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THE SOCIAL UNDERPINNINGS OF ABSORPTIVE CAPACITY: THE MODERATING EFFECTS OF STRUCTURAL HOLES ON INNOVATION GENERATION BASED ON EXTERNAL KNOWLEDGE

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Building on absorptive capacity and social network research, in this paper I investigate how individuals inside the organization use external knowledge to generate innovations. Through original sociometric data collected from 276 scientists, researchers, and engineers from the Research and Development division of a large multinational high-tech company, I show that the effects of external knowledge on individuals' innovativeness are contingent upon individuals' position in the internal social structure. In particular, results indicate that the positive effects of external knowledge on innovation generation become more positive when individuals sourcing external knowledge span structural holes in the internal knowledge-sharing network.

INTRODUCTION

Absorptive capacity, or the ability to understand, acquire, use, and ultimately take advantage of knowledge available outside the organization, has long been recognized as an important driver of firms' innovative performance (Cohen and Levinthal, 1990; Henderson and Cockburn, 1994; Tsai, 2001). Through a primary focus on companies' investment in research and development (R&D), several contributions in this research stream corroborated the original claim made by Cohen and Levinthal (1990) according to which higher R&D spending increases organization's ability to acquire and use external knowledge, which, in turn, enhances firm's innovativeness (Lane and Lubatkin, 1998; Lane, Salk, and Lyles, 2001). Implicit in the link between R&D investment and absorptive capacity is the notion that external knowledge can be easily assimilated and converted into organizational innovations. However, the actual mechanisms through which organizations *acquire and use* external knowledge to innovate remain, to date, largely under-investigated (Laursen and Salter, 2006; Volberda, Foss, and Lyles, 2010). In particular, although Cohen and Levinthal (1990: 131–134) explicitly referred to an organization's absorptive capacity as driven by the absorptive capacity of its individual members, only limited attention has been given to the role of individuals in terms of their ability to acquire, share, and finally use external knowledge to generate innovations.

Complementing the wealth of studies that have looked at absorptive capacity from the point of view of firms or business units, in this paper I

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focus on the role that individuals inside the organization play in the acquisition and use of external knowledge to generate innovations. In particular, through the adoption of a social network perspective, I show that an individual's ability to convert external knowledge into innovations is contingent upon the position that he or she occupies in the internal knowledge-sharing network.

I test this proposition in the context of knowledge-sharing relationships defined among 276 researchers, scientists, and engineers working in 16 different R&D laboratories in a large multinational high-tech company. Results indicate that the benefits of external knowledge for innovation generation are indeed contingent upon the configuration of the internal social structure in which individuals are embedded. In particular, the positive effects of external knowledge on innovation are significantly increased (reduced) by the presence (absence) of structural holes in the internal knowledge-sharing network.

ABSORPTIVE CAPACITY AND INTERNAL KNOWLEDGE-SHARING NETWORKS

Absorptive capacity (Cohen and Levinthal, 1989, 1990) has been a very influential framework[1] in the study of organizational innovation. Management and innovation scholars have tested its predictions in a variety of research settings such as strategic alliances (Mowery, Oxley, and Silverman, 1996), pharmaceutical and biotechnology companies (Penner-Hahn and Shaver, 2005), adoption of pollution prevention practices (Lenox and King, 2004), international joint ventures (Lane *et al.*, 2001), and business-unit relationships (Tsai, 2001). Such breadth of applications, however, has stopped short of examining the drivers of individuals' ability to convert external knowledge into innovations.

Existent research in this area has primarily considered absorptive capacity in terms of amount of resources invested in R&D as a proxy for a firms' stock of prior knowledge showing that greater investments are associated with higher returns on innovation. However, the emphasis on R&D investment has overshadowed equally important aspects of the process through which firms assimilate and exploit external knowledge. For instance, a recent analysis of more than 289 papers (Lane, Koka, and Pathak, 2006) revealed that only a handful of studies have looked at the mechanisms through which organizations access, assimilate, and exploit external knowledge for innovation generation. And more recently, an extensive bibliometric study of over 1,200 publications corroborated this view suggesting that more research integrating individual learning, intra-organizational relationships, and assimilation/use of external knowledge is necessary to examine the conceptual building blocks of absorptive capacity (Volberda *et al.*, 2010). Heeding these calls for a more in-depth study of the drivers of absorptive capacity, this paper focuses on how individuals' position in the internal knowledge-sharing network affects their ability to translate external knowledge into innovations. Notwithstanding the limited attention devoted to the role of individuals in the absorptive capacity process (Lane *et al.*, 2006: 853; Volberda *et al.*, 2010: 944), looking at individuals' absorptive capacity through the lenses of social network analysis is fully consistent with Cohen and Levinthal's claim that "an organizations absorptive capacity is not resident in any single individual but depends on *the links across* a mosaic of individual capabilities" (Cohen and Levinthal, 1990: 133, emphasis added).

