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Project Social Capital in Biotech R&D: Its Configuration and Impact on Knowledge Development

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7.1 Introduction

Project-based organizing of company operations is pervasive in today's economy (Cattani et al. 2011). The last twenty years have witnessed a growing scholarly interest in project-based organizations (PBOs), and this interest mirrors the diffusion of this organizational form across a wide range of industries, well beyond those where organizations traditionally have been organized by projects. Examples of research in this

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area have focused on film-making (Stjerne and Svejenova 2016), media (Manning and Sydow 2011), oil and energy (Prado and Sapsed 2016), complex products and systems (Hobday 2000), software development (Grabher 2004), construction (Bresnen et al. 2004), professional services and consulting (Semadeni and Anderson 2010), engineering design (Cacciatori 2008), and biotechnology (Ebers and Powell 2007).

Project-based organizations (PBOs) are organizational forms that create temporary arrangements and systems through which firms provide services or products to their clients, by developing customized projects (Prado and Sapsed 2016). The temporary nature of PBOs is seen as a response to the increasingly complex environments that many organizations are faced with today (Powell et al. 1996).

The PBO seems to offer positive conditions both for creating new knowledge and to foster creativity and innovation (Davies et al. 2011). Involving autonomous and interdisciplinary teams, holding less cumbersome hierarchies, and being able to find solutions in a short and intensive period of time (Bakker et al. 2016), PBOs achieve innovation by creating and recreating organizational structure depending on the demand of each project and responding quickly and flexibly to customer needs (Hobday 2000).

Thanks to this ability to realize innovation in collaboration with clients and suppliers, PBOs allow better process control (Manning and Sydow 2011), lead-time reduction (Verona and Ravasi 1999), improved output quality (Bresnen et al. 2004), have more flexible application and integration of different types of organizational knowledge and skills, improve learning within the project boundaries, provide higher effectiveness in outward knowledge transfer (Lichtenthaler 2010), and cope with emergent properties in production (Keegan and Turner 2002).

In spite of these advantages, the temporary nature of projects raises tensions and questions that lead to considerable drawbacks, occurring especially where traditional functional or matrix organizations are strong, i.e., in performing routine tasks and achieving economies of scale (Hobday 2000). In addition, PBOs face a recurring tension between the always immediate demands of the project and the opportunities for learning and disseminating best practices and innovations (Sydow et al. 2004). Given the particular discontinuity of activities

carried out in PBOs, these have a weakness concerning organizational learning from project to project (Prencipe and Tell 2001). Much of the knowledge generated in project activities is embedded in the tacit experiences of group members and it is therefore difficult to consolidate this knowledge and spread it outside the single project. Moreover, the knowledge that is accumulated during the course of a project is at risk of being dispersed in a non-productive way as projects are dissolved and members are assigned to new tasks and teams (Prencipe and Tell 2001). As stated by Davies and Brady (2000), the paradox is in the fact that to make the temporary aspects of a project become part of a permanent learning process for the organization, managers need to understand "economies of repetition." To learn from projects, organizations undertake some patterns of activities that can be predictable and repeatable, leading to a more efficient and effective performance. This means that in PBOs, economies result more from the repetition of similar types of projects than from a scale or scope (Davies and Brady 2000).

In order to handle the negative aspects of PBOs presented above, increasing emphasis is put on inter-project coordination and learning, e.g., in terms of multi-project management (Cusumano and Nobeoka 1998). By extending the management focus from single projects to families or portfolios of projects, mechanisms for purposefully transferring knowledge from one project to others can be implemented, and unnecessary redundant work can thereby be avoided. A limitation of the multi-project management approach, however, is that it normally only comprises the formal dimension of project-based organization. This excludes an important part of organizational learning, namely all the coordination and innovation that takes place informally, which—particularly in knowledge-intensive settings such as R&D—is known to be of great importance (Obstfeld 2005).

Projects are not "islands," but are connected to their surroundings in intricate ways (Grabher 2004). The integration potential residing in contacts and communication between projects arguably constitutes a source of extended resources for a given single project, and could also have an effect on its performance (Manning and Sydow 2011). In order to achieve integration effectively, a project needs to establish and maintain relations with other projects both within and outside the organization to pull in important knowledge resources that can be used to improve project performance. In order to realize this potential, we need to consider projects as being embedded in their organizational surroundings, and attend to their formal and informal external linkages as potential resources (Bakker et al. 2016). Drawing upon recent literature in the field of social networks, we use the concept of project social capital proposed by Di Vincenzo and Mascia (2012) as a fruitful way of capturing this potential for integration and learning residing in a project's external linkages. The aim of this article is to empirically investigate the impact of projects' social capital for their knowledge development.

