Early-stage success factors of R&D collaborations

Author: Tom Jesse Huiskes
University of Twente
P.O. Box 217, 7500AE Enschede
The Netherlands

ABSTRACT,

Several studies have researched the early-stage success factors in R&D collaborations. For example, scholars have defined spatial proximity as a success factor in R&D collaborations. However, there is still debate about how non-spatial proximity influences these collaborations. This thesis will focus on spatial and cognitive proximity in relation to product development and revenue generated as success of a R&D collaboration. The data of 75 R&D collaboration projects from the year 2000-2004 was enriched with specific locations, technological fields and European commission approved NACE codes to determine the linkages between different types of proximity and R&D collaboration success. The binary logistic regression results showed the following: Spatial proximity indeed has a positive influence on product development. Cognitive proximity appeared to not be of relevance for R&D collaboration success. These findings encourage further research into cognitive and other non-spatial proximities, while confirming the influence of spatial proximity on R&D collaboration success.

Graduation Committee members:

First supervisor: Igors Skute
Second supervisor: Dr. Isabella Hatak
Second examiner: Dr. Kasia Zalewska-Kurek

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1. INTRODUCTION

In today's world high quality and innovation are leading competitive pressures for organizations (Nieto and Santamaria 2007). Besides, the increase of environmental uncertainty, knowledge specialization and dispersion, and task complexity has made it increasingly difficult for firms to develop the variety of complementary knowledge needed to innovate effectively (Capaldo and Petruzelli 2014). This is why, over the last years, research and development (R&D) has grown from an internal business to an accepted type of interorganizational relation (Nooteboom 2007).

Since R&D collaborations have become more popular, the research as to what makes it successful has seen a surge. Multiple studies have focused on determinants of R&D collaboration formation and succes (e.g., Belderbos, Carree, and Lokshin, 2006; Maietta 2015; Tether, 2002). Despite being specified the importance of spatial proximity and cognitive proximity is still discussed and not without criticism (Hansen 2014). A multitude of studies argue that spatial proximity is beneficial for innovative success and R&D collaborations (Howells 2002; Morgan 2004; Oerlemans et al 2000). This means that participants in the collaboration being closer will provide benefits. These include: better availability of partners which increases personal interaction and the faster tacit knowledge transfer through visits or learning routines. Consequently partners will use their time more efficiently when closer together, thus fostering collaboration success .

According to some researchers spatial proximity is not necessary for collaboration success, yet it has a positive effect in developing non-spatial forms of proximity (Malmberg and Maskell 2006). This signifies that partners in different industries could be successful as long as they are close. Through meetings and visits; routines, business structures and knowledge can be transferred. Working in close proximity enables them to be more efficient, and fosters process optimization.

Other researchers, however, claim social networks can substitute for spatial proximity (Amin and Roberts 2008). However, it must be stated that the partners then have an already installed similar technological or cognitive framework from which to start from. All in all the role and weight of spatial proximity is disputed still.

Cognitive proximity, which is a non-physical dimension of proximity, came up more often after Boschma (2005) downplayed spatial proximity's importance and stressed the other dimensions of proximity: these include organizational, social, cognitive and institutional proximity. These dimensions seem to positively influence R&D collaboration success even if the spatial distance is big. With regard to cognitive proximity, this is because similar frameworks and industries are associated with a better understanding between the partners. In turn, physical distance (to create this understanding) might not be so important anymore. Firms and their agents may not need to agree on a personal level or have similar tacit knowledge to succeed in their collaboration efforts, but they do need to share basic perceptions and values to sufficiently align their competencies and motives (Nooteboom 2007). While this is an accepted view on cognitive proximity, the optimal influence and level of cognitive proximity is still an elusive subject.

This thesis will try to resolve the current ambiguity regarding the role of different proximities for R&D collaboration success. Within the pursued research question: 'Which factors make a R&D collaboration successful in terms of product development and commercialization?" the focus will be on spatial and cognitive proximity in R&D collaborations. Their influence on the early stage success of the collaboration shall be investigated from a random sample of Netherlands based firms and their partners. By focusing on a direct measure of success in R&D collaborations and examining the conditions under which these collaborations do or do not generate revenue or a product, this paper will help to better understand the role of spatial and cognitive proximity for early-stage success of R&D collaborations.

This paper is organized into five sections: the second section incudes elaborations on the theory and the development of hypotheses. The third section includes methodology used in the empirical analysis. The fourth section explains the construction of the key variables. The fifth shall discuss the obtained results. Finally, the sixth section will discuss the main findings and implications for theory and policy and will provide possibilities for further research against the research' limitations.