In line with this insight and building upon research that has emphasized the importance of network relationships for the creation, dissemination, and use of knowledge (Cross and Cummings, 2004; Haas and Hansen, 2007; Reagans and McEvily, 2003; Tortoriello and Krackhardt, 2010), this paper zeroes in on the specific position occupied by individuals in the internal knowledge-sharing structure and how that enables them to exploit external knowledge for the generation of innovations. In particular, arguing that the relationship between external knowledge and internal knowledge-sharing is critical for understanding organizational absorptive capacity (Cohen and Levinthal, 1990: 131–132), I propose that individuals' ability to translate external knowledge into innovations hinges on their position as brokers in the internal knowledge-sharing network (Gould and Fernandez, 1989).

[1] Google Scholar shows that as of December 2013, the three papers in which Cohen and Levinthal (1989, 1990, 1994) introduced and developed the concept of absorptive capacity have received, combined, over 28,000 citations.

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INTERNAL BROKERING POSITIONS AND EXTERNAL KNOWLEDGE

Research on knowledge sharing in organization has shown that informal networks are one important means through which different knowledge bases in organizations are integrated and combined to innovate (Burt, 2004; Hargadon, 2003). Since knowledge and information tend to be more homogeneous within rather than across groups, individuals whose network connections span social or group boundaries tend to have access to distinct sources of knowledge and information are exposed to alternative perspectives and have vision over opportunities available in different parts of the organization (Kleinbaum and Tushman, 2007).

The brokerage theory of social capital (Burt, 1992) in particular, has shown that individuals whose network relationships bridge across gaps or "holes" in the organizational social structure tend to be more creative (Burt, 2004; Perry-Smith, 2006), to have a greater capacity for knowledge sharing (Reagans and McEvily, 2003), and to generate more innovations (Hargadon, 2003) than individuals whose network connections feed into dense and overlapping systems of common third-party ties. This greater ability for generating innovations, however, has mostly been considered in terms of the knowledge available and accessible *within the organization*, without considering the situation in which individuals who bridge gaps in the internal social structure might also have access to relevant knowledge defined outside of the organization. As a result, the role of brokers in sharing, disseminating, and leveraging *external* knowledge (i.e., knowledge generated outside of the organization) through *internal* interactions has only received limited attention. This limited attention is quite surprising considering that traditional research on boundary-spanning roles (Allen and Cohen, 1969) had already highlighted the importance of key individuals (i.e., gate-keepers) for transferring knowledge and information from the external environment into the organization (Tushman, 1977). However, in spite of early attention to the impact of external knowledge and brokering of information on collective (Tushman and Katz, 1980) and individual innovative performance (Tushman and Scanlan, 1981), the issue of how external knowledge is leveraged through internal exchanges has yet to be systematically examined.

In the following section I argue that there are three primary reasons why a brokering position in the organizational knowledge-sharing network favors an individual's ability to leverage external knowledge toward the generation of innovation. Occupying a brokering position increases the likelihood of successfully translating external knowledge into innovations because of the greater number of opportunities for creative knowledge recombination it provides, the greater ease of knowledge sharing and acquisition it promotes, and the broader access to internal talent and capabilities it allows.