7.2 Theoretical Background

In this research, we choose to use the concept of project social capital, defined as the overall web of interpersonal and interorganizational relationships in which single projects are embedded, and through which important resources can be accessed (Di Vincenzo and Mascia 2012). The concept of project social capital aims to highlight a form of social capital which inheres specifically in temporary forms of organizing.

The importance of project social capital relies upon a number of studies which have stated that projects are more than just temporary systems (Arthur et al. 2001; Sydow et al. 2004), in light of the complex web of interdependences they manifest with social relationships, localities, and corporate networks, and from which they mobilize essential resources (Grabher 2002a, b; Sydow and Staber 2002). Moreover, social relationships are frequently project-specific since they are formed around project boundaries rather than around the boundaries of their respective firms. In a number of industries, single projects collaborate closely with relevant external actors while, at the same time, they become more loosely tied to the central management of the company in which they actually take part. Grabher (2002a) proposed the term "project ecology" to identify those interpersonal and interorganizational relationships from which projects draw essential resources. Projects often

become locally embedded since they "operate in a milieu of recurrent collaboration that, after several project cycles, fills a pool of resources and gels into latent networks" (Grabher 2002b: 208).

Within PBOs, project teams represent groups of people aiming to achieve well-specified objectives, in which members are aggregated in order to draw upon the joint resources of these individuals. Among such resources, social capital available through individual members' social relations appears to be of critical importance given the peculiar work performance and work processes at the project level. Whenever project tasks require new relevant knowledge located outside the project boundaries, individuals taking part in projects may be strongly motivated to communicate and exchange knowledge with members who take part in other projects, in order to have access to new knowledge. Project social capital in this context has a double effect: the interpersonal social relationships established across different, well-focused projects enhance the absorption of innovative external information that improves learning in the area of work and, as a result, the knowledge development and resulting outcomes within each individual project.

An important perspective that needs to be taken into account in project-based contexts concerns the relationship between cognitive diversity of project members and knowledge development at the project level (Cummings and Kiesler 2007). Diversity is an important characteristic of projects, whose members may bring diverse knowledge, expertise, information, and perspectives in order to perform organizational tasks and activities (van Knippenberg and Mell 2016). At an individual level, knowledge diversity is shaped by the functional background of project members, as well as by their previous work experiences. Following the arguments of project social capital, the discussion about cognitive diversity relates directly to the collaborative ties that project members may establish with other colleagues specialized in different areas of expertise. While similarity in the stock of knowledge owned by individuals can, to some extent, improve communication and commonality among them, certain levels of heterogeneity can enhance the capacity for creative problem-solving and allow individuals to share different sets of contacts, skills, information, and experiences (Reagans and Zuckerman 2001).

Network diversity is defined as the prevalence of ties that cross institutional, organizational, or social boundaries (Burt 1992). It does not take into account the number of actors, but rather the number of different types of actors. The greater the number of different types of actors to which an individual taking part in a single project is linked, the greater the diversity of information and social support that the individual in question can have access to (Burt 1983). In this research, we consider cognitive diversity in terms of both the different project members' areas of expertise and the degree of presence/absence of relations with heterogeneous project members. Each area of expertise can be viewed as a distinct pool of knowledge possessed by individuals affiliated with other projects. Network diversity reflects a property of the project social capital that takes into account the extent to which project members' interpersonal networks are rich in "cognitive diversity." Individuals are chosen and assigned to single projects on the basis of their specific competences and past experiences. Such capabilities are often represented by the functional units that overall represent the permanent part of the organizational chart. Projects that have connections across multiple pools of knowledge bridge holes between projects in the broader "community" of knowledge at the organizational level, and as a result, they are exposed to knowledge that is more diverse.

The property of diversity is of crucial importance for project social capital. Intense and frequent communication among members is normally a highly desirable condition within project teams (Obstfeld 2005), and typically these are designed with the intent to achieve homogeneity and cohesion among individuals pertaining to the same project. In contrast, connections with members of other projects who have a different background enhance an individual's capabilities to interpret ideas from people with different knowledge in a way that suits his or her knowledge and experiences. At the same time, through "different" ties, individuals can more easily transfer what they know to others with different backgrounds. The ability to transfer knowledge effectively leads to higher exposure of projects to a broader set of perspectives and cross-fertilization of ideas, and thus to variation in

knowledge and problem-solving approaches which can help project teams identify and use multiple knowledge components in their activities. In other words, projects with exposure to more diverse knowledge through their members' interpersonal networks will have access to a wider range of knowledge components and will be able to mobilize and exploit different intellectual resources embedded in the network. As a consequence, it is likely that a broader diversity of social networks will be associated with higher levels of knowledge development.