2. THEORY AND HYPOTHESES

2.1 R&D collaborations

R&D collaborations are generally seen as a gateway to productive product and process innovation. One can distinguish between four specific types of collaborations: R&D collaborations with suppliers, competitors, customers or with a university (Asakawa 2010). In this paper the focus will be mainly on R&D collaborations between firms and universities. Not only is the knowledge base of universities very broad, the barriers that competitors might have are reduced for them. Competitors might be hesitant to share technologies or ideas with one another. This lack of trust is lower with universities since they are public entities interested in researching.

Universities have become a big drive of innovation in the last years, especially because they have expanded beyond teaching and researching to become more entrepreneurial (Petruzelli 2011). This has led to more and more links with the industrial environment (e.g. Etzkowitz and Leydesdorff, 2000; Nelson, 2005; Rothaermel and Thursby, 2005; Siegel et al., 2007; Todorovic et al., 2010). This is mainly because firms have the power to commercialize these ideas and the need for continuous product innovation, hence the fast interest in R&D collaboration with universities. The university-industry collaboration includes joint research programs, licensing of university patents and joint publications (D'Este and Patel 2007) . These are also the type of manifestations in the sample used for this paper.

Assuming that the academics engage with industry to also commercialize their knowledge, most policy makers provide monetary incentives like funding or investments (Lach and Schankerman 2008; Link and Siegel 2005). In turn, D'este and Perkmann (2011) found that commercialization ranked as least important and collaboration was dominated by research-related motivations, including learning from industry and fund-raising.

A lot of research has been focusing on the likelihood of these collaborations being formed, for example Veugelers and Cassiman (2005) have shown that firms' size, type of industry, government support and the involvement in complementary innovative activities positively affect the likelihood to establish R&D collaborations with universities (Petruzelli 2011). Furthermore the firms' innovation strategy (Bercovitz and Feldman 2007), open search and investing (Laursen and Salter 2004) and knowledge base (Giuliani and Arza 2009) influences the creation of university-industry collaborations. While these variables are focused on the establishing of collaborations, they are also useful for measuring success in these collaborations. After all, this paper looks at existing collaborations and the determinants of their success. This thesis measures success in terms of the projects generating revenue or developing a product. If the projects do not accomplish any of these they are regarded as unsuccessful. However, this does not mean that the project can't be a stepping stone for better technologies or have a helpful outcome for society.

2.2 Spatial proximity and R&D collaboration success

Over the years lots of research has been done about spatial proximity in R&D collaborations. Among other reasons this is because intra-firm knowledge has fallen short to sufficiently provide a source for innovation, as firms tend to concentrate on core competencies (Hansen 2014). Furthermore knowledge tends to develop within different niches and technological trajectories spread out across the world (Capaldo and Petruzelli 2014). With geographical distance separating partners, they may find it difficult to exploit the innovative potential between them.

Spatial proximity has been defined in multiple ways, from 'a spatial separation between actors' (Gilly and Torre 2000) to 'the actors perception of their spatial area' (Bouba-Olga and Grossetti 2008). This paper will use spatial proximity in a more geographical sense: "spatial or physical distance between economic actors" (Boschma 2005, page 69), and so expresses the kilometric distance that separates the involved agents in our collaborations sample.

Previous studies have argued that spatial proximity is beneficial for innovative success and R&D collaborations (Howells 2002; Morgan 2004; Oerlemans et al 2000). Multiple studies build on this arguing; 'the main reason behind these effects is that short geographical distance bring organizations together, favor interaction with a high level of information richness and facilitate the exchange of, especially tacit, knowledge between actors'(Boschma 2005; Petruzelli 2011, page 311). This is due to the fact that close spatial proximity enables daily face-to-face contact which enables quick information exchange, formal or informal, that is especially valuable with tacit and highly complex information (Capaldo and Petruzelli 2014).

When distance increases, the opportunities to set up and maintain social links and information exchange tend to decrease (Boschma 2005). This is because distance undermines the development of trust-based relationships through opportunistic behavior of distant partners (Capaldo and Petruzelli 2014). This in turn causes the partners to shield their proprietary knowledge (Inkpen and Tsang 2005). Furthermore inter-organizational routines, which are important in knowledge intensive cooperation and their success, will be hard to develop without detailed information of organizational practices of the others (Capaldo and Petruzzelli 2014). Preventing these barriers to form by being in close proximity can positively influence the success of the collaboration.

