Conceptualizing the Role of Geographical Proximity in Project Based R&D Networks: *A Literature Survey*

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Abstract

Empirical evidence shows that research is being carried out more in cooperation or in collaboration with others, and the networks described by these collaborative research activities are becoming more and more complex. This phenomenon brings about new strands of research questions and opens up a different research context in the area of geography of innovation. The recent set of literature addressing these new issues shows a high degree of variation in terms of focus, approaches and methodology. Hence to elucidate the relationship between networks and geography it is crucial to have a review of them.

In this regard, this study focuses on a particular type of networks, namely, project based R&D networks and aims at describing the state-of-the-art in explaining the specificity of geography in formation and evolution of such networks. Towards this aim, we framed the discussion along four lenses: the specificity of geography in partner choice, in successful execution of the collaboration, in the resulting innovation performance both at the organizational and regional level, and the spatio-temporal evolution of networks. The overview provided by the survey is suggestive regarding the theorization of geography and network relationship, and informative regarding the issues demanding further research effort, and promising extensions.

Keywords: *Geographical proximity, R&D collaboration, project networks*

1. Introduction

The globalization phenomena, changing market conditions, and the greater complexity and the associated uncertainty in science and technology have been posing new imperatives on the way innovative activities are carried out. As it is described by Chesbrough (2003) as a paradigm shift from closed innovation to open innovation, it has become hardly possible to sustain and/or create competitive power by simply relying on one's own knowledge resources and knowledge production capacity. An analysis of the second half of the last century corroborates this as it reveals a sharp increase in the number of R&D partnerships starting in the late 70's and continuing during 1992-1996 (Hagedoorn, 2002). Analysis on scientific

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publications and patents also support that research is being carried out more in cooperation[2] or in collaboration with others (Wuchty, Jones and Uzzi, 2007). Hence, the networks described by these collaborative research activities are becoming more and more complex.

It is already acknowledged in the literature that this phenomenon brings about new strands of research questions and opens up a different research context in the area of geography of innovation. Breschi and Lissoni (2001) criticises the abuse of tacitness of knowledge and proposes considering networks as part of the research agenda to understand how and why geography matters. Autant-Bernard et. al. (2007) identify two main issues that considering networks would bring forth. The first one refers to the challenge in elucidating the geographical dimension of externalities, whereas the second refers to scrutinizing the spatial diffusion of knowledge through networks. In this regard, Massard and Mehier (2009) propose to change the lens from "knowledge externalities" to "accessibility to knowledge" through networks to overcome the former's limitations in distinguishing and accounting for facilitated externalities that result from the micro decisions of actors and social networks. Boschma and Frenken (2009), on the other hand, identify linking space, time, formation of networks, network structure and network performance as future challenges. Similarly, Autant-Bernard et. al. (2010-a) point out to the link between spatial structure and network performance as one of the crucial issues in terms of public policy.

A recent set of literature addresses these issues by focusing different dimensions. These dimensions encompass the determinants of partner choices, the determinants of success in collaborations, as well as the effects of collaborations on innovation performance at different levels. Furthermore, these studies differ in terms of the approach they adopt. While some of them address a phenomenon at the dyadic level, some employ a network approach. In addition to that, some studies aim at scrutinizing the role of geography at a point in time, whereas some consider the temporal changes. Accordingly, they show a great variation in terms of the methodology they adopt. It is therefore important to review them, to see what they can tell us on the relationship between networks and geography. This need constitutes the motivation of the paper.

[2] Roschelle and Teasley (1995) distinguish between cooperation and collaboration. They define cooperative work as "*the work accomplished by the division of labor among participants, as an activity where each person is responsible for a portion of the problem solving*" and collaboration "*as the mutual engagement of participants in a coordinated effort to solve the problem together*". Regarding that such a differentiation does not add a value to this study regarding its scope and objectives, these two terms will be used interchangeably throughout the document.

To achieve that, however, one needs to distinguish different types of networks as each describes a specific context for the geographical dimension. As cited in Powell and Grodal (2006), Grabher and Powell (2004) distinguish four types of networks that may overlap and can be interwoven with one another: informal networks, regional networks, business networks, and project networks. Informal networks base on shared experience, whereas in regional networks the common community is sustained by spatial proximity. While business networks represent the strategic alliances of two organizations; project networks refer to short-term combinations to complete a particular mission, where the objectives and deadlines can be subject to renewal.

Therein, this survey focuses on a particular type of networks, namely project based research and development (R&D) networks, and explores the theoretical and empirical studies to contribute to comprehending the geographical dimension of networks. Accordingly in Section 2, the role of geographical proximity in collaboration choices is addressed. This section incorporates theoretical and empirical studies from various domains like network formation theory, social network analysis, and organizational learning. Section 3 extends the discussion beyond creation of a link and explores the role of geography in maintaining the link, in other words, successfully realizing the collaboration. Section 4 provides a further extension such that the specificity of geography is investigated regarding the changes in the innovation performance that result from collaboration. This section does not only address innovation performance at the organizational level but also at the regional level.

While these three sections consider the role of geography at a particular point in time, Section 5 introduces the temporal dimension. It provides a review on rationales for assuming a temporal change and addresses relevant empirical work. Finally, Section 6 presents conclusions about the state-of-the-art, and highlights the issues demanding further effort, and promising extensions.

2. Collaboration Choices

The determinants of partner choice constitute one of the issues that received much interest in the literature. Towards the aim to scrutinize the particularity of geography in this process, one can describe the choice on partners at a particular point in time as an evaluation of the following points given the motivations to collaborate: 1. how easily a knowledge source is identified and contacted, 2.how efficient it is to access this source, 3. how risky is to access that source, 4. how much one can benefit from the knowledge that could be obtained by accession. In the sequel, these points will be brought under scrutiny.

2.1. Ease of Identifying the Knowledge Source and Contacting

A prerequisite of partner choice is to identify the candidates whose profile comply with the collaboration motivations. Without controversy, in most of the real life cases only a subset of all feasible candidates are identified and selections are made among them. Then, it is a matter of fact that who is selected is dependent on who can be identified and contacted. In that respect *"ease of access"* constitutes one dimension of the partner choice.

On the other hand, where one searches a partner, alternatively what makes an agent easily accessible do not have a trivial answer. While physical proximity can argued to be playing a role, it is not always or alone the physical proximity that ease the accession; social relations can substitute for or co-play with geographical proximity as well. The reason is that social ties can play a role to convey information on candidates and their attributes; and make it easier to identify cooperation alternatives and get into contact with them.

The idea that agents can search for candidates through their social relations constitute the distinguishing feature of the network formation model suggested by Jackson and Rogers (2007). In this model agents find some of their partners uniformly at random, and some by searching locally among friends of friends. The resulting network structure complies with the stylized facts about social networks and particularly results in high clustering, a smaller diameter as compared to random graphs and a negative relationship between clustering and degree.