Providing opportunities for creative knowledge recombination

Research on brokerage has shown that exposure to alternative ways of thinking, to different and, at times, contradictory information, and to a variety of different perspectives, provides brokers with a competitive advantage in generating new ideas (Burt, 2004). Access to diverse knowledge and information *inside* the organization however, should also favor a broker's ability to leverage *external* knowledge. External knowledge, by definition, brings elements of novelty and diversity compared to the knowledge available in the organization (Cohen and Levinthal, 1990), and this diversity might or might not find fertile ground for internal applications depending on the type of knowledge with which it has to be combined and integrated to generated innovations. An internal broker however, thanks to her ability to access diverse knowledge pools within the organization, can more easily identify possible areas of application of the newly acquired knowledge to internal problems. The diversity of knowledge available to a broker as a function of her position in the internal network multiplies the opportunities for combining and merging external knowledge with knowledge available inside the organization, thus increasing the likelihood of generating novel applications based on it. Moreover, as internal brokers have experience in dealing with diversity of knowledge and perspectives, they might find it easier to recognize the potential of external inputs to complement and integrate the existing knowledge base for the generation of innovations. Considering external knowledge through the lenses of different knowledge backgrounds and perspectives

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increases the opportunities to identify useful applications to the newly acquired knowledge.

Promoting ease of knowledge sharing and acquisition

Another advantage that accrues to individuals with a nonredundant network of contacts is their increased ability to acquire diverse knowledge. Individuals with a wide and differentiated organizational network develop a greater capacity for knowledge acquisition by being constantly exposed to colleagues who "speak" different technical languages, work on different problems, and come from different thought-worlds (Reagans and McEvily, 2003; Tortoriello, Reagans, and McEvily, 2012). While being embedded in a close-knit social system favors the development of idiosyncratic languages and shared mental models that promote "local" knowledge exchanges, familiarity with diverse and distant contacts helps individuals understand and adopt different approaches. This greater ability to deal with diversity of perspectives, mind-frames and languages is particularly relevant in the case of external knowledge. Once acquired from outside, external knowledge needs to be adapted, communicated, understood, and disseminated within the organization in order to be translated into actual innovations. A broker, thanks to her ability to communicate with individuals who have different knowledge backgrounds, can frame the newly acquired knowledge in terms that are easier for her counterparts to understand. This facilitates the sharing of complex ideas and information and the acquisition of useful inputs from others that promote the leverage of external knowledge toward the generation of innovations.

Allowing for a broader access to internal talent and capabilities

One further reason why individuals with a nonredundant organizational network are better positioned than individuals with a dense organizational network for generating innovation based on external knowledge is the broader reach that brokerage positions allow inside the organization. Generating innovations in organizations is a social endeavor and requires collaboration and support from colleagues with different backgrounds (Hargadon, 2002). Leveraging external knowledge in particular often requires to recruit collaborators with diverse skill sets, competences, and capabilities. Often, however, the most qualified collaborators do not reside within the immediate professional environment in which one is embedded. Restricting the options to local searches might, in fact, make it hard to identify the best qualified profiles to help leverage a particular type of knowledge or to favor its application to a concrete problem. The necessary skills and abilities to leverage external knowledge might reside elsewhere in the organization. Being embedded in a closed/redundant structure limits individuals' autonomy to search for and identify collaborators with the best set of skills and competences restricting the search to "local" connections (Rosenkopf and Almeida, 2003). On the contrary, a diverse network of contacts branching out to distinct parts of the organization creates flexibility in the search process and increases the likelihood of identifying the professional profiles with the necessary skills and competences to leverage external knowledge. Even in those cases in which a broker might not have direct access to a key contact, a diverse network of connections increases the likelihood of obtaining useful referrals to identify and recruit colleagues who have the ideal set of skills and expertise (Rosenkopf and Nerkar, 2001) whereas referrals from members of a same clique are likely to provide redundant solutions to the search problem.

The foregoing arguments suggest that individuals with a network rich in structural holes should have more opportunities for creative knowledge recombination, an increased ability to communicate and share knowledge with their colleagues, and access to a wider set of potential collaborators beyond what is locally available. This implies that structural holes in the internal network should have a positive effect on individuals' ability to leverage external knowledge to generate innovations.

Hypothesis: Structural holes in the internal knowledge-sharing network will have a positive effect on individuals' ability to leverage external knowledge toward the generation of innovations

EMPIRICS

Research setting

The research site used to test the relationship between external knowledge and internal structural

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holes in the generation of innovations is the research division of a large multinational semiconductors company. The company is the market leader in several segments such as industrial applications, smartcard chips, computer peripherals, and chips for wireless and mobile applications. The division studied is in charge of identifying promising technologies and developing new system architectures in areas of strategic relevance for the company. At the time of data collection it employed 276 individuals and was articulated in 16 research centers at different locations worldwide covering 21 areas of technological expertise.