This is not to say that spatial distance makes it impossible for collaborations to be successful: spatial distance can be compensated with organizational and knowledge proximity (Capaldo and Petruzelli 2014; Nooteboom 2007). Because it decreases obstacles in knowledge sharing and lessens the threat of opportunism. Besides this organizations can use temporary geographical proximity (meetings, visits, conferences) to compensate spatial distance (Torre 2008). However, the former might dampen innovative success since there is less knowledge variety, while the latter costs time, money and is not really a long-term solution. Taking all else into account; the first hypotheses of this paper are:

H1A: Spatial distance has a negative influence on R&D product development performance.

H1B: Spatial distance has a negative influence on the R&D project revenue performance.

2.3 Cognitive proximity and R&D collaboration success

Knoben and Oerlemans (2006) distinguished 6 different non-spatial proximities: institutional, cultural, social, technological, cognitive and organizational. This was quite quickly after Boschma (2005) introduced his dimensions. In this paper, we focus on the concept of cognitive distance, intended as differences in the sets of basic values, norms and mental models in universities and firms. (Muscio and Pozzali 2012). These differences are caused by actions in the world (Nooteboom 2000) which influences people on different life paths and in different environments to interpret, understand and evaluate the world in their own way (Nooteboom 2007).

In R&D collaborations cognitive proximity is a determinant not yet extensively researched. This is because R&D used to be internal or between technical companies where cognitive proximity is to a certain extent normal (Knoben and Oerlemans 2006). Since the growth of universities in R&D collaborations cognitive proximity or distance has become an issue. Jargon and mindsets are different in the two spheres and this causes problems (Muscio and Pozzali 2012). To overcome these problems the involved partners first have to become acquainted and transfer tacit traits or values and norms.

As stated before, spatial proximity can enable this transmission, especially in cases of complex, tacit knowledge that needs personal and informal interaction (Maietta 2015). Specifically, codified knowledge, which is standardized and explicit, is easy to transfer over long distances (Maietta 2015) and so ideal to improve cognitive proximity.

When cognitive proximity is high knowledge asymmetry and information thresholds are small and rapidly overcome. However, if the cognitive proximity is too high, the innovative value of the collaboration might get stuck at a point. This is because information homogeneity has limited novelty value (Nooteboom 2007). Assuming organizations try to find a complementary knowledge base in their alliances this will not happen excessively.

Universities and firms working in the same field or industry possess a same basic understanding of their field while maintaining their unique characteristics. Partner characteristics strongly influence the speed of learning in a collaboration and having similarities in knowledge base can improve collaboration success (Sampson 2007). An addition on the learning process, according to Nooteboom (2007, page 1017) "When people with different knowledge and perspectives interact, they stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse knowledge.". This will increase innovativeness and opportunities in combining complementary resources. Thus the second hypotheses of this thesis are:

H2A: Cognitive proximity has a positive influence on R&D product development performance.

H2B: Cognitive proximity has a positive influence on the R&D project revenue performance

3. METHODOLOGY

3.1 Data

Data used for this research paper is based on the larger dataset of collaborative high-tech research projects, funded by the NWO Domain Applied and Engineering Sciences (TTW, previously Technology Foundation STW). NWO "connects people and resources to develop technology with added economic value that contributes to solving societal issues. This is realised through the funding of excellent applied and engineering sciences research, by bringing users and researchers together, and by supervising projects towards optimal opportunities for knowledge transfer" (NWO website, 2017).

Dataset used for this research paper includes the leading technical Dutch universities and their spin-offs, selected research institutes and tech companies, such as Philips, DSM, TNO etc. The project participants involved in these joint research projects are researchers and scientists, both from academic and industry, as well as, the potential users of the results who are not a part of the corresponding research group (von Raesfeld, Geurts, Jansen, et al., 2012).

The time period of these collaborative research projects is between 2000 and 2004, thus it provides sufficient period to estimate the collaborative research results, in terms of generated revenue stream and degree of product development. Additionally, applied database was checked for errors and inconsistencies to detect duplicate or misspelled organisation entries.

3.2 Dependent Variables

The dependent variable in this thesis is collaboration success and is estimated by two parameters. Firstly; as generated continuous or semi-continuous revenue (1) or not generated any revenue (0). The data base provides A, B and C where A equals no revenue generated, B equals semi continuous revenue generated and C equals continuous revenue generated. Since the sample of C was extremely small it has been included with the sample of B. Secondly, in the product development score, where 1 equals a prototype or a fully produced product and 0 equals no product or prototype developed. The expectation that spatial proximity and cognitive proximity positively influence collaboration success is measured through a logistic regression.

3.3 Independent variables

The two main independent or explanatory variables are spatial distance and cognitive proximity. Spatial distance shall be measured in the average kilometric distance between the applicant of the project and the other project partners in the collaboration (Torre and Rallet 2005).The distance is measured through the 'as the crow flies' method which is a straight line between the partners.

