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The role of geographical proximity for project performance – Evidence from the German „Leading -Edge Cluster Competition"

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Abstract

The role of geographical proximity in fostering connections and knowledge flows between innovative actors ranks among the most controversial themes in the research of innovation systems, regional networks and new economic geography. While there is ample empirical evidence on the constituent force of co-location for the formation of research alliances, little attention has been paid to the actual consequences of geographical concentration of alliance partners for the subsequent performance of these linkages. In this paper we address this underexplored issue and aim to complement the rare examples of studies on the relevance of geographical proximity for research outputs. We utilize original and unique survey data from collaborative R&D projects that were funded within the "Leading-Edge Cluster Competition" – the main national cluster funding program in Germany in recent years. We find that the perception of the necessity of spatial proximity for project success is rather heterogeneous among the respondents of the funded projects. Moreover, the relationship between geographical distance and project success is by no means univocal and is mediated by various technological, organizational and institutional aspects. Our findings strongly support the assumption that the nature of knowledge involved determines the degree to which collaborators are reliant on being closely located to each other. The relevance of spatial proximity increases in exploration contexts when knowledge is novel and the innovation endeavor is more radical while this effect is less pronounced for projects with a stronger focus on basic research. Moreover, geographical proximity and project satisfaction foster cross-fertilization effects of LECC projects.

Keywords: geographical proximity; collaboration; performance; innovation policy.

JEL classification: O3, O38, L14, R1

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1. Introduction

The perception that innovative activities exhibit a strong regional component and insights into the supportive role of agglomeration and regional networking on innovation led to a shift in modern innovation policy towards the funding clusters or regional networks (Eickelpasch and Fritsch 2005, Koschatzky 2000). With the rediscovery of Marshallian agglomeration externalities in the course of the emergence of the cluster approach (Porter 1990, Baptista and Swann 1998), academia and policy makers acknowledged the role of geographical proximity of actors as an important context condition for successful knowledge production and innovation. While early approaches have assumed a linear and direct relationship between geographical proximity, learning and innovative success (Crescenzi 2014, D'Este and Iammarino 2010), the emphasis of subsequent research has shifted away from solely regarding spatial proximity as the main constituent of local knowledge spillovers (Boschma 2005, Breschi and Lissoni 2009). Rather the embeddedness into the regional network of formal and informal relationships, linkages to the main regional knowledge producers as well as the regional industry structure have been identified as decisive for access to and exploitation of the regional knowledge pool (Giuliani 2007, Beaudry and Breschi 2003, Aharonson et al. 2008, Frenken et al. 2007, Cooke et al. 1997). Moreover, the formation of these linkages and their efficiency in terms of knowledge exchange are driven by the interplay of geographical proximity with other types of non-spatial proximities (Boschma 2005, ter Wal and Boschma, 2009, Crescenzi 2014).

Regional clusters are acknowledged as spaces which combine these multiple dimensions of proximities and are therefore considered as breeding grounds for innovation and growth. The arguments offered by the cluster concept and related approaches such as regional innovation systems as well as the ongoing debate on the advantages of regional specialization versus diversification constitute the main rationale for a regionally oriented innovation policy. In 2007, the German ministry for education and research (BMBF) followed up previous, successful programs by launching the "Leading Edge Cluster Competition", an initiative that aims at funding joint R&D-projects in selected cluster regions. In three waves (2008, 2010, 2012), 15 clusters were selected to be labeled as "Leading Edge Clusters" and to be funded for a five-year period with up to 40 million Euro each. Since one of the main targets of this policy was to support regional networking, we ask whether this strong focus on supporting regional linkages is reasonable given that the evidence on the role of geographical proximity is inconclusive and scholars have stressed that it is neither a necessary nor a sufficient condition for knowledge spillovers (Breschi and Lissoni 2003).

Furthermore, even though ample empirical evidence exists on the ex-ante constituent effects of geographical proximity along with other types of proximities on the formation of research alliances, little attention has been paid to the actual consequences of geographical concentration of alliance partners for the subsequent performance of these linkages (Crescenzi 2014). Pioneering work has even pointed to a rather paradoxical effect of proximities, as they indeed foster link formation, but subsequently do not manifest in superior innovative performance (Broekel and Boschma 2012). In turn, concrete conclusions and implications can hardly be drawn from prior work as the results reveal a quite ambiguous picture and give rise to the question about unobserved factors that mediate this relationship.

The contribution of this paper is to address this underexplored issue and complement the rare examples of studies (Staber 2001, Mora-Valentin et al. 2004, Oerlemans and Meeus 2005, Lhuillery and Pfister 2009) on the relevance of geographical proximity for research outputs. We utilize an original and unique dataset from as survey with project managers of collaborative R&D projects that were funded within the “Leading-Edge Cluster Competition”. With the analysis of this rich data, we try to shed some light into the complex and multifaceted relationship between the geographical proximity and the outcome of the R&D projects under study. By means of cross-sectional analysis, we proceed in three steps to display the highly intertwined relations between geographical proximity, peculiarities of the research projects, and their subsequent successful performance. In a first step, we elaborate on the basic determinants of the relevance of geographical proximity to collaboration partners from the perspective of project managers. In a second step we link these results to intermediate project success and examine the joint effect of spatial proximity and social proximity on the overall satisfaction with project cooperation. The resulting estimates are then incorporated within a third model that relates project satisfaction to subsequent project output in terms of cross-fertilization and the introduction of product and process innovations.

Overall, we find that the relationship between geographical proximity and project success is by no means univocal but rather mediated by various technological, organizational and institutional aspects. Our findings suggest that the nature of knowledge determines the degree to which collaborators prefer to be co-located. The relevance of spatial proximity increases in contexts where knowledge is novel to the organization and the innovation endeavor is more radical while this effect is less pronounced for projects in basic research. In addition, we find significant actor specific differences concerning the role of spatial distance for project satisfaction. Firms' project satisfaction decreases significantly compared to that of research institutes with increasing distance to their collaboration partners. In line with existing studies (Gulati 1995, Gulati and Gargiuolo 1999, Mowery et al. 1998, Ahuja 2000, Singh 2005), that underpin the importance of social proximity for successful cooperation, we observe that common project experience is a strong predictor of project satisfaction. Contrariwise, we cannot observe a substitutive relationship between geographical proximity and social proximity. With regard to final project results, we find that both, geographical proximity and project satisfaction support the cross-fertilization effects between the LECC projects and other projects.

The paper is organized as follows: in Section 2, we provide a general overview of the related literature and present major findings from prior studies on the relation between proximity and project performance. Building on that, we derive our research hypotheses in Section 3. Section 4 will introduce our basic methodology. Subsequently, the hypotheses are tested in Section 5. The final section concludes, discusses our results and highlights policy implications and potential avenues for further research.

2. Proximity and Performance

The early 1990s have seen an upsurge of studies which fathomed the factors behind the phenomenon of regionally clustered innovative activities and their uneven distribution across space (Jaffe et al. 1993, Audretsch and Feldman 1996, Porter 1990, 1998). The discovery of the beneficial effects of co-location of economic actors has equally affected academia and policy makers in the development of new regional concepts and policy programs.

The economic benefits of co-location have already been described by Alfred Marshall in 1890. According to him, the basic advantages that arise from the dense location of similar actors stem from the exploitation of regional synergy effects of and opportunities for resource sharing. Co-located economic agents share access to specialized labor and supplier markets and benefit from the proximity to important customers and local markets. These ideas experienced a renaissance after Porter made the idea of agglomeration of related industries popular and subsumed them under the concept of clusters (Porter 1998). Porter added the thoughts on the vital role of increased cooperation and competitive pressure in limited geographical space as explanatory factors for superior innovative and economic performance of spatially concentrated actors. Later concepts, mainly the regional innovation systems approach, focused more on explaining the regional production of knowledge and innovations rather than on pure economic benefits (Cooke et al. 1997, Braczyk et al. 1998). The idea behind regional innovation systems is that a region's innovation potential is strongly contingent on the interplay of several actors of knowledge production and usage, the linkages among them and the involved region-specific institutions. Another ongoing debate in a related stream of literature concerns the optimal regional industry structure, that is specialization vs. diversification, in order to benefit from co-location (Frenken et al. 2007, van Oort et al. 2015, Galliano et al. 2014).

The main ingredient common to all these concepts which constitutes the importance of geographical proximity for innovative capabilities is the observation that local knowledge spillovers are spatially bounded (Jaffe et al. 1993, Mansfield and Lee 1996, Crescenzi 2014). Technological know-how is sticky since it has tacit components (Polanyi 1966, Cowan et al. 2000). Therefore its diffusion requires continuous face-to-face interactions especially in the early stages of an industry when newly generated knowledge is highly complex and specific and therefore hard to codify (Breschi and Lissoni 2001, Audretsch and Feldman 1996). In this regard, geographical proximity has been pointed out to be supportive for knowledge transfer by decreasing the costs of traveling, of obtaining face-to-face contacts and for partner search (Breschi and Lissoni 2001).

Building on that, more recent studies have challenged the view that solely being co-located to innovative actors is a sufficient precondition for the exploitation of the fruitful effects of local knowledge spillovers. They emphasize the crucial role of the embeddedness in regional networks to gain access to the prolific regional knowledge pool and to be connected to appropriate partners (Giuliani 2007). It is not only geographical proximity but also its interplay with other types of non-spatial proximities that drive the formation of these linkages and their efficiency in terms of knowledge exchange (Boschma 2005, ter Wal and Boschma 2009, Crescenzi 2014). More concretely, the probability to form research collaborations is positively affected by the regional proximity of actors certainly due to cost advantages but also through fostering the establishment of social proximity and cognitive proximity between potentially connected actors. Closely co-located actors are more prone to connect with each other as they have a higher awareness of each other and can more easily observe their respective capabilities and opportunities compared to those of more remote actors (Hazir and Autant-Bernard 2011). Over time repeated interpersonal contacts and efficient knowledge exchange are responsible for the emergence of two non-spatial proximities, cognitive proximity between partners on the one hand and social proximity (trust) among them on the other (Boschma 2005). The cognitive dimension manifests in a common knowledge base and appropriate absorptive capacities that are decisive to warrant common understanding and learning entailing efficient knowledge transfer and higher potentials to innovate (Cohen and Levinthal, 1990, Noteboom et al. 2007, Boschma 2005, Crescenzi 2014). And social proximity between the collaboration partners serves as a control mechanism to reduce the risk of undesired knowledge flows and the danger of opportunistic behavior (Breschi and Lissoni 2003, Boschma 2005, Cantner and Graf 2011).

