonging to different organizations (Granovetter 1985). We follow White (2002), and more in particular Grossetti (2008), in its definition of decoupling to analyze where personal relations come from. The process of decoupling refers to the autonomization of personal relations, i.e. when a « *relation can be decoupled from its original context and ends up existing for itself* » (Grossetti 2008, p. 632).

In the context of knowledge networks, decoupling applies for instance to employees who have been former colleagues working for the same organization in the past and who remain acquainted even if one leaves the organization (Breschi and Lissoni 2009; Buenstorf and Fornahl 2009; Miguelez 2012), or the organization ceases to exist (Broekel and Boschma 2012). Such networks are becoming ubiquitous because of the growing movement of engineers and scientists across different firms or universities throughout their career (Allison and Scott-Long 1987; Almeida and Kogut 1999; Agrawal et al. 2006; Breschi and Lissoni 2009). Yet, personal relations not only stem from a common past employer. Formal R&D collaborations between organizations also create a common social context in which personal relations develop, as social interactions not only occur *within* organizations but also *between* organizations. And if the behavior of both partners is in line with their mutual expectations during the collaboration, the repetition of these innovative ties will glue actors together through friendship and trust (Uzzi 1996; Gulati and Gargiolo 1999).

As for cognitive proximity, the dynamics of social proximity may lead to excess proximity in that personal relations become over-embedded (Uzzi 1997). A tendency for repeated collaboration will enhance social proximity over time. Moreover, the tendency to become acquainted with friend of friends ("triadic closure") will increase social proximity as personal relations become increasingly embedded in a growing network of mutual acquaintances (Granovetter 1973; Ter Wal 2013a). Excess of social proximity may lead actors to underestimate opportunistic behavior. What is more, a high degree of social proximity may block the entry of newcomers, thus affecting the flexibility of social relationships of actors (Uzzi 1997). Hence, to ensure an optimal balance of socially proximate and socially distant relations, the process of decoupling is ideally accompanied with extending the set of looser ties as well (Boschma 2005).

Institutionalization

Knowledge networks do not only influence the evolution of socially embedded relations between agents at the micro-level but also institutional proximity dynamics at the macro-level. Institutional proximity between actors may be subject to change through institutional change at the macro-scale, as formal and informal institutions evolve and change over time (North 1990). Institutional proximity is a

complex concept that comes close to the notion of *habitus* in sociology (Bourdieu 1985), which can be interpreted as a way of conduct, constructed through the socialization process of individuals and organizations. We will refer to the process of institutionalization as the progressive integration of rules and values in actors' behavior. These institutionalization processes are often supported by dense personal relations that we associate with social proximity.

Knowledge networks can play an important role in this socially constructed institutional structure and increase the degree of institutional proximity.[vi] Indeed, it is claimed that an important factor of success in the coordination of innovative activities is that actors continuously change their coordination rules through repeated past collaborations. As such, the degree of institutional proximity always needs to be adjusted to facilitate coordination (Gilly and Torre 2000). Repeated collaborations contribute to the creation of common values, goals, and ethical practices. In some cases, such institutions become even codified in framework contracts that lay down the modalities for collaboration, for example, as these exist between universities and key industrial partners. Similarly, repeated projects between countries can lead them to formalize the institutional conditions for future projects, in an attempt to integrate national systems institutionally by removing barriers and inconsistencies.[vii]

Integration

Knowledge networks can also shape the formation of corporate groups and generate organizational proximity dynamics through the process of integration. The process of integration refers to the progressive re-arrangement of subsidiaries, units, departments, or establishments within an organizational structure. The most visible phenomenon of organizational change occurs at a firm level through the process of mergers and acquisitions (M&A). Diversification through M&A is the process in which two firms are combined into one firm (Siegel and Simmons 2010). Besides the established effect of technological relatedness (Hussinger 2010, Ellwanger and Boschma 2012), past knowledge ties can motivate merger and acquisition decisions and increase the degree of organizational proximity. For instance, R&D collaboration can be considered as a first phase of an long-term integration process, eventually leading to a merger or an acquisition (Hagedoorn and Sadowski 1999).

