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How firms collaborate with public research organizations: the evolution of proximity dimensions in successful innovation projects

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Abstract

Universities and other public research organizations (PROs) are potentially valuable collaboration partners for firms in developing new innovations, but most firms find it difficult to develop and sustain fruitful collaborations with PROs. Numerous quantitative studies have shown that different proximity dimensions, such as geographical, cognitive, organizational and social proximity, are important for the establishment and performance of inter-organizational collaboration. Still, our understanding of how different proximity dimensions are related to each other and how they evolve over time is limited. This paper reports from a longitudinal study of 16 successful innovation projects in Norwegian firms involving PROs as collaboration partners. We find that different proximity dimensions are important for establishing new collaborations, depending on the firm characteristics. Engineering-based firms tend to rely on geographical proximity and social relationships with PROs, while science-based firms have closer cognitive and organizational proximity to PROs. Moreover, we observe how firms with initial social and geographical proximity to PROs can sustain and expand this collaboration through developing cognitive and organizational proximity to PROs. Our study contributes to a better understanding of how different proximity dimensions are related and their evolution over time. We develop propositions for how different types of firms can develop and sustain fruitful collaborations with PROs when developing new innovations.

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Key words: innovation, PRO collaboration, proximity, science-based firms, engineering-based firms.

1. Introduction

Although most firms know that they need to develop new or improved products, services and processes to stay competitive (Teece, 2007), they find the development of new innovations to be a difficult task (Katila & Ahuja, 2002). Many firms struggle to come up with incremental innovations that are significantly different from the firm's existing knowledge, technology and competence (Stuart & Podolny, 1996). External knowledge sources are an important supplement to the firms' internal knowledge base and are often critical for the accomplishment of innovation projects. A number of quantitative studies have looked at the role of heterogeneous external knowledge sources when firms develop radical innovations (Laursen & Salter, 2006). Different types of alliances, partnerships and collaborations play a crucial role in improving innovation performance (Nieto & Santamaría, 2007). However, our understanding of how companies can access, use and manage external knowledge successfully in their innovation processes is less developed.

An important external source for knowledge during the development of new innovations is universities and other public research institutions (henceforth PROs). PROs play crucial role for R&D and innovation across a wide range of industries (Cohen, Nelson, & Walsh, 2002) and the importance of direct interaction to release the full potential of PROs as sources of external knowledge is increasingly emphasized. PROs possess technological

expertise and knowledge that can be valuable input to the firms' innovation processes. PROs can also be a partner that facilitates organizational learning and the creation of new knowledge (Hardy, Phillips, & Lawrence, 2003), However, many firms find it difficult to collaborate with PROs. Business organizations and PROs, particularly universities, are pursuing different goals and are therefore structurally different in many aspects such as incentive structure and management. These differences often prevent firms from using PROs as a source of external information in the innovation process.

The role of university-industry links in innovation is extensively studied, but the organizational dynamics underlying these relationships is not well understood (Perkmann & Walsh, 2007). In this paper we will look at how firms are able to develop and sustain collaborations with PROs when developing new innovations. Although PROs are a potentially valuable source of new knowledge it is a challenge for firms to absorb this knowledge, as evident by the many unsuccessful attempts of knowledge transfer between universities and firms (Santoro & Bierly, 2006). This challenge often relates to the role of trust and understanding for the communication and interaction between firms and academics, which can be facilitated through various types of proximity (Boschma, 2005; D'Este, Guy, & Iammarino, 2012).

Different dimensions of proximity is seen to play an important role in explaining inter-organizational collaboration (Knoben & Oerlemans, 2006), but how different types of proximity emerges and evolve over time remains poorly understood. In particular, the literature describes the dimensions of proximity that facilitate the formation of collaborations, whereas less attention has been given to the interplay between different dimensions of proximity, the evolution of proximities over time and the outcome of these collaborations. This paper investigates the role of proximity in collaborative innovation performance. More specifically, we pose the following research question: *How do different dimensions of proximity facilitate the establishment of successful collaboration between firms and PROs and how do these dimensions evolve over time?*

The literature on inter-organizational knowledge transfer is dominated by quantitative studies and most studies focus on single informants from one partner of the alliance relationship (Meier, 2011). Hence, we know a great deal about what characterizes successful collaborations, but how these collaborations were created in the first place and the underlying mechanisms and processes of collaboratin remains largely unexplored (Balland, 2011). It is likely that different firm characteristics influence the need for different combinations of proximities. We follow a categorization of science-based firms and engineering-based firms (Autio, 1997b) to examine whether these groups of firms require different combinations of proximities. This study builds on longitudinal data about 16 successful innovation projects in firms of varying size and age. All innovation projects in our study are successful in the sense that they have produced an innovation that is considered as profitable or potentially profitable by the firm. Hence, our case material is well suited to better understand the determinants of successful university–industry collaboration.

Our paper makes several contributions to the literature on how firms use PROs as an external knowledge source for innovation. A key contribution relates to the in-depth qualitative methodology. Most prior research on the role of proximity in inter-organizational collaboration has been cross-sectional quantitative studies looking at the factors leading to the establishment of collaborations. Our study looks at successful collaborations longitudinally and thereby reveals how such collaborations emerge and evolve over time. Moreover, by using the innovation project as unit of analysis, rather than the more commonly used firm

level, we get a more precise account of the collaboration. Firm level studies are not able to account for both successful and unsuccessful innovation projects within the same firm.

Moreover, this study helps to clarify how internal and external knowledge sources interplay over time. In particular, we extend research on proximity by pointing to the important role of social and geographical proximity in establishing collaborations with external partners that are distant on the cognitive and organizational level. Moreover, we show how firms actively build absorptive capacity by becoming more proximate to PROs on the cognitive and organizational dimensions. This contributes to a more fine grained understanding of how different dimensions of proximity are related and develop, as well as under which conditions they facilitate collaborations between firms and PROs to develop new innovations.

This article proceeds as follows. Section 2 presents our theoretical framework. Section 3 presents the methodological approach. In Section 4 our findings are presented and propositions derived. Finally, conclusions and implications for further research and practice are provided.

2. Theoretical Framework

In this section, the theoretical framework of this paper will examine the concepts of absorptive capacity and different types of proximity, in addition to a table of strengths and weaknesses of proximities ant the interplay between them. At the end of this section, a discussion of firm categorization and proximity are presented.

2.1. Absorptive capacity

The ability to use external actors in the innovation process has been linked to the firm's absorptive capacity, defined as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128). A key point of the absorptive capacity perspective is that collaboration with external actors is dependent on the level of prior related knowledge between the firm and the collaboration partner. Hence, the absorptive capacity would be higher when the partners are similar and possess a similar knowledge base (Luo & Deng, 2009). Although firms are more capable of collaborating if the partners are similar, partners that are too similar may not be able to provide the type of heterogeneous resources and knowledge needed to develop radical innovations (Nooteboom, Van Haverbeke, Duysters, Gilsing, & van den Oord, 2007).