Empirical studies on this issue have emphasized various types of proximity as *constituent* factors for the formation of research collaboration (Katz 1994, Cantner and Meder 2007, Cassi et al. 2014, Balland et al. 2013, Singh 2005, Cassi and Plunket 2012). While focusing on geographical proximity, Hazir and Autant-Bernard (2011) refer to this as the *ex-ante* effect of proximity on the collaboration decision as actors expect higher returns from collaboration with proximate partners and therefore connect to them. Most work in this field studies either the collaboration propensity conditional on geographical proximity along with other proximity dimensions or explain how geographically distant partnerships are characterized.

For instance, Cantner and Meder (2007) analyse German co-applications for patents from all topical areas to investigate whether geographical and cognitive proximity increase the likelihood to collaborate. They find that both proximity dimensions increase the probability to appear on a co-patent.

D'Este and Iammarino (2010) investigate the frequency of university-firm relationships in the UK and the spanned geographic distance therein. They explain the frequency of collaborations by the distance between partners and regress geographic distance on several partner characteristics. They observe that geographical proximity fosters the frequency of interaction between industry and academia in applied research (engineering disciplines) but not in basic research. Another interesting finding is that partners' expertise might substitute for geographic distance. The benefits of expertise seem to outweigh the costs of collaboration over larger distances. However they find that this effect decays when the distance becomes too large.

Following this study, Garcia et al. (2013) ascertain whether similar patterns can be observed for industry-university linkages in Brazil. They also control for the quality of research output when explaining the geographic distance between research partners. In line with D'Este and

Iammarino (2010) they find that partners are more prone to look outward for higher expertise, but again this relationship is rather curvilinear and only holds up to an intermediate level of distance.

While there is vast empirical evidence on the interplay between (geographical) proximities and the formation of cooperation, there is sparse evidence on the role of geographical proximity for project outcomes, i.e. the *ex-post* effects of proximity on collaboration. Geographical proximity is found to be positively correlated with firm performance in terms of economic and innovative outcomes (Oerlemans and Meeus 2005), with survival rates of SMEs (Staber 2001) or with continuation respectively successful finish of research projects (Lhuillery and Pfister 2009). No proximity effects are observed on cooperation satisfaction or the longevity of industry-research partnerships (Mora-Valentin et al. 2004). However, these studies do not account for other types of proximity, such as social or cognitive ones. The study by Boschma and Broekel (2012) is the only one that considers multiple types of proximities. They find a somewhat paradoxical effect of geographical proximity on performance: while co-location seems to be a crucial driver of link formation, it does not affect subsequent innovative performance.

In sum, the ambiguous and sparse evidence on the role of geographical proximity for project success questions the necessity to primarily foster regional linkages in modern innovation policy. And in light of recent findings on the danger of regional technological lock-in and the vital role of extra-regional linkages in their prevention one may ask whether this policy perspective is too restricted and even outdated (Bathelt et al. 2004)? In order to give an answer it is necessary to analyze whether there are main confounding factors that condition the supportive role of geographical proximity on project performance. In this respect, the relevance of geographical proximity for the successful implementation of R&D projects seems to be still a relevant research issue (Hazir and Autant-Bernard 2011). Building on this, we investigate research relationships that have already been formed and analyze how project managers evaluate project performance contingent on their project partners' geographical proximity as well as further confounding, mediating or moderating factors.

3. Hypotheses

Our study raises three interrelated research questions addressing the role of geographical proximity for cooperation: Do cooperating actors perceive geographical proximity necessary in order to be successful? Does geographical proximity yield higher satisfaction in cooperative projects? Does geographical proximity indirectly via project satisfaction and directly increase success chances in terms of final project results?

We suggest that technological and organizational specificities of collaborative research projects govern the necessity for spatial proximity and that geographical proximity along with other factors increases project satisfaction and in turn the final project results. Our main assumption is that geographical proximity eases coordination and knowledge transfer within collaborations and increases the probability of success via decreasing the costs of personal contacts, leading to better communication and knowledge exchange conditions, and the creation of trust. However, the context of the research projects in terms of research orientation, exploration of new knowledge and the familiarity with research partners determines the need for continuous personal interaction and might render the argument for the advantages of geographical proximity obsolete.

To be more specific, we assume that geographical proximity is especially relevant for project success, if the project focus is on exploring a radical novelty rather than a mere advancement of previous results. Therefore, when we consider novelty, we relate it to the exploration of new opportunities rather than the continuation or exploitation of prior generated knowledge (March 1991). Because knowledge in explorative research is highly complex and specific, it is hard to codify and to share without permanent personal communication and interaction. Since, as pointed out earlier, geographical proximity eases personal interaction and knowledge exchanges, we assume that more explorative and novel research projects are more reliant on close geographical linkages. Hence, we put forward that:

H1: The relevance of geographical proximity for project success increases with the degree of novelty of the project.

Novelty can be defined along several dimensions and we apply hypothesis H1 to each one of them.

As first dimension, research endeavors can be characterized as novel when they are targeting radical novelties that significantly differ from prior research results. So for radicalness of the knowledge produced as the first dimension of novelty we suggest:

H1a: The relevance of geographical proximity for project success increases with the radicalness of the novelty.

A second dimension of novelty relates to the familiarity with the technology applied in the research project. Actors who are unfamiliar with the technology utilized in the project might require face-to-face interaction with their partners more frequently to increase learning. Therefore we assume that respondents who work with a technology that is new to them value geographical proximity to their partners higher. Hence, we propose:

H1b: The relevance of geographical proximity for project success increases with the novelty of the applied technology within the project.

A third dimension of novelty concerns whether projects establish new research lines or represent a continuation of activities from prior projects. Contrariwise to radicalness and familiarity with the applied technology, geographical proximity might be less relevant for projects that perpetuate activities from prior related projects since certain routines and processes or institutions are already established. Therefore we assume that:

H1c: The relevance of geographical proximity for project success decreases with the number of prior related projects.

Building on that, we explore how geographical proximity is associated with project performance. As a first step we consider project satisfaction as the intermediate outcome. Based on the above argument, we presume that geographically close partners tend to be more satisfied with their projects since communication and knowledge exchange is eased by geographical proximity.

H2: Project satisfaction increases with proximity between partners.

H2a: Project satisfaction increases with geographical proximity between partners.

In the same vain, we expect that social proximity also directly effects cooperation satisfaction. We assume a positive relationship between social proximity and project satisfaction.

H2b: Project satisfaction is positively associated with social proximity (acquaintance of partners).

For the direct relation formulated in H2 we additionally consider other confounding factors and moderation effects. First, this relationship might be moderated by the perceived relevance of geographical proximity for project success. For respondents who deem co-location to their partners as irrelevant, the actual distance to their partners should not affect project satisfaction. Vice versa, we expect that actors, who evaluate geographical proximity to partners as essential while their project partners are remotely located, will be less satisfied with the project.

H2c: The link between project satisfaction and geographical distance is moderated by the relevance of geographical proximity for project success.

Another important factor driving project satisfaction is the acquaintance of partners through prior project experience, i.e. social proximity. Multiple studies have pushed forward arguments for a substitutive relationship between geographical proximity and social proximity. In our study we assume that collaboration with distant partners is easier when they have previously worked together and could establish communication routines and trust. When partners are socially proximate they already exhibit a certain level of trust and are not reliant on frequent interaction and observation of the partner’s behavior. Therefore we assume that already known partners are unaffected by geographic distance in their satisfaction with the overall collaboration.

H2d: The relation between geographical proximity and project satisfaction is moderated by social proximity between the partners.

Finally, and based on the arguments that already led to hypothesis 2, we expect that projects between geographically proximate partners are more successful than between distant partners. However, we assume that in addition to a direct effect of proximity on success there is also an indirect effect via increased project satisfaction. It seems plausible to expect that more satisfied researchers display higher productivity and more outcomes. Also project satisfaction captures latent problems/ hurdles within the projects, which might hinder the success of the project. Therefore, we assume:

H3: Project outcome is positively correlated with geographical proximity.

and

H4: Project outcome is positively correlated with project satisfaction.

4. Methodology

4.1 Data

The Leading-Edge Cluster Competition (LECC) was a national, technology open cluster funding program launched by the German Federal Ministry for Education and Research (BMBF) in 2007, which aimed at funding collaborative R&D projects in selected cluster regions. Following recommendations of an expert jury, the Federal Ministry appointed 15 Clusters in three waves (2008, 2010, 2012) to be labeled as Leading-Edge Clusters and to receive funds amounting up to 40 million euros per cluster over a 5 year period. The funds were distributed to organizations in the winning clusters to conduct R&D projects in collaboration with cluster partners[1] under a common leading cluster theme. Within the scope of the BMBF funded research project "Evaluation of the German LECC", surveys were conducted between 2010 and 2013 with beneficiaries of the ten selected clusters of the first two waves[2]. As part of these surveys, project managers were asked to evaluate processes and activities within the LECC-funded projects. To analyze cooperative processes, we consider only those respondents who participated in a joint research project (i.e. we excluded information from individual projects). These joint research projects can be understood as collaborations which are divided into subprojects concerned with specific aspects relevant to the common themes. The respondents, either employees of a research institute, a university or a firm, were the managers of these subprojects. Therefore, our dataset includes multiple responses within the same joint projects. This allows us to calculate relative distance measures within one joint project as well as to observe deviations in satisfaction levels of respondents within the same project. We exploit this unique dataset and complement information on project activities and outcomes with information on respondent's geographical location. Even though the data was collected in consecutive interrogation rounds at different points in time, several items were not repeatedly reported and therefore our data is of cross-sectional nature.

