The architecture of R&D joint projects: the social network analysis approach

This paper examines the effect of network properties on the performance R&D joint projects. In particular, we examine the impact of network cohesion, diversity and shape on the performance of these of exploration and exploitation R&D projects. We test these measures using data on projects from European R&D networks developed under the framework of Eureka projects. The empirical results indicated some network properties enhance the project's performance and these differ depending on the kind of technological project developed. Our results suggest a lower heterogeneity, greater cohesion and network centralization in exploitation than in exploration projects. Our findings show different types of structures depending on the aim of the joint project and that there exist different degrees of cohesion between the partners that comprise the core and the peripheral nodes.

Keywords: R&D joint projects; Architecture; Social Network Analysis.

1. Introduction

Networks as a way to organize partnership in joint projects have received considerable attention in the management and organization literature (Zheng et al., 2016; Schilling and Phelps, 2007). Although research has long recognized the importance of networks in technological fields, only recently have researchers begun to assess the structural properties of networks and their impact on innovation and performance (Arroyabe et al., 2015; Rank, 2008). Research on partnership considers that the role of network structure is critical to the performance of the project (Martínez-Torres, 2014; Bosch-Sijtsema and Postma, 2010). Since partners often turn to their social contacts to seek information or resources (Arranz and Fernandez de Arroyabe, 2013), such structures are a crucial means of accessing diverse sources of knowledge (Bjorvatn and Wald, 2018). In addition, network structures help technology adoption providing intense interaction and communication among partners. This reason has led to study networks beyond the dyadic level to the network level seeking to understand the nature, effects and interdependencies in technological networks (Borgatti and Halgin, 2011). Despite researchers have recently addressed aspects of these questions (Martínez-Torres, 2014; Braha and Bar-Yam, 2007), studies have focused on firm's position in alliances or in the proximity of the potential partners rather than the structure of the overall network.

Joint R&D projects based on networks continue to be one of the most important ways for innovation. R&D projects make reference mainly two broad categories: exploration and exploitation. March defined exploration activities as those which includes "things captured by terms such as search, variation, risk-taking, experimentation, play, flexibility, discovery, innovation", while exploitation comprises "such things as refinement, choice, production, efficiency, selection, implementation, execution" (1991: 71). Researchers have pointed out that the flows and relations in these two kinds of projects structures may differ (Arranz and Fernandez de Arroyabe, 2013). Thus, assuming March's learning model (1991), in the case of exploration projects, the main structural characteristics are sparse and diverse networks, which facilitate access to a range of information that increases the diversity of the firm's knowledge bases (Gilsing et al., 2008). In the case of exploitation projects, the structural characteristics are cohesive and tightly-integrated networks, which favour cooperation, sharing, and access to resources, all of which reinforce the firm's knowledge bases (Bjorvatn and Wald, 2018). However, as noted by Gilsing and Duysters (2008), networks abundant in structural holes promote knowledge diversity, but this also results in high costs of knowledge implementation. Similarly, closed network structures reduce knowledge novelty and enhance the risk of obsolescence. These arguments raise the following question: what network properties will enhance the exploration and exploitation performance of projects?

To address this question, we examine a group of network-based measures that capture the essence of joint projects and discuss the effect of these network properties on the performance of exploration and exploitation of technological projects. We test these measures using data on projects from European R&D networks developed under the Framework Programs. In particular, we examine the impact of network cohesion, diversity and shape on the performance of these projects. Thus, the level of cohesion in R&D projects accounts for how strongly interconnected its project members are, and is generally used to highlight the degree of constraint of actors as network members (Leon et al., 2017). The diversity in technological projects reflects how different the partners involved in exchanges are (Bessant et al., 2014). Finally, the shape informs about the heterogeneity of network connections as a result of the affinity between certain partners (Borgatti and Halgin, 2011).