Jackson and Rogers (2007) also fit the process to data from six[3] different networks and show that the relative role of random and network processes in partner selection differs for different types of networks. For example, in the co-authorship network of economists, the role of network processes is almost eight times less as compared to www network; on the other hand for the network described by friendship among prisoners and romance among high school students partner selection is almost uniformly random. While this study shows that some portion of partners are identified and contacted through local search, it is not possible to draw

[3] Links among the web sites on Notre Dame www, co-authorship among economists publishing in journals listed by Econlit in 1990's, citations among research articles stemming from Milgram's 1960 paper, friendship among 67 prison inmates in 1950s, ham radio calls during a one month period, and romantic relationships among high school students.

conclusions for R&D project networks, which are not studied among the six types of networks, due to the fact that the relative importance of these two processes vary significantly for different types of networks.

Fafchamps et. al. (2010), base on the idea that social ties can facilitate access to information about the candidates and reduce the matching frictions; and investigate whether a negative relationship exists between social distance and cooperation probability. They conduct an econometric study on the bibliography of Journal of Economic Literature for the period 1970-1999 to draw information on co-authorship network of economists during 1980-1999. They suggest that new collaborations are more likely to emerge if the agents are closer to each other in the co-author network, where being close in the co-author network is an indication of a possibly much shorter social distance in the acquaintance network. To illustrate, reducing the geodesic distance between two agents from 3 to 2 increases the probability of initiating collaboration by 27%, from 6 to 5 by 18%.

The study by Fafchamps et. al. (2010) is promising in terms of assuming a more general role for social proximity due to the fact that their study corroborates its role even in a context where availability of public information on candidates indicates a low level of matching friction. On the other hand, they do not elaborate on the rationales for why the probability to cooperate increases with decreasing social distance. Since costs associated with collaboration lead agents to take also into account the "*efficiency of access*" (Massard and Mehier, 2009), it is not possible to merely relate social proximity and cooperation choices via "*ease of access*".

2.2. Efficiency of Access

The term efficiency is used in general as an indication of how well inputs are converted to outputs. Inputs, in this context, could be considered simply as the associated costs of collaboration, which could be expressed based on time, monetary terms or effort. On the other hand, outputs could be defined as the value that could be obtained through collaboration, which is quite vague as the vast literature on motivations to collaborate (see Oliver, 1990 and Hagedoorn, 1993 for a review) reveal that value might relate to knowledge as well as risk and uncertainty sharing, cost sharing, legitimization/reputation, etc.

In this study, however we choose to focus on accessible knowledge due to two reasons. First, the aim of this study is to explore the relationship between geographical proximity and knowledge creation and diffusion within project based R&D networks; which narrows down the scope. Second, scientific knowledge creation and diffusion constitute one of the characteristics of such networks that distinguish them from other kinds of networks like informal or business networks; and hence require a deeper look on the knowledge aspect. In this regard, we will consider accessible knowledge, yet not only in terms of knowledge barter but also in terms of co-creation. As a result, other dimensions like risks, uncertainty, cost, etc. could only implicitly be addressed to the extent that they are related with accessing new knowledge.

In this framework, partner selection could be viewed as an evaluation of candidates on the basis of the knowledge that could be accessed in return for the associated costs. One can distinguish two main perspectives used in the literature to address this phenomenon. While the first approach considers the formation of a dyadic link by focusing on own properties of both sides; the second approach consider the properties of the network they are embedded in as well. Hence, the former represents an analytic perspective on network formation, whereas the latter represents a systems perspective.

2.2.1. Analytic Perspective

Indeed, the literature is quite rich in providing explanations on why and how geographical proximity might affect the efficiency of access. These are largely bestowed by research on localization of knowledge spillovers and indicate that geographical proximity can play a part in both increasing the knowledge that can be accessed and decreasing the cost of accession. The explanation the most called upon is that geographical proximity acts as a facilitator for face-to-face interactions and promotes transmission of tacit knowledge (Feldman and Florida, 1994; Anselin, Varga, and Acs, 2000; Balland, 2009); and hence, increases the amount and the scope of knowledge that can be accessed. Feldman and Florida (1994) suggest that geographical proximity also facilitates cross-fertilization of ideas, pointing out a higher potential of knowledge that could be co-created. In addition to that, Feldman (1993) argues that geographical proximity enables timely inflows of information, which can be associated with the value of knowledge. Finally, Hoekman et. al. (2009) argue that geographical distance affects the cost of collaboration and hence a determinant in collaboration choices.

However, as mentioned above, these explanations shed a partial light upon partner choice as they address only the effect of one particular attribute on efficiency of access. Other attributes like other forms of proximity (Shaw and Gilly, 2000; Boschma, 2005) also offer some explanations regarding the efficiency of access, which makes it necessary to consider to elucidate to what extent geographical proximity matters in the overall set of attributes.

a) Social Proximity

While discussing the relation between "*ease of access*" and social proximity, it has already been raised that this relation can also be investigated well beyond to cover the "*efficiency of access*". The reason is that social ties might be an indicator of trust among agents; and trust can affect both the amount of knowledge accessed and the cost of accession. For instance, Zand (1972) argues that high trust enables the exchange of ideas more openly; and Zaheer et.al. (1998) suggest that the higher the level of inter-organizational trust the less the cost of negotiations and conflicts. Furthermore, Uzzi (1996) argues that embedded ties transmit more private and tacit knowledge as compared to the information exchanged at arm's-length.

These explanations provide a rationale to consider the role of social proximity along with geographical proximity in explaining partner choices in a research collaboration context. However, empirical studies addressing the role of social and geographical proximity provide partial evidence in that they do not address collaboration choices but knowledge diffusion.

Among those studies, Singh (2005) address the role of social ties in explaining knowledge diffusion, by analyzing patent citations based on USPTO[4] data. He employs a regression analysis based on choice-based sampling and suggests that introducing social distance measures to the model reduces the marginal effect of being co-located in the same region or in the same firm on the probability of citation. This decrease is small in magnitude; however, when the interaction of social distance with co-location and firm boundaries is introduced to the model the decrease is substantial. Hence, the study implies that for inventors with close network ties, the additionality of being in the same region or in the same firm on knowledge flows through patent citations is low.

The study by Agrawal et. al. (2008) is similar to the one by Singh (2005) regarding that both examine the influence of social and spatial proximity on access to knowledge through an analysis of citations to US patents. The major difference lies in the way social distance is defined and in the methodology. While Singh (2005) defines the social distance with

[4] United States Patent and Trademark Office.

reference to existence of direct or indirect social ties in former patenting activities[5]; Agrawal et. al. (2008) defines it on the basis of co-ethnicity. Estimating a knowledge flow production function, Agrawal et. al. (2008) find out that these two types of proximity are substitutes rather than complements for each other. Hence, in line with Singh (2005) they suggest that "geographical proximity matters most in the absence of social proximity that may otherwise facilitate access to knowledge".