4.2 Sample characteristics

In total, our sample comprises 475 consistent responses across all interrogation rounds by project managers of 101 joint projects. Table 1 provides an overview of the sample

[1] Cluster partners do not necessarily have to be located in the cluster region.
[2] Since the third wave was selected in 2012 and the distribution of funds for the single projects effectively started in 2013, it was too early to collect meaningful data by means of surveys with these beneficiaries.

characteristics and the distribution of responses across clusters and actor types. The responses are almost equally distributed across actor types (last column). When annulling size differences and aggregate answers of large firms and SMEs, a dominance of firms prevails in the data set (two thirds of the respondents are enterprises). The number of responses per cluster is very uneven (last row), ranging from a minimum of 23 to a maximum of 98 cases. This can partly be explained by the fact that the second wave clusters comprise a larger number of beneficiaries.

Table 1
Distribution of answers across Clusters and actor type

	First round					Second round					
	BioRN	Cool Silicon	FOE	Aviation	Solar Valley	m4	MV	MicroTec	Software	Logistic	∑
Large firms	5	8	15	20	19	2	12	19	7	35	142
SME	16	10	3	8	7	17	24	35	11	31	162
RI	2	15	10	11	22	22	13	35	9	32	171
∑	23	33	28	39	48	41	49	89	27	98	

4.3 Variables

In order to analyze the interplay between geographical proximity, project satisfaction and project performance, we estimate three models with different dependent variables capturing three interrelated topics: the *relevance of geographical proximity for project success*, *project satisfaction* and *project results*. The description of the variables including selected summary statistics can be found in table A-1 in the appendix.

Dependent Variables

Relevance of geographical proximity for project success (self-reported). In the first model, we aim to explain under which circumstances geographical proximity between project partners is relevant for the success of the research project (*Relev.geo*). Project managers were asked to evaluate on a scale from 1 to 5 (where 1 equals “I strongly disagree” and 5 “I strongly agree”) whether geographical proximity is a central precondition for their project success.

Project satisfaction. For the second model, we include project managers’ satisfaction with several aspects of the project implementation depending on the type of partner (research institute *.ri* or company *.comp*) as intermediate outcome variable. The project managers were asked to evaluate the cooperation in general (*coop.ri* for cooperations with public research institutes or universities, *coop.comp* for cooperations with companies), know-how transfer into their own organization (*KH.ri, KH.comp*), information transfer between the partners (*info.ri, info.comp*), and coordination with the partners (*coord.ri, coord.comp*). Respondents could express their satisfaction with each project attribute (item) on a scale from 1 to 5, where lower values correspond to lower satisfaction and vice versa. Since some of the projects were still running while the survey was conducted, we assume that project satisfaction items already capture the prospective project success that manifests in concrete project outputs in later stages.

Project results. In order to analyze the relation between project satisfaction and final project results in the third model, we proxy project success by indicators for cross-fertilization effects (*cross.fert*) and innovation production (*inno.bin*). Concerning cross fertilization, respondents were asked if project results can already be used as inputs for other projects in the organization's portfolio (from 1 – strong disagreement to 5 – strong agreement). Innovation output is captured as binary information (0=no, 1=yes) if novel and significantly improved products, services and processes have been launched by the respondent organization as a result of the project work.

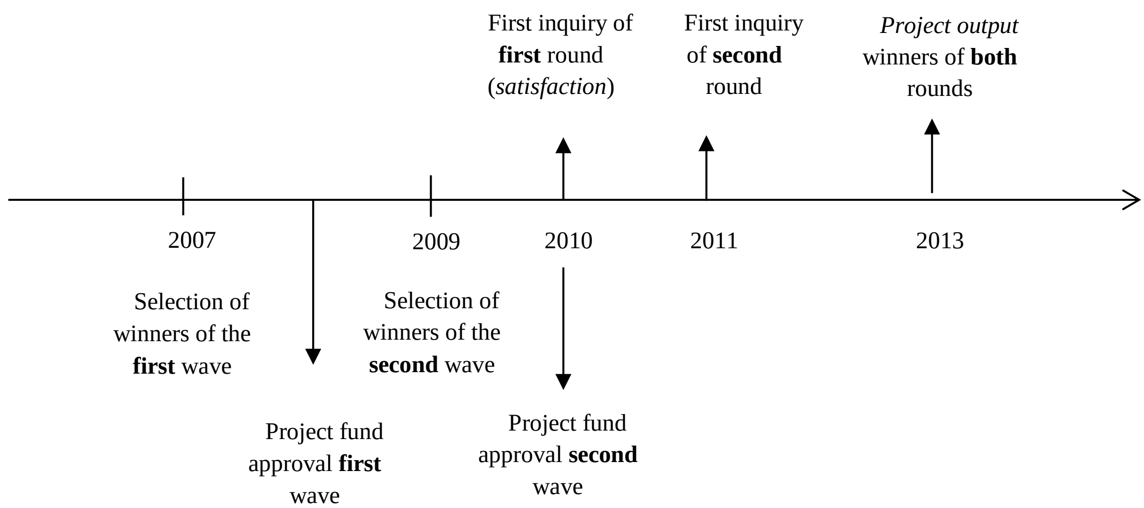

Fig. 1
Timeline of data collection and project progress

We assume project satisfaction and project results to be strongly correlated. This could be simply due to the fact that both proxies might capture the same underlying factor and face the danger of being highly endogenous. The separate collection of information on project satisfaction and project output in different interrogation rounds – project satisfaction was asked in 2010/2011, the project results in 2013 – reduces this risk. The data collection process along with the project progress is shown in figure 1.

Independent Variables

Novelty. We assume that the degree of novelty of the project determines the relevance of partners' geographical proximity for successful project accomplishment. To test this, we divide novelty into three sub aspects. First, we measure the degree of radicalness of the targeted innovation production (*radical.inn).* Respondents were asked to indicate on a scale from 1 (strongly disagree) to 5 (strongly agree) whether the project aimed at generating a radical novelty. Second, the familiarity with the knowledge applied in the project might shape the necessity for geographically close interaction. This aspect (*tech.new*) is measured by the respondents' agreement to the item "*The technology used in this project is completely new to us*" (same 5 point likert scale as before). Third, we also want to consider internal aspects of novelty by asking whether there have been prior projects to the current project (*prev.proj*). This variable is of binary nature, indicating whether the current project continues work from previous projects (one) or not (zero). Of these three novelty aspects, only *radical.inn* and *tech.new* are correlated (see results section and table A-3 in appendix).

Geographic distance. To analyse the correlation between geographical distance and project satisfaction, we employ several distance measures. Based on the respondents' locations, we compute the average distance in km to all partners (managers of subprojects) within the joint project (*avrg.dist*). To also differentiate between projects that are clustered close in space as compared to projects with core-periphery structures, we calculate a relative distance measure that takes into account the distance of each respondent to a pre-defined geographical core or center of the joint project (*cent.dist*). We identify those cities as project centers where the majority of partners is located. We assume that this center hosts the core activity of the project work due to the clustering of project partners.

Social proximity. In previous research, social proximity has been identified as a crucial factor in mediating the positive effects of geographical proximity on collaboration (Breschi and Lissoni 2009). We measure social proximity (*soc.prox*) on a scale from 0 to 3, increasing with the share of partners known from previous collaborations.

Controls. Apart from these main variables of interest, we include additional variables to control for factors that might influence our dependent variables. When talking about the importance of geographical proximity, one has to control for the general goal of the project as the relevance of geographical proximity for project success might differ for projects that aim at establishing regional infrastructure (qualification programs, start-up climate) as compared to ones that explicitly aim at producing novel knowledge. Therefore we differentiate between projects that aim primarily on the development of new product and process innovation (*goal.prod.inn, goal.proc.inn*), the support of start-ups (*goal.found*) or the development of qualification and educational programs (*goal.quali*). Since projects might pursue different goals simultaneously, each of these variables indicates the relative importance of each goal on a five point Likert scale. Closely related to that, it has been found that effects of geographical proximity on success are less pronounced for research endeavors that are basic rather than applied (Mansfield and Lee 1996). For this reason, the basic nature of each research project is proxied by the respondent’s binary indication regarding the potential of the project results to be implemented directly in new products/processes (*applied*).

In the second model, further confounding factors that might drive the variance in perceived project satisfaction are project size as measured by the number of organizations collaborating in one project (*proj.size*), whether the respondent was the initiator of the project (*proj.init*), the general importance (*proj.import*) of the project for the respondent in terms of network activities (i.e. to identify low engagement in joint projects due to deviating targets) and whether the project would have been dismissed without funding (*proj.dismiss*). Larger projects might receive lower satisfaction scores since they require higher coordination, communication and transaction costs. Likewise, projects which are more important for the respondent organization might be evaluated better.

In explaining project results in terms of the generation of innovation and cross fertilization effects, we also control for R&D-input measured by the number of highly skilled employees in the project (Human Capital Input - *highskill*).

Moreover, in all three models we control for actor type (*Comp.* or *RI* - whether the respondent is an enterprise or research institute) and cluster specific effects (to account for unobserved differences between clusters, such as technology, potential governance, overall network structure, etc.).