Firms that seek to engage external actors in their innovation processes face the paradox that the type of actors that are likely to provide the most complementary knowledge also would be the most challenging actors to collaborate with. Collaboration between firms and PROs clearly illustrates this point. One the one hand, PROs are valuable collaboration partners and firms collaborating with PROs are much more likely to develop new innovations (Howells, Ramlogan, & Cheng, 2012). Several studies indicates that previous collaboration facilitates successful collaboration (Petruzzelli, 2011). On the other hand, most firms find it difficult to collaborate with PROs and firms in general rate PROs very low as information sources and potential partners (Howells et al., 2012). It seems clear that there are a number of

both orientation and transaction related barriers to firm-PRO collaboration (Bruneel, D'Este, & Salter, 2010). In particular, establishing new collaborations seems to be a major barrier.

2.2. The proximity perspective

As a framework to better understand how firms can overcome the barriers of collaborating with PROs, we rely on the proximity perspective. The proximity literature has developed a more fine-grained framework for understanding different aspects of inter-organizational collaboration (Boschma, 2005; Knoben & Oerlemans, 2006). This literature suggests that different types of proximity facilitate successful inter-organizational collaboration (Knoben & Oerlemans, 2006). Different types of proximities contributes to interaction, knowledge transfer and is an important condition for innovation (Boschma, 2005; Gertler, 1995). In understanding the factors behind the process of interaction and knowledge transfer, proximity is useful, as it promotes trust and understanding when complex and high-risk innovation activities are created (Menzel, 2008).

The proximity concept is useful because it allows for alternative ways to reach the same outcome and it is well suited to study qualitative changes in the relationship between collaboration partners over time. Different dimensions of proximity may be important depending on characteristics of the firm and the type and phase of the innovation project. Moreover, one dimension of proximity may be a substitute for another, while other dimensions may complement each other. The literature has suggested many different dimensions of proximity that may have an impact on collaboration and innovation (Boschma, 2005). In the following we will review four key dimensions of proximity and how these are likely to influence the creation, evolution and performance of collaborations between firms and PROs. Our focus is in line with Broekel and Boschma (2012) who studied the role of geographical, cognitive, social, and organizational proximity for innovation performance.

Geographical proximity is in the literature referred to as territorial, spatial, local or physical proximity. Small geographical distances facilitates face-to-face interactions, which promotes transfer of knowledge and innovation (Knoben & Oerlemans, 2006). It is easier to interact when actors are co-located, and the need for this dimension of proximity may be covered by temporary co-location like conferences and business meetings (André Torre, 2008). It is well established that firms tend to collaborate with geographically close universities and PROs (Slavtchev, 2010). This is, however, strongly depending on the characteristics of the firm. Firms with higher levels of absorptive capacity tends to collaborate with partners, such as universities and PROs, independently of geographical distance (Laursen, Reichstein, & Salter, 2010). Geographical proximity is also related to better performance of collaborations (Broekel & Boschma, 2012; Petruzzelli, 2011). Because the role of geographical proximity shows large variations depending on the characteristics of the collaboration partners, it might be reflecting the role of other types of proximity as well (Boschma, 2005). For instance, the likeliness of social proximity between two actors increases when they are geographically close, especially outside the most heavily populated urban areas. A study of university-industry collaborations suggests that geographically proximate linkages are more likely to facilitate innovation and learning effects at the firm (Broström, 2010). Moreover, geographic proximate interaction is related to successful R&D projects with short time to market, while geographic proximity is generally seen as a less critical factor for long-term R&D projects (Broström, 2010).

Cognitive proximity refers to the similarities in the way actors perceive, interpret, understand and evaluate the world (Wuyts, Colombo, Dutta, & Nooteboom, 2005). To be able to communicate and transfer knowledge effectively, actors need to have similar frames of references (Knoben & Oerlemans, 2006). Nooteboom et al. (2007) have found that cognitive proximity is an important determinant for R&D collaboration. When people share the same knowledge base and expertise they may learn from each other (Nooteboom, 2000). Cognitive proximity between actors facilitates understanding, effective communication and absorption of new information, but only at a certain level; too much can decrease the level of learning and innovation (Boschma, 2005). Dissimilar and complementary knowledge is important for knowledge building. Hence, some level of cognitive distance should be maintained as it often enables new ideas and creativity (Cohendet & Llerena, 1997). It is important that firms have a comparable knowledge basis to be able to recognize opportunities created by collaborations, but fairly diverse specialized knowledge base in order to attain effective and creative knowledge utilization (Colombo, 2003). Partners' technological relatedness has an inverted U-shaped relationship with innovation value in the context of university-industry collaborations (Petruzzelli, 2011).

Organizational proximity refers to shared relations within or between organizations, and are advantageous for innovation networks (Boschma, 2005). This dimension of proximity is supported by common rules and routines in organizations (Andre Torre & Rallet, 2005). Arguably, there is a significant organizational distance between industrial firms and PROs. Firms and PROs have different purposes and experiences and there might be significant tensions between academic and commercial activities within universities (Ambos, Mäkelä, Birkinshaw, & D'Este, 2008). Organizational proximity is known as closeness among firms within the same corporate group (Boschma, 2005), and when the level of organizational proximity are high, organizations are more likely to interact (D`Este et al., 2012). Because of trust and relevant information organizations prefer collaborating with organizations of their corporate group (Balland, 2011). People within an organization interact more easily with each other than with units outside the organizations, which is explained as interaction facilitated through shared language, norms and routines (Andre Torre & Rallet, 2005). Organizational proximity can be facilitated by prior collaboration experience, and such prior experience is related to the creation of collaboration partnerships (D'Este et al., 2012).

Social proximity refers to actors that belong to same space of relations (Knoben & Oerlemans, 2006). Relations between actors are social build when they involve trust, friendship, kinship and common experiences (Boschma, 2005). Social proximity is required for firms capacity to learn and innovate, and social relationships consisting of trust and kinship facilitate effective communication (Maskell & Malmberg, 1999). This dimension of proximity often refers to past collaborations and repeated contacts between partners, where reputation and trust are created (Balland, 2011), and increase the probability that firms engage in innovative networks (Boschma, 2005). It has been shown that high degree of feelings of personal and emotional closeness is important for creation and sharing of knowledge, and this dimension of proximity are not depended of spatial closeness (Huber, 2011). Social interactions is a pre-condition to attain absorptive capacity as it enables cooperative partners to participate in a common context (Hotho, Becker-Ritterspach, & Sake-Helmhout, 2011). In the context of EU Framework Projects in micro- and nano-technology, Autant-Bernard et al. (2007) found that social proximity was more important for the probability of collaboration than geographical proximity, especially for firms with a central network position.