Similarly, past participation in research projects may underlie organizational restructuring processes in academia as well (Gumport 2000).

The strategic management literature refers to the process of *« encroachment »* when the progressive integration of firms is a voluntary strategy (Haspeslagh and Jemison 1991). This transition process going from a certain type of relation (knowledge networking) to merger or acquisition is not systematic nor automatic[viii], nor it is necessarily decided and calculated in advance. A key element of the relationship between knowledge networks and organizational proximity dynamics is the nature of knowledge involved in the innovation tie. For instance, integration process can be particularly important when it becomes necessary to ensure the control of strategic knowledge diffusion, and to avoid unintended knowledge spillovers to the partner (Brossard and Vicente 2010). In this case, increasing organizational proximity is a way to exert more direct control on the behavior of the partner, but also more indirectly by influencing its further collaboration choices.

Agglomeration

Geographical proximity between organizations changes according to the location decisions of organizations and their subsidiaries. Location and relocation decisions, at least for what concerns knowledge-intensive organizations, are likely to be driven by the opportunities for knowledge networking at the local level (Knoben 2011). For example, multi-national firms locate their R&D labs in the vicinity of relevant research universities (Cantwell and Santangelo 2002), while business service providers tend to look for vicinity to major clients (Weterings 2006).

The choice of location, however, is a complex process involving many uncertainties and high sunk costs (Stam 2007). For this reason, organizations will tend to rely on information and advice from and experiences with past partners at a particular location. What is more, the wish to intensify knowledge networking with past partners may itself become a motive to relocate, with the purpose to shorten the geographical distance between the network partners involved. In all, past collaborations may induce location decisions that decrease geographical proximity between agents and lead to a process of agglomeration. As localized knowledge networks grow and develop, they play the role of a magnet. Their attractive force may increase over time and the decision of new nodes to enter the network

become associated with location choices, as the expected benefits of agglomeration also increase (Vicente and Suire 2007). Again, this is a long term process, as there is a strong inertia in geographical proximity dynamics because the mobility of firms and individuals in space is rather limited (Breschi and Lissoni 2009, Stam 2007).

Proximity dimensions are dynamic by nature. The spatial, cognitive, social, institutional or organizational characteristics of actors change over time, largely influenced by knowledge ties among actors.[ix] But proximity dimensions are not evenly dynamic. Some dimensions display a higher degree of inertia and stability, per se, because changes along the different proximity dimensions do not imply the same economic costs. Cognitive proximity, for instance, is probably the most dynamic dimension, as knowledge bases change continuously (Dosi and Nelson, 1994). Knowledge bases are frequently adapted and updated as an outcome of interactions with others, often without an explicit decision for change. And learning is not necessarily reciprocal, which makes cognitive settings even more dynamic. A can learn from B, without B learning from A. Although it is true that, similarly, A can adopt norms, values or ethical positions from B without a reciprocal adoption from B, it often requires some mutual agreement to change institutional settings and reach institutional proximity. Institutional proximity is indeed continuously adjusted as an outcome of mutual interactions and discussions (Gilly and Torre 2000). The dynamics of other dimensions, such as organizational or social proximity, not only intrinsically requires some mutual agreement: changing them is also more costly. Decoupling does not happen systematically out of any knowledge network, since actors have a limited capacity of maintaining social relationships (Dunbar 1993). Organizational integration is even more costly, as it is one of the most important strategic decisions for a firm involving high sunk investments. Deciding to belong to the same group affects the mutual autonomy and control of actors, and it has important consequences for their long-term survival and economic performance (Datta 1991). But the least dynamic dimension is probably geographical proximity. One can learn from several actors at the same time, and move cognitively closer to them without necessarily facing a strong arbitrage. Decoupling might lead to the removal of old social ties to make room for the new ones. But very often with the dynamics of geographical proximity, moving to a new location comes at the expense of another

(previous) location (Stam 2007). Actors face a strong arbitrage, being closer from some actors almost automatically means being more distant to others. Of course, co-location dynamics can be affected by the possibility to chose several locations and the cost of moving. More interestingly, the dynamics of geographical proximity would be higher in a setting defined by ever-changing attractive forces of localized knowledge networks in different spatial areas.