Another study by Sorenson et. al. (2006) defines knowledge assimilation as a search process, where agents engage in search to fill in the missing or incorrect parts of received knowledge. The study makes use of different levels of knowledge complexity (simple, intermediate, complex) in explaining the knowledge inequality across social boundaries. Employing a regression model based on case-control approach and analyzing data on citations to US patents granted in May and June of 1990; it reveals that for intermediate levels of knowledge complexity the inequality across social boundaries is maximum. The linkage to geographical proximity in the study stems from the argument that social networks tend to localize geographically and the communication can get affected by differences across regions in terms of language, assumptions, beliefs, background, etc. Considering geography as a type of social boundary corroborates the findings.

Finally, Gomes-Casseres et. al. (2006) conduct a regression analysis on patent citations; but they define the social relations by means of former alliances and investigate whether alliances, regardless of the form, result in higher levels of knowledge flows through patent citations. Unlike the above-mentioned studies the data set covers not only US but also European countries, Japan, and others. This geographical information is incorporated into the regression analysis as a dummy variable indicating co-location of citing and cited patents in the same region. Since that such a measure is quite rough, the authors interpret the joint effect of alliances and co-location on the citation probability instead of the effect of co-location alone on the citation probability. They suggest that a firm allied with a co-located partner is twice likely to cite its partner as compared to a firm allied with a partner that is not-co-located. Nevertheless, as discussed by the authors this result offers limited evidence in the sense that whether alliances result in citations or citations lead to the formation of alliances is vague.

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[5] For example, a social distance of 1 is assumed if at least one of the inventors of two patents themselves collaborated, and a social distance of 2 is assumed if inventors of two patents did not collaborated with each other but collaborated with the same third inventor previously, etc.

To sum up, two major conclusions can be derived from the empirical studies reviewed above. First, these studies point out to the role of social ties as channels for diffusion of knowledge and to the interplay between social and geographical proximity. However, this result is derived from patent citation analysis, which reveals partial information on the overall knowledge diffusion that takes place. Second and the most important regarding the context of this study is that the first conclusion though related with knowledge flows in collaborative networks, cannot be extended to explain for the partner choices. Hence, the effect of social proximity on partner choice still remains to be addressed, as well as the interplay between social and geographical proximity in this process.

b) Technological proximity

Another candidate attribute that can affect the transmission and co-creation of knowledge and associated costs is technological proximity. The rationale for expecting such an effect has its roots in inter-organizational learning theories, particularly with *absorption capacity* (Cohen and Levinthal, 1990) and *relative absorption capacity concepts* (Lane and Lubatkin, 1998). Since this research domain will be visited to some extent in Section 2.4, suffice it to say that the idea is the following: “some degree of similarity in knowledge bases is necessary for partners to understand each other”.

Cantner and Meder (2007) provide some empirical evidence particularly on this issue. They analyze the data on patent applications to German Patent office to investigate the role of technological proximity in collaboration choices. Joint patent applications in 2003 are considered as the collaborative ties and each firm’s patent applications for the period 1998-2003 are used to measure the technological overlap of the knowledge base of two potential partners. The logistic regression model employed in the study reveals for the German cooperation relations in 2003 that the higher the technological overlap between two firms, the higher their cooperation probability.

While Cantner and Meder (2007) consider only the technology as a proximity dimension in investigating the partner choices; Paier and Scherngell (2008) and Scherngell and Barber (2009) incorporate the geographical proximity as well. Indeed, the interplay between technological and geographical proximity has been subject to analysis much earlier but in knowledge spillovers context (Jaffe, 1986, Autant-Bernard, 2001; Moreno et. al., 2003).

In the context of collaborative research networks however, the particularity of the study by Paier and Scherngell (2008) is that they consider thematic proximity instead of technological proximity. Their analysis bases on two sets of data: data on projects funded by European Union Fifth Framework Programme (FP5), and results of a survey (responses represent 3% of participants and 12% of projects) on FP5 participants. Expecting that thematic specialization of organizations within FP5 will affect the cooperation decisions; they define thematic specialization of each organisation as a unit vector showing its project participations in seven subprograms of FP5 and then measure the thematic proximity as the Euclidean distance between the specialisation vectors. On the other hand, they use two measures for geographical proximity; one indicating the geographical distance between organizations and the other for to control for the country border effect. Their binary logistic regression model reveals that geographical proximity matters but similarity in partners' thematic profile in FP has a higher effect on collaboration decisions.

Similarly, Scherngell and Barber (2009) work on the data set on projects funded by FP5, yet they address the role of technological proximity instead of thematic proximity, and cross-regional collaboration at NUTS 2 level instead of inter-organizational collaboration. To measure technological proximity they make use of European Patent Office (EPO) database, they define a vector indicating a region's share of patenting at each International Patent Classification (IPC) at 3 digit-level; and make use of a Pearson correlation coefficient for region pairs to measure their proximity in the technological space. To measure geographical proximity, however, they employ the same logic as Paier and Scherngell (2008). Their Poisson spatial interaction model confirms that geographical factors significantly affect EU regional R&D collaboration; but also reveals that these effects are less than the effects of technological proximity.

c) Institutional Proximity

Institutional proximity constitutes another evaluation dimension in terms of "*efficiency of access*". The study by Ponds et. al. (2007) addresses this issue together with its relations with geographical proximity. They claim that geographical proximity can help overcoming problems resulting from differences among goals in research, institutional backgrounds and constraints. To test this claim they analyze publications data for eight[6] science based

[6] Agriculture & food chemistry, biotechnology, organic fine chemistry; analysis, measurement & control technology; optics, information technology, semiconductors, and telecommunication.

technologies for the period 1988-2004 with at least one address in the Netherlands, using both a censored tobit regression and a gravity model. They define geographical proximity in terms of travel time between the regions in which collaborating organizations are located. For institutional proximity, however, they use two different set of measures: one based on institutional homogeneity versus heterogeneity; and the other distinguishing six different combinations for three types of institutions (academic, private, governmental). Their findings for the Netherlands context suggest that homogenous collaborations take place over longer distances than heterogeneous collaborations. Furthermore, as compared to within academy cooperation, geographical proximity is found out to be more relevant for cooperation between academia and other institutional types. However, regional level is not found out to be a proper geographical scale for all types of heterogeneous collaborations; particularly for collaborations between private and academic organizations national level is suggested to be more relevant.

2.2.2. Systems Perspective

Unlike the preceding section, the approaches that will be reviewed here address "*efficiency of access*" via accounting for the network effects. In other words, they extend the basis of the candidate evaluation beyond its stock of knowledge and co-learning opportunities it offers on its own in such a way that it encompasses the "*capacity to know*" that could be accessed through its ego-network. In that case, what matters is not only the value and cost of accessing an agent, but also the value that could be seized through its links per unit cost. Hence, network structure and network position becomes relevant concepts in maximizing the "*efficiency of access*".

a) Connections Model

The connections model by Jackson and Wolinsky (1996), bases on the idea that agents not only benefit from those they are linked directly; but also from those they are linked indirectly. The benefit they can obtain from others decreases with distance; but direct links are costly implying a trade-off between the benefits and costs of a direct link.