2. Network structure and project performance

Joint projects in their development and organization are supported within a network structure, that is, in a set of partners connected by a set of ties (Borgatti and Halgin, 2011). The partners can be firms and institutions of at least four different countries national or international firms and institutions, and the ties that connect partners serve as the "pipes" through which information flows (Takanashi and Lee, 2018; Gilsing et al, 2008). Joint projects, therefore, constitute a network structure in which each partner is considered a node of the network and network ties represent the relationship of collaboration in the development of the joint project. This provides a framework in which to understand network properties. Thus, the types of connections may vary from project to project, in what Rothaermel Deeds (2004) described as an exploration-exploitation model of organizational learning. Therefore, the partner's choice to take part in a joint R&D project can be distinguished in terms of its motivation to exploit an existing capability or to explore new opportunities. Exploration involves innovation, basic research, invention, and new lines of business (Arranz and Fernandez de Arroyabe, 2013). It focuses on the 'R' in the research and development process in which Rothaermel and Deeds (2004) define as search, variation, risk-taking, experimentation, play, flexibility, discovery, or innovation. Exploitation, in contrast, is associated with standardization, routinization, and systematic cost reduction, increasing the productivity of employed capital and assets and improving and refining existing capabilities and technologies (Gilsing et al., 2008). It focuses on the 'D' in the research and development process and is defined by Rothaermel and Deeds (2004) as refinement, choice, production, efficiency, selection, implementation, or execution. According to Rothaermel and Deeds (2004), exploration and exploitation projects are related to and built on each other: exploration develops into exploitation, and exploration emerges from exploitation; exploration concludes with the product development process and exploitation finalizes when the product is on the market.

Three structural characteristics of networks, as defined by Borgatti and Halgin (2011), play a particularly important role in the performance of projects: diversity, cohesion and shape. Diversity makes reference to the variety of alters which connect a partner with respect to a relevant dimension; cohesion explains the general level of connectedness of a structure, and shape indicates the overall distribution of ties. These measures are closely related to research conducted in recent years relating social structures and group performance, and so allows the results of our study to be interpreted within the context of previous research.

2.1. Diversity

From a structural viewpoint, the network of partners that develop a joint technological project may be made up of companies, universities, and other science-based institutions, which implies a great structural heterogeneity due to the diverse types of organizations that take part (Mitsuhashi and Min, 2016). In fact, from the social capital perspective, the necessity of this structural heterogeneity is emphasized. Thus, Vincenzo and Mascia (2012) point out that cognitive diversity derives from the collaborative ties that project members establish with other colleagues in different areas of expertise. This diversity also enhances the capacity for creative problem-solving and allows individuals to share different sets of contacts, skills, information, and experiences (Schilling and Phelps, 2007). Therefore, the greater the number of different types of actors to which a partner is linked, the greater the diversity of information and social support to which the partner has access.

In the performance of the exploration projects, Gilsing et al. (2008), explain that while large distances in cognition have a negative effect on absorptive capacity, they have a positive effect on the potential for novelty creation. Gilsing et al. (2008) also point out the positive effects of large distances between partners on learning because of interaction yields opportunities for novel combinations of complementary resources. These authors conclude that while absorptive capacity declines with technological distance, novelty value increases. Rothaermel and Deeds (2004), suggested that exploration projects are characterized by partners' heterogeneity (partners whose attributes differ from those of prior partners), while exploitation projects whose objectives involve the use and development of things already known, and in which absorptive capacity is a fundamental element (Arranz and Fernandez de Arroyabe, 2013), they observed a lesser heterogeneity. Therefore, we hypothesize:

Hypothesis 1a: The heterogeneity of partners will be more effective in improving project performance in exploration joint R&D projects than in exploitation projects.

Additionally, the structure of the joint R&D project is not only affected by this diversity of partners at its activity level (firm, university or research centre) but also in its cultural dimension due to the different countries from which the partners that normally take part in European projects proceed. Therefore, we hypothesize:

Hypothesis 1b: The heterogeneity of countries will be more effective in improving project performance in exploration joint R&D projects than in exploitation projects.

Since exploitative and explorative joint projects are fundamentally different in nature, the combination of countries and partners' heterogeneity is expected to have a different impact on the two types of projects, therefore, we hypothesize:

Hypothesis 1c: The multiplicative interaction between heterogeneity of partners and countries will be more effective in improving project performance in exploration joint R&D projects than in exploitation projects.