4. Conclusion and further discussion

In this paper, we adopted a dynamic perspective on knowledge networking and proximity, and we argued that all five proximity dimensions are likely to change over time through the processes of learning, decoupling, institutionalization, integration and agglomeration. We also pointed out that knowledge networks are likely to influence these processes, as knowledge networking may typically increase the degree of proximity between the actors involved. But this dynamic proximity framework also calls for further research regarding (1) the specific contexts in which more proximity is most likely to develop as an outcome of knowledge ties, (2) the extent to which this convergence process might be detrimental for innovation and how to overcome it, and (3) whether proximity can change out of a co-evolution process between the different dimensions.

The co-evolutionary dynamics between knowledge networking and proximity, however, remains a complex process and its specifics may well depend on contextual factors. One could think of moderating conditions that affect the extent to which knowledge networking increases proximity. For instance, this might depend on the intensity and length of the collaboration. Less intense and short interactions are expected to have less of an effect on proximity than more intense and longer types of interaction. As pointed out before, attributes of actors display a certain degree of inertia compared to network ties (Padgett and Powell 2012), and the progressive convergence of proximity dimensions is a long-term phenomenon. The structure of the collaboration may also be crucial. For instance, collaborations in which tasks are highly divided or centrally organized by a coordinator (and involving multiple partners) are less likely to increase the level of proximity. The extent to which organizations compete for the same resources may also affect the process of proximity convergence. In a context of

strong competition, a common interest is to avoid proximity to converge too much, since an organization's competitiveness depends on the uniqueness of its capabilities. Hence, they are expected to structure collaboration projects such that crucial knowledge does not spillover, and sufficient cognitive distant is kept. And, the resulting degree of proximity may also be related to the success of knowledge networking. A past collaboration can represent a positive, but also a negative experience. Unachieved goals or project failure can even lead to an increase of distance between actors.

The co-evolutionary dynamics between knowledge networking and proximity further depends on incentives for collaboration. As proximity increases due to past interactions, the cost of future collaborations is likely to go down since coordination and communication costs are a function of proximity. Nevertheless, the returns to future collaborations may go down even quicker, as high levels of proximity may hamper creativity and increase the risk of involuntary knowledge spillovers. Possibly, then, the net returns can become negative and collaboration may come to a halt altogether.

Examples of such excess proximity can be given for all five proximity dimensions (see on this, Boschma 2005), but is best illustrated in the context of cognitive proximity. When knowledge networking leads to higher levels of cognitive proximity, this will facilitate future interactions as partners communicate more easily. However, as knowledge bases of actors become more similar, there is less scope for learning through exchange and recombination of knowledge (Nooteboom 1999). An optimal cognitive distance valued by actors at the starting point of a collaboration can turn out to become sub-optimal after a set of repeated interactions. What is more, past interactions may have raised proximity in other proximity dimensions above their optimal level as well, further reducing the returns of future collaborations. Once recognized, this may spur partners to end their collaboration and look for new partners. Such dynamics would render the co-evolutionary logic between proximity and knowledge networking fully endogenous.

What is crucial to note is that this reasoning applies to the dyadic level of two organizations, while organizations entertain multiple knowledge ties simultaneously. This means that the proximity between any two organizations may not necessarily increase due to past interactions, since the change in attributes of organizations is the joint result of all knowledge networking activities. From a managerial point of view, this means that the net gains of collaboration with very proximate partners

