Does firm's network position enhance open innovation performance? Evidences from the biopharmaceutical industry

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ABSTRACT
This paper explores the relationship between open innovation (OI) and firm's network position on enhancing firm's innovation performance, such as new product development (NPD). We build a theoretical framework and test it on the biopharmaceutical context. Our result shows how firm's network position influences NPD performance obtained through OI practices.

Keywords: Open Innovation, Network strategy, Ambidexterity

Introduction
This paper explores the relationship between open innovation and firm's network embeddedness on enhancing the development of new product. Recent literature has acknowledged the importance of both open innovation and firm's network strategies on innovation performances of the firm. However, the two strands of literature have remained detached up to now. After the publication of Chesbrough's seminal book (2003a), open innovation has mostly interested innovation management scholars. In the field of open innovation scholars have focused their interest in evidencing the impact of open innovation processes such as *inbound*, *outbound*, *coupled* or even a combination of the aforementioned processes on several innovation performance such as new product development (NPD), applied patents, turnover from innovative products, value added and so forth (Laursen and Salter, 2006). Conversely, firm's network strategy has interested mostly scholars from strategic management field. Within this field scholars have tried to understand how firm's position in inter-firm networks, such as centrality, structural holes, cluster position, network density, and cliques are able to drive innovation performance (Ahujia, 2000; Zaheer and Bell, 2005). Thus, open innovation and firm's network strategies are both able to influence firm's innovation performance. However, as matter of fact, these two roads have never met up to now. Thus, the aim of this paper is to bridge this gap in the innovation management and, conversely, in the strategic management literature, by exploring whether firm's network strategy enhances, or on the contrary weakens, performance obtainable through open innovation strategies.

Bridging this gap has important theoretical implications. Indeed, open innovation and network strategies have been addressed as a way to 'explore' and/or to 'exploit' external innovation resources and information. On the other hand, Koka and Prescott (2002) have pointed out how 'prominence' or 'entrepreneurial' positions in a network of inter-firm relationships are a way to explore/exploit information assets provided by the network. Furthermore, organization science scholars have evidenced how the interaction and balance between explorative and exploitative innovation strategies, the so-called *ambidexterity*, provides superior firm's performance. However, the ambidexterity concept has never been developed with regard to the mix of innovation and network strategies. Thus, our research aims at understanding whether a more explorative or exploitative network strategy can enhance or weaken the likelihood to develop new products obtainable through a more explorative or exploitative open innovation strategies, i.e. inbound or outbound processes. Hence, this paper aims at filling the aforementioned gaps in innovation and strategic management literature. In particular, we analyze the firm's network strategy under three different network features mainly devoted to explore, exploit and embed information. Thus, we hypothesize an influence of such firm's network features on the likelihood to develop new products obtainable through open innovation processes (i.e. inbound and outbound).

Inter-firm network embeddedness, information dimensions and exploitation and exploration processes

Firms, in the course of their business activities, establish a variety of inter-firm relationships. This trend to make multiple relations with several partners embeds firms in intricate webs of inter-firm networks. Recognizing the complex interdependencies between firms within inter-firm networks, strategy scholars have increasingly moved from a dyadic level of analysis to a network level in order to understand the nature and effect of such networks (Ahuja, 2000). Focusing on the effect issue, there is a large consensus in literature about the importance of inter-firm networks in influencing firm's innovation outcomes. For their importance on firm's competitive performance, networks of inter-firm ties have been considered themselves as a strategic resource ables to hold significant implications for firm performance (Gulati et al., 2000). Thus, resource based view (RBV) scholars have analyzed the combination of resources/partners involved in the networks and the firm's network position (Zaheer and Bell, 2005). Conversely, we wish to focus only on the information dimension involved in the network strategy, i.e. the network embeddedness. The network embeddedness can be analyzed under two perspectives: the *structural embeddedness* and the *relational embeddedness*. *Structural embeddedness* defines the extent of information spread within the network and it can be analyzed along the two following network features. The first is centrality (Koka and Prescott, 2002); having a central network position provides to the ego firm a high amount of information *volume*, i.e. a dimension emphasizing the quantity of information that a firm can access and acquire through its position in the network of inter-firm ties. Furthermore, features of centrality have also been associated to the possibility to exploit the information potentiality of the firm's network (Ahuja, 2000). Exploitation is aimed at strengthening and broadening basic knowledge of established technologies and products. Through exploitation firms develop more and more competences in their core field, further increasing the chance of immediate and positive returns. A central or prominent network position allows at exploitationing since centrality implies 'local or proximity search' in which the ego firm searches for new knowledge that is less likely to conflict with its existing cognitive and mental models so producing recombination of familiar and well-known knowledge elements. Also, through more ties the information flows more efficiently and effectively and it can be gained in a short time and from a short distance, therefore at a lower search cost, increasing the likely of immediate and positive returns.