2.3. Strengths, weaknesses and the interplay between different dimensions of proximity

The mentioned dimensions of proximities are known as drivers for learning and innovation (Balland, 2011; Boschma, 2005) as they emphasize advantages of being geographical, cognitive, organizational and social proximate to collaborative partners. However, studies have examine weaknesses of proximity in a sense that too much proximity may be harmful for learning and innovation (Boschma, 2005; Cassi & Plunket, 2012a). Some recent studies have also started to explore the interplay between different types of proximity. For instance, Huber (2011) found that lack of proximity in one dimension may be substituted in at least one of the other dimensions. Moreover, Menzel (2008) found that if one proximity changes, it leads to changes in other dimensions of proximities. Table 1 summarizes strengths and weaknesses of proximities, ant the interplay between them.

Table 1
Strengths, weaknesses and the interplay between different dimensions of proximity

Proximity	Strengths	Weaknesses	Interplay
Geo-graphical	• Brings people together and makes knowledge transfer easier (Boschma, 2005). • Firms proximate to knowledge sources shows innovative performance (Audretsch & Feldman, 1996). • Positive impact on establishment of collaboration because frequent interaction enables to spend resources in more complex learning processes (Cassi & Plunket, 2012a).	• Proximate collaborative partners can be a source of mistrust as they may feel threatened in local markets (Ben Lataifa & Rabeau, 2013). • Some firms see rather see local actors as competitors and thereby have lack of confidence to them (Lagendijk & Oinas, 2005). • Plays a role for establishment of collaboration, but minor role for consecutive collaborations (Cassi & Plunket, 2012a). • Too much geographical proximity may be weakened innovative performance and lack of respondents to new developments (Boschma, 2005).	• May play a role in building social, organizational, institutional and cognitive proximity (Boschma, 2005). • More important when firms lack social proximity (Cassi & Plunket, 2012b). • Geographical proximity overlaps cognitive distance for young firms with low level of technological knowledge (Broekel & Boschma, 2011).
Cognitive	• Facilitates effective communication (Boschma, 2005). • People with shared knowledge base may learn effectively from each other (Nooteboom, 2000). • Similar technical language is important for innovation (Huber, 2011).	• Too much cognitive proximity may weak learning and innovation as interactive learning require complimentary knowledge (Boschma, 2005). • High level of cognitive proximity may hinder firms to exploit new knowledge as they often are in the same paradigm (Nooteboom, 2000).	• Cognitive proximity and geographical proximity are complementary for smaller firms (not younger) (Broekel & Boschma, 2011).
Organi-zational	• Positive effect on establishing collaboration (Cassi & Plunket, 2012a). • As firms are close connected to each other it fosters collaboration and knowledge spill-over (Balland, 2011). • Firms knowledge bases are more available for collaborative partners (Balland, 2011).	• Too much geographical proximity may be harmful to learning and innovation as lack of flexibility (Boschma, 2005). • Risk of being closed to specific relations which may hinder access to other sources of useful information (Boschma, 2005). • Interactive learning is hard to find in bureaucratic systems (Boschma, 2005)	• Often leverage with social proximity (Ben Lataifa & Rabeau, 2013). • Firms can compensate with organizational proximity when they lack cognitive or social proximity (Cassi & Plunket, 2012b).
Social	• Socially embedded firms fosters interactive learning and innovation (Boschma, 2005). • Facilitate trust needed for effective collaboration (Boschma & Frenken, 2009). • Social proximity makes communication and collaboration easier as trust and mutual commitment is build when people know each other (Ben Lataifa & Rabeau, 2013).	• Too much social proximity may lead to deception because of closed communities of people (Ben Lataifa & Rabeau, 2013). • Risk of opportunistic behavior as too close social relationships may have negative outputs for calculating actors (Boschma, 2005). • May lock out other outsiders with new ideas from close social networks (Boschma, 2005).	• Geographical and organizational proximity determine the establishment of collaboration. Social proximity act as substitute for these proximities for further collaborations (Cassi & Plunket, 2012b). • Social proximity overlaps need for geographical proximity and organizational proximity (Cassi & Plunket, 2012b).

Our conceptual framework shows that different dimension of proximities enables effective collaborations between firms and PROs. We suggest that firms need various combinations of proximities to successfully collaborate with PROs depending of firm characteristics.

2.4. Firm categorization and proximity

Different categorization of firms comes in many forms and is much debated in the literature. Beise and Stahl (1999) made a distinction between manufacturing firms, R&D intensive firms and non R&D intensive firms, and Pavitt (1984) suggested a distinction between supplier dominated firms, product intensive firms and science-based firms. The present study follow a categorization of science-based firms and engineering-based firms (Autio, 1997b). When looking at motivation of firms to develop new technologies, science-based firms tend to be technological driven, whereas engineering-based firms is marked driven (Chidamber, Shyam, & Henry, 1994). When firms exploit new opportunities, science-based firms mostly exploit scientific breakthroughs, whereas engineering-based firms exploit marked opportunities (Autio, 1997b). Moreover, the science-based firms are more R&D intensive than the engineering-based firms (Autio, 1997b), and have stronger R&D ties to external knowledge sources (Arrow, 1994). The location of external knowledge sources differs between these two group of firms, as the science-based firms tends to locate external knowledge from academic research whilst the engineering-based firms locate knowledge from within the industry (Autio, 1997a).

Presumable, a science-based firm which is highly familiar with using external knowledge sources in developing innovations would rely on different combinations of proximities to successfully collaborate with PROs than an engineering-based firm which is less familiar with R&D. The role of geographical proximity depends on whether the organizations are similar on other dimensions. For instance, as science-based firms are R&D intensive they most likely have high level of absorptive capacity which makes them more independent of geographical proximity compared to other firms (Laursen et al., 2010). Ponds et al. (2007) found that geographical proximity was more important for collaborations between academic and non-academic organizations compared to purely academic collaborations. Moreover, the role of geographical proximity for university-industry interaction is more important for less R&D intensive firms, while more R&D intensive firms tend to collaborate with top-tier universities irrespectively of geographical distance (Laursen et al., 2010). Another study found that the more distinguished researchers had relatively more distant connections and that collaborations between researchers and large firms took place over larger geographical distances compared to collaborations with small firms (Slavtchev, 2010). It is assumable that the science-based firms also have similar frames of reference (Knoben & Oerlemans, 2006) and social ties to PROs (Balland, 2011) and thereby are cognitive and social proximate to PROs from the foundation of the collaboration. Because of their marked orientation and lower R&D intensity, the engineering-based firms presumable have more cognitive, organizational and social distances to PROs from the foundation of collaboration and thereby need to build other combinations of proximity to succeed with PRO collaboration over time. Our study explores which combinations of proximities science-based firms and engineering-based firms rely on to benefit from collaboration with PROs over time.