However, although networks across disciplines can be beneficial, excessively high levels of network diversity can be problematic. First, to the extent that knowledge is transferred across boundaries that demarcate distinct bodies of knowledge, it is unlikely that individuals on opposite sides of a boundary will have much knowledge in common. Cohen and Levinthal (1990) labeled the ability to assimilate and replicate new knowledge gained from external sources as "absorptive capacity." In discussing how this contributes to innovation, they argued that absorptive capacity tends to develop cumulatively and builds on prior-related knowledge. High levels of network diversity could result in a lack of common knowledge among linked projects, thus decreasing absorptive capacity and making attempts to transfer knowledge across the boundaries vulnerable. A lower ability to transfer knowledge will in turn reduce opportunities to gain access to different cognitive strategies and others' experiences, diminishing the potential for knowledge development.

Turning to other works in the broader field of innovation management, we can also here see that the proposed effects of diversity are not straightforward. Whereas most of the literature on creativity highlights the importance of heterogeneous ties, some authors point to the risk of diversity becoming a double-edged sword, where too high levels of diversity can have adverse effects on creative performance as it may bring about misunderstandings, and possibly also conflicts (Milliken and Martins 1996; Pelled et al. 1999).

As pointed out already in the seminal work by Lawrence and Lorsch (1967), high performance in organizations is achieved when there are high levels of both differentiation and integration, and the latter is the result of using certain integration mechanisms. Hence, in order to manage a team with high diversity, there is a need for increased integration. Moreover, as organizations find themselves situated in increasingly complex environments, systems theory informs us that the organizations in question, too, must increase their requisite variety in order to accommodate the resulting variation and knowledge needs. In addition, research highlights the importance of requisite variety for innovation, while at the same time they argue the need for redundancy (Liebeskind et al. 1996; Reagans and Zuckerman 2001). To handle these paradoxical ideas, Bhidé (2000) proposes a modification of the theory proposed by Lawrence and Lorsch (1967), arguing that there is an optimal level of diversity in organizations as the costs related to increased diversity, in terms of conflicts and/or necessary integration efforts, may actually exceed its benefits.

Building upon this discussion, the goal of the present research is to explore whether and to what extent the levels of project diversity can have both positive and negative effects on knowledge development, and if it, therefore, appears fruitful to avoid both low levels of diversity and excessively high ones.

7.3 Methods

7.3.1 Research Setting

To test our hypotheses, we explored structural properties of project social capital and the degree of knowledge development of a population of 53 biotech R&D projects located at one of the most important science parks in Sweden. Of all the projects considered, seven were academic and related to different university departments, the rest related to several pharmaceutical companies involved in the biotech industry. We chose this particular setting for a number of reasons that we will now explain in more detail.

First, the adoption of "temporary systems" through project-based forms of organizing is important in this field given the increasing instability and uncertainty under the environmental conditions

which organizations have to deal with (Whitley 2004; Zeller 2002). Biotechnology is a high-technology industry, characterized by radical innovation, adaptation pressures, and frequent alliances between large pharmaceutical firms and new biotechnology firms (Powell et al. 1996). Biomedical innovation has been defined in various ways, but here we see it as a process involving the creation and application of scientific and technological knowledge to improve the delivery of human health care and the treatment of disease. Biomedical innovation processes have been described as typically nonlinear or "interactive," comprising complex, uncertain, high-risk, and iterative cycles of knowledge integration and networking across diverse groups and organizations (Powell et al. 1996). Given this backdrop, the adoption of a temporary project structure allows strategic flexibility within organizations undertaking biomedical research and commercialization. Although it is primarily adopted by academic institutions and start-ups and new ventures, previous studies have also reported the "projectification" tendency for pharmaceutical companies in this field through the establishment of cross-functional autonomous units (Zeller 2002).

Second, biotech R&D is an ideal setting to study project social capital because it has widely been recognized as a context in which the social capital is an important performance determinant (Maurer and Ebers 2006). The social exchange relationships that are supported by trustworthy behavior "...play an important role in promoting organizational learning and in fostering organizational flexibility" (Liebeskind et al. 1996: 438) through increasing knowledge integration and reducing rivalry among research actors. Ample evidence has been provided that such benefits concern actors of different types and at different levels, such as scientists and academic researchers (Liebeskind et al. 1996), individual firms and organizations (Powell et al. 1996), as well as single projects (Zeller 2002; Whitley 2004). Networks of project teams represent, in particular, an important mechanism through which organizations involved in innovation processes acquire and create relevant expertise.