Among the numerous studies, quoting this model the studies by Carayol and Roux (2007) and Johnson and Gilles (2000) reveal interesting results regarding the scope of this paper. The reason is that they incorporate the geographical dimension into the cost of maintaining a link as an extension. Hence, they provide an understanding on "efficiency of access" and geographical proximity relation not through one single connection but through a portfolio of connections.

As in the connections model, Johnson and Gilles (2000) define a utility function as the difference between the share of knowledge that could be transmitted through direct and indirect connections and the cost of link formation. While the portion of effectively transmitted knowledge decays with geodesic distance, the cost of link formation increases with geographical distance. In incorporating geographical distance, they assume that the individuals are uniformly distributed along the real line segment [0,1] and the cost of maintaining a link is symmetric for both sides. Finally, their theoretical model suggests that when costs are low as compared to the potential benefits of cooperation, among the stable network types locally complete networks are the most prominent ones.

The study by Carayol and Roux (2007) is very similar to that of Johnson and Gilles (2000) in terms of results despite some differences in defining the geographical dimension and costs, and including an empirical part. While Johnson and Gilles (2000) assume that individuals are uniformly distributed along a real line segment and the cost of maintaining a link is symmetric for both sides; Carayol and Roux (2007) assume that the agents are ordered and located on a circle with equal intervals, and the costs differ due to agents' heterogeneous abilities. They suggest that for a wide range of intermediary values of decay in transmission of knowledge, their theoretical model generates a particular stable network structure called "small world", where the average path length is small and local clustering is high with scarce exceptions of distant connections. They also provide some empirical evidence by fitting the model to actual co-inventions that took place during 1977-2003 with at least one inventor located in France. They found out that their theoretical model is capable of predicting most of the structural properties of the actual network. While these results point out to the joint effect of the rate of decay in knowledge that could be seized from partners of partners and the spatial aspect of the cost of cooperation, the connections model fails to account for the fact that there exists a budget or time constraint that limits the number of ties each agent can establish.

b) Preferential Attachment and the Cameo Principle

"Preferential attachment" is a mechanism in network formation proposed by Barabási and Albert (1999) where an agent prefers establishing a link with the agent who has the largest number of direct connections (i.e. degree). They suggest this mechanism to explain for the property of large scale complex networks that the probability distribution of an agent's number of direct links with other agents is independent of the scale of the system and the properties of its constituents. Indeed, they show that this property holds for the network defined by the World Wide Web or patent citations.

Preferential attachment, in other words degree affinity, stands as a strategy to increase the "efficiency of access". In this regard, the study by Vinciguerra et. al. (2010) provides an interesting perspective in that it brings preferential attachment and geographical proximity together in the context of infrastructure networks. While in the original model by Barabasi and Albert (1999) the probability that an agent gets connected to the second is defined as the ratio of the second agent's degree to the network degree; Vinciguerra et. al. (2010) incorporates the effect of geographical distance and country borders to the definition of this probability. The model is simulated for different parameter values for the effect of spatial variables and the resulting networks are compared with the actual Internet infrastructure network in 2001 in Europe. They show that without spatial extensions the properties of the network generated by the Barabási-Albert model differs significantly from those of the actual network. On the other hand, it is possible to find a set of parameter values such that the spatially extended model manages to reproduce the average path length and average clustering coefficients of the actual network.

This study illustrates the simultaneous effect of preferential attachment and ease of overcoming geographical distance. As partner choices would differ from those in the pure Barabási-Albert model, Boschma and Frenken (2009) argue that the degree distribution would vary with the ease of overcoming the distance; when these two effects are simultaneously considered.

However, the interpretation of these findings in the context of project based R&D networks is not straightforward. One of the reasons is that getting attached to the agent with the highest degree might be incongruent in the context of project based R&D networks, where the cooperation is embodied in a project aiming at realizing some defined objectives. The effect of this possible incongruence might be counterbalanced in some cases, where formation of networks is facilitated by public support. For instance, in the case of direct funds granted to collaborative research projects, the criteria set used to evaluate the applications might value consortiums with members, which are actively engaged in a wide range of collaborations.

Hence, the design of these support mechanisms could affect the partner choice by favouring the degree of applicants as a factor increasing the likelihood of receiving a grant.

The other reason stems from the degree of awareness of a node on the entire network. For an infrastructure network, where there is a single decision-maker with the map of existing investments at hand, it may be plausible to assume that information on the degree of each node in the network is available. However, for project based R&D networks it is not reasonable to expect that each organization has complete information on others' collaboration activities. In fact, a study by Lhuillery and Pfister (2011) provide empirical evidence for this argument to some extent.

Using French data collected through a survey conducted in 2003 on inter-firm relationships (ERIE survey) and the R&D survey carried out in 2000, they investigate whether firms are aware of the indirect relationships among their three most strategic partners. The results reveal that firms are aware of less than half of the potential indirect ties among their direct partners and several factors affect the degree of their awareness. Due to the fact that the study is confined with the indirect relationship of three direct partners and the type of the indirect relationship is unknown; it provides a limited explanation for the network awareness phenomenon. However, it is suggestive for conceiving why agents might be far from a decision making situation with complete information on the entire network.

At this point, the study by Mossa et. al. (2002) is interesting as it integrates "the limited information-processing capability" of agents to a network growth model based on preferential attachment processes. They argue that since the nodes cannot process information on the entire network but on a subset of it, they filter information based on their interests. In this respect, the study by Mossa et. al. (2002) interweaves the discussion on two dimensions of accessibility, namely the ease and the efficiency of access. Accordingly, in the model they constrain the information processing either by keeping the fraction or the number of interesting nodes. Tested with WWW data, the model reveals that the in-coming degree distribution, controlled by the network size and nodes' information processing capabilities, decays as a power law with an exponential truncation. Hence, the degree of the most connected node is smaller than that of a scale-free network, which affects the spread of knowledge together with the exponential truncation.

Blanchard and Krüger (2004) also depart from the fact that "knowledge about the degree of a vertex is in real networks seldom available for other vertices", but they suggest Cameo principle instead of preferential attachment mechanism to explain for the network formation process. They argue that agents decide on their partners by considering their attractiveness, rareness or beauty. Hence, the probability that a candidate is selected depends on the relative frequency of his attracting or beautiful attribute in the population. Their model shows that a scale-free degree distribution, which has also been reported for the project based networks supported by European Union through Framework Programs (Barber et. al., 2006), can result from not only preferential attachment mechanism but also from the Cameo principle.