An acknowledged drawback of having a central or prominent position is the information redundancy that might lead to adverse consequences mainly deriving from the limited exploration of new information and knowledge that might reduce the firm from exploring and widening its horizon. For such reasons, scholars have highlighted the importance of network features allowing the brokerage opportunities created by an open social structure.

Open and not densely tied network structures provide the ego firm with entrepreneurial opportunities, i.e. the possibility to act as bridges between the different parts of the network (Koka and Prescott, 2002). A key construct that underlies the entrepreneurial position is the structural hole construct that emphasizes the social capital benefits arising out of control over the flow of information and the access to diverse information (Burt, 2000). Indeed, as well argued by Koka and Prescott (2002), the source of advantage in this case is the information *diversity*, i.e. the variety and to a somewhat lesser extent quantity of information that a firm can access through its relationships. Furthermore, alliance network scholars have associated structure holes, or entrepreneurial network positions, to exploration, i.e. an innovation process associated with search, experimentation and risk taking. Thus, contrarily to exploitation, exploration is not 'local search' but a 'broad search'. Structural holes in network of inter-firm relationships allow exploration for several reasons. First, they provide connections with so-called weak partners that provide non-redundant, or diverse information, that, by means of re-combination mechanisms help to develop new ideas, knowledge or technologies (Burt, 2000). Also, firms bridging structural holes access to new information faster than other firms, providing them the opportunity for a first move advantage. Similarly, actor who bridge structural holes will be able to develop new understandings, especially regarding emergent threats and opportunities not possible to those who do not bridge holes (Zaheer and Bell, 2005).

While structural embeddedness determines the extent and range of resources that are within a firm's reach, *relational embeddedness* concerns which of those information that are within reach will be accessed, and to what extent (Moran, 2005). Thus, relational embeddedness is associated with information *richness*, i.e. the quality and nature of information that a firm can access through its relationships. Relational embeddedness is related with network structures characterized by repeated ties (Koka and Prescott, 2002) and/or closed cohesive groups such as cliques (Baum et al., 2003). Relational embeddedness has also been associated with deeper exploiting opportunities for the ego firm since repeated ties or cliques determine 'strong ties' which are a prerequisite for the intensive knowledge exchange and co-specialization and they facilitate the formation of trust and reputation among the partners (Gulati et al., 2000). This enables exploitation for several reasons: firms gather superior information on each other by reducing in this way the information asymmetry that increases the likelihood of opportunism behavior; reputation allows mutual safeguards able to mitigate opportunism and appropriation concern; finally, firms exchange broader and deeper information and knowledge allowing to improve the cooperation effectiveness and efficiency. Hence, higher relational embeddedness exalts exploitation opportunities because it allows extracting better information from the available volume of information. On the contrary, high relational embeddedness focuses the firm on particular relationships, neglecting in this way other possible ties; therefore it limits the exploration opportunities of the firm.

Summing up, we explore the information dimension of the network strategy along the two dimensions of the network embeddedness: structural and relational. Structural embeddedness can be analyzed along two network features: central and structural holes positions; while, relational embeddedness can be analyzed through network features such as repeated ties or cliques. To each of these network embeddedness features we associate three kinds of information dimensions, respectively: volume, diversity and richness. Finally, we associate to central and structural hole positions respectively exploitation and exploration processes, while relational embeddedness exalts exploitation and limits exploration.