Table 1. External knowledge variables

	Mean	S.D.	Loading
Industrial external knowledge			
Funded projects	4.23	1.85	0.61
Standardization committees	4.68	1.82	0.67
Collaboration with clients	4.11	1.92	0.84
Collaboration with suppliers	3.43	1.83	0.87
Scientific external knowledge			
Conferences	4.67	1.84	0.81
Scientific journals	5.01	1.65	0.84
Patents	3.71	1.82	0.55
Collaboration with research Institutions	5.06	1.79	0.78

The question asked was: For each item please indicate the extent to which it represents an important source of technical and/or scientific knowledge for your professional activity at < name of the company > Items were measured with a 7-point Likert scale, ranging from "Not at all"' to "To a great extent."' Loadings are based on Varimax rotation.

Survey

The questionnaire for external sources of knowledge and social network relationships was developed after extensive field interviews with senior managers, researchers and engineers, and it was pretested prior to the beginning of the data collection process. The survey yielded a response rate of about 91 percent (249 complete responses out of the 276 potential respondents). Tests for nonresponse bias revealed no significant differences between respondents and nonrespondents in terms of lab size, organizational tenure, job grade, level of education, gender, and patents filed. Respondents were asked to rate on a scale from 1 to 7 (1 being "not at all" and 7 being "to a very large extent") the extent to which different sources of external knowledge were important for them in their professional activity (see Table 1).

Network data were collected through a combination of name-generating and name-interpreting questions (Marsden, 1990). For generating contacts' names, I asked respondents to check in a roster with the 276 members of the research division the names of those with whom they have worked in the past two years on one or more projects. This generated a unique list of contacts for each respondent. Subsequently I asked specific name-interpreting questions for each of the contacts identified in order to capture frequency of communication and structure of the network.

Archival data

Additional data obtained from the company's archive complemented data collected through the survey. In particular, I collected information about respondents' gender, level of education, organizational tenure, areas of technological expertise, and organizational job grade, which I used as individual-level control variables.

Dependent variable

Using information obtained from 288 R&D reports compiled monthly by each laboratory after the collection of network data, I tracked down each patent application filed internally by respondents to determine whether or not it was ultimately granted by the United States Patent and Trademark Office (USPTO). The number of patents generated by respondents and granted by the USPTO represents the study's dependent variable.

Independent variables

A principal component factor analysis with varimax rotation performed on the external knowledge items reported in Table 1[2] revealed the existence of two distinct factors: external scientific knowledge (Cronbach's alpha = 0.77 and principal component explaining 63.2% of the variance) and external industrial knowledge (Cronbach's alpha = 0.81

[2] The items in Table 1 assume that the importance of diverse sources of knowledge is a proxy for how much individuals rely and use those sources in the pursuit of their professional goal of generating innovations.

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and principal component explaining 58.4% of the variance). Consequently, I measured external knowledge distinguishing between external scientific knowledge and external industrial knowledge.[3]

Structural holes were measured (Burt, 1992) using respondents' answers to the question: "*Please indicate how often you generally go to this person for information or knowledge on work-related topics*". Respondents were asked to answer this question about each of their contacts on a one-to-five scale, one being "seldom" and five being "very frequently".

$$SH_i = 1 - \sum_j c_{ij}$$

According to the equation above, for each individual in the sample structural holes are expressed as a decreasing function of the extent to which his/her relationships are embedded in a dense system of common third-party ties. The term c_{ij} measures dyadic constraint and is described in the formula below (Burt, 1992: 55).

$$c_{ij} = \left(p_{ij} + \sum_{q \neq i \neq j} p_{iq} p_{qj} \right)^2$$

Dyadic constraint has two components, the first term, p_{ij} reflects the proportion of i's interaction devoted to colleague j:

$$p_{ij} = z_{ij} / \sum_{q=1}^{N_{ego}} z_{iq} \quad i \neq q$$

where z_{ij} is the frequency of communication from i to j and $\sum_{q=1}^{N_{ego}} z_{iq}$ is the amount of network time that i allocates to his or her own ego network. The second term in brackets, $\sum_{q \neq i \neq j} p_{iq} p_{qj}$, measures indirect dyadic constraint by taking into account the strength of third-party ties around the dyad i, j (i.e., measuring triadic closure between i, j and common third-parties q). When summed over js (ego's alters) dyadic constraint gives the extent to which ego's network is concentrated in redundant contacts and ranges in values from 0 to 1 (Burt, 1992: 55); 1 - *constraint* indicates network rich in structural holes.