To conclude, the context specific characteristics of project based R&D networks require some attention in considering degree affinity as a factor affecting collaboration choices. First of all, the attributes of the candidate with the highest degree may not comply with the project objectives; hence considering the degree of the candidate may not suffice or may not be relevant to explain partner choices although it stands as a strategy to increase the efficiency of access. Nevertheless, existence of public support might bestow reasons to consider preferential attachment as a relevant mechanism due to the design features of the support mechanism. Second, the fact that there are limits in agents' information about the others has to be reckoned with whenever it is plausible to assume degree affinity. On the one hand, this fact rejuvenates the question on the interplay between geographical proximity and preferential attachment mechanisms under the constraint of "limited information-processing capability". On the other hand, the possibility that a scale-free degree distribution could also result from partner choices based on Cameo principle, signals a need for further research to arrive at a concrete conclusion on the specificity of cameo and preferential attachment processes.

c) Closure and Structural Holes

Two concepts bestowed by the social network theory, namely closure (Coleman, 1988) and structural holes (Burt, 1992), broaden the understanding from the point of view of "efficiency of access" regarding that each implies a different architecture for knowledge flows. Among these concepts the former refers to the case where two partners of an agent form a link and close the triad. On the other hand, the latter refers to the case where two partners of an agent are not connected; hence the agent's ties are non-redundant. The relationship of redundant and non-redundant ties with efficiency is orthogonal. While redundant ties enable higher rate of diffusion and increase the likelihood that an agent receives a particular piece of knowledge; non-redundancy enables an agent to have access to a wider variety of knowledge.

In their theoretical work Cowan and Jonard (2004) model knowledge diffusion in networks (i.e. no innovations, only diffusion at a single innovation episode) investigate the effects of cliquishness and average path length on knowledge diffusion in a setting, where the network density is assumed to be constant. They argue that the level of average knowledge, knowledge disparity, and the rate and continuity of diffusion are higher when the spatial structure is a small-world (i.e. only 5 to 10% of all the direct ties are distant ties where the rest are local ties, indicating that the average path length is small and local clustering is high).

2.3. Appropriability

In the preceding part, the emphasis is given to "accessibility" in terms of identification of relevant knowledge sources and efficiency. However, accession has some associated risks about control on the knowledge. Massard and Mehier (2009) argue that there exists a trade-off in maximizing the knowledge acquired and minimizing the loss of appropriability. Hence, appropriability refers to another dimension in partner-choice.

The study by Cassiman and Veugelers (2002) address this issue in Belgian context. The effects of incoming spillovers and the level of appropriability on R&D collaboration decisions constitute the main motivation of the study. It bases on data on Belgian manufacturing industry collected through the Community Innovation Survey (CIS) in 1993. The measure for appropriability is constructed using the part of the CIS questionnaire where respondents rate the effectiveness of various mechanisms for protecting innovations through a 5-point Likert scale. The protection types concerned in the study are legal protection through patents and strategic protection through secrecy, complexity and lead times. They employ a probit regression model by which vertical cooperation and cooperation with research institutes are estimated separately. The results show that the probability to cooperate is positively related with the level of strategic protection. Distinguishing vertical cooperation and cooperation with research institutes reveals further that appropriability increases the probability of vertical cooperation and it is unrelated with cooperative agreements with research institutes. Effectiveness of appropriation, on the other hand, is found out to be strongly related with the R&D capabilities of a firm measured by permanence of R&D activities. They also find out some evidence for the effect of R&D cooperation on appropriability such that vertical cooperation reduces the effectiveness of strategic protection measures; while cooperation with research institutes increases it.

The above-mentioned appropriability concerns bring also trust into play in partner choices. As Coleman (1988) suggests friends of friends are perceived to be less reluctant to opportunistic behaviour. This underlines the relevance of social relations which have already been addressed two times in the previous sections through its role in ease of access and efficiency of access. Here from the point of view of appropriability, social ties become a matter of concern through its role in breeding trust. However, as Weterings and Boschma (2009) suggest trust may also be bred by co-location to some extent. Moreover, to the extent that social ties are localized, closure facilitated by trust may result in local clustering in cooperation networks.

Regarding the role of trust in partner choices, the study by Gulati and Singh (1998), provides a different perspective on the issue as its results call upon a further investigation on the link between geographical proximity, trust and governance structure. The study, indeed, aims at explaining firms' different choices on governance structure in different alliances by European, American, and Japanese firms. In this context it also investigates whether the governance choice among joint ventures, minority alliances and contractual alliances, which represent the degree of hierarchy in descending order, differs for local or cross-region alliances. The empirical analysis bases mainly on CATI[7] database and employs a multinomial logistic regression model. The results provide limited evidence to support the expectation of choices of less hierarchic alliances for local alliances due to a higher degree of trust. Hence it remains uncertain whether observing a geographical concentration in a project network results from the fact that distant collaborations exist but in the form of more hierarchical alliances or not. Indeed, reducing this uncertainty and elaborating the link between geographical proximity and governance structures, which define the formal channels for knowledge flow, might be promising also in understanding the efficiency of access.

2.4. Absorption Capacity

While discussing accessibility and appropriability, the focus has been more on the external conditions i.e. given the partner or given the external conditions, the capacity and the abilities of an organization that is willing to cooperate has left almost untouched. A widely influential

[7] Cooperative Agreements and Technology Indicators (CATI)

concept to explain for the internal factors is called the *absorption capacity* (Cohen and Levinthal, 1990).

Absorption capacity is defined as “the ability to recognize the value of new information, assimilate it, and apply it to commercial ends”. This means that determination of the candidates, the amount of knowledge that could be seized from a partner and the degree that the results of the collaborative research process are appropriated are all dependent on the absorption capacity of an organization. However, the fact that this concept refers to equal capacity to learn regardless of the partner, gave rise to a dyad-level re-conceptualisation by Lane and Lubatkin (1998) called the “*relative absorptive capacity”*.

“*Relative absorption capacity*” concept bases on the idea that an organisation’s ability to learn changes from partner to partner. This change results from the degree of similarity in knowledge bases, compensation practices and organisational structures, and organisational problem set. In this regard, relative absorption capacity concept gives a rationale for considering technological proximity as a determinant of partner choice.

Whether defined relatively or not, the concept of absorption capacity sheds some light upon the partner choice through “ability to learn” lens. Indeed, the characteristics of learning process itself provides further insight, yet the dynamic nature of learning led us to leave this issue to the end to discuss as a time effect.

3. Successful Realization of Collaborations

While discussing the role of geographical proximity together with other determinants of partner choice, the effects that shape the expectations of an organisation from collaboration, are described. In that sense they can be considered as the ex-ante effects of geographical proximity on collaborations. Indeed, following partner choice and formation of the tie, geographical proximity could take part in the success of the collaboration as well. Nevertheless, the word success is used in the literature in such a comprehensive manner that sometimes it refers to successful realization of the alliance, and sometimes to the additionality of collaboration on the firm’s innovation performance. This section will focus on the role of geographical proximity in successful realization of the collaboration, leaving the second issue to the next section.