may still be positive as long as organizations participate in multiple partnerships at the same time where partners are dissimilar. For example, collaboration with cognitively similar partners does not necessarily lead to excess proximity when complemented with collaboration with cognitively dissimilar partners. Such a strategy supports organizational ambidexterity balancing exploration and exploitation (Gibson and Birkenshaw 2004). Similarly, it has been argued that firms benefit from having partners with high and low social proximity, as some knowledge relations require high levels of trust while other activities can be organized at arm's length (Uzzi 1996). And geographically, scholars have pointed out that firms benefit from being co-located in industrial clusters, but there might be a risk of lock-in, and therefore, maintaining long-distance relations with organizations outside the cluster is said to be crucial (Bathelt et al. 2004; Menzel and Fornahl 2010). In a dynamic setting, then, one can expect as an actor increases its proximity in one relation, it may look for ways to decrease proximity in other relations, for example, by establishing completely new distant relations. This means that the proximity dynamics between two actors may well affect the proximity dynamics of the other relations that these actors have, as well. Hence, future research could move from the dyadic level to the network level as to understand how relations can be influenced by changing proximities in other relations.

Lastly, the dynamics of the different proximity dimensions might also be the outcome of a co-evolution process between geographical, cognitive or social proximity for instance. This issue has started to be tackled empirically by Broekel (2012). The main idea is that the attributes of actors in a given dimension might change as a result of changes in another dimension. For instance, it is often argued that a new social setting provides new economic opportunities and can lead to the evolution of knowledge bases. But it can also lead to less proximity in another dimension. Having strong social ties with other innovative actors can compensate the need for geographical proximity. Being cognitively close, communication and coordination cost might be reduced and it might reduce the returns to face-to-face contacts and geographical proximity. Having strong common rules, ethical practices or incentive structure (i.e. institutional proximity) might also reduce the need for trust conveyed in social or organizational ties.

In conclusion, a dynamic approach to proximity opens up a range of new research questions and hypotheses for future research. Our main proposition holds that, in the short run, proximity is expected to drive the formation of knowledge networks, while, in the long run, knowledge networking in turn increases proximity levels. We also discussed some of the auxiliary hypotheses that may guide future research avenues, highlighting the uneven pace of change in proximity dimensions, the need to move from the dyadic level to the network level, as well as the co-evolutionary dynamics among different proximity dimensions.

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[i] See Carrincazeaux et al. (2008) and Balland, Boschma and Frenken (2012) on the various approaches within the proximity framework.

[ii] Noticeable exceptions are the conceptual paper on dynamic proximities by Menzel (2008) and the empirical study on co-evolution of proximities by Broekel (2012).

[iii] Our paper focuses essentially on knowledge networks. But more generally, understanding whether similarity leads to network ties (selection) or whether network ties lead to similarity (influence) is a key question for network science (Van der Leij 2011). Empirically, separating selection and influence mechanisms is difficult, and it requires specific statistical models for network dynamics (Snijders et al. 2010; Steglich et al. 2010).

[iv] Strictly speaking, the authors show that the negative effect of geographical distance of co-authorship is increasing over time.

[v] See Grossetti and Bès (2001) and Grossetti (2005) for in-depth analyses of personal networks formation.

[vi] This dynamic approach of institutional proximity lies at the heart of the French proximity school (Bellet et al. 1993; Kirat and Lung 1999). Since the very existence of the French proximity school, the dynamic construction of institutional proximity has been a central idea, which contributed to the name-giving of the French group as «proximity dynamics ».

[vii] In this context, the construction of a common European Research Area is a telling example and its continuing construction is informed by experiences and practices in the past (Banchoff 2002).

[viii] Using data on 13,000 technology agreements and 5,000 parent companies from the MERIT-CATI database, Hagedoorn and Sadowski (1999) find little empirical evidence to support this idea.

[ix] In this paper we mainly focus on the influence of direct ties between actors. But proximity dynamics can also emerge out of indirect ties. This network configuration is known as triadic closure for network selection and it can explain the emergence of social and organizational ties, but it can also be extended to other social influence mechanisms and explain cognitive or institutional convergence. This is for instance the case when two (unconnected) actors become more cognitively proximate because they learn from the same third actor (to which they are both directly connected). Therefore, the influence of local network structures such as triadic configurations can be integrated in our dynamic framework. The influence of global network structures, such as density, connectivity or small world topologies is however more complex and would probably require a different approach.