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Proximity and Innovation: From Statics to Dynamics

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BALLAND P.-A., BOSCHMA R. and FRENKEN K. Proximity and innovation: from statics to dynamics, *Regional Studies*. Despite theoretical and empirical advances, the proximity framework has remained essentially static. A dynamic extension of the proximity framework is proposed that accounts for co-evolutionary dynamics between knowledge networking and proximity. For each proximity dimension, how proximities might increase over time as a result of past knowledge ties is described. These dynamics are captured through the processes of learning (cognitive proximity), integration (organizational proximity), decoupling (social proximity), institutionalization (institutional proximity), and agglomeration (geographical proximity). The paper ends with a discussion of several avenues for future research on the dynamics of knowledge networking and proximity.

Proximity Innovation Knowledge networks Proximity dynamics Geographical proximity

BALLAND P.-A., BOSCHMA R. and FRENKEN K. 临近性与创新：从静态到动态，*区域研究*。儘管理论与经验已有所进展，但临近性的架构仍然维持本质上的静态。本文提出临近性架构的动态延伸，以说明知识网络建立与临近性之间共同演化的动态。本文将描绘，对临近性的每个面向而言，过去的知识联繫如何可能导致临近性的增加。本文并将透过学习（认知临近性）、整合（组织临近性）、脱离（社会临近性）、制度化（制度临近性）以及聚集（地理临近性）等过程，捕捉上述的动态。文末将探讨未来研究知识网络建立与临近性动态的几个方向。

临近性 创新 知识网络 临近性动态 地理临近性

BALLAND P.-A., BOSCHMA R. et FRENKEN K. La proximité et l'innovation: de la statique à la dynamique, *Regional Studies*. En dépit des progrès théoriques et empiriques, le cadre de proximité est resté dans une large mesure statique. On propose une extension dynamique du cadre de proximité qui tient compte des dynamiques coévolutionnaires entre la mise en réseaux des connaissances et la proximité. On présente pour chaque dimension de proximité comment les proximités pourraient augmenter au fil des années à cause des liens de connaissances antérieurs. Ces dynamiques sont saisies au moyen des processus d'apprentissage (proximité cognitive), d'intégration (proximité organisationnelle), de découplage (proximité sociale), d'institutionnalisation (proximité institutionnelle), et d'agglomération (proximité géographique). En conclusion, cet article examine plusieurs pistes de recherche future sur la dynamique de la mise en réseaux des connaissances et de la proximité.

Proximité Innovation Réseaux de connaissances Dynamiques de proximité Proximité geographique

BALLAND P.-A., BOSCHMA R. und FRENKEN K. Nähe und Innovation: von der Statik zur Dynamik, *Regional Studies*. Trotz theoretischer und empirischer Fortschritte ist der Rahmen der Nähe im Wesentlichen statisch geblieben. Wir schlagen eine dynamische Erweiterung des Näherahmens vor, bei der die koevolutionäre Dynamik zwischen Wissensnetzwerken und Nähe berücksichtigt wird. Für jede Dimension der Nähe wird beschrieben, wie die Nähen im Laufe der Zeit aufgrund früherer Wissensverknüpfungen zunehmen können. Diese Dynamiken werden durch die Prozesse des Lernens (kognitive Nähe), der Integration (organisationelle Nähe), Entkopplung (soziale Nähe), Institutionalisierung (institutionelle Nähe) und Agglomeration (geografische Nähe) erfasst. Der Beitrag endet mit einer Erörterung verschiedener Richtungen in der künftigen Erforschung der Dynamik von Wissensnetzwerken und Nähe.