Control variables

In each model, I control for several elements that might provide alternative explanations for the hypothesized effect of structural holes on the relationship between external knowledge and individual innovativeness. For instance, I use a dummy variable to identify laboratory leaders to control for the possibility that, because of their formal role, they might be involved in more patent filings than their colleagues. I control for gender in order to account for disparity in patenting propensities between men and women (Whittington and Smith-Doerr, 2008). I also control for levels of education[4] and job grade as proxies for individuals competence and capabilities, for the number of people working in each technological area, and for the number of contacts in individuals' networks.[5] Finally, to account for individuals' track record in terms of patenting activities, I control for the number of patents filed by each respondent in the three years before the data collection.

ANALYSIS AND RESULTS

Descriptive statistics and correlation coefficients are presented in Table 2.

Results of the analysis are reported in Table 3. Overdispersion in the dependent variable suggested the use of Negative Binomial modeling[6]; standard errors are clustered by area of technological expertise.[7] To reduce concerns about the possible endogenous nature of network positions, I

[3] The same results are obtained using different rotational strategies such as, for instance, oblique rotation. I used the average of the respective four items to measure scientific and industrial external knowledge; substantively similar results are obtained using factor scores instead of averages.

[4] The population of respondents had the following distribution of education levels: PhD, 9 percent; MS, 80 percent; college degree, 10 percent; high school diploma or associate degree, 1 percent.

[5] The nature of knowledge sourced from outside could possibly be affected by type and amount of knowledge available through the internal network of contacts.

[6] Consistent results are obtained using zero-inflated negative binomial regressions.

[7] Consistent results are obtained when clustering standard errors by both Laboratory and Area of Technological Expertise (Cameron, Gelbach, and Miller, 2011; Kleinbaum, Stuart, and Tushman, 2013)

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Table 2. Descriptives and correlations

		Mean	Stdv	1	2	3	4	5	6	7	8	9	10	11
1	Patents	0.43	1.02											
2	Probability of having > avg. structural holes	0.70	0.07	−0.119										
3	Laboratory leader	0.06	0.23	0.002	−0.211*									
4	Size of areas of tech expertise	18.04	6.66	0.017	0.240*	−0.173*								
5	Gender	0.90	0.30	0.054	−0.035	0.030	0.080							
6	Job grade	13.67	2.28	0.095	−0.424*	0.345*	−0.185*	0.060						
7	Level of education	2.95	0.49	0.098	0.039	−0.071	−0.021	−0.057	0.120*					
8	Number of ties (network size)	5.41	3.70	−0.038	−0.021	0.081	0.033	0.090	0.209*	0.055				
9	Number of previous patents	0.24	1.04	0.142*	−0.185*	0.047	−0.024	0.042	0.146*	−0.078	0.119			
10	External scientific knowledge	4.60	1.39	0.145*	−0.088	−0.027	−0.081	−0.041	0.119	0.115	0.036	0.008		
11	External industrial knowledge	4.23	1.50	−0.032	−0.040	0.131*	−0.209*	−0.061	0.091	−0.002	0.010	0.090	0.384*	
12	Structural holes	0.81	0.09	0.101	−0.334*	0.198*	−0.123*	0.006	0.453*	0.042	0.477*	0.141*	0.166*	0.198*

*Significant at $p < 0.05$.

identified a set of variables that were significantly associated with the likelihood of spanning structural holes but that were not significantly associated with the ability to generate innovations. Empirically, I determined that laboratory size (e.g., number of people working in the lab) and seniority affected the likelihood of developing a network rich in structural holes (respectively, $p < 0.05$ and $p < 0.01$) while being unrelated to individuals' ability to generate patents. Through a probit model (Hamilton and Nickerson, 2003; Heckman, 1979), I estimated, for each respondent, the likelihood of having a greater-than-average number of structural holes as a function of laboratory size and seniority. As a next step, I transformed the predicted probability obtained from the probit model computing an inverse Mills ratio (e.g., Hamilton and Nickerson, 2003) and added it as an additional control variable in the patent equation models reported in Table 3.