4.4 Estimation strategy

The relations that we aim to analyze are highly intertwined. Geographical proximity between the research collaborators as our main variable of interest is assumed to be a crucial determinant of project satisfaction which in turn should affect later project outcomes. The relation between geographical proximity and project success is in turn mediated by other factors. For this reason, we follow a three stage estimation strategy in which the predicted values of the previous step are integrated as independent variables in the subsequent step. Since all our dependent variables represent a set of choices (response categories), we apply discrete choice models. In these models one estimates the probability for a certain choice dependent on the characteristics of the individual respondent. For the n response categories, we estimate the following models:

Step I. In the first model, we estimate the conditions (novelty, project goals) under which geographical proximity is seen as a necessity for the successful accomplishment of the project. Since the response categories are ordered along ascending agreement we estimate an ordered logistic regression model. For each response category j from 1 to n-1[3] the ratio between the probability that the observed response is below category j and the probability that the response score is above the category j is calculated (left hand side) (Wooldridge 2003). In this step, the categories range from 1 to 5. To be more specific, we regress the response for the relevance of geographical proximity $relev.geo_i$ on the radicalness of the project ($radical.inn_i$), the familiarity with the technology applied ($tech.new_i$) and whether the current project is based on previous project activities ($prev.proj_i$). The last summation term represents further control variables.

$$ln\left[\frac{P(relev.geo_i \leq j)}{1 - P(relev.geo_i \leq j)}\right] = \beta_0 - (\beta_1 radical.inn_i + \beta_2 tech.new_i + \beta_3 prev.proj_i + \sum_{k=1}^{n} \gamma_k c_{ik})$$

$$j = 1,2,\ldots,n-1$$

Step II. In the second model, we regress the satisfaction of project managers with certain aspects of the project work ($coop_i$) on their geographic distance ($geogr.dist_i$) to partners within the joint project, the predicted values of the perceived relevance of geographical proximity from the first model ($relev.geo_i$), their social proximity ($soc.prox_i$) and other confounding factors. $Coop_i$ represents the various aspects of project work that the respondents

[3] n-1 because the cumulative probabilities are computed and this would equal 1 for the n[th] category.

were asked to evaluate: general cooperation satisfaction (*coop*), know-how transfer (*KH*), information transfer (*info*) and coordination (*coord*). The response options again range between 1 and 5 in ascending order. $geogr.dist_i$ stands for the two spatial distant measures *avrg.dist* and *cent.dist*. Just as in step I, the last term represents the further control variables.

$$ln\left[\frac{P(coop_i \leq j)}{1-P(coop_i \leq j)}\right] = \beta_0 - (\beta_1 geogr.dist_i + \beta_2 relev.geo_i + \beta_3 soc.prox_i + \beta_4 geogr.dist_i * relev.geo_i + \beta_5 geogr.dist_i * soc.prox_i + \beta_6 geogr.dist_i * Comp_i + \sum_{k=1}^{n} \gamma_k \, c_{ik})$$

Step III. In step three we finally want to elaborate, whether projects with more satisfied participants exhibit a higher success probability. Therefore we relate the predicted values of overall project satisfaction ($coop_i$) from the second step and the geographic distance to the partners ($geogr.dist_i$) to the project results ($result_i$) in terms of cross fertilization effects (*cross.fert*) and innovative performance (*inno*). The response categories j for *cross.fert* range from 1 to 5 and we apply an ordered logit model as well. Since the responses for *inno* are binary (0 – no innovation, 1 – innovation), we employ a binary logistic regression model. Analogue to the first two steps, the last term represents further control variables.

$$ln\left[\frac{P(result_i \leq j)}{1-P(result_i \leq j)}\right] = \beta_0 - (\beta_1 coop_i + \beta_2 geogr.dist_i + \sum_{k=1}^{n} \gamma_k \, c_{ik})$$

5. Results

There is suggestive evidence that the probability to form a collaboration is highest when actors are located close-by and that the interaction likelihood decreases sharply above a distance of about 100 km between the partners, which equals approximately one hour of travel time between collaborators (Garcia et. al 2013).

Accordingly, as can be seen in figure 1 (and table A-1 in the appendix), the spatial distance between participants in the funded R&D projects in our sample conforms to prior findings with the majority of project partners being located within (median of *avrg.dist*) 107 km of each other. Beyond this threshold, the number of distant project members drops sharply. Additionally, the highly skewed distribution of the average distance (red line) and its concentration at rather small values (75% of observations are below 166 km) reflects the strong regional focus of the competition. Far distant partners can inflate the average distance measure of the respondents to their partners. Therefore we also calculated the distance of each respondent to the identified geographical core of the joint project (*cent.dist*). The distribution of this measure is represented by the blue line in the same figure. The median distance of partners to the center equals 20.1 km, which also mirrors the selective support of regional linkages by the program.

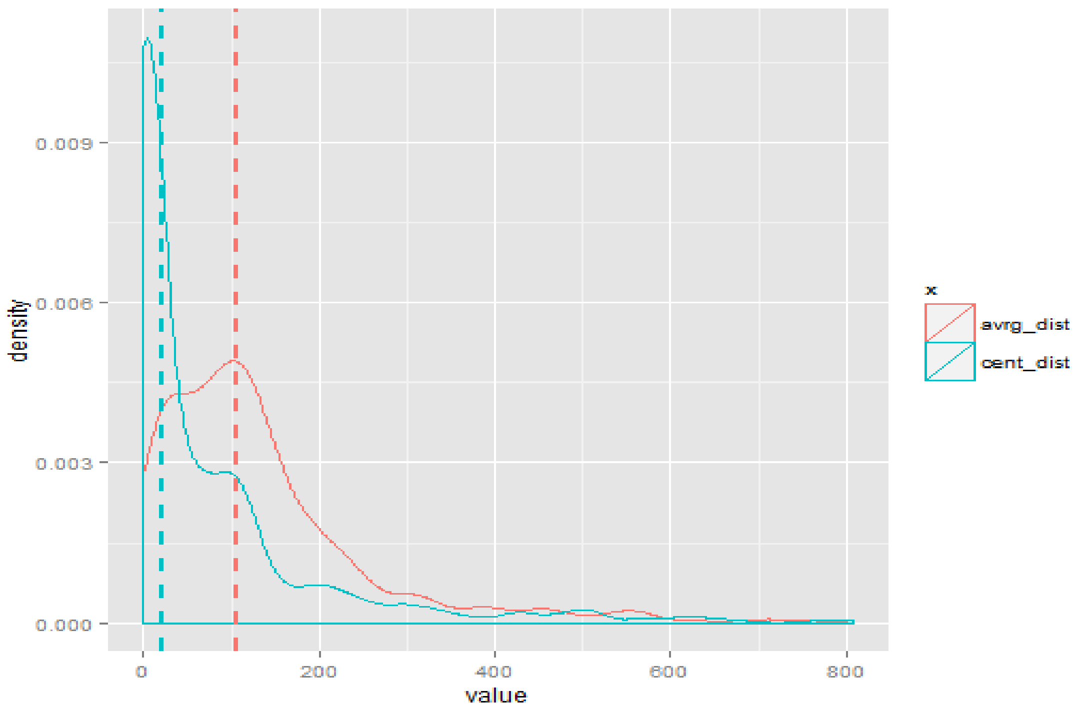

Fig. 2
Distribution of *avrg.dist* and *cent.dist* with respective median (dashed line)

Table 2
Distance between project partners by collaboration type (absolute numbers of cases per collaboration category)

	1 research-industry	2 inter-academia	3 interfirm
No. of collaborations with distance ≥ 100 km	50	2	4
No. of collaborations with distance < 100 km	33	4	8
Median of avrg_dist to project partners	118.20	73.45	56.33

Furthermore, Garcia et al. (2013) have also stressed, that geographical proximity particularly plays a role in industry-university collaborations. In their study, the majority of collaborations of this type were formed with partners that were less than 100 km away. When subdividing our sample by the type of collaboration (research-industry, inter-academia, interfirm) and comparing them in terms of their average distance between the partners in one project, reveals a somewhat deviating picture (table 2). Collaborations that exhibit some degree of institutional proximity, i.e. between actors of the same type as shown in column 2 and 3 are more proximate to their partners. In contrast, collaborations between research institutes and firms are more likely to include more distant partners. However, the number of industry-research collaborations in our sample is far higher than for the other cases.

These results are also mirrored in the self-reported evaluations of the project managers when asked whether geographical proximity is an important precondition for project success. Figure 2 shows the distribution of answers across agreement levels. In general, slightly more than half of the respondents (52%) confirm the need of being closely located to each other in order to be successful. However a non-negligible share of respondents is rather neutral or disagrees to this statement.

To elaborate further on what drives this heterogeneity concerning the perceived relevance of co-location, we regress the categorical responses on certain peculiarities of the research projects such as the novelty of the project activities, the applicability of the results as well as the targeted goals and control for actor and cluster specific effects. Table 3 presents the estimation results of our first model. We start by including our main variables of interest and then stepwise introduce the dummies for actor type and cluster to check the robustness of our findings.

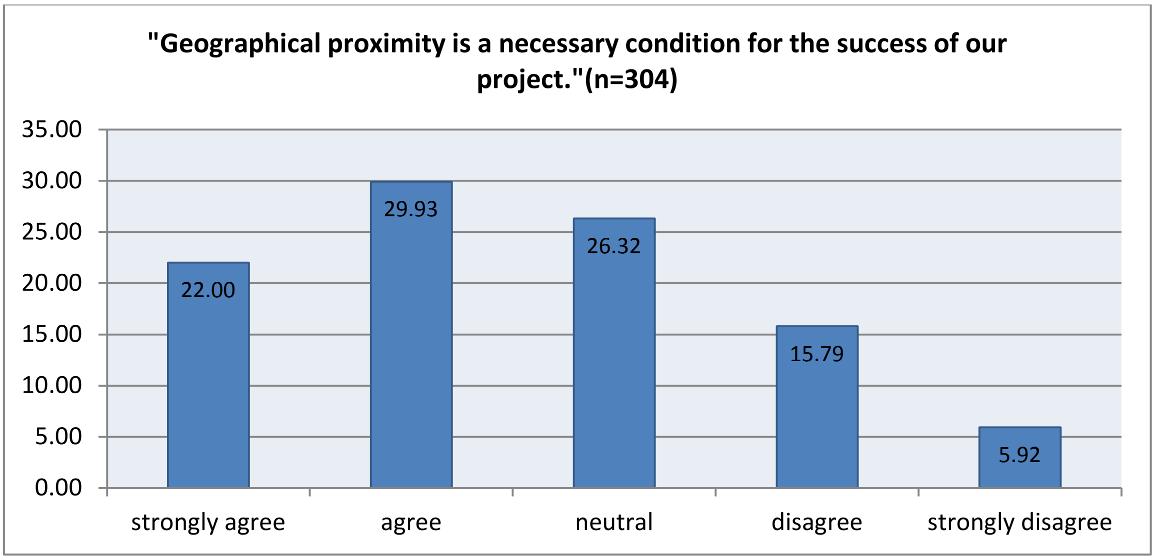

Fig. 3
The necessity of geographical proximity for project success (own analysis based on the surveys from the LECC)

Basically, we find mixed results for the hypothesized positive relation between novelty of the collaborative research endeavor and the relevance of geographical proximity to warrant success (H1). Concerning the extent of novelty production and the familiarity with the technology applied, we find partial support for our hypotheses 1a and 1b. The relevance of geographical proximity for successful project implementation increases with the exploratory nature of the project activities in terms of producing more radical innovations (*radical.inn*) as well as applying new technologies (*tech.new*). But this effect disappears after controlling for specific project goals, type of respondent and cluster. Instead we observe that for members of projects focusing on the development of process innovations, geographical proximity is of minor importance. This relation holds in all model specifications.