Nähe Innovation Wissensnetzwerke Dynamik der Nähe Geografische Nähe

BALLAND P.-A., BOSCHMA R. y FRENKEN K. Proximidad e innovación: de estáticas a dinámicas, *Regional Studies*. Pese a los avances teóricos y empíricos, el marco de proximidad ha permanecido básicamente estático. Proponemos una extensión dinámica del marco de proximidad que responde a las dinámicas coevolutivas entre las redes de conocimiento y la proximidad. Para cada

dimensión de proximidad, describimos cómo las proximidades podrían aumentar con el tiempo como resultado de los vínculos pasados del conocimiento. Estas dinámicas se captan mediante los procesos de aprendizaje (proximidad cognitiva), integración (proximidad organizativa), disociación (proximidad social), institucionalización (proximidad institucional), y aglomeración (proximidad geográfica). Concluimos este artículo con un debate sobre las diferentes vías para la futura investigación de las dinámicas de las redes del conocimiento y la proximidad.

Proximidad Innovación Redes de conocimiento Dinámicas de proximidad Proximidad geográfica

JEL classifications: B52, R10, R11

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 Zimmerman, 2004; Boschma, 2005; Lagendijk and Oinas, 2005; Torre and Rallet, 2005; Knoben and Oerlemans, 2006; Bouba-Olga and Grossetti, 2008). Notwithstanding the varieties in approaches in proximity research,[1] 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; Mattes, 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, there has been witnessed not only 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 merger and acquisition activity (Ellwanger and Boschma, 2013).

A recent development has been the integration of network theory into the proximity framework (Boschma and Frenken, 2010; Balland, 2012). 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 (Jackson, 2008; Schweitzer *et al.*, 2009). 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 research and development (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; Crescenzi *et al.*, 2013; Ter Wal, 2013b), organizations (Giuliani and Bell, 2005; Cantner and Graf, 2006; Autant-Bernard *et al.*, 2007; Boschma and Ter Wal, 2007; Giuliani, 2007; Morrison, 2008; Balland, 2012; Broekel and Boschma, 2012; Hardeman *et al.*, 2012), regions (Ponds *et al.*, 2007; Maggioni *et al.*, 2007; Hoekman *et al.*, 2009; 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, it is argued that a fully fledged dynamic theory of proximity and knowledge networks in the context of innovation is still lacking. It is important to note that a dynamic approach lies at the heart of the proximity school from the very beginning (Gilly and Torre, 2000). The different proximity dimensions have in fact been proposed as analytical tools to understand the underlying process of territorial dynamics. In this context, the formation of 'territories' is understood as a socio-economic construct emerging out of interactions between local actors, therefore continuously changing over time. Instead, this paper focuses on the dynamics of the proximity dimensions themselves as a means to explore the co-evolutionary dynamics between proximity and knowledge networks.

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 analysed 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 the wish is certainly not to depart from the basic hypothesis, it is argued in this paper that the uni-causal logic does not always apply, and that the dynamics of proximities are an important issue themselves, a topic which has not been sufficiently addressed.[2] To understand fully the underlying processes that associates proximity and knowledge ties, it is argued that a shift should be made from a static to a dynamic perspective. Such a dynamic approach allows it to be understood 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.[3] It is argued here that time plays a crucial role in the co-evolution of proximity and knowledge ties, and 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) is followed.

The paper is structured as follows. It first takes stock of the current state of the proximity framework with reference to the analysis of knowledge networks and innovation (second section). It then proposes a dynamic extension of the proximity framework where proximity drives knowledge networking, and knowledge networking in turn affects proximity (third section). It does so for all five proximity dimensions proposed by Boschma (2005) to extend this framework to include the co-evolutionary dynamics between proximity and knowledge networks in the context of innovation. The paper concludes with a number of research avenues for a dynamic approach to knowledge networks and proximity (fourth section).

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 came 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 (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), e.g. resulting from past collaboration (Breschi and Lissoni, 2009). Institutional proximity is high when actors operate under the same set of norms and incentives, e.g. 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 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 can one understand the determinants of knowledge networking and the specific role geographical proximity may have. Indeed, the last five years or so have witnessed a surge of studies covering knowledge networks at national levels (Ponds *et al.*, 2007; Breschi and Lissoni, 2009; Scherngell and Hu, 2011; Broekel and Boschma, 2012; Bouba-Olga *et al.*, 2012; Cassi and Plunket, 2012; D'Este *et al.*, 2013), the European level (Autant-Bernard *et al.*, 2007; Maggioni *et al.*, 2007; Hoekman *et al.*, 2009; Scherngell and Barber, 2009; Marrocu *et al.*, 2011; Balland, 2012), and

even at a global scale (Cassi *et al.*, 2012; Hardeman *et al.*, 2012; Balland *et al.*, 2013b).