The cognitive proximity shall be measured according to how similar the technical fields and industries of the partners are. The database provides types of faculty for universities and shall be enriched with type of industry for firm partners and its NACE code, as approved by the European commission. The cutoff for enough overlap and not enough overlap of cognitive proximity is made at the median: If more than half of the partners work in the same fields and industries, the overlap is high which means it equals 1. If this is less, the indicator is 0. The relationship between the independent and dependent variables shall then be modeled with a logistic regression.

3.4 Logistic regression

A logistic regression is a regression model where the dependent variable, in this case collaboration success, is categorical. Because the outcome of the dependent variable can only be a 1 or a 0 it is called a binary dependent variable and thus the logistic regression is also called binary (Field and Miles 2012). This particular regression model estimates the probability of a binary response based on the two independent variables mentioned above. The result should provide answers as to the significance of cognitive and spatial proximity toward collaboration success.

3.5 Control variables

Controls have been included for the number of participants per project and the departments the participants were in. The database was enriched with the former, while the latter was already included. As shown the range of number of participants per project is one to twelve and the number of different departments is 66. These variables where chosen because they have the potential to influence performance of the dependent variables. The number of participants can influence the variables through the combination of resources or through the multiple communication lines that could become confusing. The department codes within a project could be too similar or too different.

4. RESULTS

A step wise, binary logistic regression was performed to determine the effects of cognitive and spatial proximity on the likelihood of developing a product and generating revenue. Besides this the correlation between the variables have been tested. In table 1 one can see that revenue score and product development show a moderate positive correlation. This shows that having a working prototype or product can increase the revenue for the project. Furthermore, cognitive proximity seems to have a moderate correlation with revenue score and a weak correlation with product development. Signifying that when being in the same technological field or industry it is more likely to make money than producing a product.

In case of spatial proximity, the table shows; the further apart, the less likely to develop a product. This correlation is moderate to weak, the revenue score is also weakly and negatively correlated with spatial distance. In terms of product development, when cognitive proximity changes from 0 to 1 the likelihood of having a product developed decreases by 0.630, the likelihood of revenue generated is significantly decreased by 2.505. The influence of spatial distance is small because it goes by kilometers. For both product development score and revenue score their likelihood is decreased with 0.001 per kilometer.

Hypothesis 1 predicted that spatial distance would have a negative influence on performance which is what the tables (1, 2 and 3) show. In case of product development score the test was statistically significant. Consequently, hypothesis 1a can be confirmed. However, hypothesis 1b can be rejected since the result was not significant. The model explained 16% of the variance in product development score and correctly classified 76% of cases. An increase in partners is associated with the increase of the likelihood of product development and revenue score.

Table 1

Range, Mean, standard deviation and correlations of the variables. (N = 75)

	Range	Mean	S. D.	Revenue score	Product Development score	Cognitive Proximity	Spatial Proximity	Number of Participants	Department code
Revenue score	0-1	0.240	0.430	1					
Product Development score	0-1	0.707	0.458	0.362	1				
Cognitive Proximity	0-1	0.680	0.469	0.319	0.123	1			
Spatial Distance	19.87 – 6247.3	485.694	950.531	-0.126	-0.284	0.008	1		
Number of Participants	1 – 12	5.400	2.493	0.149	0.104	-0.028	0.079	1	
Department Code	1-66	32.093	19.532	-0.157	-0.038	0.005	-0.010	-0.082	1

Table 2

Determinants of Product Development. (N = 75)

	Product development							
	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Constant	0.486	0.774	0.634	0.814	0.658	0.820	0.820	0.840
Cognitive proximity					-0.584	0.535	-0.630	0.556
Spatial Distance			-0.001**	0.000			-0.001**	0.000
Department code	-0.003	0.013	-0.004	0.014	-0.003	0.013	-0.004	0.014
Number of Participants	0.095	0.109	0.152	0.121	0.100	0.110	0.160	0.124
Nagelkerke R^2	0.017		0.138		0.039		0.160	
Chi square	12.685		5.068		7.290		8.071	

** = significant with a score < 0.10*

*** = significant with a score < 0.05*

Table 3

Determinants of Revenue score. (N = 75)

	Revenue score							
	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Constant	-1.296	0.810	-1.231	0.828	-0.876	0.840	-0.737	0.867
Cognitive Proximity					-2.612**	1.088	-2.505**	1.082
Spatial Distance			-0.001	0.001			-0.001	0.001
Department Code	-0.019	0.015	-0.021	0.015	-0.023	0.016	-0.023	0.016
Number of participants	0.126	0.107	0.177	0.116	0.161	0.116	0.176	0.120
Nagelkerke R^2	0.064		0.116		0.248		0.277	
Chi square	5.64		3.852		4.015		3.884	

Hypotheses 2A and 2B predicted that cognitive proximity has a positive effect on performance. Nevertheless, the test concludes that cognitive proximity has a negative effect on product development and revenue score. The latter (table 3) shows a statistically significant result. Therefore, 2A and 2B are rejected. This model explained 27.7% of the variance in revenue score and correctly classified 77.3% of cases. Again the control variable 'number of participants' seems to have an effect on the likelihood of product development and revenue score.