With regard to the organizational aspect of novelty, we find that projects that were established as continuation of prior project activities are more likely to rate geographical proximity more important for project success. The coefficient of *prev.proj* does not show the expected sign and the result is not robust to the inclusion of actor and cluster dummy variables. Consequently we find no support for hypothesis 1c.

Another interesting and strong finding is related to the applicability of project results (*applied*). In line with prior studies on collaborations (D'Este and Iammarino 2010, Mansfield and Lee 1996), we can assert that members of projects with a focus on basic research are less reliant on spatial proximity to their partners as compared to actors in applied research projects. Probably the solving of more applied problems in the development of a ready to implement product and/or process requires more frequent interaction due to experimentations and observations processes which in turn are facilitated by geographical proximity of the collaborators.

Concerning actor and cluster heterogeneity, we find no significant differences in the respondent behavior between research institutes and firms. It is not very surprising that controlling for cluster membership reduces the variation explained by the technological and novelty aspects of the projects since the cluster technologies differ in terms of novelty and radicalness. This can also be seen in the significant bilateral correlations of some of the cluster dummies with the *tech.new* and *radical.inn* variables (table A-3 in the appendix).

Table 3
Estimation results Step 1: dependent variable is the relevance of geographic proximity for project success (Coefficients of ordinal logistic regression)

Ordered logistic regression

Dep. var: *Relev.geo*	1	2	3	4	Full
prev.proj	**0.423 **** (0.216)	**0.362 *** (0.219)	0.259 (0.234)	0.235 (0.245)	0.219 (0.275)
tech.new	**0.146 *** (0.087)	0.134 (0.086)	0.093 (0.089)	0.091 (0.089)	0.066 (0.087)
radical.inn			**0.200 *** (0.103)	**0.199 *** (0.103)	0.157 (0.109)
goal.found			0.175 (0.143)	0.163 (0.146)	0.240 (0.165)
goal.proc.inno			**-0.292 **** (0.138)	**-0.294 **** (0.138)	**-0.272 *** (0.152)
goal.prod.inno			-0.255 (0.176)	-0.243 (0.181)	-0.152 (0.193)
goal.quali			0.086 (0.149)	0.088 (0.150)	0.164 (0.168)
applied		**0.612 **** (0.265)	**0.507 *** (0.271)	**0.514 *** (0.272)	**0.598 **** (0.277)
comp				-0.102 (0.245)	-0.043 (0.269)
BioRN					-0.927 (0.634)
CoolSilicon					0.745 (0.520)
FOE					0.371 (0.630)
Logistik					**-0.638 *** (0.380)
Luftfahrt					-0.084 (0.520)
m4					-0.316 (0.458)
MedicalValley					**-0.619** (0.438)
Software					0.143 (0.412)
Solarvalley					-0.101 (0.473)
Observations	282	278	263	263	263
LR chi2	7.402	12.356	22.509	22.681	34.432
Pr(> chi2)	0.025	0.006	0.004	0.007	0.011
R2	0.027	0.046	0.086	0.087	0.129

Robust standard errors in parentheses; *p < 0.10, ** p < 0.05, *** p < 0.01

Table 4

Estimation results Step 2: dependent variables are project satisfaction in cooperation with research institutes (ri) and companies (comp) in general and along various dimensions (KH: knowledge transfer; Info: Information transfer; Coord: Coordination) (Coefficients of ordinal logistic regression)

Ordered logistic regression												
	1	2	3	4	5	6	7	8	9	10	11	12
Dep. var.			Coop.ri		KH.ri	Info.ri	Coord.ri		Coop.comp	KH.comp	Info.comp	Coord.comp
avrg.dist	0.001	0.019			0.003	-0.024	0.003	**0.034** *	**0.036** *	-0.006	-0.012	0
	(0.001)	(0.026)			(0.018)	(0.022)	(0.016)	(0.02)	(0.02)	(0.023)	(0.022)	(0.017)
cent.dist			-0.005									
			(0.021)									
cent.dist.bin				-1.355								
				(4.464)								
predict. relev.geo	0.428	0.568	-0.032	0.002	-0.077	-0.041	-0.344	0.6	0.358	-0.406	-0.735	-0.762
	(0.459)	(0.936)	(0.623)	(0.571)	(0.862)	(0.84)	(0.752)	(0.807)	(0.868)	(0.787)	(0.82)	(0.721)
soc.prox	**0.333** *	0.055	0.369	0.336	0.389	-0.285	0.011	**0.569** *	**0.574** *	0.573	0.444	0.364
	(0.172)	(0.314)	(0.226)	(0.209)	(0.333)	(0.317)	(0.334)	(0.32)	(0.315)	(0.407)	(0.383)	(0.331)
avrg.dist * soc.prox		0.003			**0.005** **	**0.005** **	0.002	0	0	0.001	0	-0.001
		(0.002)			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)
cent.dist * soc.prox			-0.001									
			(0.002)									
cent.dist.bin* soc.prox				-0.224								
				(0.467)								
avrg.dist * predict. relev.geo		-0.003			0	0.005	0	-0.008	-0.008	0.002	0.005	0.002
		(0.007)			(0.005)	(0.006)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.005)
cent.dist * predict. relev.geo			0.005									
			(0.006)									
cent.dist.bin * predict. relev.geo				0.958								
				(1.186)								
avrg.dist * comp		**-0.011** **			**-0.007** **	-0.001	-0.004	**-0.007** **	**-0.009** ***	-0.005	-0.005	**-0.006** *
		(0.004)			(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)
cent.dist * comp			**-0.013** ***									
			(0.005)									
cent.dist.bin * comp				**-2.072** **								
				(0.898)								
Comp	0.14	**1.263** **	**0.749** *	0.537	-0.076	-0.514	-0.49	0.594	**0.904** *	0.375	0	-0.183
	(0.333)	(0.567)	(0.406)	(0.394)	(0.556)	(0.51)	(0.501)	(0.492)	(0.538)	(0.586)	(0.504)	(0.495)
proj.size	-0.021	**-0.091** **	**-0.097** **	**-0.082** **	0.034	-0.043	0.021	0.012	-0.023	-0.011	-0.032	-0.053
	(0.023)	(0.038)	(0.038)	(0.036)	(0.039)	(0.036)	(0.046)	(0.027)	(0.054)	(0.051)	(0.044)	(0.049)
proj.dismiss	0.347	0.235	0.197	0.16	0.129	**0.593** *	0.286	0.194	0.119	-0.147	0.227	0.142
	(0.318)	(0.368)	(0.374)	(0.365)	(0.348)	(0.335)	(0.365)	(0.3)	(0.337)	(0.345)	(0.325)	(0.308)
proj.init	0.203	0.119	0.156	0.157	0.04	-0.189	-0.002	-0.03	-0.098	-0.177	0.061	-0.066
	(0.304)	(0.365)	(0.359)	(0.358)	(0.371)	(0.368)	(0.334)	(0.322)	(0.353)	(0.411)	(0.355)	(0.336)
proj.import	**0.375** **	**0.392** *	**0.391** *	**0.414** **	**0.416** **	**0.346** *	**0.444** **	**0.413** **	**0.381** *	0.068	**0.327** *	0.28
	(0.186)	(0.223)	(0.2)	(0.2)	(0.18)	(0.193)	(0.211)	(0.197)	(0.195)	(0.191)	(0.19)	(0.183)
Cluster dummies	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Observations	198	198	198	198	188	206	204	197	197	183	206	200
LR chi2	15.564	46.870	46.769	43.268	56.957	42.274	35.397	21.196	34.226	32.553	33.381	29.054
Pr(> chi2)	0.049	0.001	0.001	0.002	0.000	0.003	0.018	0.031	0.025	0.038	0.031	0.087
R2	0.089	0.248	0.248	0.231	0.290	0.209	0.182	0.116	0.182	0.177	0.167	0.153

Robust standard errors in parentheses; *p < 0.10, ** p < 0.05, *** p < 0.01

After identifying the circumstances that guide the perceived relevance of co-location for project success, we are interested whether projects with local partners are indeed outperforming the ones with distant partners. Therefore, we use the predictions for perceived relevance of geographical proximity of step I (Model 3[4]) along with the de-facto geographical proximity to explain the project satisfaction as an intermediate outcome of the project work. Table 4 provides the estimated parameters for our second model.

Overall, our estimates do not support the presumed direct relationship between the distance of collaboration partners and project satisfaction (H2a). Neither the single average distance (*avrg.dist*) nor the single distance to the project center (*cent.dist*) turn out to play a significant role for most of the project aspects such as the general cooperation satisfaction (*coop*), the knowledge transfer (*KH*), the information transfer (*info*) as well as the coordination of project members (*coord*). Distance only becomes relevant with regards to overall satisfaction in cooperation with firms. However, the coefficients do not show the expected signs. Checking for a threshold distance (both the mean and the sophisticated 1 hour travel distance (100 km)) by compiling the distance values to the binary information distant (one) or close (zero) did not yield different results. Although we ran both regressions for binary *avrg.dist* and *cent.dist*, the table only contains the model modification for *cent.dist.bin* (column 4).

Contrary to geographical distance, the individual effect of social proximity (*soc.prox*) on project success is significant for the overall cooperation satisfaction, with a more pronounced effect for collaborations with firms (coop.ri and coop.comp, column 1, 8, 9). This conforms to the ample evidence provided by a multitude of prior studies (Mora-Valentin et al. 2004, Breschi and Lissoni 2009). Projects that involve more familiar partners have higher chances to contain highly satisfied partners than projects where completely new partners interact. Consequently, our findings underpin our H2b.

Finding only partial support for a direct link between distance and satisfaction is hardly surprising, since the relation between co-location of partners and project satisfaction is very complex and mediated by project peculiarities as seen in our step one estimations. Thus, geographic proximity might affect satisfaction levels through multiple channels. First, the preference for being closely located might determine whether distant project members appoint high satisfaction scores or not. If respondents deem proximity to their partners as irrelevant,

[4] For the further analysis we always consider the predicted values from the reduced model either without actor and cluster dummies (step 1) or without cluster dummies (step 2).

we would expect that the satisfaction scores do not decrease with geographic distance and vice versa (H2c). The inclusion of a joint effect of the perceived relevance of proximity and the actual distance of the partners on project satisfaction (*dist*predict.relev.geo*) does not support this hypothesis.