3. Methodology

3.1. Research design

We use a sample of 16 top performing innovation projects where firms collaborated with PROs. By looking at the most successful projects our aim was to reveal the collaboration patterns leading to the creation of successful innovations. A longitudinal case-study design was chosen to examine how firms were able to collaborate successfully with PROs (Eisenhardt, 1989). This approach allowed for richer contextual insight and an in-depth understanding of a process that has been scarcely investigated in prior studies. Multiple-cases studies provide a stronger base for theory building (Yin, 1989) as emergent findings can be compared across cases and the findings may be grounded in varied empirical evidence (Eisenhardt & Graebner, 2007). Such use of comparative case studies is arguably appropriate to promote insight into organizational phenomena over time (Eisenhardt, 1989).

3.2. Case selection

The research was conducted in Norway, which can be seen as a typical Western European context regarding the university system and how firms collaborate with universities. Firms in Norway face high costs and a small domestic market but good access to technological infrastructure and personnel with higher education degrees. The sample is drawn from a public support scheme that supports high-potential user-driven innovation projects in Norwegian industry (The Research Council of Norway's BIP-program). We selected 16 user driven innovation projects from a population of 709 projects that have received public support in the period 1996 to 2005. Each project was managed by a lead firm and included PROs and sometimes other firms as partners. The 16 projects were among the top-performing in the sense that the firms reported highest contribution to profit from the project three years after the project was finished. Our sample represents a variety in context by includes firms that vary in size from small start-ups to large industrial firms (Yin, 1989). The firms varied in their R&D experience and connections to PROs. Moreover, the firms characterisation varied and is classified as science-based firms or engineering-based (Autio, 1997b) firms as illustrated in Table 2.

Table 2
Classification of firms included in the study

Type of firm	Exploitation of technology (Autio, 1997b)	Motivation of technology (Chidamber et al., 1994)	R&D ties (Arrow, 1994)	R&D orientation (Autio, 1997b)
Science-based (2 Projects)	Exploiting scientific breakthrough	Technology-driven	Connections with several universities and R&D organizations	R&D key part of firm's operation. Long experience with internal R&D
Science-based	Exploiting scientific breakthrough	Technology-driven	Firm established by researcher and several researchers in the firm's management	R&D is the main activity of the firm. Close relationships with academic research
Engineering-based	Exploiting market opportunity	Market-driven	Several connections with national and international universities and R&D organizations	Own R&D department. Long experience with R&D
Engineering-based	Market opportunity	Market-driven	Limited use of research organizations in this project	Internal R&D. Good knowledge about prior R&D projects
Engineering-based	Market opportunity	Market-driven	Strong connection with research institute	Own R&D department. Long experience with R&D
Engineering-based	Market opportunity	Market-driven	Strong connection with research institute and university	Internal R&D team. Long experience with R&D
Network, several engineering-based firms	Implementing new technology	Technology-driven	Research institute play a key role in planning and conducting the project	Several smaller projects conducted by different partners. Project initiated by public research institute
Science-based	Testing of a basic scientific patent	Technology-driven (lack of market motivation)	Strong connection with research institute	R&D is the main activity of the firm. Firm established by researcher
Science-based	Technological opportunity	Technological-driven	Establish a new relationship with another research institute as part of the project	R&D Key part of firm's operation. Firm spun-off from research institute
Engineering-based	Technological opportunity	Technology-driven	Several connections with research organizations	Own R&D department. Experience from similar projects
Science-based	Spun-off basic research	Technology-driven	Firm spun-off from university and maintains strong connections	R&D is the main activity of the firm. Close relationships with academic research
Engineering-based	Technological opportunity	Market-driven	Firm spun-off from research institute and has a good relationship with university department	Internal R&D team. Ongoing R&D activity
Engineering-based	Market opportunity	Market-driven	Existing relationship to research organization	Internal R&D team. Low R&D experience, but intention of increasing the R&D activity
Engineering-based	Market opportunity	Market-driven	Strong connection with research institute	R&D key part of firm's operation. R&D important building the firm
Engineering-based	Market opportunity	Market-driven	Connections with several organizations	R&D team with internal and external members. R&D important building the firm.

3.3. Data collection

Archival data regarding the pre start-up and start-up activities of innovation projects are hard to find. Because all projects in our study had been part of a public support program, we were able to obtain similar information about all cases. Our data includes archival material, such as the initial project description, the final report, and the assessment made by

the R&D program, as well as survey responses from the firm at the start of the project period, finish, and three years after the project finished. In addition, relevant written documentation was collected from sources such as press articles and web-pages.

Furthermore we have interviewed, in average, three key persons in each case to get an in-depth understanding of how the innovation process unfolded in each case, including the role of public support and interactions between the project and firm level. The use of multiple informants were used to increase the validity of the retrospective accounts (Miller, Cardinal, & Glick, 1997). In total we conducted face to face interviews with 34 persons and telephone interview with 10 persons in October and November 2010. The interviews were recorded and transcribed by the authors as part of the data analysis process. To get an in-depth understanding of how the innovation process unfolded in each case we followed a narrative approach (Polkinghorne, 1988). The interviewers asked the informant to describe the process from inception to present with a minimum of interruptions by the interviewers. As an overall interview template, we aimed at revealing the history in chronological order starting with the background for the initiation of the innovation project, then the planning of the project, the execution of the project and finally the results gained from the project. To gain more detailed information concerning the critical events and the actors involved throughout the process, we used open follow-up questions such as: “Why did you do that?” “Who was involved in this event?” “Did you consider alternative actions?” “When did this happen?” We focused on facts and concrete events to avoid cognitive biases and impression management (Miller et al., 1997). To avoid biases, the theoretical concepts used in this paper were not explicitly referred to by the interviewers. This type of narrative interviewing was done to get a better understanding of the actual events and to avoid the influence of personal views, theoretical perspectives and recall biases on the data collection.

3.4. Data analysis

The collected data provided both narrative accounts of the process (Pentland, 1999) and factual descriptions of context, actors, and events from a large number of sources. Although the extensive documentation of each project provided additional information to the interviews, we fund that the retrospective interviews gave accurate information about the project histories (Miller et al., 1997). Based on the interviews and available documents we wrote case descriptions of each case that were verified by the project manager as a validity check. The data analysis is based on triangulation of data sources to analyze each case, followed by cross-case comparison. From this we got a comprehensive picture of how the project and firm levels interacted with the external collaboration partners such as the universities. To derive theoretical explanations for the processes observed, we identified observations that matched theoretical concepts (Orton, 1997). To avoid conflating the multiple levels of analysis, the strategy of retroduction was used (Downward & Mearman, 2007). Thus, as the analysis proceeded, the overarching logical frame shifted from exploring data, to building theoretical models, and empirically scrutinizing these models (Van de Ven & Poole, 2002).

4. Results

The purpose of this study was to better understand how firms are able to develop successful collaborations with PROs to improve their innovation activities. The findings are

presented in two steps. First, we present the overall findings from the cases regarding the creation, evolution and outcomes from the collaborations. Then, we present the key findings from our study as an integration of the case findings with the scholarly literature on proximity and inter-organizational innovation.