Among the limited number of studies focusing on the successful realization of the R&D collaborations, the study by Mora-Valentin et.al. (2004) is interesting in that it also considers geographical proximity as a potential factor. However, the study focuses on a particular kind of collaboration; i.e. cooperative agreements between firms and research organizations. The analysis bases on Spanish data representing a sample of national collaborative projects run by the Centre for Technological and Industrial Development (CSTI). They define success along two dimensions: evolution of the relationship and global satisfaction. Among these dimensions, the former refers to the continuance of the link for five different cases described by completion status of the project. On the other hand, the latter refers to satisfaction with respect to five different criteria. Furthermore, they define the determinants of success as two sets of factors, called the contextual and organizational factors[8]. Geographical proximity is considered in the study as one of the organizational factors. They employ a structural equations model and find out that the factor set affecting the success for the two types of organizations have some commonalities and differences. While commitment and previous links are observed to be a common factor; definition of objectives and conflict affect success for firms; on the other hand, communication, trust and the partners' reputation affect success for research organisations. Hence, for none of the organization types geographical proximity is found out to be a determinant of success.

Another study by Lhuillery and Pfister (2009) address the same issue, not through determinants of success but through determinants of cooperation failures. It bases on French CIS data covering 1994-1996, which includes manufacturing enterprises with more than 19 employees in France. The study defines cooperation failures by making use of a set of questions on difficulties in cooperation projects and resulting effects. More specifically, cooperation failure is defined by the cases when the project was stopped or seriously delayed. Geographical proximity is incorporated into the study via distinguishing foreign partners from domestic ones. Employing probit regression models, the study reveals that collaborating with a foreign partner increases the risk of having a serious delay or abandoning the project when the foreign partner is a competitor or a public research organization.

[8] Mora-Valentin et.al. (2004) describes the organizational factors as previous links, reputation, a clear definition of objectives, institutionalization, and geographical proximity. On the other hand, they describe contextual factors as commitment, communication, trust, conflict, and dependence.

4. Collaborations and Innovation Performance

Extending the view to cover the changes in the innovation performance resulting from collaboration; this section tries to complement the discussion on the specificity of geography in partner choice and successful realization of collaborations with the resulting innovation performance. In this regard, this section will proceed distinguishing the performance at the individual level from that at the regional level.

4.1. Organizational Level

The effects of collaboration on an organization's performance have been addressed through a wide range of measures. For instance, based on Dutch part of the CIS covering 1992, the study by Brouwer and Kleinknecht (1999) considers the effect on innovation output. The study reveals that the propensity to patent is considerably higher for R&D collaborations despite some differences across sectors and firm size. Becker and Dietz (2004), however, investigates the effect of collaborations on both innovation inputs and output in their study based on data on German manufacturing industry covering the period 1990-1992. They measure innovation input in terms of R&D intensity and innovation output in terms or realization of product innovations. The analysis reveals that R&D collaboration affects both of them positively and the probability of realization of product innovations increases with the number of partners. On the other hand, Autant-Bernard et. al. (2010-b) address the relationship between cooperation and adoption of innovations through the analysis of CIS data covering the period 1998-2000. They reveal that among innovative firms, those who cooperate are more likely to adopt innovation.

Another strand of work relates innovation performance to partner selection. Among those, Belderbos et. al. (2004) employ two measures of performance (labour productivity and productivity in innovative sales) and investigate how these measures behave for different types of partners (competitors, suppliers, customers; and universities and research institutes). The analysis bases on Dutch part of the CIS data and considers the effects of cooperation in 1996 on productivity growth in 1998. The results suggest that the rationales and goals of cooperation vary across partners, and hence for different types of partners different impacts are created on the innovation performance. Faems et. al. (2005) also confirm that different types of partners correspond to different types of innovation outcomes based on an analysis on CIS data for 1997 for Belgian manufacturing firms. Furthermore, they argue that the more the variety in an organization's partners the higher the proportion of turnover resulting from new and improved products.

Pieters et. al. (2009), however, relate innovation performance to partner selection through network position. They analyze the data on Application Specific Integrated Circuits Producers covering the period 1987-2000 and measure innovation performance in terms of patent applications to US Patent Office. The study suggests that clique-membership has a positive effect on a firm's innovative performance. However, it is not only the position in the network, but also the position and embeddedness in the clique that matters. Furthermore, clique spanning ties affect the innovation performance as well. Yet the highest effect is observed for moderate numbers of ties, implying a U-shape relationship.

In addition to the studies mentioned above, management studies also address the link between collaboration and innovation performance, but focusing inside the collaboration process and considering the organization and conduct of collaborative work. While not fundamental for the scope of this paper, it should be noted that management literature on collaboration networks and R&D team performance is promising for enriching the understanding the effects of collaboration on innovation performance (as an example we refer readers to Cummings, 2004)

4.2. Regional Level

Having considered the relationship between collaboration and innovation performance at the organizational level, zooming out to the regional level provides some additional understanding, which would contribute to formulation of regional policies. In this respect, two recent studies, comparing intra-regional vs. inter-regional cooperative subsidies and intra-regional agglomeration vs. inter-regional networking, suggest interesting findings.

Among those, the study by Broekel (2011) address the impact of subsidized knowledge networks on regional innovation performance using data on 270 German labour market regions covering four industries[9] for the 1999-2004. Regional innovation performance is measured in terms of innovation efficiency, i.e. by relating innovation inputs (R&D employees) to innovation outputs (patent applications) using the robust version of the Data

[9] The industries covered are the following: 1. Chemicals, 2. Manufacturing of transport equipment, 3. Manufacturing of electrical and electronic devices, 4. Manufacturing of precision instruments, measurement devices, optics, and medical apparatus.

Envelopment Analysis. Then, panel regression method is employed to test the relationship between innovation efficiency, and subsidies and some control variables. The results reveal that in the German context cooperative subsidies have a greater effect than non-cooperative subsidies on regional innovation performance. Second, subsidizing intra-regional cooperation does not have a greater effect than subsidizing inter-regional cooperation, indeed, there is evidence supporting the reverse. Third, regarding inter-regional collaboration, holding brokerage positions is found out to be more preferable to maintaining a high number of ties. Finally, the regions with a low innovation capacity benefit from subsidized inter-regional ties with partners having a wide variety of industrial backgrounds, yet those with a high capacity benefit from related variety. While these results provide interesting perspectives on the relationship between inter-regional collaboration and regional performance, there is an important shortcoming of the study as raised by the author. This limitation results from the fact that it is not possible to distinguish the root cause of an observed cooperation; i.e. whether it results from the subsidy or not is ambiguous.

The second study (Varga et. al., 2010), on the other hand, covers 189 European regions and investigates the effects of intra-regional agglomeration and interregional networking on their R&D productivity. To do that they distinguish two types of research, called Edison-type and the Pasteur-type. The former refers to research towards an economic application; whereas the latter refers to the science-oriented research. Accordingly, patent applications are used as a proxy for the Edison-type and scientific publications indexed by ISI for Pasteur-type research.