Second, the substitutive relationship between geographical proximity and social proximity has been stressed by multiple studies (Agrawal et al. 2008, Singh 2005, Breschi and Lissoni 2003, ter Wal and Boschma 2009, Boschma 2005). In our study we assume that collaboration with distant partners is easier when they already have worked together in the past and have already established communication routines and trust and therefore do not evaluate the collaboration with distant partners worse than with close ones (H2d). However, we only find weak evidence for an interaction effect between social proximity and geographic distance (*dist*soc.prox*) on cooperation satisfaction. Solely with respect to know how transfer and information transfer in collaboration with research institutes (column 5 and 6) a significant relation becomes apparent, showing that socially proximate partners are more likely to award higher scores to distant partners as compared to formerly unknown partners. This relationship is depicted in the left-hand side graph in figure 2. The mean predicted satisfaction levels for collaboration partners of research institutes are separated between previously known compared to previously unknown partners (social proximity was transformed into a binary variable) and plotted against the average distance (whether partners are located below 100km or above 100km distant from each other). The mean predicted cooperation satisfaction decreases with distance when the partners in the respective project do not share prior common work experience, i.e. are socially distant. So there is a somewhat partial evidence that collaborations over larger distances (here over 100 km) can be successful when the partners already know each other.

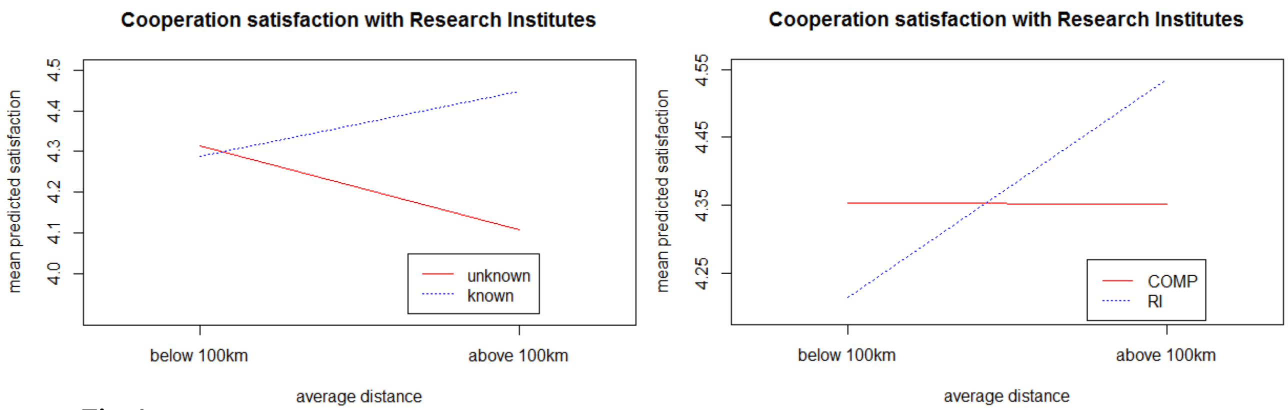

Fig. 4
Joint/ Interaction effects of social proximity/ actor type and average distance on cooperation satisfaction

Third, if we scrutinize the influence of geographical distance on project satisfaction by actor groups, we find that the interaction effect of distance with the actor dummy (*comp*) is significant and negative. This means that if the distance to the partners increases, companies are less satisfied with the collaboration. This effect is most pronounced for overall satisfaction levels (*coop.ri* and *coop.comp*, column 2 – 4, 8, 9) and independent of the type of cooperation partner (so regardless whether they should evaluate cooperation with research institutes or other firms). Moreover, the observed significant relation is robust to the modification of the distance measures (column 3 & 4). These finding are visualized in the right-hand side graph in figure 2. The mean predicted satisfaction levels for collaboration partners from research institutes are separated by type of respondent (comp – company or ri – research institute) and are again plotted against the average distance (below 100km or above 100km). As can be seen, the mean predicted satisfaction levels decrease slightly for firms when partners (research institutes) are located more than 100 km away. Collaborations between research institutes however, appear to perform better if they are located in geographical distance to each other. From this we can conclude that the respondent companies in our sample are more reliant on being close to their cooperation partners as compared to the research institutes in our sample.

Apart from these major findings, satisfaction levels over all project aspects are primarily driven by the main motif of the respondents to participate in the project (*proj.imp*). Project managers who rated the project to be of minor importance in their organization's project portfolio are less satisfied with all cooperation aspects (except *KH.comp* and *Coord.comp*).

Also respondents within larger projects in terms of number of collaboration partners (*proj.size*) are comparably less satisfied with the overall cooperation – at least with research institutes – than those in smaller projects. Other controls, such as initiating the project (*proj.init*) or necessity of public funding (*proj.dismiss*) show no robust significant influence.

Table 5

Estimation results Model 3: dependent variables are cross-fertilization effects (cross.fert) and innovation production (inno.bin) (Coefficients of ordinal and binary logistic regression)

	1	2	3	4	5	6	7	8
Model	Ordered Logit				Logit			
Dep.var.	Cross.fert				Inno.bin			
Predict.coop.ri	**2.247 *****	**2.543 *****	**2.282 *****		-0.280	-0.087	-0.324	
	0.829	0.794	0.811		1.104	1.144	1.104	
Predict.coop.comp				**1.263 ***				0.365
				0.718				1.003
avrg.dist		**-0.003 ***				-0.003		
		0.001				0.003		
cent.dist			-0.001				-0.002	
			0.001				0.002	
highskill	-0.029	-0.027	-0.030	-0.027	0.028	0.035	0.026	0.041
	0.031	0.028	0.032	0.030	0.036	0.034	0.037	0.042
applied	**1.147 *****	**1.045 *****	**1.090 *****	**1.175 *****	**0.885 ***	0.812	**0.856 ***	0.317
	0.349	0.349	0.352	0.369	0.505	0.500	0.498	0.503
RI	**1.046 *****	**0.928 ****	**0.964 ****		**1.018 ****	0.775	**0.858 ***	
	0.373	0.376	0.381		0.489	0.516	0.492	
Comp				**-1.016 *****				**-1.349 *****
				0.381				0.513
BioRN	0.599	0.132	0.444	**1.446 ****				
	0.523	0.541	0.519	0.736				
CoolSilicon	**1.341 ***	1.144	**1.293 ***	0.779	**6.750 *****	**6.969 *****	**6.821 *****	0.278
	0.706	0.697	0.706	0.624	1.251	1.239	1.231	1.538
FOE	-0.098	-0.239	-0.106	-0.011	**5.325 *****	**5.824 *****	**5.590 *****	-1.428
	1.015	1.028	1.012	0.924	1.510	1.543	1.501	1.684
Logistic	0.516	0.478	0.478	0.464	**7.442 *****	**7.929 *****	**7.584 *****	1.381
	0.443	0.444	0.447	0.395	0.930	1.028	0.938	1.264
Aviation	-0.684	-0.848	-0.723	-0.36	**6.486 *****	**6.798 *****	**6.647 *****	-0.044
	0.488	0.537	0.513	0.595	1.157	1.172	1.178	1.581
m4	**1.257 ***	**1.179 ***	**1.276 ***	0.949	**6.928 *****	**7.446 *****	**7.193 *****	0.126
	0.679	0.679	0.675	0.902	1.001	1.011	0.987	1.465
MedicalValley	**-1.523 ***	**-1.909 ****	**-1.610 ****	**-1.112 ****	-0.457	0.108	-0.114	**-6.119 *****
	0.793	0.811	0.797	0.51	1.397	1.458	1.417	1.641
Software	**1.398 *****	**1.209 *****	**1.346 *****	**1.126 *****	**8.877 *****	**9.134 *****	**8.972 *****	**2.696 ***
	0.454	0.462	0.456	0.404	1.135	1.152	1.150	1.404
Solarvalley	0.234	0.292	0.234	0.054	**8.825 *****	**9.459 *****	**9.043 *****	2.501
	0.539	0.509	0.528	0.538	1.557	1.522	1.562	1.759
MicroTec					**7.066 *****	**7.677 *****	**7.280 *****	1.057
					0.930	1.035	0.937	1.256
Observations	189	189	189	190	104	104	104	111
LR chi2	56.446	61.017	58.326	46.201	22.146	24.303	23.679	24.798
Pr(> chi2)	0.000	0.000	0.000	0.000	0.053	0.042	0.050	0.025
R2	0.274	0.293	0.282	0.231	0.256	0.278	0.272	0.268

Robust standard errors in parentheses; *p < 0.10, ** p < 0.05, *** p < 0.01

In the last step we want to clarify if geographical proximity has a direct effect on project results and if project satisfaction is indeed an appropriate indication for later projects success in terms of producing valuable results[5]. Therefore we regress two success variables on both geographic distance and the predicted cooperation satisfaction from step II (Model 1) while controlling for the application of project results (*applied*), human capital input, actor type and cluster differences. The first success variable relates to the cross-fertilization effects of the funded projects on other projects in the same organization (*cross.fert*). The second output variable captures whether project activities already resulted in novel products, services or processes (*inno.bin*). Since the two success variables are of different scale, we first estimate an ordered logit model for *cross.fert* and then a binary logistic regression model for *inno.bin*. The resulting parameter estimates can be found in table 5.

Overall, we find that the relation between project satisfaction and project outcome only holds for potential cross-fertilization effects but not for the probability of introducing an innovation. The estimations support hypothesis 4 in that projects that receive a higher rating on the satisfaction scale are more likely to report project results that can be applied in and fertilize other project (*cross.fert*). This effect is robust against the inclusion of all control variables including actor type and cluster dummies. Likewise and in accordance with H3, geographical proximity is also only relevant for projects in terms of the production of the cross-usage of results but not for innovative outcome. Here, the average distance to partners hampers the appearance of cross-fertilization effects. This effect does not appear for cent.dist (the distance to the project center). However, the responses also vary significantly between applied and basic research projects, between research institutes and companies as well as between the individual clusters. Project managers who do research in rather applied areas are more likely to report cross-usage of project results in other projects. Furthermore, research institutes are more likely to report that project results add value to other projects as compared to companies. Since we can assume that the main activities of research institutes are within earlier phases of the innovation process this result is not surprising. The projects within the LECC are required to be at a pre-market stage and effects for firms might show somewhat later. In contrast, projects with higher satisfaction ratings do not necessarily manifest in superior innovative performance (*inno.bin*). The reporting of innovative outcome is also quite heterogeneous across clusters and actor types. Managers of applied research projects are again more likely to report innovations and research institutes are also more likely to introduce a

[5] Some of the projects were still running while the survey was conducted.

novel product, service or process as a result of the project as compared to respondent firms. Consequently we find only partial support for our hypothesis 4.