4.1. The creation, evolution and outcomes of the collaboration with PROs

The rationale for collaborating with PROs was related to creating new product, process of organizational innovations (see Table 3). Typically, the external PRO partners added new knowledge, as expressed by one project manager describing the PRO partner: "*We would not be able to succeed without them. We did not have enough knowledge in our R&D department or in the company to succeed with this project*".

Overall, the firms were conscious of why they involved external partners in their innovation projects. The following quote from a relatively small engineering firm illustrates why and how they seek to integrate internal and external R&D: "*We have had a key person at [Research Institute] who has followed us since 1994, I think. He is still there and is often used in new projects. He has been very good for [the Firm]. The reason for [this collaboration] is that we thought that if we [hired a researcher in the Firm] […], he would fade as researcher. Then it is better to have him situated and mingling in a research group.*"

The cases selected for our study were all examples of successful collaboration projects with PROs. The firms that manage these projects are either medium to large firms with some level of internal R&D activity or they are small research intensive firms, usually started by people with an academic background. This seems to confirm the absorptive capacity thesis; some level of internal R&D expertise is necessary to be able to successfully use external information (Cohen & Levinthal, 1990). Although a minimum level of internal R&D seems to be a prerequisite for achieving successful collaboration with PROs, the case firms exhibit great variation in the type and extent of prior R&D experience.

We observe a distinction between two groups of firms; scientific-based firms and engineering-based firms (see Table 2). Although there is great heterogeneity within these groups, we will distinguish between these groups in the following to clarify some of our key findings. The science oriented firms are highly familiar with academic research and consists of 5 firms (see Table 3). They share social ties, common language and technological knowledge with PROs. These characteristics presume certain combinations of proximity for successful collaboration over time. The engineering-based firms consist of 9 engineering firms, and one network of engineering firms. These firms are less research intensive than the first group; they have less social ties with PROs and do not have the same level of shared common language and technological knowledge. Because of relatively lower levels of internal research activities, or absorptive capacity, different types of proximity seems important for successful collaboration with PROs over time for this group of firms compared to the science-based firms.

The innovation types developed in the projects and the main university R&D partners in each case are shown in Table 3.

Table 3
Type of innovation and relationships with the main R&D partners

Type of firm	Innovation type	Quotes about the type of innovation developed in the R&D project	Main R&D partners	Examples of relationships between firm and PROs
Science-based (2 Projects)	Product (New technology)	"*We managed to transform a high tech research tool to be applicable on a lower level*"	Hospital and several university research groups	The Firm had a high level of internal R&D and were able to collaborate with several university partners.
Science-based	Product (New technology)	*"This project was the first of its kind in Norway...in retrospect it turns out that we were the first in the world on this, but we chose not to publish it"*	Public research institute	The Firm had a high level of internal R&D and the company founder were a prior employee at the collaborating research institute.
Engineering-based	Process (Technical improvement)	"*Unfortunately we had to close down the plant where this technology was implemented, but in the time period from implementation to plant closure it had a substantial effect*"	Several universities, (national and international) and public research institutes	The Firm had significant internal R&D effort and knew the research partners from prior collaborations.
Engineering-based	Product (New technology)	"*We developed new technology for a conservative industry and needed a reference installation to convince [Coustomer group] to go for our technology*"	Technology developed in prior research projects with research institutes	The Firm were development oriented, but the Project manager had followed the technology development over 10 years (with different employers).
Engineering-based	Process (Improved technology)	*"...we developed a radically new tool-technology which improved the duration of tools by 400-500 percent*"	Public research institute	Long standing close relationship between the Firm and the Research institute.
Engineering-based	Process (Improved energy efficiency)	*"To be competitive we had to improve our concept, which we succeed in"*	Public research institutes, universities	The Firm were development oriented, but Project leader at the research institute were former employee of firm.
Network, several engineering-based firms	Organizational (Improved knowledge in new business area)	*"There has been a large increase in the use of [Technology X] in Norway...this project has contributed to this increase both through building knowledge and diffusion of interest*s"	Public research institute	The project was development oriented, but based on prior working relationships among several of the project partners.
Science-based	Product (New technology)	*"Developed a new method that was cheaper and easier to use than competing technologies"*	Public research institute	The firm's founder and the PRO researcher had studied together and worked together on a previous project.
Science-based	Process (Method improvement)	*"Increased value by developing a more predictable method"*	Public research institutes	The Firm founders were prior employees at another PRO. The relationship with the PRO in this project was new.
Engineering-based	Process (Technology improvement)	*"This technology has led to a quadruple efficiency, which has given a noticeable sale-effect"*	Universities	Prior relationship with both universities.
Science-based	Product (New technology)	*"Diagnostic and treatment methods that can detect disease at an early stage, and slow or stop a disease process"*	Universities, both national and international	The firm's founders were university scientists. New university collaboration based on scientist's network.
Engineering-based	Process (Technology improvement)	*"Fundamental technological changes to secure marked position"*	University, public research institute	Firm and research partners had collaborated before.
Engineering-based	Organizational (Innovation process and marketing)	*"It was about building a brand; integrated product development, innovative solution-methods and differentiation through industry-design"*	Public research institute	Project manager in Firm had previously worked at the research institute.
Engineering-based	Product (New technology)	*"First product in the marked"*	Public research institute	Contact and collaboration with one key person at the research institute since the Firm was founded.
Engineering-based	Process (Technology improvement)	*"That improvement was worth a lot; over a 100 million NOK per year"*	Public research institute, consultants, and supplier	Prior collaboration with consultants, but new relationship with the research institute.

4.2. PRO collaboration and the role of proximity

All firms have achieved successful collaboration with PROs. However, we observed a variety of proximity relationships behind the collaboration and how the ability to collaborate developed over time. Different combinations of proximity seems necessary for establishing collaborations, than for developing successful collaboration over time. Our findings clearly indicate that different combinations of proximity types contribute to successful collaboration over time between firms and PROs and thereby increase the firms' innovativeness and inter-organizational learning. Table 4 briefly describes the relationship between the firm and the PRO in terms of cognitive, organizational, social and geographical proximity.