Model 1 presents control variables only. Models 2–4 consider the direct impact of external knowledge on individual innovativeness. Model 5 introduces the main effect of structural holes in internal structures, and finally, Model 6 tests for the predicted positive effect of structural holes on individuals' ability to generate innovations based on external knowledge.[8] In the full model, level of education and previous patenting experience are, as expected, positively and significantly associated with patent generation (both at $p < 0.01$ significance level) and so is external scientific knowledge ($p < 0.01$), while external industrial knowledge is negatively related to patent generation ($p < 0.05$). The moderating effect of structural holes on external knowledge is tested through an interaction term obtained by multiplying structural holes and external scientific knowledge (both terms mean-centered).[9] As predicted, the coefficient for the interaction term is positive and strongly significant ($p = 0.002$), suggesting that individuals' position in the internal social structure is a critical factor to driving their ability to generate innovations based on external knowledge. The multiplying effect of

[8] In other analyses not reported here I performed additional robustness checks controlling for geographical distance among contacts and for the preponderance of network connections spanning lab boundaries but found no significant effects on the likelihood of patent generation while results presented in Table 3 remained substantively unchanged.

[9] I also tested for the interaction between industrial external knowledge and structural holes but, as it was not statistically significant, I left it out from the analysis presented in Table 3.

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Table 3. Negative binomial regressions dependent variables: number of patents granted

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Controls												
Probability of having > avg. structural holes	-3.495^{**}	(1.287)	-2.667^{*}	(1.327)	-3.043^{*}	(1.500)	−2.203	(1.399)	−0.792	(1.533)	−0.133	(1.421)
Laboratory leader	−0.118	(0.543)	0.057	(0.494)	−0.019	(0.515)	0.226	(0.516)	0.181	(0.507)	0.212	(0.506)
Size of areas of tech expertise	0.018	(0.030)	0.032	(0.033)	0.019	(0.036)	0.024	(0.033)	0.006	(0.032)	−0.003	(0.032)
Gender	0.372	(0.580)	0.709	(0.617)	0.619	(0.652)	0.668	(0.594)	0.586	(0.590)	0.608	(0.611)
Job grade	0.069	(0.056)	0.063	(0.048)	0.071	(0.061)	0.053	(0.055)	0.034	(0.054)	−0.003	(0.045)
Level of education	0.751^{***}	(0.191)	0.67^{***}	(0.196)	0.807^{***}	(0.208)	0.679^{**}	(0.200)	0.684^{**}	(0.214)	0.685^{**}	(0.225)
Number of ties (network size)	-0.077^{**}	(0.032)	-0.07^{**}	(0.032)	-0.073^{*}	(0.034)	-0.076^{*}	(0.036)	−0.085	(0.084)	−0.081	(0.085)
Number of previous patents	0.243	(0.134)	0.273^{**}	(0.137)	0.254	(0.133)	0.313^{*}	(0.133)	0.316^{**}	(0.116)	0.35^{**}	(0.122)
Explanatory variables												
External scientific knowledge			0.31^{**}	(0.114)			0.417^{**}	(0.135)	0.389^{**}	(0.147)	0.439^{**}	(0.153)
External industrial knowledge					−0.064	(0.063)	-0.205^{*}	(0.096)	-0.251^{*}	(0.111)	-0.251^{*}	(0.114)
Structural holes									2.699	(2.671)	2.977	(1.932)
Structural holes * external scientific knowledge											2.421^{**}	(0.777)
Constant term	−2.004	(1.701)	-4.419^{**}	(1.494)	−2.558	(1.823)	−4.12	$(1.384)^{**}$	-6.307^{**}	(2.498)	-6.719^{**}	(2.146)
Log likelihood	−226.502		−196.24		−197.93		−191.00		−175.31		−172.973	
Chi2	38.794^{***}		58.935^{***}		47.219^{***}		50.016^{***}		56.934^{***}		87.241^{***}	
Number of observations	245		245		245		245		245		245	
Pseudo R2 (maximum likelihood R2)	0.058		0.079		0.057		0.090		0.087		0.099	

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

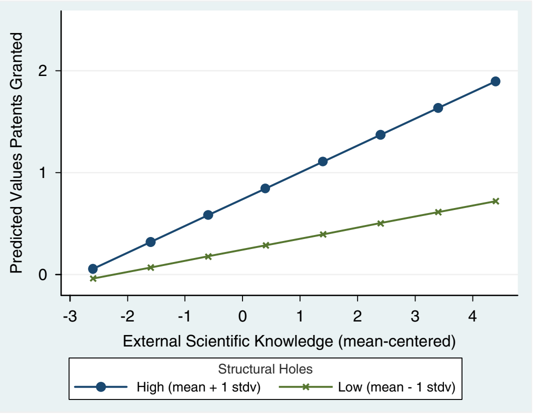

Figure 1. Effect of structural holes on the relationship between external knowledge and generation of innovations