2.2 Cohesion

Borgatti and Halgin (2011) defined the structural cohesion of a network as the degree to which actors are connected directly to each other by cohesive bonds. These connections between partners constitute an important source of information and resources for participants in the project. The social capital theory emphasizes the role of cohesion in networks not only as structures of exchange but also as governance mechanisms. Thus, Martinez-Torres (2014) indicated that strong ties are the appropriate channel for transferring tacit knowledge, while Gilsing et al (2008) argued that weak ties are conduits whereby an actor can access novel information. Moreover, other researchers have explained that the cohesion serves as a governance mechanism since these connections promote shared behavioural norms and cooperation (Bendoly et al., 2014) and increase mutual gains, reciprocity and long-term perspectives through repeated contacts (Bessant et al., 2014).

The cohesion of a network may be measured by density, which is a ratio between the links present in the network and the total of all possible links between partners. Thus, depending on this variable it may define sparse networks if they have low contacts and dense networks if they have high links. Dyer and Nobeoka (2000) showed in the case of Toyota's suppliers two levels of network density depending on the processing of technological knowledge. Low density in those devoted to exploring technological information, and highly dense networks in those devoted to exploiting information for obtaining innovative products. Gilsing et al. (2008) also found that sparse networks are conduits whereby an actor can access novel information, while Burt (2004) suggested that people who stand near the holes in a social structure run a higher risk of having good ideas, and other studies have pointed out that network density limits the potential for novelty creation (Tseng et al., 2016). Based on these ideas, we suggest that in the performance of exploration projects, the influence of density will be less positive than in exploitation projects. While density ensures a greater quantity of information, this property may saturate the ability of the project to create new alternatives as a result of a large amount of information received by participating in multiple projects. Accordingly, we propose:

Hypothesis 2a: The density of the network will be more effective in improving project performance in exploitation joint R&D projects than in exploration projects.

Another way to examine the cohesion of a network is by measuring reach, that is, the degree to which any member of a network can reach other members of that network. Reach diminishes when the network has structural holes, i.e. static holes that can be strategically filled by connecting one or more links to join other points. Gilsing et al. (2008) pointed out that partners' proximity is a structural property that facilitates the transfer of tacit knowledge and enhances the build-up of absorptive capacity. In a similar sense, Bouncken (2011) concluded that absorptive capacity declines with the distance between partners. Hence, this approach suggests that network structures vary from highly integrated with close ties among partners whose fundamental goal is to exploit information, to networks with large distances between partners whose aim is to explore information. Alternatively, as Rothaermel and Deeds (2004) pointed out, reach serves as a governance mechanism. These authors conclude that the higher degree of proximity or reach among partners encourage the performance of collaboration projects –lessening situations of opportunistic behaviour–, and that exploitation projects are more binding than exploration projects. In essence, the greater the applicability of projects, as in the case of exploitation projects versus exploration projects, the greater the risk of opportunistic behaviour. Thus, we would expect that in the performance of exploitation projects reach would be an important structural characteristic of the network. Overall, this suggests the following:

Hypothesis 2b: The proximity of partners will be more effective in improving project performance in exploitation joint R&D projects than in exploration projects.

Hypothesis 2c: The multiplicative interaction between density and proximity will be more effective in improving project performance in the exploitation of joint R&D projects than in exploration projects.

2.2. Shape

Shape indicates the affinity between certain partners and derives from the homophily principle proposed by Borgatti et al. (2009). Borgatti et al. (2009) pointed out that homophily is produced when the members of the group have their closest ties to members who are similar to themselves. Borgatti and Halgint (2011) also noted that the heterogeneous distribution of connections in technological and social networks is the consequence of the affinity and privileged relations between partners resulting from the different roles that they adopt. Thus, in a homogeneous or random network the majority of nodes have the same number of links; in contrast, in a heterogeneous network, small groups of nodes, implying that there are dominant nodes, dominates the flows. Therefore, the shape shows the heterogeneity distribution of ties among nodes.