Conceptual model development

Open innovation strategies and new product development

Chesbrough (2003) argues that the advantages that firms gain from internal R&D expenditure have progressively declined, while an increasing number of innovative firms spend less on internal R&D and yet they are able to successfully innovate by drawing in knowledge and expertise from a wide range of external sources. According to the considerations of Chesbrough (2003) is possible to locate three basic processes in the open innovation strategy: inbound, outbound and coupled. The *inbound* process refers to the purposive inflows of knowledge and it regards the technology exploration and innovation activities to capture and benefit from external sources of knowledge. *Outbound* is the process of establishing relationships with external partners with the purpose to bring ideas to market faster and to commercially exploit technological opportunities. Finally, in the *coupled* process companies combine the inbound with the outbound processes, to bring ideas to market and, in doing so, jointly develop and commercialize innovation. This focalization on managerial practices has produced a great interest of scholars in trying to understand how different open innovation practices are able to influence innovation or financial performance of the firm (Mazzola et al., 2012).

In literature there is a wide consensus around the possibility that inbound practices are able to positively improve firm's innovation performances. The idea here is that the use of external technology might improve firm's innovation performance for several reasons such as avoiding the high costs of internal development, achieving fast growth, and even gaining access to state of the art technology (Inauen and Schenker-Wicki, 2011). As matter of fact, supplier collaborations have been positively correlated with improvements in product/service innovation and technology innovation performances. Similarly, collaborations with universities or public research institutions have been positively related with product/service innovation. Also patents acquisition (in-licensing) is able to improve product innovation performances and patents application. Finally, also merger and technology acquisitions have been positively related with innovation performances such as product added value and product innovation performance.

Turning on *outbound* practices such as out-licensing, divesting or spin-offing, it is quite acknowledged how they are able to improve financial and economic performances of the firm by speeding innovation products commercialization, by providing additional revenues or even by acquiring new financial resources coming from the selling of non core knowledge or technological assets (Lichtenthaler, 2009). In case of innovation performance, the main understanding among open innovation scholars is that the outward of internal knowledge negatively effect innovation performance (Arora and Fosfuri, 2003). Indeed, managers that decide to license out their IP or divesting knowledge assets might, in a long-range horizon, negatively affect the firm's internal innovation processes (Lichtenthaler, 2005). Thus, from a long-term perspective, these practices may weaken the specific R&D-capabilities of a firm leading to a lower innovation performance.

Thus, in line with the above considerations we formulate the first hypothesis:

H1. *Inbound process increases the likelihood to develop new products. Outbound process decreases the likelihood to develop new products.*

Open innovation and new product development: the moderating role of the inter-firm network embeddedness

Open innovation scholars have associated open innovation processes, inbound and outbound, to the concepts of exploration and exploitation (Chesbrough, 2003; Lichtenthaler, 2005; van de Vrande et al. 2009). Indeed, an inbound process has been widely recognized as source of technology exploration, while an outbound process has been widely associated to technology exploitation. Thus, as the reader can notice both open innovation processes, inbound and outbound, and inter-firm networking embeddedness dimensions can be associated to the exploitation and exploration processes. However, they provide different perspectives.

First of all, open innovation processes and network embeddedness aim at exploring and exploiting different things. Indeed, as already stressed, inbound and outbound practices deal with innovation processes, i.e. how the firms explore and/or exploit *innovation assets* (knowledge, resources, technologies); on the other hand, network embeddedness deals with *information processes*, i.e. how the firms explore and/or exploit the information available around them. This fundamental difference brings other dissimilarities. Since open innovation deals with innovation assets, open innovation processes are resource-specific and endogenous to the firm. Indeed, through inbound practices the firm aims at exploring new sources of knowledge, technologies, and resources provided by the partner, while, through outbound practices, the firm exploits internal knowledge or assets through the relation with an external partner. Table 1 summarizes the different perspectives of exploitation and exploration provided by open innovation processes and network embeddedness. Furthermore, as already mentioned, high relational embeddedness exalts network feature exploitation and limits network feature exploration.

Table 1. Exploitation and exploration processes in open innovation processes and network embeddedness

		NETWORK EMBEDDEDNESS (NETWORK FEATURES)		
		Centrality	**Structural holes**	**Relational embeddedness**
OPEN INNOVATION PROCESSES		*Exploitation of information*	*Exploration of information*	*Exalts exploitation of information* *Weaken exploration of information*
Inbound	*Exploration of innovation assets*	Increase the likelihood to develop new products *(H2a)*	Reduce the likelihood to develop new products *(H3a)*	Increase the likelihood to develop new products *(H4a)*
Outbound	*Exploitation of innovation assets*	Reduce the likelihood to develop new products *(H2B)*	Increase the likelihood to develop new products *(H3b)*	Reduce the likelihood to develop new products *(H4b)*

Open innovation practices and network embeddedness both allow exploitation and exploration from different perspectives; thus, how different network features enhance or limit the relation between open innovation process and the likelihood to develop new products? Specifically, literature has acknowledged how inbound exploration practices allow improving the development of new products; how network features in which the firm is plunged are able to impact such development? Also, literature has acknowledged how outbound exploitation practices have a negative impact on the development of new products; thus, in which the firm is plunged are able to impact such development?