In this sector, technology development is particularly boundary spanning since sources of expertise are widely dispersed (Powell et al. 1996). Firms often take the decision to delocalize project units in order to better benefit from the relationships they may establish with other important knowledge sources. Proximity to actors external to firms serves these firms' capability to scan and absorb externally produced knowledge and technologies, which are extremely localized. The literature on localized knowledge spillovers and regional innovation suggests that research projects and teams in close geographical proximity are likely to be more productive than more dispersed teams (Audretsch and Feldman 1996). Especially in the biotech industry, knowledge, ideas, and innovation appear to be extremely localized spatially (McKelvey et al. 2003). Here, personal networks seem strongly rooted in a particular locality, giving rise to a number of benefits for organizational project units, e.g., the reduction of communication costs and a higher efficacy in the transmission of tacit knowledge as a result of the possibility of having frequent face-to-face interaction (Ebers and Powell 2007).

Projects often become highly embedded in a complex web of interdependences manifested in social relationships, localities, and corporate networks, from which they mobilize essential resources (Sydow and Staber 2002). In light of these interdependences, which projects frequently exhibit in this specific sector, it is likely that "organizational boundaries of projects operating within or across different firms (…) are more often decisive as boundaries of the respective firms" (Grabher 2002a: 246).

In this chapter, we analyze project social capital in a particular "project ecology" (Grabher 2002a) which comprises all exchange relationships established between co-located projects in one of the most important science parks in Sweden. Science parks are regional innovation policy instruments that aim for the effective transfer of public knowledge to high-technology-based firms in a well-defined geographical area (Storey and Tether 1998). A number of instruments and tools are often put in place to increase the concentration of knowledge-based actors and in turn the production of innovation at the local level. Facilities can, for instance, be set up to facilitate the location of research units in close vicinity of important universities or public laboratories, and business services are provided for those who aim to start or already have established new technology-based firms. Firms are encouraged to locate laboratories, research units, or entire projects in science parks

because of the increasing possibility to collaborate with important academic institutions, around which science parks are usually established, as well as to gather prestige and visibility in the business community (Felsenstein 1994).

7.3.2 Data Collection

In the present study, the single temporary project is the unit of analysis. The present analysis is developed both with the support of primary data collected through a questionnaire-based survey and with the use of secondary data already available. In particular, primary data relate to the collection of information about the structure of single projects' social capital. In this vein, pilot interviews with project leaders allowed us to make assumptions, develop the methodology of investigation, and make a pre-test of the subsequently administered questionnaires.

A sociometric questionnaire, structured into different sections, was administered during the summer and late fall of 2003 to project managers and team members in order to gather relational data about each investigated project. In the first section, each project manager was found to indicate inter-project exchange relationships. We developed a set of questions in order to see how the project units exchanged informational resources with other actors in the science park. An example of the questions we asked is: "Has your project unit conducted repeated exchanges of information/resources with other on-park tenants through, for example, shared research programs, rotation of researchers or Ph.D. students, joint presentations, or meetings? If yes, please indicate the name of organizations, specific projects, or other tenants within the science park that were involved in this collaboration." The questionnaire was designed to gather data about technical inter-project relationships. The project members were given a questionnaire and asked to indicate with whom they usually discussed three predefined matters integral to project activities: (1) the major *source* for the development of the project activities, (2) the current dialogue and *exchange of opinions* about the development of the project, and (3) the *utilization* of specific knowledge to develop specific parts of their work. We obtained valued relational data between members of each project, since the average frequency of the interaction on a weekly basis during the last year was also checked.

There are a number of proxies for the success of biotechnology projects, including measures such as net margin, revenue growth, employment growth, and patenting rate (Maurer and Ebers 2006). In the present study, given the R&D nature of the investigated project activities, we considered the number of patents granted by each project as a proxy for project knowledge development. Using patent data also allowed us to identify project members' contribution to the innovation performance, measuring knowledge development at project, rather than organizational, level. Data on patents of biomedical projects were obtained through direct interviews with project leaders, and later complemented by two major patent databases. Another archival material available from project leaders was used to collect additional project data concerning tenure and project teams' composition.