Such heterogeneity, on the one hand, maybe due to the existence of a core and a peripheral partition of nodes that lead to a medium degree of centralization in the network, such as Gilsing and Duyster (2008) highlighted in the biotechnology sector. These authors also note that the core shows a high density as opposed to the low density exhibited by the connections in the peripheral nodes. Cuevas-Rodríguez (2014) attributed this distribution of ties among nodes to the requirements of governance structures, whose objectives are to solve conflicts, coordinate common tasks and distribute results. On the other hand, other authors remarked that technological networks are founded on a simple consensus-based structure, supported in a small group or central core of partners (Bessant et al., 2014), and coordinated generally by a network promoter whose capacity for decision-taking is limited and subject to the consensus of that central core (Fabrizi et al., 2016). Borgatti and Halgin (2011) also indicated that a network with high centralization has a high degree of robustness which can prevent the collapse of the network caused by the failure of a node when clusters of unrelated partners are formed. Given the different objectives described by Rothaermel and Deeds (2004) for exploration and exploitation projects, it may be suggested that the influence of network centralization should be more positive in exploitation projects than in the case of exploration projects. Since the existence of a central core of partners will facilitate the process of task execution and decision-making in the network, which may improve the performance of the project. Accordingly, we propose:

Hypothesis 3a: Network centralization will be more effective in improving project performance in exploitation joint R&D projects than in exploration projects.

On the other hand, heterogeneity may be because partners who share similar characteristics interact more among themselves than with partners that do not. This affinity results in denser areas in the network with the highest levels of interconnection between partners (clustering). Clustering allows quickly exchanging and integrating a wide range of sources leading to greater knowledge creation (Schilling and Phelps, 2007) so that clustering improves the transmission of information and the absorptive capacity between partners. Uzzi and Spiro (2005) also argue that bridges between clusters enable that different ideas and routines are distributed to other clusters, facilitating the recombination of previous and novel approaches. However, Braha and Bar-Yam (2007) point out that high clustering hinders the governance of the network, as a result of creating isolated units that neither facilitate the creation of trust nor eliminate the possibility of opportunistic behaviour between partners. Therefore, we can anticipate that the influence of clustering will be more positive in the performance of exploration projects than in exploitation projects. Accordingly, we propose:

Hypothesis 3b: Clustering will be more effective in improving project performance in exploration joint R&D projects than in exploitation projects.

On the other hand, from the small size of exploitation projects, it is expected that the combination of clustering and centralization will enable that information to be exchanged and integrated quickly, facilitating both knowledge absorption and the governance of the project. Overall, this suggests the following:

Hypothesis 3c: The multiplicative interaction between clustering and centralization will be more effective in improving project performance in exploitation joint R&D projects than in exploration projects.

3. Methods

3.1.Data

In order to test the effect of network properties on the performance of the R&D projects, the data used in this study were extracted from a database built up in the context of a wider research on R&D projects developed within the framework of Eureka Program. The targeted population was made up of Eureka project managers. The literature has considered the project manager as the sponsor, who has the initiative for the development of the project, is in charge of coordinating all the partners, and maintains the contractual responsibility between the partners and the European Union (Arranz and Fernandez de Arroyabe, 2013). In fact, the project manager is responsible for the execution of the tasks, the budget and the execution time. The sample size was selected at random by stratified sampling, proportional to groups of project type (exploration /exploitation) and European country, getting 650 projects managers. The data were obtained through a mail survey. The questionnaire was pretested on 10 project managers located in different countries. We thus obtained a final sample of 297 usable responses (121 for project managers of exploration projects and 176 for project managers of exploitation projects).

In order to rule out possible biases of the survey, we conducted several ANOVA analyses at different mailing stages. No significant differences emerged between the different groups of responses. Because our dependent variables and some independent variables were obtained using the same survey instrument, we follow the methodology proposed by Podsakoff et al. (2003) in order to avoid common-method bias. Furthermore, we performed Harman’s single-factor test whose result suggested the absence of common method bias.