Table 4
Different dimensions of proximity between firms and collaborating PROs

Firm	Cognitive proximity	Organizational proximity	Social proximity	Geographical proximity
Science-based (2 Projects)	High level of R&D experience (including PhD). Technological similarity	High (very integrated teams of academics and company employees)	High level of acquaintance to the first PROs, and low level to the consecutive partners	Using different PROs that typically were located with geographical distance
Science-based	High level of R&D experience (common understanding and technological similarity)	High (integrated teams of academics and company employees)	Low (lack of acquaintance to all of the PROs)	Low level (national and international located PROs)
Engineering-based	Moderate level of R&D experience. Technological differences	High (integrated teams of academics and company employees	Moderate; all PROs, except the international were known partners	Low level (national and international located)
Engineering-based	Low level of R&D experience (lack communication and technological similarity)	Low (lack of integrated teams of academics and company employees)	High level of acquaintance to PROs	High (PROs located in same area)
Engineering-based	High level of R&D experience (common understanding and technological similarity)	High (very integrated teams of academics and company employees)	High level (long standing close relationship with PROs)	Low (none of PROs located in same area)
Engineering-based	High level of R&D experience (common understanding and technological similarity)	High (integrated teams of academics and company employees)	High level of acquaintance to PROs	First PROs located in same area, Long distance to consecutive partners (international)
Network, several engineering-based firms	Medium level (technological similarity and common language between some project partners)	Low (organizational linkages between project partners)	Medium level (priori working relations among several of the project partners)	Low (national distance between project partners)
Science-based	High level (common understanding and technological similarity)	High (very integrated teams of academics and company employees)	High level (company founder and researcher was previous classmates and colleagues)	High level to the first PROs, low level to the consecutive partners
Science-based	High level of R&D experience (technological similarity)	Low (but R&D are main activity in firm)	High level of acquaintance to the first PRO, low level to the consecutive partners	High level to all PROs (located in same area)
Engineering-based	Medium R&D experience (technological similarity)	Medium (teams of academics and company employees)	Medium level (some prior relations to all of the PROs)	Firm and PROs located in same area
Science-based	High level of R&D experience (technological similarity)	Low (but R&D are main activity in firm)	High level of acquaintance to PROs	First PRO located in same area. Long distance to consecutive partners
Engineering-based	Medium level of R&D experience (including PhD), and technology similarity	Medium (teams of academics and company employees)	Some level of acquaintance to all the PROs	Firm and PROs located in same area
Engineering-based	Low R&D experience (develop common understanding during collaboration)	Low	Some level (contact with one key person for years)	Firm and PROs located in same area
Engineering-based	Medium level of R&D experience	Medium (team of academics and company employees)	High (acquaintance trough earlier employments)	Firm and PRO located in same area
Engineering-based	Low level of R&D experience (lack of technological similarity)	Low (lack of integrated teams of academics and company employees)	Low (lack of acquaintance to PROs)	Significant geographical distance to all PROs

4.3. Proximity and the establishment of collaboration

Our findings indicate that for the science-based firms, geographical proximity is not necessary for successful collaboration with PROs. These firms collaborate with PROs regardless of geographical distance as long as the collaborative partners possess relevant expertise and knowledge that benefit the firm's innovation activity. As stated by one PRO researcher: *"The physical contact between the projects participants are very good despite that all work in different locations. I had more contact with those I worked with in this project, than with many of my colleagues here [at the research institute]"*.

For the engineering-based firms, geographical proximity to the PROs is a clear advantage because it facilitates face to face interaction and helps overcome challenges related to lack of common understanding. The engineering-based firms often experience different focus from PROs, such as one firm representative state: *"In collaboration with research organizations we often experience that the focus lies in their manner. They want to obtain further commissioned research, whereas we as a firm are interested in commercializing the technology"*.

Social proximity and geographical proximity are important for both groups of firms when it comes to establishing the collaboration with PROs. Almost all firms had prior relationships to research organizations before they started collaborating. However, the science-based firms are more conscious about the value of using external R&D and thereby chose collaborative research partners based on relevance, rather than based on social and geographical proximity. To quote one informant from a R&D intensive firm: *"We collaborate with research groups and universities internationally, which have the relevant [technological knowledge] for further development of the technology"*.

Collaboration with PROs is typically a less familiar activity for the engineering-based firms, which requires both social proximity and geographical proximity for establishing collaboration. The level of organizational proximity influences the science-based firms when establishing collaboration with PROs. Because these firms often have integrated teams of academics and company employees, they have joint R&D experience with their partners and do not require the same level of proximity on other dimensions compared to the engineering-based firms. It appears that the science-based firms are depended of different dimensions of proximity when establishing collaboration with PROs compared to the engineering-based firms. Thus, we propose that:

> Proposition 1a: Engineering-based firms are more dependent on social proximity to establish R&D collaborations with PROs than science-based firms.
>
> Proposition 1b: Engineering-based firms are more dependent on geographical proximity to establish R&D collaborations with PROs than science-based firms.
>
> Proposition 1c: Science-based firms are more likely to have organizational proximity with PROs which makes them less depended on social proximity and geographical proximity to establish R&D collaborations with PROs than engineering-based firms.
>
> Proposition 1d: Science-based firms are more likely to search for technological relevance rather than social proximity and geographical proximity when establishing collaboration with PROs than engineering-based firms.

To sum up, these propositions claim that different types of proximity are substitutes when firms seek to establish collaborations with PROs. Furthermore, science-based firms have developed a general organizational proximity towards PROs that gives them a flexibility to choose a technologically more relevant PRO for the collaboration than the engineering-based firms that rely more on social and geographical proximity. Table 5 summarize the relevance of proximity for each group of firms related to the establishment of collaborations.

Table 5
Proximity and the establishment of collaborations

Proximity	Science-based firms	Engineering-based firms
Geographical	Not necessary as long as the collaborative partners possess relevant knowledge	Clear advantage as it facilitates face-to-face interaction and helps overcome challenges related to lack of common understanding
Social	Prior relationships to PROs Choose partners based on relevance, rather than social relations	Prior relationships to PROs before collaboration. Helps overcome communication challenges
Cognitive	Cognitive proximity to R&D partners	Compensate lack of cognitive proximity with geographical and social proximity
Organizational	Influence these firms because of joint R&D experience with their partners	Compensate lack of organizational proximity with geographical and social proximity

4.4. The evolution of proximity over time

Geographical proximity facilitates trust by facilitating face-to-face interaction. As one informant from an engineering-based firm state: "*We have had projects with them ever since we started developing this [technology] and before that too. That has built mutual relationships of trust"*. Being located in geographical proximity can be an important door opener for firms to start collaborating with PROs, as it influences common understanding and trust. The collaboration with a proximate PRO can then be used to build the firm's ability to establish collaborations with geographically more distant PROs. Once contacts with local PROs are established, the firm can enter a reinforcing circle by further developing new external research contacts.

Social proximity is a necessary dimension for successful collaboration over time. Technological heterogeneity combined with social proximity fosters good communication and trust between the collaborative partners, both the science-based and the engineering-based firms. Some of the science-based firms were very conscious that social proximity is crucial for effective collaboration. Hence, they invested resources in achieving social proximity by visiting PROs and getting to know potential collaborative research partners before they committed to collaborate. As one representative stated: "*We travelled around [internationally] and visited relevant research partners who we committed collaboration with"*. Some of these firms also build longstanding relations to individuals in PROs who function as a network other PROs.