6. Conclusion

The purpose of this study was to add to the rare empirical evidence on the relationship between geographical proximity of collaboration partners and the success of their joint research endeavor. While the constituent role of spatial proximity for the formation of research alliances came to the fore on the innovation research agenda, the consequences for subsequent project performance were still underexplored.

To address this matter, we utilized data from a unique survey conducted with beneficiaries from the German Leading-Edge Cluster Competition, one of the main national cluster funding programs in recent years. In detail, we analyzed the simultaneous effects of geographical along with social proximity, technological aspects and actor heterogeneity on intermediate outcome in terms of project satisfaction and final project output in terms of cross-fertilization effects and the introduction of a product or process innovation.

We find that geographical proximity of collaboration partners is not a universal precondition for project success. In fact, the picture on how the individual respondents perceive the necessity of being closely located in order to be successful is quite heterogeneous. Our findings suggest that the nature of knowledge involved determines the degree to which collaborators are reliant on being closely located to each other. Spatial proximity between partners is deemed especially important in exploration contexts when projects aim at the production of radical novelty or experiment with new technologies. Contrariwise but in line with prior findings, this effect is less pronounced for projects focusing on basic research (Mansfield and Lee 1996, D’Este and Iammarino 2010, Garcia 2013). Furthermore, we find significant actor specific differences concerning the role of spatial distance to the project partners for project satisfaction levels. The project satisfaction of firms decreases significantly as compared to research institutes the more distant they are located from their collaboration partners. In line with prior studies we further observe that prior common work experience has a significant explanatory power for project satisfaction levels. Contrariwise, we only partially observe the often suggested substitutive relationship between geographical proximity and social proximity. With regard to final project results, we find that both, geographical proximity and project satisfaction foster the cross-fertilization of other projects.

Conforming to findings of D'Este and Iammarino (2010), our results leave us to the conclusion that the link between geographical proximity and project success is rather complex and characterized by strong interdependencies with other contextual factors. Consequently, not only the connection to the nearest partners should be supported, but also that the "right" actors have to be chosen. Our results speak against a one-fits-all type of policy which merely strengthens regional linkages, since other important contextual factors might be overlooked and the policy program will not yield the ex-ante expected effects (Crescenzi 2014, Koschatzy 2000). In consideration of the relative importance of other proximity dimensions and contextual factors, policy makers should shift their focus away from this restrictive view and include these factors into their decision. Regional proximity per se might not always be a warrant for successful research, as the benefits of the expertise might outweigh the cost for the collaboration with a distant partner (Garcia et al. 2013). Moreover, geographical proximity can be even detrimental when regional knowledge has been exploited and there is not access to fresh outward knowledge (Bathelt et al. 2004). Extraregional connections might serve as a source for new knowledge to overcome these critical situations. Also geographical distance can be substituted by other forms of proximities between actors (Boschma 2005, Cerscenzi 2014).

Furthermore policy has to find a balance between funding research with new partners for the reason of access to novel knowledge and the exploiting the benefits of conducting joint R&D with old acquaintances based on established trust and institutions. Therefore, the stage of the technology of projects and the prevailing network structures should be taken into consideration as the growth of regions specialized on old technologies might be hindered by the mere focus on regional networking.

Besides these findings, the analysis in this paper faces some limitations and accordingly leaves room for further research endeavors. The main limitation of this study is the focus on publicly funded R&D projects due to the data availability. The extent of the generalizability of our results needs to be tested on the basis of comparable data from non-funded projects. Moreover, the static nature of the analysis does not allow for any conclusions on causal mechanisms or statements about the development of the necessity for proximity over time. More dynamic approaches are needed to further understand, whether the mechanisms of proximity exhibit stability over time and how their interrelations change when collaborations end or persist.

Appendix

Table A-1: Description of Variables

Concept	Code	Description	Scale	Obs	Min	Max	Mean	Std.Dev
Geogr. prox and project success	*relev.geo*	Geographical proximity is a central precondition for the successful accomplishment of our project.	Categorical (1=strongly disagree, 5=strongly agree)	304	1	5.00	3.46	1.17
Project satisfaction in collaborations with companies and research institutes	*coop.ri*	Satisfaction with the cooperation during the implemenation of the project. (with research institutes as cooperation partners)	Categorical (1=very low, 5=very high)	398	2	5.00	4.28	0.70
	coop.comp	Satisfaction with the cooperation during the implemenation of the project (with companies as cooperation partners).	Categorical (1=very low, 5=very high)	402	2	5.00	4.19	0.76
	KH.ri	Satisfaction with the know how transfer into the own organsation (with research institutes as cooperation partners).	Categorical (1=very low, 5=very high)	377	1	5.00	3.92	0.85
	KH.comp	Satisfaction with the know how transfer into the own organsation (with companies as cooperation partners).	Categorical (1=very low, 5=very high)	376	1	5.00	3.75	0.89
	info.ri	Satisfaction with the information transfer between the project partners (with research institutes as cooperation partners).	Categorical (1=very low, 5=very high)	409	1	5.00	4.08	0.76
	info.comp	Satisfaction with the information transfer between the project partners (with companies as cooperation partners).	Categorical (1=very low, 5=very high)	414	1	5.00	3.96	0.82
	coord.ri	Satisfaction with the coordiantion with the project partners (with research institutes as cooperation partners).	Categorical (1=strongly disagree, 5=strongly agree)	403	2	5.00	4.15	0.76
	coord.comp	Satisfaction with the coordiantion with the project partners (with companies as cooperation partners).	Categorical (1=very low, 5=very high)	406	1	5.00	4.06	0.78
Project Output	*cross.fert*	We already can/ could use the project results as inputs for other current projects and planned projects.	Categorical (1=strongly disagree, 5=strongly agree)	326	1	5.00	3.64	1.15
	inno.bin	Has your organization so far introduced a novel product, service or process as a result of the work in this project?	Binary(0=no,1=yes)	191	0	1.00	0.55	0.50
Novelty	*radical.inn*	Did the project aim at developing a radical novelty?	Categorical (1=strongly disagree, 5=strongly agree)	317	1	5.00	2.79	1.30
	tech.new	The technology that is used in this project is new to us.	Categorical (1=strongly disagree, 5=strongly agree)	322	1	5.00	3.24	1.41
	prev.proj	Does this project base on prior research projects ?	Binary(0=no,1=yes)	455	0	1.00	0.47	0.50
Project Goals	*goal.prod.inno*	How important is the development of product or service innovation as a result of your project?	Categorical (1=not important, 5=very important)	468	1	5.00	4.57	0.76
	goal.proc.inno	How important is the development of process innovation as a result of your project?	Categorical (1=not important, 5=very important)	462	1	5.00	4.31	0.83
	goal.found	How important is the support of new business formation as a result of your project?	Categorical (1=not important, 5=very important)	461	1	5.00	2.92	1.03

Table A-1: Description of Variables (continued)

Concept	Code	Description	Scale	Obs	Min	Max	Mean	Std.Dev
Project Goals	*goal.quali*	How important is the development of educational and qualification programs as a result of your project?	Categorical (1=not important, 5=very important)	462	1	5.00	2.92	1.00
Geographical distance	*avrg.dist*	Average distance of the respondent to the project partnersin km.	Continous	475	0	754.50	106.96 [6]	122.04
	cent.dist	Distance in km to the project's geographical center.	Continous	475	0	809.00	20.10[7]	127.15
	cent.dist.bin	Is the respondent more than 100 km away from the project's geographical center?	Binary(0=no,1=yes)	475	0	1.00	0.24	0.43
Social proximity	*soc.prox*	Did you work with some of your partners previously?	Categorical (0=no,1=yes, with less than 50% of them, 2=yes, with more than 50% of them, 3=all)	468	0	3.00	1.34	0.89
Controls	*pro.size*	Project size in number of organisations involved	Count	475	2	24.00	9.04	6.04
	applied	The project results can/ could be directly implemented into new products/ processes.	Binary(1=yes ,0=no)	323	0	1.00	0.29	0.45
	proj.import	What is the relevance of the project in your general project portfolio? The project itself is of minor importance to us.	Categorical (1=strongly agree, 5=strongly disagree)	290	1	5.00	4.49	0.87
	proj.init	Was the project initiated by your organization?	Binary(0=no,1=yes)	475	0	1.00	0.44	0.50
	proj.dismiss	The project would have not existed without the funding.	Binary(0=no,1=yes)	475	0	1.00	0.29	0.45
	highskill	Number of highly skilled researchers working in the project (university degree).	Count	423	0	50.00	4.00	4.72
	Comp	Is the respondent a company?	Binary(0=no,1=yes)	475	0	1.00	0.64	0.48
	RI	Is the respondent a research institute (university, public research institute)?	Binary(0=no,1=yes)	475	0	1.00	0.36	0.48
	BioRN	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.05	0.21
	CoolSilicon	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.07	0.25
	FOE	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.06	0.24
	Logistic	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.21	0.41
	Software	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.06	0.23
	MicroTec	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.19	0.39
	Solarvalley	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.10	0.30
	MedicalValley	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.10	0.30
	m4	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.09	0.28
	Aviation	Dummy variable for Cluster of respondent	Binary(0=no,1=yes)	475	0	1.00	0.08	0.27

[6] This is the median. The mean for avrg.dist equals 130.84.
[7] This is the median. The mean for cent.dist equals 74.73.