Table 1 suggests how such research questions can be addressed in term of ambidexterity. Maintaining an appropriate balance between exploration and exploitation is critical for firm survival and prosperity. In particular, balancing exploration and exploitation processes has been associated with superior firm performances by several scholars (Lin et al. 2007). Especially in the field of technological innovation, ambidexterity has obtained several empirical confirmations (Katila and Ahuja, 2002). However, ambidexterity has never been associated with a mix of open innovation and networking strategies as we propose in this paper. In this case the ambidexterity ability of the firm consists on combining exploration and exploitation processes concerning innovation assets, i.e. the firm external innovation strategy, with exploration and exploitation processes concerning information, i.e. the network strategy of the firm. Concerning this specific ambidexterity ability we argue that, if the firm wants to explore innovation assets to improve NPD performance, it needs to exploit as much as possible the information it might gather from its network; on the other hand, if the firm wants to exploit innovation assets to improve NPD performance, it needs to explore as much as possible the information it might gather from its network.

Indeed, exploring innovation assets through inbound practices means to search partners' assets that when introduced in the NPD process of the firm, will allow enhancing the effectiveness of such a process. These assets can be achieved, for instance, through relationships with suppliers or the acquisitions of scientific services for instance. Exploiting the information capital of the firm, through central positions and/or high relational embeddedness, makes the exploration of external innovation assets more likely and more successful. Indeed, more is the amount of information the firm can access through its central network position, easier would be to select a suitable technological supplier for improving product development. Furthermore, the access to the high volume of information will allow the firm to scout several patent acquisition possibilities improving the possibility of in-licensing deals. Finally, by accessing to a wide amount of information the firm could easily detect promising acquisition opportunities in the industry. Also, by being central in the network the firm could easily reach suppliers providing the best knowledge and capabilities for making the NPD relationship more successful. Similarly, by leveraging its position the firm can locate partners with patents who better match the pipeline characteristic of the firm. For instance, in case of the biopharmaceutical industry, this means to buy patents that are in the same therapeutic area of the firm. Furthermore, accessing partners whose knowledge/technological base is not distant from the ego firm's, the firm could reduce the performance risk of unsuccessful acquisitions. Finally, the learning capabilities provided by exploitative network position, allow improving the inbound relationships efficiency. High relational embeddedness has similar enhancing effects on explorative processes of innovation assets. Indeed, close and strong ties with suppliers allow building trustful relationships that have been associated to superior number of product developed especially in high technology industries, such as the biopharmaceutical market, where the performance risk is particularly high (Rothaermael, 2001). Finally, repeated ties or closed cohesive cliques allow reducing the risk of technological acquisitions improving the likely of successful development of new products (van de Vrande et al. 2009).

On the contrary, the exploration of the network information deteriorates the likelihood to develop new products obtainable from explorative innovation practices. Indeed, 'weak' ties are normally far from the technology core of the firm and not involved with the ego firm. Thus, weak ties do not assure the necessary level of knowledge sharing and involvement that is required for successful product development with suppliers' contribution. Furthermore, technological distance has been associated with failure in product development either because the acquiring firm has not the necessary knowledge to make good evaluation of patents/acquisition potentiality, or because it lacks of the necessary knowledge to bring patents or acquired assets in the further developing processes.

Exploiting innovation assets through outbound practices means to search partners' assets that can be used to commercially exploit internal knowledge asset of the firm. These assets can be achieved through relationships with suppliers, the selling of scientific services for instance, or the selling of patents or other forms of IP. As already mentioned, outbound practices are expected to have a negative impact on likelihood to develop new products. However, exploring the information capital of the firm, through structural holes might mitigate this negative impact, enhancing the likelihood to develop new products. Indeed, weak ties provide information about new opportunities coming from market or technologies that are far from the firm. This, combined with outbound practices, can improve the effectiveness of the NPD process of the firm. Indeed, by exploring new information, the firm can get new ideas for products to be developed (Rothaermael, 2001); this idea can be fostered by the financial resources provided by the outbound abilities of the firm. Thus, the combination of the financial strength provided by the outbound practices and the creative processes due to the relationships with weak ties, might foster the NPD team of the firm to enhance its productivity.