Cognitive proximity is another important dimension for collaboration with PROs. For successful collaboration over time it is important with shared understanding and common

goals. Like one representative from a PRO stated: *"Based on general experience, it is important that we academics are aware that the [industry] work on other conditions than us. Opposite, that the [industry] have understanding of our way of working. [Firm/PRO collaboration] must be performed on both sets of premises"*. Another firm representative state: *"It is extremely important that the industry and the [PRO] clearly express our targets; where we want to go, and simultaneously give space to the involved [PROs] to create something new"*. Cognitive proximity also includes technological similarity which is important for both types of firms for successful collaboration with PROs over time, but only at a certain level. The firms need to add more specialized technological knowledge when they have become too proximate with the collaborative partners, and science-based firms are likely to search for partners who can add this new knowledge.

Organizational proximity has a similar influence on how collaborations evolve over time as for the establishment of collaborations. The engineering-based firms may lack organizational proximity and one of the PRO partners highlighted the challenges when firms lack internal R&D activity: *"It is important for us researchers to have directly contact with someone connected to an R&D department of a firm, someone who is in between us [PRO] and the commercial actor. That functions very well. It have been happenings were i `we been in contact with typical sales people, that has not been easy. You don`t communicate very well"*.

The interplay between different types of proximity

In all cases we see that cognitive proximity is important for successful collaboration over time between firms and PROs, but this proximity were achieved in different ways. Our findings show that the science-based firms have cognitive proximity to PROs as the firm's internal research experience creates common understanding and good communication from the beginning. For the engineering-based firms, cognitive proximity is often missing in the beginning of the collaboration with PROs. The engineering-based firms and the collaborative research partners have often different understanding and motivation regarding the technology they are developing, as one representative from a firm quote: *"My experience with the academic community is that they have a lot of knowledge, but the things we work with are relative easy technology that cannot be transferred to the "latest vogue" within research"*.

We further see that from being close to and have social proximity to the research partners some of the firms build cognitive proximity with the first collaborative partners, and the level of cognitive proximity increase over time; the firms achieve common understanding with the PROs and they learn how to effectively communicate with them as they have learned the research "language". The firms increasingly see the value of R&D collaboration and may search for research collaborations independently of geographical distance the next time they need new technological knowledge. One representative from an engineering-based firm illustrates the learning curve when working with a PRO: *"It is not easy in the daily life to read heavy scientific articles you don`t understand, but when working together with someone a few years you really understand more"*. Hence, a firm can have social proximity to one actor, but cognitive proximity is a more general proximity that relates to a group of actors.

The engineering-based firms build cognitive proximity trough geographical and social proximate partners which gives them needed understanding to collaborate with consecutive

PRO partners. Some of the larger firms strategically build cognitive proximity to PROs, as described by a PRO researcher: *"When the firm has decided to use us over such a long period of time it is also because they see it as an investment in our competency. When we then comprise the competence that is built we become very useful for the firm."* This quote from a firm project manager is also illustrative: *"This fits into a kind of tradition in this department that we have used to have at least one relatively long term basic project running with the Research Council and different PROs in Norway and/or internationally on selected topics."*

The engineering-based firms have to compensate the lack of organizational and cognitive proximity with geographical and social proximity to establish a relationship with the first collaborative partners. When building cognitive proximity trough social and geographical proximity to PROs, it overlaps the need for organizational proximity over time. Whereas, for the science-based firms this is a valuable dimension of proximity as they have knowledge about R&D and can search for the right PROs immediately, without having to build other proximities first.

In sum, social proximity is important for both group of firms, but the science-based firms are more likely to build this proximity before they enter a PRO collaboration. Geographical proximity is an important door opener for the engineering-based firms to achieve successful collaboration over time with other PROs. The dimension of organizational proximity is useful for the science-based firms, but can be substituted by cognitive proximity for the engineering-based firms. This leads to the following propositions:

> Proposition 2a: Firms can leverage social proximity to one specific PRO partner into cognitive proximity to many PROs by investing in internal R&D in collaboration with the socially proximate PRO partner.

> Proposition 2b: Firms can leverage geographical proximity to one specific PRO into cognitive proximity to many PROs by actively engaging in R&D collaboration with the geographically proximate PRO.

Table 6 sums up relevance of proximity for each group of firms related to the evolution of proximity over time.

Table 6
The evolution of proximity over time

Proximity	Science-based firms	Engineering-based firms
Geographical	Not necessary; search for PRO partners based on relevance and technological heterogeneity	Door opener for firms to start collaborating with PROs. Collaboration with a proximate PRO can be used to build the firm's ability to establish collaborations with geographically more distant PROs.
Social	Necessary as it fosters good communication and trust. Some of them build social proximity to PROs before entering collaboration, and some also build longstanding relations to individuals in PROs who function as a network to other PROs.	Necessary as it fosters good communication and trust. Collaboration with known partner can be used to build the firm's ability to collaborate with other unknown PROs.
Cognitive	Important. Shared understanding and motivation between these firms and PROs	Important, but often missing in the beginning. Build over time through geographical and social proximity. When they have learned the research "language" it becomes gradually easier to collaborate successfully with new PROs
Organizational	Valuable as they have knowledge about R&D and can search for the right PROs immediately, without having to build other proximities first	When cognitive proximity is built it overlaps the need for organizational proximity over time.

5. Discussion and Implications

By focusing on the role of proximity for the ability of firms to collaborate with universities, we offer novel insights into the mechanisms that make such collaborations successful. In particular, we show that different forms of proximity can substitute each other and that the types of proximities that facilitate collaboration depend on the characteristics of the firm. For analytical purposes we separated between science-based and engineering-based firms in our analysis. Figure 1 shows the combinations of proximities needed for successful collaboration between the firms when it comes to the establishment of collaboration and the evolution of proximity over time. We illustrate the importance of each proximity trough different sizes of the boxes in the figure.