3.2 Measures

Independent variables

In social literature, *diversity* has been proposed under other terminologies such as bridging social capital, which explains its importance in many social phenomena (Borgatti et al., 2011). Diversity allows partners to connect with partners of many different types, which means that they could reach potential collaborators of a much wider spectrum of varied knowledge and expertise. Two main dimensions of diversity affect European joint R&D projects: the heterogeneity of both the partners and the countries.

Heterogeneity of partners across R&D projects provides the requisite variety for recombination as pointed out by Martinez-Torres (2014). Regarding the heterogeneity of partners, Vincenzo and Mascia (2012) distinguished the following types: universities, research centres, and industries. In our study, each partner typology was determined by its frequency of participation in the network and measured by a Likert scale from 1 (low) to 7 (high frequency). Then we use the Gini coefficient *dispersion degree of partners* (*Gp*) to measure the degree of homogeneity of partners that take part in the project-network. This coefficient varies from 0 (heterogeneity of partners) to 1 (homogeneity of partners).

As regards the *heterogeneity of countries*, and following a similar scheme, we measured the geographical heterogeneity taking into account the different countries that the partners involved in the project were from. We use the Gini coefficient *countries heterogeneity* (*Gc*) to measure the degree of homogeneity among the countries taking part in the network, which ranges between 0 (heterogeneity of countries) and 1 (homogeneity of countries).

The network *cohesion* refers to the connectedness of the structure and includes measures such as *density* and *reach (*Borgatti et al, 2009). The first measure we reported was d*ensity*, defined by Borgatti et al. (2009) as the proportion of group members who are linked together in the network; the more partners are connected to one another, the denser the network is. Based on previous findings, density was measured as the sum of the actual number of ties of all the partners of the ego network and divided this by the sum of the maximum possible number of ties of all the components (Contractor and Monge, 2003). Thus, values close to 1 correspond to very dense networks; on the contrary, values close to 0 correspond to very sparse networks.

Regarding *reach*, Borgatti and Halgin (2011) defined it as the average path distance between all pairs of members in a group. Reach, therefore, measures the extent to which all the nodes in the network are accessible to each other and then offers an overall idea of how cohesive the network is. Following Borgatti et al. (2002), this measure was calculated as the average distance-weighted reach which can range from *zero* to *n*, with larger values indicating higher reach.

Shape (Borgatti et al., 2009) is the overall distribution of ties in a network and includes measures such as *centralization* and *clustering*. *Centralization* reflects the extent to which interactions are concentrated in a small number of individuals rather than distributed equally among all members of the network; this is analogous to the variance of network ties per group member. We used the centralization measure defined by Borgatti and Halgin (2011), which is an expression of how tightly the network is organized around its most central node. Centralization reflects the extent to which interactions are concentrated in a small number of partners rather than distributed equally among all members of the network.

Clustering measures the probability that 'the partner of my partner is also my partner', and provides insight into what is referred to as the neighbourhood structure of the network (Borgatti and Halgin, 2011). Following Borgatti et al. (2009), we measured the *clustering coefficient or transitivity* as the number of transitive triples divided by the number of potential transitive triples. Thus, if the value is near 1, the partners of anyone node have a high probability of being partners with each other.

Dependent variable

The project performance was measured using a survey completed by the project managers of the network. We used a perception measure that assessed partners' satisfaction, defined as the degree to which project members consider association with the partners (Arranz and Fernandez de Arroyabe, 2013). Each of the survey respondents was asked about the extent to which they are satisfied: (1) with the overall performance of the project; (2) the financial performance of the project; and (3) with respect to the attainment of goals.

Control variables

Size of the network. The size was measured considering only those partners that take part in the project (with a contractual relation).

Estimated Effort and *Duration*. Projects that involve more effort hours or work days may have been more difficult and may have required greater contacts between partners. To control for both of these potential effects we included the log of the estimated total person-hours and the total days.

R&D intensity. Dichotomy variables were included to indicate whether the project in which the partner is involved was high-tech (HT), mid-high-tech (MHT), mid-low-tech (MLT) or low-tech (LT), using OECD (1997) classification, such that "0= non-belong to this group and 1= belong to this group".