5. CONCLUSIONS, DISCUSSION AND IMPLICATION FOR FURTHER RESEARCH

5.1 Conclusions and theoretical implications

After multiple papers focusing on spatial proximity (Torre 2000; Morgan 2004 and Malmberg and Maskell 2006) which found a positive relation, Boschma (2005) introduced non-spatial proximity. By taking one of the dimensions, that is cognitive proximity, this paper has put focus on researching ambiguity. Since the effect of cognitive proximity is still disputed and the effect of spatial proximity has been shown to be dampened by the non-spatial proximities, this paper tried to find a balance and so contribute to the existing research.

Looking at the findings, both revenue generated and product development are positively influenced by spatial proximity. Solely in the case of product development was it significant. This result could mean that being closer together and transferring tacit knowledge faster comes to a quicker product idea and development.

Revenue generated is a different story, while it is influenced by spatial proximity the result appears to be insignificant. Revenue generated wouldn't actually need a product, it could come from selling intellectual property or findings from the project. In any case, this paper has confirmed that spatial proximity has a positive effect on R&D collaboration success in terms of product development. This is in line with previous research (Balland 2012; Capaldo 2014).

Given that the findings resulted in rejecting hypothesis 2, it seems that, as indicated by Nooteboom (2007), information homogeneity limits innovation value. The difference of impact on the likelihood of revenue and product development, might be explained by the fact that having the same frameworks leads to agreeing on a design faster, yet this design lacks in innovativeness and fails to generate revenue.

5.1.1 Discussion and Limitations

While this thesis encourages debate about the effects of non-spatial proximity on collaborations, it also confirms with the general consensus on the effects of spatial proximity for R&D collaboration success. The positive influence may be explained by the quick trust, accessibility of tacit knowledge and face to face contact (Capaldo and Petruzelli 2014). While the outcome of this test should be taken seriously, one could think of multiple improvements. First, the sample of 75 projects could be larger, so one could inspect a broader spectrum of different and similar projects. Most of the project participants were small businesses within the Netherlands, so that the outcome could be specific to the location at the time of the projects (2000 – 2004). Since then technological advancements have increased possibilities in the high-tech sector, maybe some of the projects could succeed now or succeeded already in a different project composition.

The rejection of hypothesis 2 sparks debate over whether cognitive proximity influences collaboration performance positively or negatively. As mentioned the results could be specific to their time and place. On the one hand, cognitive proximity decreases obstacles of knowledge sharing and improves relationship (Capaldo and Petruzelli 2014). On the other it makes for a similar set of routines, frameworks and resources. This result shows that, in this case, cognitive proximity can dampen innovativeness and new knowledge combinations and so negatively influences collaboration performance.

5.1.2 Implications for further research

Following the recent research on the interaction between spatial and non-spatial proximity, this research adds up to the need for balance of the different proximities. Cognitive proximity seems to have a curvilinear or inverted U-shape relationship with R&D collaboration performance, thus cognitive proximity is beneficial until a certain point, but afterwards has a detrimental effect. Nooteboom (2007) has made a beginning in the search for the optimal cognitive proximity. This research adds to the demand for such an optimal framework.

Researching how spatial proximity is influenced by cognitive, organizational, institutional, social, cultural and technological proximity could support a framework for fruitful collaborations. Furthermore the interplay of these proximities with each other needs exploring. Of course proximity alone is not a guarantee for success. One should realize there are a huge amount of factors influencing a collaborations success. Whether it is the differences in the firms working together, or the team responsible for the development of the concept. As seen in this research, databases could be larger so one can research a broader collection of projects. Multiple timeframes could be investigated for similar projects.

Besides researching a balance in proximities, there seems to be need for a more hands-on approach to success in R&D collaborations. Taking a look at the team's composition and its leaders seems interesting. Researching of the decision making process and concept management could prove important. Furthermore it would be valuable to investigate the innovative capacity of the firms on their joint product development performance. Various control variables can be implemented as well: firm size, firm resources and firm reputation, among others, are interesting.

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