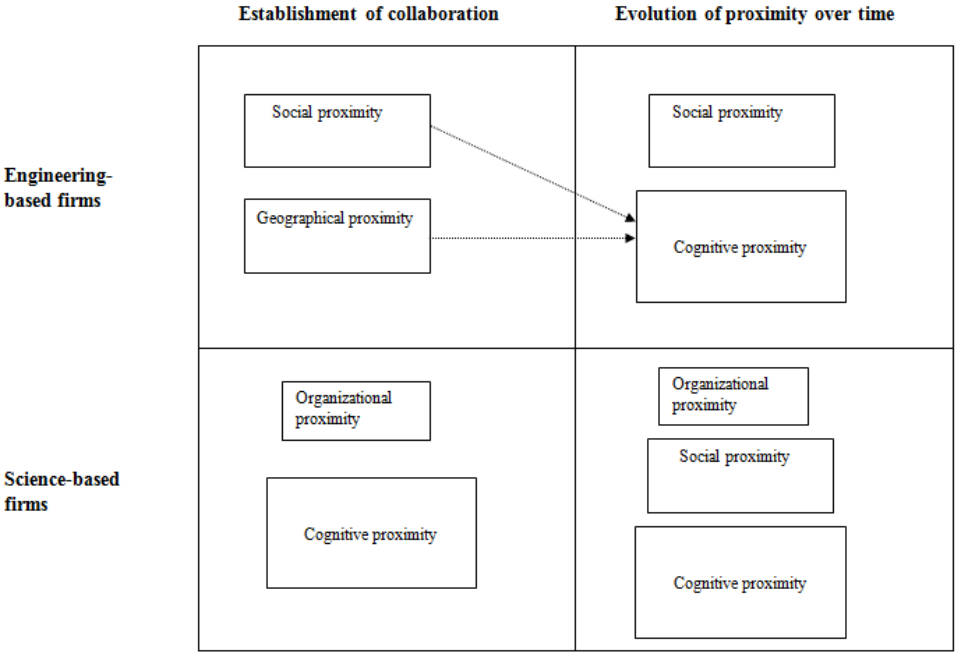

Figure 1. Establishment and evolution of proximities

We find that different proximity dimensions are important for establishing new collaborations, depending on the firm characteristics. Engineering-based firms with limited internal R&D tend to rely on geographically proximate PROs and social relationships, while more R&D intensive science-based firms have developed closer cognitive relationships and organizational proximity to PROs. Moreover, we observe that firms with initial social and geographical proximity to PROs can sustain and expand this collaboration over time through developing cognitive proximity to PROs.

Geographical proximity and social proximity are important for the engineering-based firms when establishing collaborations, because they lack the necessary research experience. Gradually when these firms learn to collaborate with PROs they build cognitive proximity which substitutes the need for geographical proximity in subsequent research collaborations. The firms often use their first PRO collaboration partner to access networks for further research collaboration, and thereby build social proximity to other research organizations via their first geographically proximate collaborator.

Geographical proximity and social proximity is less important for the science-based firms when establishing research collaborations. These firms have the research experience and the cognitive proximity to PROs that make them able to collaborate effective with geographical distant research organizations.

Common for both groups of firms is the need for some level of new knowledge and absorptive capacity; the collaborative PROs must have valuable knowledge for the firms and ability to communicate effectively with the firms for achieving successful collaboration over time. A striking observation is that many of the firms, independent of type, are conscious about the need of good communication skills and build up these skills before they start collaborating.

Different types of proximity have often been compared at the same level of analysis. Our longitudinal case approach show that the type of proximity considered as important will be influenced by the level of analysis adopted by the study. For instance, social proximity is a key enabler for collaboration at individual level while it seems that cognitive proximity is more important to maintain long term collaboration at organizational level. This means that firms can develop their ability to collaborate with universities by collaborating with social and geographical proximate partners. Active engagement with such initial partners can make the firms more cognitively and technologically proximate to other PROs. In other words, the firms can leverage social and geographically proximate relationships to increase their absorptive capacity in terms of closer cognitive and organizational proximity towards PROs.

6. Limitations and Implications for Further Research

Our findings clearly illustrate that collaborations between firms and PROs are path dependent and often change in character over time. Hence, longitudinal studies are needed to capture the dynamic relationships in such collaborations.

Since R&D collaborations frequently fail, it is important to distinguish between the process of establishing any collaboration and establishing successful collaborations. A strength of our approach compared to many studies of firm-PRO collaborations is that the outcome of all collaborations in the study is reported to be successful. The inclusion of only successful cases, however, makes it difficult to conclude whether some of the characteristics of successful cases also apply to unsuccessful cases. Futures studies should therefore use long term outcome measures and include both successful and unsuccessful collaborations to better understand the effects of different proximity dimensions.

We believe there is potential for more conceptual development of the different proximity dimensions and the relationships between them. For instance, dimensions such as social and cognitive proximity seems to be linked to the individual level of analysis, while dimensions such as geographical and technological proximity is more related to the organizational level. Understanding these differences may help firms to develop and maintain fruitful collaborations with PROs that are less vulnerable to the relationships of single individuals. A better conceptual framework is necessary to design empirical studies that study the role of proximity at different levels of analysis.

This study focused on the role of different proximity dimensions in collaborations between firms and PROs. For some of the larger firms in our sample we observed that having a dedicated internal R&D activity made communication with PROs easier because of closer cognitive and organizational proximity. Still, there could be challenges related to lack of proximity between the R&D unit and more operational levels within the firm. In other words, a good collaboration between the firm's R&D unit and PROs may not succeed in developing new innovations if there is weak collaboration with other more operative units within the firm. While inter-organizational and intra-organizational collaboration usually are studied separately, the interplay between different dimensions of proximity towards external partners and different units within the firms warrants more research.

7. Managerial Implications

Most firms are not in a position to take advantage of the knowledge residing within universities and other PROs because they lack the absorptive capacity needed. The literature seems to agree that the more firms invest in internal R&D and the higher level of proximity towards relevant collaboration partners, the more they are able to make use of external knowledge in innovation. Although it seems like firms can compensate for lack of proximity to alliance partners by stronger resource allocation (Simonin, 1999), this may be a very costly strategy without further guidance about how to develop the ability to work with universities. This study has identified some pathways for firms in how to successfully collaborate with universities in developing new innovations. Our study shows that firms can rely on different dimensions of proximity to PROs to develop such collaborations depending on the characterisitics of the firm.

For engineering-based firms it would be a relatively cheaper and faster strategy to develop new collaborations with PROs on the basis of social and geographical proximity than making heavy investments in internal R&D to become more cognitive proximate. However, this strategy is less flexible because the possible collaboration partners will be limited to the PROs where the firm has social relations and are geographically close. Hence, the firm may use social and geographical proximity as a first step to develop collaborations with PROs and later bring in new PROs as collaboration partners when the firm has increased its absorptive capacity.

Our study also provides implications for policy makers. All cases had received a government grant to support the firms' innovation project in collaboration with PROs. This grant provided an opportunity to leverage the firms' absorptive capacity by investing in collaborations with PROs. When designing support schemes, policy makers should be aware that firms do such investments differently depending on their characteristics. Engineering-based firms with lower levels of absorptive capacity tend to build on social and geographical proximity when selecting their PRO partners. More experienced science-based firms tend to use the government grant as a tool to build social proximity and further strengthen their cognitive and organizational proximity with leading PROs in their field. Hence, different policies for increased collaboration between firms and PROs may be adopted depending on whether the aim is to increase the number of firms collaborating with PROs or expand the extent of each collaboration.

8. Conclusions

The literature has frequently explored the conditions for the creation of collaboration between firms and PROs and the characteristics of the actors involved, particularly the factors that shape the propensity of firms to draw from PROs in their innovative activities. This study extends this research by exploring the underlying mechanisms that promote successful innovation projects. By examining how different forms of proximity between firms and PROs influence collaborative relationships, we contribute to a better understanding of how firms can develop their absorptive capacity.

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