7.3.3 Variables and Measures

Dependent variable Our dependent variable is represented by project knowledge development, measured as the number of patents granted. Prior studies consistently suggest that the number of patents is a key indicator of innovation performance, whenever performance is investigated at different levels of analysis. In a study of 258 R&D professionals, Keller and Holland (1982) found that the number of patents granted to each surveyed individual was positively and significantly associated with both superiors' ratings of performance and self-ratings of performance. In a recent study of 1200 companies, Hagedoorn and Cloodt (2003) documented that the number of patents is an indicator that captures the organizational innovation performance. The usage of the number of patents has also been shown to be fairly appropriate as a performance indicator at the project level (Linton et al. 2002).
Data were gathered by querying two large international databases which contain a large amount of detailed information about patents granted: the European Patent Office (EPO) and the World Organization for Intellectual Property (WIPO). We collected patent data by counting

the number of patents for each surveyed project during years 2003 and 2004. To evaluate project performance more accurately, we recorded the patent application date rather than the time of invention. The time that elapses between the date of a completed invention and the patent application date has been shown to be no more than 2–3 months, and thus the patent application date is a good time proxy for when the invention occurred. We note here that, in both of the abovementioned databases, application dates are recorded only for those patents that are finally granted, and thus that all patents recorded by application date are patents that were also granted. Extant research suggests that even the total number of submitted patent applications is an ideal proxy of knowledge development at project level (Cummings and Kiesler 2007). We thus decided to complement our analysis by using as dependent variable the number of submitted patent applications in the period 2003–2004. Data on submitted patent applications were self-reported by project leaders in the course of interviews we conducted. The findings (not shown) obtained from a separate analysis conducted on these additional data were qualitatively similar to those described below.

Independent variable Our indicator measuring the level of diversity of project social capital is *Network range* (Burt 1983). Projects are surrounded by a "diverse" network to the extent that their members spread their network ties across multiple areas of expertise and the connections within contacted areas are weak. Network range has two distinct components. The first is a function of how project members' ties are spread across different areas of knowledge and expertise. The second is a function of the strength of connections with projects working in those areas. Thus, network diversity is defined as:

$$NR_{ij} = 1 - \sum_{k=1}^{N} v_k v_{ik}^2$$

where v_{ik} is the strength of the network connection from member i to area k, and v_k describes the strength of the connections between projects in area k, while v_{ik} is in turn defined as:

$$v_{ik} = \frac{\sum_{j=1}^{N_k} x_{ij}}{\sum_{q=1}^{N} x_{iq,\, q=j}}$$

where N_k is the number of ties that project i has with other projects working in area k, N is the total number of network relationships of project i, and x_{ij} is the number of ties that project i has with project j. Tie strength v_k within area k can be expressed as follows:

$$v_k = \frac{\sum_{j=1}^{M_k} x_{ij}}{\sum_{q=1}^{S_k} x_{iq,\, q=j}}$$

where S_k is the number of contacts that a given project maintains in area k, M_k is the number of projects with expertise in the area k, x_{ij} is the intensity of the relationship between a given project in area k and any project, and x_{iq} is the intensity of the relationship between a project member in area k and a project member working in the same area of research. Therefore, increasing v_k indicates the absence of diverse knowledge inside a knowledge network. We test curvilinear association by including *Network range squared.* For further discussion about this measure, see Burt (Burt 1992) or refer to the application provided by Reagans and Zuckerman (2001).

Control variables We used several control variables to capture the effects of other factors that are potentially important to explain projects' knowledge development, but not theoretically interesting in this specific study. We controlled for the amount of annual *budget* available for each project, as it is likely that the availability of resources would enable research teams to have broader access to technologies, external support, or other important resources ultimately important for knowledge development. This variable is expressed as the (natural logarithm) of the amount of the annual R&D budget expressed in Swedish Kronor. Since the size of projects might also affect the level of performance achieved at the project level, we controlled for the *dimension* by considering the number of scientists and/or corporate researchers affiliated with each project. Also, project *duration* may affect the level of performance achieved, and in the current study, we controlled for the number of months passed since the starting date of the project. A number of the behaviors and outcomes of the project are subject to variation on the basis of their type of ownership. In spite of those owned by private corporations, academic projects are more likely to be oriented toward streams and purposes that reflect those of open-end research (McKelvey et al. 2003). For this reason, we included a dummy variable labeled *Corporation* that equals 1 for projects pertaining to private corporations, and 0 for projects affiliated with academic organizations. Recent studies have shown that patenting can be hindered by the amount of scientific material that scientists publish in peer-reviewed journals or conference proceedings etc. (Blumenthal et al. 1996; Czarnitzki et al. 2009). For this reason, we finally controlled for the *Number of publications* achieved by researchers in each sampled project. Lastly, three control variables concerned the dimension and the general structure of projects' social capital. Since larger networks tend to be less cohesive and also less constrained (Burt 1992), we controlled for these possibilities by controlling for the number of other projects to which single projects are directly connected (*Degree*). The second variable included was the *Total Number of ties* calculated as the total number of inter-project relations connecting projects that compose the focal project's network, leaving out the ties that the latter has with all the others. Given two networks of the same size, composed of the same number of alters, the network with the highest number of ties is characterized by a greater level of interaction. A third, final measure takes into consideration *Network constraint*, along with its squared term, which indicates the general level of cohesion and redundancy characterizing the social capital of each project (Burt 1992). The inclusion of the squared term seems appropriate in light of the hypothesized U-shaped relationship regarding network diversity.