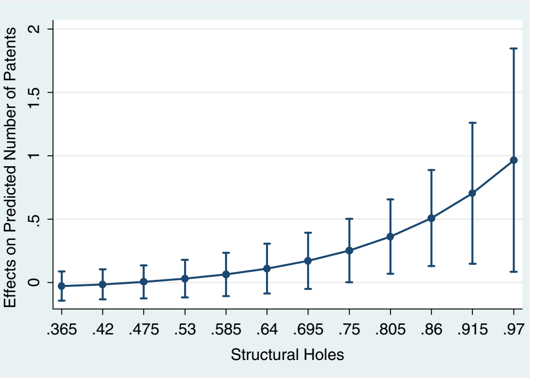

Figure 2. Marginal effects of structural holes on the relationship between external knowledge and generation of innovations

structural holes on the relationship between external scientific knowledge and innovation generation is plotted in Figure 1, for high versus low levels of structural holes (i.e., mean ± one st.dev.).

The graphical representation of the predicted occurrence of patents reported in Figure 1 is consistent with the prediction that the likelihood of generating patents is positively correlated with sourcing external scientific knowledge, and this positive correlation is greater for individuals who span more structural holes in the internal knowledge-sharing network than for individuals who span fewer structural holes. To examine the significance of the change in slope determined by spanning more or less structural holes at high versus low levels of external scientific knowledge I computed marginal effects as suggested by Zelner (2009) for the interpretation of interactions in nonlinear models. Figure 2 plots the change in the incidence of patent generation associated with an increase in the number of structural holes spanned over the range of values taken by external scientific knowledge. Most importantly, Figure 2 identifies the statistical significance of the marginal effect of structural holes on patent generation. The sloping line in Figure 2 shows how the impact of structural holes changes with the increase in external scientific knowledge and, based on the computation of 95 percent confidence intervals around the line, visualizes of the range of values for which the impact of structural holes on external knowledge has a significant effect on patent generation. Structural holes have a strong and significant multiplier effect on the likelihood of generating patents based on external scientific knowledge for values equal to or greater than 0.75.

According to the distribution of structural holes values, more than 77 percent of the observations falls in this range, suggesting that the moderating effects of structural holes on the relationship between external knowledge and innovation is substantively meaningful.

DISCUSSION

This paper identifies individuals' position in the internal knowledge-sharing network as an important contingency in the relationship between external knowledge and individuals' ability to generate innovations based on that knowledge. As such this paper contributes to absorptive capacity research suggesting that the ability to leverage external knowledge toward the generation of innovation is contingent upon the bridging opportunities available to individuals inside the organization. In particular, occupying positions rich in structural holes is significantly associated with a higher likelihood of generating innovations based on external knowledge. This finding substantiates the claim according to which an organization's absorptive capacity depends on the absorptive capacity of its individual members (Cohen and Levinthal, 1990: 131) and shows that the ability to recombine successfully diverse sources of knowledge acquired outside of the organization critically depends on the position occupied by individuals in the internal knowledge-sharing network. In addition to that, the findings presented in this paper, although defined at the individual level of analysis, have clear implications for the promotion and development of organizational absorptive capacity. Encouraging the formation of internal networks that span distinct parts of the organization could systematically enhance collective ability to leverage external knowledge by favoring the creative recombination of different viewpoints and perspectives.