On the other hand, the exploitation of the information assets of the firm, through central position or high relational embeddedness features, contributes to further deteriorate the likelihood of a company to develop new products. Indeed, the volume of information provided by a central position accelerates the possibility to exploit the internal knowledge resource of the firm. Thus, the firm improves the likely to find customers for selling its patents or technological services. This, of course, reduces the possibility to develop new products since the firm can easily sell its technological assets. Also, this creates a sort of specialization that is quite common in the biopharmaceutical context, in which a lot of biotech are specialized in selling technology services, through technological platform, or patents, without developing any products. This specialization is also fostered by repeated ties or cohesive closed cliques. Indeed, once a biotech has found a good customer, for instance a pharmaceutical company acquiring its technological services and patents, this represents a source of cash to finance the biotech's research activities. Thus, through repeated ties the pharma acquires the technology needed to develop its products, and the biotech obtains cash to foster research activities. However, by staying far from the market, the biotech loses, or never acquires, the ability to develop final, marketable, products. Thus, according to these reasoning we formulate the following hypotheses also summarized in Table 1:

H2a: Centrality network feature moderates the relation between inbound process and new product development by further increasing the likelihood to develop new products.
H2b: Centrality network feature moderates the relation between outbound process and new product development by further decreasing the likelihood to develop new products.

H3a: Structural holes network feature moderates the relation between inbound process and new product development by further decreasing the likelihood to develop new products.
H3b: Structural holes network feature moderates the relation between outbound process and new product development by further increasing the likelihood to develop new products.

H4a: High relational embeddedness moderates the relation between inbound process and new product development by further increasing the likelihood to develop new products.
H4b: High relational embeddedness moderates the relation between outbound process and new product development by further decreasing the likelihood to develop new products.

Research method

The research setting of this study is the biotechnology industry. Since all the necessary skills and organizational capabilities needed to compete in biotechnology are not readily found in a single company and the sources of knowledge are widely dispersed, over the last two decades biotech firms entered into an array of inter-firm strategic relationships. For these reasons and because it is characterized by a high level of innovation openness, we chose the biotechnology industry as research setting of this paper (Rothaermel, 2001).

We gather data from multiple sources. We obtain data on inter-firm collaborations through *BioWorld* database, an among its sections, we focus on collecting exclusively data about collaborations between biotech and biotech companies in the years 2006-2010, where biotech company means both pure biotechnological and bio-pharmaceutical. The full dataset includes 1772 agreements among 1842 biotechnology firms. Then, from this dataset, we select only the public companies, specifically 366 firms, to ensure the availability and reliability of firm-attribute data. Thus, we collect data about new products, patenting, and firm-attributes of this selected sample. The open innovation practices and the embeddedness network data of each of these 366 firms are computed by considering their relationships with all the companies included into the full dataset. We retrieve data on new product development from the "biotech products" section of *BioWorld* database. The patenting data are retrieved from US Patents Office database. Finally, we collect firm-attribute data from the companies' annual reports.

As dependent variable of our model we use the total number of new biotechnological products introduced in the market throughout 2006-2012 (*New biotech products*). To assess different lag specifications between open innovation variables, embeddedness network variables, and new product output we calculate the dependent variable considering 2 further years subsequent to the 5-year biotech-biotech agreements' observations.

As concerns the open innovation variables, we consider the following explanatory variables: *inbound* and *outbound*. The inbound variable is an aggregate variable that sums how many times each company is involved in the following inbound practices, in-licensing, purchasing of R&D services, and acquisitions. The outbound variable is an aggregate variable that sums how many times each company is involved in the following outbound practices, out-licensing, supply of R&D services, and external technology commercialization.