Table A-2: Cluster deviations per dependent variable (*relev.geo, coop.ri, cross.fert, inno.bin*) [8] - Basis for the choice of the reference category (*cluster*)

	Cluster	BioRN	CoolSilicon	FOE	Logistic	Aviation	m4	Medical Valley	MicroTec	Software	Solarvalley
	relev.geo mean	3.077	3.840	3.750	3.178	3.367	3.679	3.333	3.507	3.840	3.250
RQ 1	abs.mean.dev	0.387	0.376	0.286	0.286	0.097	0.215	0.130	0.044	0.376	0.214
	n	13	25	20	73	30	28	3	67	25	20
	coop.ri mean	4.333	4.226	4.348	4.333	4.412	4.424	4.342	4.360	4.185	3.864
RQ 2	abs.mean.dev	0.049	0.058	0.064	0.049	0.128	0.140	0.058	0.076	0.099	0.420
	n	9	31	23	84	34	33	38	75	27	44
	cross.fert mean	3.250	4.148	3.286	3.737	2.794	3.914	2.250	3.657	4.040	4.000
	abs.mean.dev	0.394	0.504	0.358	0.093	0.850	0.270	1.394	0.013	0.396	0.356
RQ 3	n	16	27	21	76	34	35	4	67	25	21
	inno.bin mean	0.545	0.647	0.154	0.625	0.588	0.414	0.000	0.514	0.800	0.867
	abs.mean.dev	0.010	0.092	0.401	0.070	0.033	0.141	0.555	0.041	0.245	0.312
	n	11	17	13	40	17	29	2	37	10	15

[8] The table contains all mean responses per cluster and the respective absolute deviations from the mean. The grey cells represent the minimal deviation in each row. The cluster with the minimal deviation from the overall mean was chosen to be the reference cluster in the estimations.

Table A-3: Correlation tables

Model 1/ RQ 1

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
I. relev.geo	******	0.104*	0.102*	0.139**	-0.06	-0.13**	0.104*	0.062	0.127**	-0.084	-0.074	0.099	0.051	-0.128**	0.103*	-0.064	-0.013	0.011	-0.047
II. tech.new		******	0.017	0.034	-0.051	0.008	-0.032	-0.045	0.24***	-0.058	-0.122**	0.085	0.172***	0.03	0.04	-0.168***	-0.001	-0.063	0.057
III. prev.proj			******	0.084	0.072	-0.103*	0.145**	-0.02	0.079	-0.236***	0.075	0.086	-0.105*	-0.083	0.044	-0.1	0.037	0.172***	-0.021
IV. applied				******	-0.008	-0.021	0.109*	0.036	0.037	0.005	0.113*	-0.06	-0.055	-0.015	-0.067	0.062	-0.065	0.095	-0.099
V. goal.prod.inno					******	-0.067	0.16***	0.011	0.086	0.121*	0.097	-0.082	-0.214***	0.132**	0.066	-0.093	0.059	0.078	-0.176***
VI. goal.proc.inno						******	0.069	0.041	-0.036	-0.037	-0.225***	-0.075	0.024	0.209***	-0.095	0.082	-0.132**	-0.007	0.084
VII. goal.found							******	0.545***	-0.052	-0.238***	-0.072	-0.278***	-0.085	0.294***	0.183***	-0.244***	0.04	0.226***	-0.349***
VIII. goal.quali								******	-0.171***	-0.108*	-0.108*	-0.343***	-0.085	0.271***	0.148**	-0.181***	0.009	0.132**	-0.277***
IX. radical.inn									******	0.006	-0.017	-0.008	0.128**	-0.167***	0.121*	-0.094	-0.016	-0.044	0.166***
X. Comp										******	0.135**	-0.016	-0.047	-0.022	0.051	-0.112*	0.011	-0.117*	0.095
XI. BioRN											******	-0.066	-0.057	-0.121**	-0.068	-0.061	-0.023	-0.071	-0.075
XII. CoolSilicon												******	-0.079	-0.168***	-0.094	-0.084	-0.032	-0.098	-0.104*
XIII. FOE													******	-0.146**	-0.081	-0.073	-0.028	-0.085	-0.091
XIV. Logistic														******	-0.172***	-0.155**	-0.06	-0.18***	-0.192***
XV. Software															******	-0.086	-0.033	-0.1	-0.107*
XVI. Solarvalley																******	-0.03	-0.09	-0.096
XVII. MV																	******	-0.035	-0.037
XVIII. m4																		******	-0.112*
XIX. Aviation																			******

Model 2/ RQ 2

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	XXI.	XXII.
I. coop.comp	******	0.605***	0.017	0.222***	-0.081	-0.06	0.134*	-0.002	0.077	0.045	0.038	0.064	-0.106	0.035	0.08	0.102	0.092	-0.088	-0.088	0.119*	-0.073	0.014
II. coop.ri		******	0.085	0.171**	0.007	-0.073	0.172**	0.094	0.115	0.062	-0.056	0.052	-0.012	0.055	0.09	-0.004	0.11	-0.028	-0.268***	0.21***	0.019	0.096
III. avrg.dist			******	-0.043	0.186***	-0.107	-0.052	-0.064	0.002	-0.093	-0.165**	-0.044	0.059	-0.033	-0.02	-0.095	0.215***	-0.116	0.089	0.765***	0.829***	0.992***
IV. soc.prox				******	-0.118*	-0.128*	0.159**	0.194***	0.219***	-0.119*	0.08	-0.034	-0.143**	-0.054	0.088	0.105	0.111	-0.065	-0.014	0.489***	-0.098	-0.023
V. Comp					******	0.003	-0.05	-0.224***	-0.243***	0.047	-0.031	-0.161**	0.053	0.082	-0.149**	0.008	0.093	0.045	-0.092	0.074	0.569***	0.161**
VI. proj.size						******	-0.029	0.11	0.072	-0.004	-0.217***	-0.119*	-0.178**	0.029	0.423***	0.078	-0.346***	0.565***	-0.074	-0.117	-0.08	-0.091
VII. proj.import							******	0.038	0.12*	-0.016	0.044	0.048	-0.209***	0.089	-0.003	0.072	0.048	0.016	0.005	0.076	-0.07	-0.048
VIII. predict.relev.geo								******	0.141**	-0.083	-0.072	0.089	-0.117	-0.098	0.072	0.027	0.064	0.17**	-0.172**	0.057	-0.151**	0.036
IX. proj.init									******	0.061	-0.008	-0.105	-0.076	0.175**	0.169**	0.144**	-0.105	-0.056	-0.074	0.146**	-0.144**	0.023
X. proj.dismiss										******	-0.11	0.217***	0.055	0.132*	-0.067	0.015	0.056	-0.154**	-0.15**	-0.133*	-0.055	-0.099
XI. CoolSilicon											******	-0.071	-0.178**	-0.094	-0.106	-0.038	-0.161**	-0.111	-0.074	-0.147**	-0.152**	-0.162**
XII. FOE												******	-0.134*	-0.071	-0.079	-0.029	-0.121*	-0.084	-0.056	-0.042	-0.119*	-0.036
XIII. Logistic													******	-0.178**	-0.2***	-0.072	-0.306***	-0.211***	-0.141**	-0.042	0.053	0.053
XIV. Aviation														******	-0.106	-0.038	-0.161**	-0.111	-0.074	-0.03	0.044	-0.04
XV. m4															******	-0.043	-0.181**	-0.125*	-0.084	0.084	-0.037	-0.013
XVI. MedicalValley																******	-0.065	-0.045	-0.03	-0.079	-0.087	-0.092
XVII. MicroTec																	******	-0.191***	-0.128*	0.244***	0.222***	0.214***
XVIII. Software																		******	-0.088	-0.121*	-0.072	-0.102
XIX. Solarvalley																			******	0.046	-0.015	0.069
XX. avrg.dist * soc.prox																				******	0.572***	0.774***
XXI. avrg.dist * Comp																					******	0.804***
XXII. avrg.dist * predict.relev.geo																						******

Model 3/ RQ 3

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.
I. Cross	******	-	0.196**	0.271***	-0.184**	-0.141*	-0.128	0.202***	0.275***	0.025	0.106	-0.063	-0.021	0.123	0.037	-0.08	0.128	-0.224***	-
II. Inno.bin		******	0.029	0.072	-0.082	-0.095	0.028	0.08	0.065	-	-0.097	-0.153	0.036	0.199*	0.197*	-0.109	0.067	-0.133	-0.045
III. Predict.coop.ri			******	0.743***	0.265***	0.09	0.117	0.244***	0.000	0.068	-0.019	0.102	-0.073	-0.192**	-0.029	0.028	-0.137*	0.051	0.157
IV. Predict.coop.comp				******	0.007	-0.052	0.047	0.113	0.229***	0.042	0.03	0.05	-0.138*	-0.025	0.092	0.094	-0.023	-0.015	-0.06
V. Avrg.dist					******	0.846***	0.055	0.022	-0.205***	-0.117	-0.124	-0.062	0.041	-0.152*	0.087	-0.08	-0.01	0.044	0.211**
VI. Cent.dist						******	-0.016	-0.036	-0.16**	-0.066	-0.051	-0.022	-0.058	-0.035	0.025	-0.021	0.089	0.045	0.064
VII. highskill							******	-0.016	-0.254***	0.037	0.041	-0.077	0.012	0.083	-0.107	0.094	-0.042	0.256***	-0.174*
VIII. Applied								******	-0.053	0.073	-0.095	-0.076	0.035	-0.049	0.089	-0.06	-0.039	-0.095	0.079
IX. RI									******	-0.09	0.105	0.156**	-0.087	-0.079	0.079	0.023	0.248***	-0.086	-0.068
X. BioRN										******	-0.031	-0.028	-0.063	-0.045	-0.03	-0.012	-0.031	-0.031	-
XI. CoolSilicon											******	-0.071	-0.158**	-0.113	-0.075	-0.031	-0.078	-0.078	-0.164
XII. FOE												******	-0.144*	-0.102	-0.068	-0.028	-0.071	-0.071	-0.148
XIII. Logistic													******	-0.228***	-0.151*	-0.063	-0.158**	-0.158**	-0.327***
XIV. Software														******	-0.108	-0.045	-0.113	-0.113	-0.216**
XV. Solarvalley															******	-0.03	-0.075	-0.075	-0.178*
XVI. MedicalValley																******	-0.031	-0.031	-0.065
XVII. m4																	******	-0.078	-0.191*
XVIII. Aviation																		******	-0.178*
XIX. MicroTec																			******

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