Beyond research on absorptive capacity, the findings presented in this paper have also implications for the broader literature on organizational learning and knowledge management and innovation. In particular, this paper extends current work on networks and knowledge management by focusing on the relationship between external knowledge and individuals' position in the internal social structure. Past research in this area has relied on the assumption that knowledge available to individuals is primarily a function of the knowledge flowing in their local/immediate network. While this is certainly plausible, past network research has never considered the equally plausible assumption that critical sources of knowledge might come from outside of an individuals' immediate network of contacts and that the structure of its local network can affect the ability to take advantage of those heterogeneous sources of knowledge. For instance, it is informative to notice that, while there is no main effect of structural holes on innovation generation (Model 5), the traditionally observed performance effects of structural holes do become apparent when taking external knowledge into account (interaction term in Model 6). These findings suggest that occupying advantageous positions in the organizational network structure might be a necessary but not sufficient condition to support individuals' ability to generate innovations. While structural holes might still be beneficial for different types of individual level and/or organizational outcomes, generating concrete innovative outputs might require more restrictive conditions than occupying favorable network positions in the organization such as, in this case, access to knowledge developed outside the organization. In addition to scholarly contributions, there are also important managerial implications that can be derived from this study. Primarily, that while investment in R&D matters to foster organizational absorptive capacity, also the formation and nurturing of internal networks that promote diversity and accessing to different parts of the organization is of primary importance to increase the benefits of R&D investment. Indeed, while individuals should be encouraged to build network connections that allow access to external sources of knowledge, they should also invest, at the same time, in developing internal connections with colleagues who have diverse knowledge backgrounds and operate in different parts of the organization. It is from this specific configuration of internal network connections (i.e., rich in structural holes) that external knowledge can more effectively be converted in organizational innovations.

The findings discussed above, while contributing to both absorptive capacity and network research on innovation, have also important limitations that should be acknowledged. Primarily, the cross-sectional design of the study raises concerns of endogeneity and reverse causality. For instance, it is possible that people who are better at generating innovations because of idiosyncratic reasons (experience, abilities, expertise, talent, etc.) have learned over time to access the most promising knowledge from outside the organization and/or have moved to network positions inside the organization that are more consequential for the generation of innovation based on the use of external knowledge. In the analysis, I took several steps to minimize this concern. First, all the models include several individual-level covariates to control for differences in individuals' experience, ability, and knowledge such as network size, level of education, and organizational job grade. In addition to that, prior patenting experience accounts for individuals' previous track records as a proxy for their ability to patent. Second, the pattern of results observed is difficult to reconcile with an endogeneity-based theory. For instance, if the "best" researchers could over time learn that some positions in the organizational social structures are better than others for generating innovations and position themselves accordingly, one would expect to observe a positive and significant main effect for social structure positions (i.e. structural holes) on the likelihood of patent generation. However, the positive association between structural positions and innovative performance is only observed in conjunction with the sourcing of external scientific knowledge. Lastly, the results observed remained robust to the introduction of estimates predicting the likelihood of spanning structural holes as a function of exogenous variables such as size of the laboratory and individual seniority.

While these robustness checks are encouraging, lacking access to longitudinal data, the risk of endogeneity cannot be ruled out definitively. For instance, there could be unobserved dynamics driving the formation of structural holes or external forces driving technological development that favor patenting activities in a certain area. Neither of these possibilities can be directly addressed given data limitation and the cross-sectional design of the study. Another limitation associated with the data is given by the measures used to capture external knowledge. While asking respondents what sources of external knowledge are important for their professional activities is consistent with the individual-level conceptualization of absorptive capacity, there could be also other ways to measure access and use of external knowledge (e.g., patents citations, external collaboration, etc.).

Notwithstanding the limitations of the data collected and used in this study, there are important features in this paper that hold the potential for stimulating theoretical and empirical development in the study of absorptive capacity and corporate innovativeness. For instance, future research can explore distinct roles that brokers can play in the distribution and circulation of external knowledge inside the organization. In this paper I observed that brokers are ideally positioned to take advantage of external knowledge. However, working as information/knowledge hubs, brokers might also be ideally positioned to share external knowledge with their colleagues in a way that enhances their ability to generate innovations.

A further possibility to extend the findings presented here could be to assess the “indirect” impact of external knowledge on individual innovativeness. For instance, the nature of knowledge internally available to a focal node could also change as a function of the type of external knowledge that her direct contacts source from outside. This additional source of heterogeneity (i.e., external knowledge sourced *from others*) could also impact on a focal node’s ability to generate innovations. More broadly, the adoption of an individual level of analysis with an explicit focus on the actual knowledge accessed by individuals outside the organization, as well as their position in the organizational social structure, could advance our understanding of how the innovative process unfolds and develops. In this study, I focused on the joint effect of external knowledge and internal network structure, showing the positive effects of structural holes for reaping the benefits of scientific knowledge accessed outside the organization. Clarifying other types of contingencies in the relationship between external knowledge and innovation generation could provide important insights into how organizations benefit from their employees’ absorptive capacity.

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