In the study, intra-regional agglomeration is measured by size adjusted location quotient of employment in technology and knowledge intensive sectors. On the other hand, inter-regional network effects are measured on the basis of total R&D expenditures in partner regions for each region. Estimating knowledge production functions, the study reveals that there is a strict distinction between Edison and Pasteur-type research in terms of determinants of R&D productivity. While for Edison-type research intra-regional agglomeration is an important determinant; for Pasteur-type it is inter-regional networking. The authors conclude that these factors "*are neither substitutes nor complements but operate at distinct parts of knowledge production process*".

5. Temporal Dimension

While exploring the specificity of geographical proximity in collaborative networks in the previous sections, temporal dimension been demarcated on purpose and reserved for this section. In the sequel, the rationales for assuming a spatio-temporal change will be discussed and empirical findings will be reviewed.

5.1. Why time might matter

The mechanisms through which time creates a change could be considered under four main headings: partner specific learning, change in the scope of knowledge, accumulation of absorption capacity, and industry life-cycles.

a) Partner Specific Learning

When two organizations collaborate they do not only learn from each other but also they learn about each other (Inkpen and Currall, 2004). This information can facilitate better management of the collaboration through development of a common language and result in developing some skills to handle differences in values, perspectives and organizational constraints. Hence, in the subsequent partner choices it may offer a reason to favour candidates that are old partners. Then, with the repetition of ties partner specific learning would further be reinforced.

On the other hand, partner specific learning results in evolution of trust in the relationship (Mayer et. al., 1995; Inkpen and Currall, 2004). Hence, past collaborations can affect partner choices through reinforcing or diminishing trust. Gulati (1995) provides some evidence indicating that partner choices are dependent on trust that results from repeated ties.

b) Change in the Scope of Knowledge

Apart from partner specific learning, time also facilitates changes in the scope of knowledge an organization possesses. These changes not only frame the future needs to collaborate and hence frame what makes an organization a candidate, but also affect efficiency of access through their affects on absorption capacity. Leaving the link with absorption capacity to the next section, this section will address the central question on how changes in the scope of knowledge may affect the role of geographical proximity.

The literature already offers some answers to this question. For instance Cowan, Jonard, and Zimmermann (2006) argue that learning together results in similar knowledge profiles and reduces partners' attractiveness to each other for further collaboration. Autant-Bernard et. al. (2010-a) suggest that in that case geographical proximity can substitute for technological proximity, as it may create confidence in the relationship.

On the other hand, the literature on learning puts some challenges to the argument that states learning together results in similarity in knowledge profiles, along two dimensions. The first dimension refers to the characteristics of learning, while the second refers to distinguishing learning at different levels.

Theories and models on individual and organizational learning describe learning as a process of construction and reorganization of knowledge structures that takes place uniquely for each learning agent (Packer and Goicoechea, 2000; Jonassen, 1991; Nonaka, 1994). As Jonassen (1991) suggests for the individual context, the meaning is determined by the understander and dependent upon understanding. Furthermore, Powell et. al. (1996) argues that learning through collaborations does not take place independently for each tie. In contrast, in a project network setting, an organization simultaneously learns from different partners of the project and from other projects as well. Hence, deriving conclusions on the degree of similarity of knowledge bases after cooperation is not straightforward.

Besides, it is necessary to distinguish individual learning from organizational learning although it is an important constituent of the organizational learning process (Kim, 1993; Nonaka 1994; Crossan, Lane and White, 1999). The reason is that, the knowledge possessed by the organizations is not the bare sum of the knowledge of individuals but it is embedded in systems, structures, procedures and strategy that exist independently of any individual, and at the same time it affects and gets affected by individuals (Crossan, Lane and White, 1999). Furthermore, the change in the scope of knowledge at the employee level (collaboration team) cannot be amplified to the organizational level in the same way and to the same extent (Kim, 1993[10]; Nonaka, 1994[11]; Crossan, Lane and White, 1999[12]). Therefore, again it is not

[10] Kim (1993) links individual learning to organizational learning through development of shared mental models based on individual mental models developed through individual learning. He argues that the organization's view of the world (Weltanschauung) changes slowly to cover the current thinking of the individuals, while sound individual routines become standard operating procedures. He suggests two concepts called "individual double-loop learning" and "organizational double-loop learning" implying that former individual learning can affect the individual and organizational actions provided that they become integrated to the individual and shared mental models, respectively.

straightforward to figure out the contribution of collaboration to the similarity in knowledge profiles.

Another issue related with distinguishing different learning levels is that learning within and between organizations differ not only from the individual level, but also they differ from learning by the network as a whole (Knight and Pye, 2003; Capello, 1999). This challenges the view that confines the effects of learning through collaboration to the knowledge profiles of the organizations. Despite a limited literature, addressing the relationship between learning by a network and geographical proximity might enrich the understanding on the spatio-temporal evolution of research networks.

Returning back to the central question of this section, the main conclusion is that further work seems to be necessary for understanding the change in partners' scope of knowledge, which is a prerequisite for discussing its effects on the role of geographical proximity. In this regard, better exploitation of research on characteristics of learning and different learning levels could be promising.

c) Accumulation of Absorption Capacity

Earlier, the relevance of absorption capacity at a point in time to partner choice and appropriability concerns has been raised. The fact that the absorption capacity at a point in time bases on prior knowledge as it enables absorption of new knowledge requires revisiting this concept to elaborate the temporal dimension.

Cohen and Levinthal (1990) argue that dependence on prior knowledge brings in two properties to absorption capacity: cumulativeness and its effect on expectation formation. Cumulativeness refers to the property that some absorptive capacity accumulated earlier enables more efficient accumulation of absorption capacity in the succeeding periods. Cumulativeness property affects the organizations ability to recognize and evaluate the technological opportunities in a field better, and hence contributes to expectation formation.

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[11] Nonaka (1994) argues that whenever a new concept is integrated to the organizational knowledge base, this knowledge base is "re-organized through a mutually-inducing process of interaction between the established organizational vision and the newly-created concept".

[12] Crossan, Lane and White (1999) define a 4I framework, that consists of four related processes called intuiting, interpreting, integrating, and institutionalizing, taking place at three levels (i.e. individual, group, and learning). While intuiting and interpreting take place at the individual level, interpreting and integrating occur at the group level and at the organizational level integrating and institutionalization take place. They argue that institutionalization is the distinguishing feature of organizational learning when compared to other levels of learning and describe institutionalization as "the process of embedding learning that has occurred by individuals and groups into the organization, and it includes systems, structures, procedures, and strategy".