As concerns the embeddedness network variables, reach centrality (*Reach_centr*) is widely used in social network studies to measure the firm's reachability to every other firm on the shortest path. To evaluate reach centrality we use UCINET, a network analysis program that computes network variables by using as dyadic data. We measure structural holes (*Str_hole*) as constraint using the "Network>Ego Network>Structural Holes" routine in UCINET. We calculate this variable as one minus the firm's constraint score and zero for all other cases. Regarding the variable *Relational embeddedness* (*Rel_Em*b), as already explained, we measure it as the sum of *repeated ties* and *cliques*. Repeated ties is the ratio of the total number of partners with whom the firm has repeated ties to the total number of partners. To measure the variable cliques, we use the "Network>Subgroups>Cliques" procedure implemented in UCINET to detect the presence of relevant cliques; this procedure allows to measure how many cliques each company is embedded in. Many other factors may influence the development of new biotechnological products. Accordingly, we include five control variables, *Patent stock, Size, Age, R&D Intensity* and *Industry* to remove any potential confounding correlation of other factors on the new product development.

Results

Since our dependent variable is a count variable that takes only non-negative integer values, we test our hypotheses by using a negative binomial regression. Table 2 provides an overview of the results of the negative binomial analysis.

Table 2. Results of the negative binomial analysis

	Dep. Var. - New Biotech Products					
	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Patent Stock	0.0000719	-0.000720***	-0.000718***	-0.000825***	-0.000767***	-0.000724***
	(0.000567)	(0.000209)	(0.000187)	(0.000173)	(0.000175)	(0.000192)
Age	-0.00413	0.00170	0.00213	0.000571	0.00173	0.00133
	(0.00356)	(0.00336)	(0.00290)	(0.00296)	(0.00302)	(0.00282)

Size	0.465***	0.325***	0.323***	0.332***	0.314***	0.324***
	(0.0734)	(0.0633)	(0.0601)	(0.0578)	(0.0578)	(0.0580)
R&D intensity	0.0000756	-0.0000796	-0.000280	-0.0000177	-0.0000336	0.0000774
	(0.000312)	(0.000322)	(0.000329)	(0.000355)	(0.000395)	(0.000399)
Industry	0.586*	0.994***	0.891***	1.044***	0.998***	1.004***
	(0.255)	(0.260)	(0.261)	(0.267)	(0.266)	(0.273)
Inbound		0.518***	0.480***	0.320*	0.205	0.418***
		(0.0656)	(0.107)	(0.144)	(0.272)	(0.121)
Outbound		-0.311**	-0.375*	-0.229†	-0.0597	-0.228
		(0.117)	(0.170)	(0.153)	(0.181)	(0.186)
Reach_centr			-0.214	-0.228†	-0.166	-0.192
			(0.145)	(0.131)	(0.141)	(0.142)
Str_hole			0.460*	0.479**	0.400*	0.399*
			(0.185)	(0.175)	(0.193)	(0.191)
Rel_Emb			-0.0757	0.0618	-0.0199	0.176
			(0.159)	(0.183)	(0.161)	(0.236)
InbXReach_centr				0.131†		
				(0.0829)		
OutXReach_centr				-0.414***		
				(0.106)		
InbXStr_hole					0.222	
					(0.197)	
OutXStr_hole					-0.433**	
					(0.152)	
InbXRel_emb						0.0374†
						(0.0234)
OutXRel_emb						-0.280*
						(0.126)
Constant	-3.694***	-3.442***	-3.451***	-3.513***	-3.377***	-3.439***
	(0.375)	(0.338)	(0.333)	(0.336)	(0.320)	(0.329)
Alpha	1.055***	0.505*	0.291***	0.197**	0.214**	0.249**
	(0.189)	(0.237)	(0.294)	(0.302)	(0.305)	(0.295)
N	366	366	366	366	366	366
Wald $\chi 2$	114.18***	182.21***	222.24***	351.84***	329.65***	381.51***
Log-likelihood	-313.36	-297.36	-292.29	-287.87	-289.07	-290.03
Likelihood ratio test		19.82***	17.22***	15.31***	16.31***	16.00***