4. Results and discussion

Tables 1a and 1b present the descriptive statistics and Pearson correlation coefficients for all variables used in the models in order to distinguish the pattern of properties in the projects. Table 2 presents the results of the regression analysis. Model fits are acceptable with significant chi-square values ($p < 0.01$) and R^2 values ranging from 0.299 to 0.501 for all specifications.

Observing the results of Tables 1a and 1b it is possible to get an overall idea of how homogeneous a network is. Thus, regarding the type of partners, networks that develop exploration projects are more heterogeneous (heterogeneity partners, Gini= 0.44) than networks of exploitation projects, whose Gini coefficient is near to 1 (0.67). In the case of heterogeneity/homogeneity of countries, a slightly greater homogeneity is observed. This is also observed in the exploration projects (0.28) compared to the exploitation projects (0.45). On the other hand, in Table 2, it is observed that in the exploration networks the country heterogeneity ($\beta = -0.284$, $p < 0.05$) is the variable with a positive and significant impact on the exploration projects performance. This positive effect suggests the importance of the geographical dispersion in the composition of partners that take part in exploration networks. Also, our results show that partners and geographical dispersion acting jointly ($\beta = -0.225$, $p < 0.05$) are more forceful in improving the performance of exploration projects. These findings provide support for Hypothesis 1b and 1c since it is observed that for the case of exploitation projects the dispersion variables (partner and country heterogeneity) are not significant in their effect on project performance. These results complement previous studies from Gilsing and Duyster (2008), which identify the heterogeneity of resources as a condition for competitive advantages in the network. We extend their results by finding that this heterogeneity may act in R&D partnerships performance depending on the objective of projects. Our empirical evidence shows two characteristics, which may possess the information as a resource in an exploration project: heterogeneity, which allows partners to access novel information, and non-redundancy, which avoids the overload in the information processing capacity and facilitates the ability to detect new alternatives.

The second block of descriptive variables of structural cohesion (*density* and *reach*) presents the degree of linkages among the partners of the network. It is observed, as the first group of characteristics, the important variability in the results of density (from 0.3 to 0.9, reaching average values of 0.51 for exploration and 0.77 for exploitation). These results are consistent with the arguments of Gilsing et al. (2008) which stated in the case of exploration networks in the automotive and pharmaceutical industries, that density values were near zero indicating very sparse networks; and with Fabrizi et al. (2016) which concluded that density values were near to one in networks for technical consulting, indicating very dense networks. In the case of reach, we have obtained a variation from 0 to 4 nodes of distance between partners with average values of 2.02 and 1.15. We note that these results show a low variability compared with previous studies. As Newman (2010) noted, the reason for that is due to the small size of networks. Thus in the case of exploration, we obtain an average value of about 10 partners per project, and in exploitation an average value close to 5 partners. As the second group of characteristics derived from cohesion variables, it is observed that results show a higher density in the case of exploitation projects (0.77) than in the case of exploration projects (0.51). Similarly, the reach variable shows a shorter distance in the case of exploitation (1.15) than in exploration projects (2.02). The reach variable tells us that, in exploitation projects, the average distance between pairs of nodes is "one degree of separation", that is, there is a direct contact between partners, thus resulting in a more cohesive network than in the case of networks of exploration projects. Alternatively, the degree of cohesion is an important factor for the performance of the projects, based on the results of density ($\beta = 0.475$; $p < 0.01$) and reach ($\beta = -0.322$, $p < 0.05$) variables. These findings support Hypothesis 2a and 2b. Moreover, the results indicated support for our argument that density and reach acting jointly ($\beta = 0.392$, $p < 0.05$) are more forceful in improving the performance of exploitation projects (Hypothesis 2c). Our results are consistent with previous literature in which it is pointed out that cohesion is a central variable for the governance of networks (Arroyabe et al., 2015), especially when the transmission of knowledge, its appropriateness, and avoidance of opportunistic behaviour are key factors in the success of the project.