Table 7.1 summarizes our discussion by reporting the descriptive statistics of all the variables included in our empirical model specifications. Table 7.1 also reports the first-order correlation coefficients among all the relevant variables.

Table 7.1 Descriptive statistics and correlation matrix for variables

	Mean	Std dev	Min	Max	1	2	3	4	5	6	7	8	9
1 Budget (log)	6.0111	0.0323	6	6,65	1								
2 Dimension	0.1717	0.3777	6	25	0.0094	1							
3 Duration	0.4074	0.4921	11	34	−0.2514	0.0222	1						
4 Corporation	0.1717	0.2301	0	1	0.0257	0.1191	−0.0397	1					
5 #Publications	11.9448	8.9694	1	37	0.1236	0.2337	0.1895	−0.1301	1				
6 Degree	8.2020	4.9714	0	33	0.0145	0.4096	0.1333	0.0769	0.1989	1			
7 Number of ties	42.1616	31.9721	0	98	0.3310	0.3901	0.2971	0.0019	0.1527	0.5421	1		
8 Network constraint	0.3310	0.1927	0	1	−0.0036	−0.2386	−0.2301	−0.1203	−0.0411	−0.6964	−0.2133	1	
9 Network range	−0.0512	0.5956	−1	1	−0.1308	−0.0553	0.1838	−0.1062	0.0306	0.0082	0.1235	−0.0133	1

7.4 Results and Analysis

We used negative binomial regression to estimate the effect that project social capital closure and range have on the number of patents (Long and Freese 2006). The results are displayed in Table 7.2.

Model 1 in Table 7.2 regresses the number of patents on the set of control variables. Overall, the inclusion of the control variables results in a model that is significantly different from a null model. All of the control variables are significant. As expected, surveyed projects

Table 7.2 Negative binomial regression estimates (standard error in parentheses)

	Model 1	Model 2	Model 3
Constant	−0.8774***	−0.3212	−0.1236
	(0.1642)	(0.3113)	(0.3246)
Budget	1.9837***	1.8812***	1.8921***
	(0.0838)	(0.0791)	(0.0863)
Dimension	0.9494***	0.9075***	0.8788***
	(0.0776)	(0.0712)	(0.0895)
Duration	0.6589***	0.6012***	0.7148***
	(0.0810)	(0.0839)	(0.0779)
Corporation	0.5763***	0.5623***	0.5100***
	(0.0597)	(0.0599)	(0.0509)
Number of Publications	−0.0314***	−0.0316***	−0.0291***
	(0.0039)	(0.0035)	(0.0042)
Degree		0.0211	0.0206
		(0.0190)	(0.0194)
Total number of ties		0.0410**	0.0512
		(0.0199)	(0.0272)
Network constraint			2.4477***
			(0.8444)
Network constraint squared			−3.1864***
			(0.9856)
Network range			0.4180***
			(0.0910)
Network range squared			−0.2473***
			(0.0497)
Number of Obs	53	53	53
Log-likelihood	−1068.9640	−1060.5611	−1036.9011
Pseudo R squared	0.3359	0.3401	0.3671

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

characterized by higher tenure and dimension are more likely to achieve higher levels of knowledge development. This makes sense since tenure indicates the previous experience developed at the project level, which in turn can influence the projects' patenting activity. Also, the dimension variable is positively and significantly associated with the number of patents. Even in this case, it is reasonable to expect that projects with many team members perform better, at least in terms of number of patents. The positive and significant coefficient for the variable "Corporation" indicates that the institutional profile of projects also matters for the levels of knowledge development achieved by projects in our sample. In particular, we can see that corporate projects are more likely to develop new knowledge than academic projects. Our findings also document that the coefficient for the variable "# Publications" is negative and significant, which indicates that the propensity to publish research results of a project is negatively associated with the levels of new knowledge developed at the project level. Although there is no general consensus about this in the extant literature, our results are in line with the evidence provided by recent studies in this field (Czarnitzki et al. 2009).