From empirical studies it has been learnt that when 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 the fact 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.*, 2013b).

Some studies also looked at whether geographical and non-geographical proximities can be substitutes, i.e. whether the lack of one proximity can be compensated for by the presence of another form of proximity. For example, some claim that in high-technology clusters geographical proximity may help to overcome institutional differences between university, industry and government. Such an effect was indeed found by Ponds *et al.* (2007) when 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-technology ventures in their home countries trading with Silicon Valley companies.

A number of studies have investigated whether an optimal level of proximity between actors, as too little and too much proximity may both harm performance, can be spoken of (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-technology alliance networks. Other scholars have 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 be 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 holds 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 analysing 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 to comparative analysis between territories. Hardeman *et al.* (2012) compared the extent to which different proximity dimensions played a role in scientific collaboration within both Europe and North America. Including all five proximity dimensions, they found that geographical, organizational and social proximity plays 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.

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, i.e. 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 analyse 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 over time, which was 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.[4] Similarly, BALLAND *et al.* (2013b) 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 of 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 behavioural 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, the aim is to explore the co-evolutionary dynamic between proximity and knowledge networking at the level of organizations. The paper goes into the processes that lead to changing proximities as a result of inter-organizational knowledge networks, and discusses 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. Their line of reasoning is followed and extended to the dynamics of proximity dimensions. Paraphrasing them, it is argued here 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.

This idea will be elaborated on for all of BOSCHMA's (2005) five forms of proximity. That is, the co-evolution of knowledge networking and proximity will be considered 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 the underlying mechanism of its evolution is described, i.e. how proximities might increase over time as a result of past knowledge interactions. As such, it is argued that proximity should be analysed as a dynamic process by itself, largely constructed from interactions between actors, as depicted in Fig. 1. Thus, the discussion is intended as a first step to a fully fledged dynamic theory of proximity, knowledge networking and innovation.

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 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 communicate effectively as to transfer or create knowledge. But the degree of similarity