The third block of Tables 1a and 1b shows the structural variables related to the network shape. The first measure we explored was the centralization of the network. As Newman (2010) points out, one network is more centralized than another is when it has a core formed by a group of core nodes. With this objective, we calculated the K-core in both types of networks. Our results show two cores in the case of exploitation projects and three cores in the networks of exploration projects. These results provide some insights. The main core in exploitation projects contains on average 68% of the nodes, while only 23% are included in exploration projects. In the secondary core, in contrast, the distribution of partners in the core is more similar: on average 32% in exploitation projects and 35% in exploration projects. There is another secondary core in the case of exploration networks, which on average contains 42% of the remaining nodes. Therefore, a greater degree of centralization is observed for exploitation projects –through the participation of most of the partners in the main core–, which also reflects a high level of interconnection between nodes, than in the case of exploration projects. This outcome was confirmed as well by the results of clustering measurement. Moreover, our results show that centralization has a positive and significant effect on the performance of exploration ($\beta = 0.199$, $p < 0.10$) and exploitation projects ($\beta = 0.210$, $p < 0.05$). To confirm or refute Hypothesis 3a we performed a graphical analysis of the effect that centralization has on both types of projects, and as represented by the Figure 1, we observed a greater impact on the performance of the project in the case of exploitation projects than in exploration projects, which corroborates Hypothesis 3a. The literature has considered the centralization as a nearly exclusive property of exploitation activities and our results corroborate this empirical evidence. However, it also highlights the existence of a certain degree of centralization in exploration projects. These results are similar to Gilsing and Duyster (2008) when they indicated the existence of central and peripheral nodes in exploration projects, and when they highlighted the need for a certain degree of cohesion among partners as a governance mechanism of exploration networks. This argument is consistent with Cuevas-Rodriguez et al. (2014) who pointed out that many non-redundant ties will decrease the potential for novelty absorption because of the consumption of time and resources as well as the difficulty to absorb and integrate these novel insights.

Alternatively, the clustering measure indicates an important variability. Thus, we have obtained values ranging from 0.10 to 0.90. Schilling and Phelps (2007), who obtained values from 0.05 to 0.8, in projects whose objective was to obtain patents, also noted this variability, as a first aspect. A second aspect to highlight is that we find a higher level of clustering in exploitation projects (0.72) compared with exploration projects (0.45), which means that the probability of transitivity in interconnections is greater in exploitation than in exploration projects. Additionally, the smaller size of exploitation networks (5 nodes on average) versus exploration networks (10 nodes on average), provides a picture of the shape of exploitation projects compared with exploration projects: they are smaller, more centralized and have greater levels of interconnection among all nodes. Regarding the effect, that clustering has on the performance of the project, we note that neither of the two types of projects has obtained significant values, but we may state that the joint action of centralization and clustering has a positive and significant effect on exploitation projects (Hypothesis 3c). This finding is coherent with Bouncken (2011) arguments that the clustering with high proximity between the partners was an important factor in the transmission, and especially, in the absorption of knowledge by partners.

5. Conclusion

We have studied the effect of network properties on the performance of exploration and exploitation joint projects from the social network perspective. The empirical results indicated support for our argument: some network properties enhance R&D project's performance and these differ depending on the kind of technological project developed. Our results suggest a lower heterogeneity, greater cohesion and network centralization in exploitation than in exploration projects. Our findings are consistent with those of prior research in showing different types of structures depending on the aim of the R&D project (Arranz and Fernandez de Arroyabe, 2015) and that there exist different degrees of cohesion between the partners that comprise the core and the peripheral nodes (Gilsing and Duyster, 2008). Thus, our results for exploration are similar to Gilsing et al., (2008) which show that these networks have a low centrality level, and little cohesion (Cuevas-Rodríguez et al., 2014; Martínez-Torres, 2014). Regarding the networks whose objectives are exploitation, the properties displayed such as the creation of work teams, the participation of different types of partners and a high level of centralization are similar to those shown in previous studies (Rothaermel and Deeds, 2004).