Compared to the variables of Model M1, Models M2 and M3 include measures characterizing the network structure of the project social capital. Model M2 includes the "Degree" and "Total number of ties." Whereas Degree was not significantly associated with the dependent variable, the positive coefficient for the Total Number of Ties highlights that a greater number of relationships between projects composing the project social capital corresponds to a higher level of knowledge development.

In Model 3, we include two variables that directly speak about the structure of projects' social capital, namely "Network constraint" and "Network range," along with their squared terms are labeled "Network constraint squared" and "Network range squared."

Model 3 in Table 7.2 shows that the coefficient for "Network constraint" is positive and significant, and the coefficient for "Network constraint squared" is negative and significant, suggesting an inverted U-shaped curvilinear relationship that maximizes the number of patents at moderate levels of network constraint. Results also document that the coefficient for "Network range" is positive and significant and the coefficient for "Network range squared" is negative and significant. These results support the hypothesized inverted U-shaped relationship between the range of project social capital and the number of patents achieved at the project level. This pattern of results implies that even though the creation of collaborative ties with other projects operating in different areas of expertise enriches the effectiveness of projects (Reagans and Zuckermann 2001), there are also costs for projects that seek other units to add and integrate new know-how to their knowledge stock (McFayden and Cannella 2004). As further collaborative ties which cut across areas of expertise boundaries are added, the costs of assimilating, absorbing, and combining diverse information eventually outweigh the benefits (Zahra and George 2002). Hence, the logical reasoning used by Bhidé (2000) regarding costs and benefits of diversity at the organizational level appears to be applicable also at the level of project networks.

7.5 Discussion and Conclusion

Drawing upon the recent literature in social capital, we used the construct of project social capital in order to investigate its influence on knowledge development in R&D projects in the biotech field. Our results suggest that certain structural configurations of project social capital maximize the level of effectiveness in knowledge development. More specifically, the empirical observations show that moderate levels of project diversity are correlated with higher knowledge development performance.

The level of diversity of project social capital relates to how different the partners involved in social exchanges are, taking into account the prevalence of cross-boundary social interactions between projects. Our findings show an inverted U-shaped relationship between projects' network diversity and their level of knowledge development, demonstrating that intermediate levels of diversity maximize project knowledge development.

The present study contributes to previous research in several ways. First, the empirical results underscore that project social capital is a useful concept to capture the embeddedness of projects and highlight the importance of external links for project knowledge development. With the exception of a few cases (Arthur et al. 2001; Grabher 2002a; Di Vincenzo and Mascia 2012), there is to our knowledge a lack of studies exploring analytically and with empirical data the interdependences between projects and the network of personal relationships built around projects (Grabher 2002a). In this study, we extend the existing literature on social capital examining how resources and knowledge are channeled through network relations that involve the project level. Project social capital adapts and extends the more established notions of social capital to the specific context in which PBOs operate and perform (Di Vincenzo and Mascia 2012), a setting which is characterized by a number of particularities that bring the importance of social capital to the foreground. Indeed, projects are formed by multiple members who are engaged in frequent communication with other individuals within and outside the project. In addition, projects often involve people working together on complex innovative tasks for a well-defined limited period of time. Finally, it is likely that projects will become highly embedded in a set of project-specific relationships in addition to those that their individual members develop.

The second point of this chapter is that it makes a contribution to the debate among scholars regarding what kind of network structure is the "best" for knowledge development. On the one hand, the theory on structural holes states that individuals who hold heterogeneous ties, connecting two or more otherwise disconnected actors, have more social capital than other individuals (Burt 1992), even though this theory does not specify whether these benefits can be realized under all conditions. On the other hand, a different approach to social capital instead recognizes the advantages of homogeneous social networks and strong ties, which (among other things) should result in a more effective exchange of knowledge (Obstfeld 2005). Our empirical findings support the view that, at least within a project-based context, the more effective network structure seems to be a combination of these two, seemingly incommensurable, structures. A possible explanation for a third way out of these conflicting ideas may be provided by the cognitive distance theory, and specifically by Noteboom et al. (2007), who state that "the challenge is to find a partner at a sufficient cognitive distance to tell something new, but not so distant as to preclude mutual understanding" (p. 1017). At first, as cognitive distance increases, it has a positive effect on knowledge development. 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. However, at a certain point, the cognitive distance becomes so large that it precludes the mutual understanding needed to utilize those opportunities.