Robust standard errors in parentheses † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Looking at the results from model 2, it introduces the two open innovation processes as explanatory variables. The coefficients of the inbound and outbound variables have the expected signs and are both significant. In line with H1, the coefficient inbound is positive, implying that companies that purchase more R&D services, technologies and patents also develop more new biotech products. Always in line with H1, the coefficient outbound is negative, meaning that selling R&D services, technologies and patents brings negative effects on innovation outcome of the firms in terms of the development of new products. Summing up, the first results corroborate H1. Model 3 introduces the three embeddedness network variables. We find that structural holes is significant and positively related to the likelihood to develop new products, while reach centrality and relational embeddedness are both not significant. Model 4 introduces the pairwise interaction terms between the structural embeddedness dimension of centrality and the two open innovation processes in order to test hypotheses H2a and H2b. We expect a positive interaction effect between inbound process and centrality (H2a) and a negative interaction effect between outbound process and centrality (H2b). As Table 2 shows, the two interaction terms are significant and the hypothesized signs are corrects, so H2a and H2b are confirmed. Model 5 introduces the pairwise interaction terms between the structural embeddedness dimension of structural holes and the two open innovation processes in order to test hypotheses H3a and H3b. We expect a negative interaction effect between inbound process and structural holes (H3a) and a positive interaction effect between outbound process and structural holes (H3b). As Table 2 shows the interaction term is not significant while the interaction terms is significant but negative. So we do not confirm both H3a and H3b. Finally, Model 6 introduces the pairwise interaction terms between the relational embeddedness dimension of relational embeddedness and the two open innovation processes in order to test hypotheses H4a and H4b. We expect a positive interaction effect between inbound process and relational embeddedness (H4a) and a negative interaction effect between outbound process and relational embeddedness (H4b). As depicted in Table 2, the two interaction terms are significant and the hypothesized signs are corrects, but just H4a is confirmed. Indeed, although the sign of the main effect (*Outbound*) is negative it is not significant, so we do not confirm the H4b.

Essential references

Ahuja, G. 2000. Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly* **45**(3): 425–455.

Arora, A and A Fosfuri. 2003. Licensing the market for technology. *Journal of Economic Behavior and Organization* **52**(2): 277–295.

Baum, J., Shipolov, A.V. and Rowley, T. J. 2003. Where do small worlds come from?. *Industrial and Corporate Change* **12**: 697–725.

Burt, R. 2000. The network entrepreneur. In *Entrepreneurship: The social science view,* Edited by R. Swedberg. Oxford: Oxford University Press, pp. 281-307.

Chesbrough, H. 2003. *Open Innovation: The New Imperative for Creating and Profiting From Technology*. Boston, MA: Harvard Business School Press.

Gulati, R., Nohria, N., and Zaheer, A. 2000. Strategic networks. *Strategic Management Journal* **21**(3): 203-215.

Inauen, M. and Schenker-Wicki, A. 2011. The Impact of Outside-in Open Innovation on Innovation Performance, *European Journal of Innovation Management* **14**(4): 496– 520.

Katila, R. and Ahuja, G. 2002. Something old, something new: a longitudinal study of search behavior and new product introduction. *Academy of Management Journal* **45**: 1183–94.

Koka, B., and Prescott, J. E. 2002. Strategic alliances as social capital: A multidimensional view. *Strategic Management Journal* **23**: 795–816.

Laursen, K. and Salter, A. 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. *Strategic Management Journal* **27**: 131–150.

Lichtenthaler, U. 2009. Outbound open innovation and its effect on firm performance: Examining environmental influences. R*&D Management* **39**(4): 317–330.

Lin, C., Wu, Y.J., Chang, C., Wang, W. and Lee, C.Y. 2012. The alliance innovation performance of R&D alliances: the absorptive capacity perspective. *Technovation,* **32**(5): 282-292.

Mazzola, E., Bruccoleri, M., and Perrone, G. 2012. The effect of inbound, outbound and coupled innovation on performance. *International Journal of Innovation Management*. **16**(6): 1240008.

Moran, P., 2005. Structural versus relational embeddedness: social capital and managerial performance. *Strategic Management Journal* **26**: 1129–1151.

Rothaermel, F. T. 2001. Complementary assets, strategic alliances, and the incumbent's advantage: an empirical study of industry and firm effects in the biopharmaceutical industry. *Research Policy* **30**: 1235–51.

van de Vrande, V, JPJ de Jong, W Vanhaverbeke and M de Rochemont. 2009. Open innovation in SMEs: Trends, motives and management challenges. *Technovation* **29**(6–7): 423–437.

Zaheer, A., and Bell, G. G. 2005. Benefiting from network position: firm capabilities, structural holes, and performance. *Strategic Management Journal* **26**: 809–25.