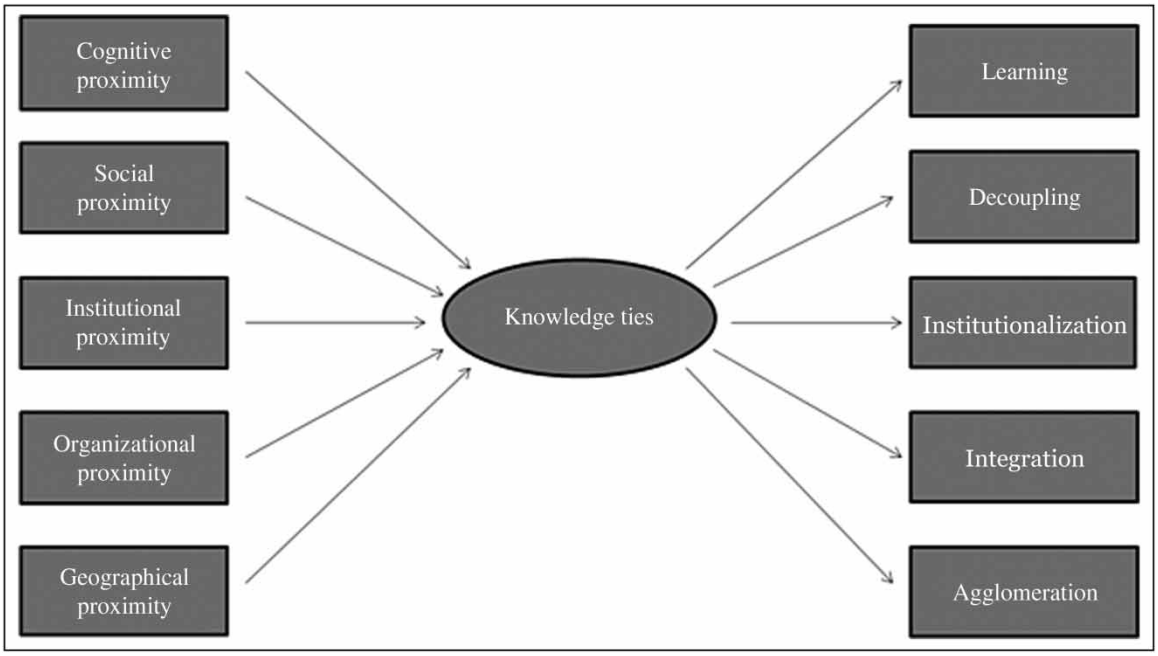

Fig. 1. *Joint dynamics of knowledge networks and proximity*

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 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.*, 2007). Building on the communication model developed by Denzau and North (1994), Menzel (2013) 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). Analysing social proximity dynamics goes back to the emergence of interpersonal relations[5] between individuals belonging to different organizations (Granovetter, 1985). This paper follows White (2002) and, more particularly, Grossetti (2008) in its definition of decoupling to analyse 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 occur not only *within* organizations but also *between* them. And if the behaviour 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 Gargiulo, 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 a 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). An excess of social proximity may lead actors to underestimate opportunistic behaviour. What is more, a high degree of social proximity may block the entry of newcomers, thus affecting the flexibility of the 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 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. The process of institutionalization will be referred to here as the progressive integration of rules and values in actors' behaviour. These institutionalization processes are often supported by dense personal relations that are associated with social proximity.

Knowledge networks can play an important role in this socially constructed institutional structure and increase the degree of institutional proximity.[6] 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, e.g. 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.[7]

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 rearrangement 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 by which two firms are combined into one firm (Siegel and Simmons, 2010). Besides the established effect of technological relatedness (Hussinger, 2010; Ellwanger and Boschma, 2013), past knowledge ties can motivate M&A decisions and increase the degree of organizational proximity. For instance, R&D collaboration can be considered as a first phase of a 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 a merger or an acquisition is not systematic or automatic,[8] 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 behaviour 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, multinational firms locate their R&D laboratories 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 of shortening 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 (STAM, 2007; BRESCHI and LISSONI, 2009).

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.[9] 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 but also changing them is 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 of choosing 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.

CONCLUSIONS AND FURTHER DISCUSSION

This paper adopted a dynamic perspective on knowledge networking and proximity and argued that all five proximity dimensions are likely to change over time through the processes of learning, decoupling, institutionalization, integration and agglomeration. It 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 above, attributes of actors display a certain degree of inertia compared with 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 depend 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 more rapidly 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 (on this, see 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 the recombination of knowledge (NOOTEBOOM, 1999). An optimal cognitive distance valued by actors at the starting point of a collaboration can turn out to become suboptimal 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 BIRKINSHAW, 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; FITJAR and RODRÍGUEZ-POSE 2011). In a dynamic setting, then, one can expect as an actor increases in its proximity in one relation, but it may look for ways to decrease proximity in other relations, e.g. 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 so 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. BROEKEL (2012) has started to tackle this issue empirically. The 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, the 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. The 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. The paper 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.

NOTES

1. On the various approaches within the proximity framework, see CARRINCAZEAUX *et al.* (2008) and BALLAND *et al.* (2013a).
2. Noticeable exceptions are the conceptual paper on dynamic proximities by MENZEL (2013) and the empirical study on co-evolution of proximities by BROEKEL (2012).
3. This 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).
4. Strictly speaking, the authors show that the negative effect of geographical distance of co-authorship is increasing over time.
5. For in-depth analyses of personal networks formation, see GROSSETTI and BÈS (2001) and GROSSETTI (2005).
6. 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, that contributed to the name-giving of the French group as 'proximity dynamics'.
7. 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).
8. Using data on 13 000 technology agreements and 5000 parent companies from the MERIT-CATI database, HAGEDOORN and SADOWSKI (1999) find little empirical evidence to support this idea.
9. This paper mainly focuses 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 the 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.

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