One of the key contributions of this paper is to highlight the effect of network structures in joint R&D projects. We contribute to the literature on project management by showing the impact of network properties on the performance of exploration and exploitation of joint R&D projects. Our results confirm that the diversity of partners, the cohesion and the overall distribution of ties in the network have a great impact on project results and on the performance perceived by partners, as well as the contingent character of the structure with the type of R&D project.

Second, our research extends the social capital theory (Borgatti and Halgin, 2011) by analyzing the impact of some structural properties of networks on the performance of joint R&D projects. Our results add to this literature by suggesting that cohesive or closed networks are most appropriate when the goal of the network is more applied, whereas networks with structural holes or those that are more sparse and heterogeneous are suitable for finding novel information. Moreover, the results of this study also inform about the debate over network governance (Bendoli et al., 2014) indicating not only the role that social cohesion plays as a control mechanism but stressing the importance of the existence of a central core in the governance of the network regardless of the project developed.

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Table 1a. Descriptive dates and correlation matrix (Exploration)

	Mean	SD	1	2	3	4	5	6	7
1. Density	0.51	0.23	1.000						
2. Reach	2.02	0.85	0.219**	1.000					
3. Clustering	0.45	0.27	0.199**	0.103*	1.000				
4. Centralization	0.33	0.16	0.015	0.092	0.059	1.000			
5. Heterogeneity (partners)	0.44	0.08	0.048	0.103*	0.017	-0.094	1.000		
6. Heterogeneity (countries)	0.28	0.07	0.076	0.056	0.015	-0.032	0.139**	1.000	
7. Performance	3.41	1.99	-0.121*	0.054	-0.034	-0.158	0.098	0.124*	1.000

*p < 0.10; **p < 0.05; ***p < 0.01

Table 1b. Descriptive dates and correlation matrix (Exploitation)

	Mean	SD	1	2	3	4	5	6	7
1. Density	0.77	0.13	1.000						
2. Reach	1.15	0.44	0.119**	1.000					
3. Clustering	0.72	0.10	0.145***	0.160*	1.000				
4. Centralization	0.86	0.10	0.017	0.081	0.004	1.000			
5. Heterogeneity (partners)	0.67	0.19	0.020	0.099	0.045	-0.002	1.000		
6. Heterogeneity (countries)	0.45	0.14	0.051	0.053	0.037	-0.078	0.177	1.000	
7. Performance	4.37	1.52	0.203**	0.174*	0.113*	0.029	-0.014	-0.153	1.000

*p < 0.10; **p < 0.05; ***p < 0.01

Table 2. Hypotheses testing

Variables	Exploration					Exploitation				
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
Heterogeneity (partners)		-0.018			-0.049		0.099			0.072
Heterogeneity (countries)		-0.284**			-0.216*		0.088			0.054
H. partners x H. countries		-0.225*			-0.197*		0.046			0.066
Density			-0.087		-0.074			0.475***		0.442***
Reach			0.028		0.033			-0.322**		-0.318**
Density x proximity[1]			-0.034		-0.051			0.392**		0.330**
Centralization				0.199*	0.181*				0.210**	0.204*
Clustering				0.027	0.032				0.095	0.096
Centralization x Clustering				0.074	0.099				0.125*	0.118*
Size	0.328***	0.297**	0.215**	0.310**	0.280***	-0.281**	-0.118*	-0.174*	-0.150*	-0.113*
Effort	0.033	0.012	0.007	0.054	0.037	0.094	0.032	0.037	0.068	0.072
HT	0.112*	0.099	0.084	0.109*	0.113*	0.123*	0.186*	0.194**	0.188*	0.159*
MHT	0.095	0.074	0.101*	0.098	0.071	0.110*	0.092	0.136*	0.109*	0.077
MLT	0.021	0.010	0.032	0.034	0.005	0.027	0.084	0.099	0.071	0.075
LT	0.084	0.037	0.025	0.066	0.012	0.019	0.050	0.043	0.054	0.092
$\mathbb{R}^2$	0.311	0.328	0.394	0.350	0.477	0.299	0.399	0.351	0.304	0.501

*p < 0.10; **p < 0.05; ***p < 0.01. [1]Proximity is measure as the invest of reach

Figure 1: Effect of network properties on performance project