The dynamic and path-dependent nature of absorptive capacity implies that in time the relative roles played by geography and absorption capacity can change. Moreover, the effect of cumulativeness of absorption capacity on an organizations ability to identify technological opportunities means a change in the definition of a candidate. Hence, at each time interval, the set of available candidates and the space defined by their locations might change. At the one extreme an agent may not find available candidates in its close neighbourhood regarding the technological opportunities that wants to invest in; and, at the other extreme it might find them all in the same location.

Finally, recalling from the previous section that learning can take place at different levels, including the network level, considering the changes in absorption capacity at the network level provides an interesting extension. Unsal and Taylor (2010) address this issue by simulating the absorption capacity of a project network and investigating the effects of innovation type and relational stability of the network. While, the assumptions made to execute the simulation display a high degree of idealization, the phenomenon addressed by the study is inspiring.

In the study, innovation types refer to incremental, modular, architectural and radical innovations. On the other hand, relational stability indicates the extent that the same group of firms keeps working together. The variation in relational stability is defined as 1 firm per role to 5 firms per role; corresponding to the cases that the group collaborates in each project without a change in members, and each of the 5 firms has 20% probability to be selected, respectively. The simulation runs suggest a positive relationship between relational stability and absorption capacity and a larger effect of relational stability on absorption capacity for architectural innovations as compared to modular innovations.

d) Industry Life-Cycles

Another rationale for assuming a spatio-temporal change bases on the industrial life-cycle perspective as suggested by Boschma and Frenken (2009). Asheim and Coenen (2005) address this issue by distinguishing between two types of knowledge bases, ‘analytical’ and ‘synthetic’ and argue that the characteristics of the innovation process are contingent on the knowledge base that a firm or industry draws upon. They define the analytical knowledge base as the one “where scientific knowledge is highly important, and where knowledge creation is often based on cognitive and rational processes, or on formal models” and the synthetic knowledge as the one “where the innovation takes place mainly through the application of existing knowledge or through new combinations of knowledge”. They propose that the analytical knowledge base is dominated by codified knowledge and research collaborations between R&D departments of firms and research organisations are more common. In the synthetic knowledge base, on the other hand, tacit knowledge dominates and interactive learning takes place with clients and suppliers. Hence, in the case of R&D project networks, geographical proximity as an enabler of transmission of tacit knowledge might have different importance across sectors and through an industrial life-cycle.

5.2. Empirical Evidence

Empirical evidence on spatio-temporal evolution of networks constitutes one of the least developed domains of the relevant literature. A recent study by Hoekman et.al. (2010) addresses this need by analyzing co-publication network across 313 European regions covering the period 2000-2007. They define geographical proximity in various ways to investigate how spatial patterns of the network evolve in time. On the one hand they include a continuous variable indicating the distance between the centres of two regions. On the other hand, they define a set of binary variables indicating co-location in a region, in a country and in a linguistic area. They employ a gravity model to estimate the importance of distance and borders on co-publication activity in six[13] science fields. The results reveal that the effect of territorial borders on co-publishing decreases over time for all fields, whereas the effect of distance either remains almost the same or increase in importance. The authors explain this phenomenon through increasing collaboration with close territories, which is facilitated by the decreasing importance of territorial borders. They point out that diminishing importance of territorial borders does not mean randomness in partner selection, indeed the importance of physical distance increases for some regions and science fields.

While Hoekman et.al. (2010) consider the change in the spatial configuration at the network level, an earlier study by Cowan and Jonard (2007) consider the effect the level of maturity of an industry on partner choice. They show that the preference in redundant or non-redundant ties depends on the level of maturity of an industry in terms of the degree of availability of knowledge. In their model they investigate the effect of clustering, path length and degree distribution on knowledge diffusion through direct ties. Yet, they distinguish the agents as traders and givers and the amount of knowledge as scarce and abundant. In this setting, they

[13] Physical sciences, life sciences, medicine, engineering, social sciences, and humanities.

argue that at the early development stages of an industry where knowledge is scarce, structural holes are preferable; but as the industry matures and the knowledge becomes abundant, non-redundant ties lose their attractiveness and clustered networks become preferable.

6. Conclusions

In this study, we focused on project based R&D networks and tried to describe the state-of-the-art in explaining the specificity of geography in formation and evolution of such networks. Towards this aim, we framed the discussion along four dimensions: the specificity of geography in partner choice, in successful execution of the collaboration, in the resulting innovation performance both at the organizational and regional level, and the spatio-temporal evolution of networks.

The review is suggestive regarding the theorization of geography and network relationship for several reasons. First of all, as emphasized by the organization of the paper, existing studies show that the relationship between geography and network is not confined to partner choice; in contrast, it encompasses realization of collaborations and the resulting innovation performance as well.

Second, the section on partner choice, which tapped the proximity and network perspectives into accessibility-appropriability-absorption capacity framework, reveals that it is not possible to describe a one-for-all role for geography; it is indeed contingent on other determinants. Furthermore, this section points out to the fact that conceiving the role of geography in terms of efficiency of access requires alternating systems and analytic perspectives. While the analytic perspective; i.e. the study of the dyad, provides some insight on the interplay with different proximity dimensions; the study of network enriches this understanding by incorporating the ego-network of candidates into the discussion on efficiency of access.

Third, accounting for the temporal dimension brings forth further complexity to conceptualizing the dynamics of partner choice. The reason is that time facilitates partner specific learning, change in the scope of partners' knowledge, their ability to absorb knowledge, and maturity of industries; and hence change the context for subsequent partner choices.

Beside these conclusions that are informative regarding the conceptualization of the role of geographical proximity in project based R&D networks, the review also identifies some issues demanding further research effort. The role of geographical proximity in successful realization of collaborations constitutes one of those issues. It can be observed from the literature that the possible roles that could be played by geography after the formation of ties has received relatively less attention as compared to the immediate link between geography and network formation. The two studies reviewed in the paper address this issue through two angles, namely determinants of collaboration failure and determinants of successful collaborations, and reveal different results. Hence, shedding more light upon this difference together with elaborating definition of success of collaborations comes to forth as important challenges in casting ex-post roles of geographical proximity following the formation of ties.

Another point that requires further research is the interplay between social proximity and geographical proximity. As mentioned before, available empirical evidence focuses on knowledge diffusion but not on partner choice. Hence it remains undiscovered how partner choice is affected by geographical proximity in the absence and presence of social proximity.

Finally, it appears that the temporal dimension is still far from being exhausted. On the one hand, spatio-temporal evolution of networks requires more empirical evidence. Whether spatial constraints loose or gain importance in time and implications regarding regional policy lack further research effort. On the other hand, there seems to be some ambiguity that has to be resolved regarding our understanding on the effects of time. Change in the scope of knowledge constitutes one of the issues to be clarified. Incorporating the advancements in two research topics would be promising for a better conceptualization of this change. These are characteristics of learning by organizations within a network, and learning by a network as a whole. As the study by Unsal and Taylor (2010) illustrates, considering the project network itself as a learning entity, can provide extensions to studying the role of absorption capacity and possibly to other factors that cannot be foreseen here.

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