Another plausible explanation concerns the disadvantages associated with highly closed and overly embedded networks. One important risk, especially in knowledge-intensive work, is that subjects may start to trust their group judgment more than information from the surrounding scientific world. Known as "group-think," group cohesion tends to generate mutually affirming effects that can reduce or restrict access to the more diverse resources and innovative information that might be available beyond the closed group (McCauley 1989). In particular, the resources and information that flow through external ties might be ignored or discounted when they enter a closed project, or more generally, the lack of information utilization might be due to the development of strong positive intra-project biases and negative extra-project biases that prejudice a project's members against absorbing and using information from outside their project (Oh et al. 2004 use similar arguments about groups). Furthermore, the findings corroborate some of the existing ideas on creativity in organizations (Milliken and Martins 1996) by indicating both the potential positive and the possible negative sides of diversity, pointing out the value of a balanced use of diversity in project portfolios and networks.

The findings of this study also have a number of direct implications for project management. One is that it highlights the need to regard projects as embedded entities, and that project managers should deliberately consider project network aspects in order to better leverage the resources available in project team members' formal and informal relationships, both inside a single project and between different projects. Consequently, there is a need to build and use relationships in a fruitful way, calling for the development of appropriate competences.

Moreover, we see that deliberately managing project social capital is largely about handling the paradox of simultaneously allowing moderate levels of project network diversity and project network constraint, two things that at first sight seem incommensurable. Even though these two dimensions of project social capital may somewhat counteract each other, the pragmatic managerial solution is to accommodate their coexistence by using a suitable set of integration mechanisms within and between projects, in order to create prerequisites in terms of levels of redundancy and absorptive capacity. By extending the view of the relevant system boundaries to include other projects and the relationships to them, managers can reveal opportunities to move beyond the earlier perceived trade-offs and thereby reach new levels of performance (Di Vincenzo and Mascia 2012). Arguably, an important contingency factor to consider in relation to the effects of project social capital is the extent to which projects aim at generating new knowledge through creative processes, and the extent to which they are vehicles for efficiently bringing together already existing knowledge.

The study has a number of limitations that invite further investigation. As with most network research, the design was cross-sectional, preventing determination of causality. Although we have argued that a project's configuration of social capital determines its level of knowledge development, future longitudinal research might be able to determine the direction of causality. Recent studies have documented that the analysis of the evolution of collaborative patterns is especially essential for better understanding of a number of relevant project-based outcomes such as learning and innovation (Manning and Sydow 2011). Longitudinal data would allow us to explore in depth the links between project social capital and knowledge development. Such data would also enable us to examine how different inter-project relationships emerge, evolve, or are abandoned, in accordance with a truly dynamic process (Guimerà et al. 2005). However, such longitudinal models face considerable challenges in terms of data collection, notably as far as network data are concerned.

Another limitation is that our analysis of the structural aspects of project social capital is limited to those collaborative relationships established by, and among, projects localized within the science park. We are aware that projects' relationships with actors localized in different contexts also play an important role for project behavior and performance. However, there is ample evidence about the importance that co-location has for research actors in highly uncertain and complex industries such as biotech R&D (Liebeskind et al. 1996). In this context, the rise of trustworthy, frequent, and reciprocal exchange of relevant resources, which is strictly related to the possibility to achieve important outcomes, dramatically depends upon the availability of potential partners in the immediate network around a project. A deeper understanding of how projects develop new knowledge in this field strongly relies on the way they build upon existing networks with other projects to generate and use resources, which is a fruitful avenue for future research.

A third limitation concerns the proxy we adopted for the measurement of knowledge development at the project level. Previous studies have indicated that, other than the number of patents granted, there are a multitude of project aspects that may be referred to as project knowledge outcomes—such as new grants achieved, new spin-off projects, development of models or approaches in the field (Cummings and Kiesler 2007). In addition, in this study, we focused on short-term outcomes in research collaboration, rather than the quality of a particular outcome or long-term outcomes. Notwithstanding this limitation, extant research has largely documented that patents granted can be considered a proxy of knowledge development at the project level in biotech R&D (Maurer and Ebers 2006). Future work would benefit greatly from exploring whether the hypothesized structural configurations of project social capital do play the same role for other project outcomes achieved in this industry.

A final limitation refers to a number of idiosyncrasies pertaining to the non-random choice of the research setting adopted in this study. As the specialized literature has recently theorized, project-based forms of organizing are not homogeneous: they differ in a number of important respects (Whitley 2004). The data employed in this study refer to only 53 projects in biotech R&D, leaving open the question of whether our results would generalize to a broader population of projects in different industries.

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