

How do R&D project networks support the adoption of open innovation practice?

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Abstract

Purpose of the paper: *The aim of this paper is to investigate how firms develop the transition from closed to open innovation and how this process occurs throughout R&D project networks.*

Methodology: *The work carries out a multiple case study analysis of 8 Tuscan companies that have developed R&D projects in inter-organizational networks during the period under analysis. It investigates the opening of the innovation process starting from the firms' ego-networks over a period of several years.*

Findings: *Results show that small and medium firms are not lagging behind large firms in the adoption of open innovation practices and that the industry where firms operate is not a discriminating factor for opening up of firms' innovation process. Besides, the technological complexity of the production process that companies adopt is one of the main determinants in the implementation of open innovation practices.*

Research limits: *The study deals with temporary project networks, which represent the tip of the iceberg of the relational innovation processes of the analyzed firms.*

Practical implications: *The study underlines the importance of opening an innovation process outside of the boundaries of the firms through the privileged tools of temporary R&D networks that are financed by public policies. Managers and entrepreneurs should carefully dedicate resources and competences to this process, in accordance with the increasing relevance of the open innovation paradigm.*

Originality of the paper: *Three network configurations of the opening of the innovation process within R&D networks are described in order to contribute to our knowledge on the transition from closed to open innovation in small and large firms.*

Key words: Open innovation; R&D networks; multiple case study; ego-network.

1. Introduction

Research on Open Innovation (OI) has been exponentially developed in recent years (Vanhaverbeke *et al.*, 2014; Kovacs *et al.*, 2014; Di Minin *et al.*, 2010; 2014) and OI is increasingly integrated into firms' business strategy (Chesbrough *et al.*, 2014; Chesbrough and Appleyard, 2007; Capone, 2016).

Notwithstanding the rising number of publications on OI, some research gaps still exist in relation to how firms implement the transition from closed to open innovation (Mortara and Minshall, 2011), and in particular to how this process is implemented in small and medium firms in high and low technology industries (Vanhaverbeke *et al.*, 2018; Hossain, 2015; Wynarczyk *et al.*, 2013).

The aim of this paper is to investigate the opening of firms' innovation process and the implementation of open innovation practices throughout R&D projects. The work focuses on a longitudinal analysis of the ego-networks of firms participating in R&D projects.

How do firms open up their innovation process through networking? How do firms implement OI within R&D network projects? Are there any differences between small and large firms in the implementation of OI in R&D networks? Are there any differences on the basis on the sectors where the firms operate? The paper will try to answer some of these questions.

There are numerous studies that underline the relevance of networks in OI (Dittrich and Duysters, 2007; Belussi and Orsi, 2016; Enkel, 2010; Martinez-Torres, 2014, among others), however the link between these two streams of research is undervalued. It is therefore crucial to investigate the implementation process of OI and how the innovation process opens up through R&D projects. This work aims to contribute to this debate by investigating the opening up of innovation processes through firms' network dynamics.

The paper carries out a multiple case study analysis of 8 Tuscan companies that developed R&D projects within inter-organizational networks during the period under analysis (2010-2015). The case studies were developed on the basis of the firms' involvement in R&D projects that were conducted during the considered period and through the analysis of the internal documents and secondary data that were provided by the studied firms (balance sheets, websites, project documentation, etc.).

Every firm was monitored throughout one or more funded R&D projects, observing its approach to innovation, the openness of the innovation process and the dynamics of knowledge management with its partners. The case studies were based on research conducted by Chesbrough and Crowther (2006) on the analysis of the implementation of open innovation (Fig. 1).

Results led to the identification of three types of network configurations for the implementation of OI. The firms' network fits in a continuum of the degree of openness of the innovation process, thus presenting interesting cases involving full open or in-transition innovation processes.

Interesting managerial implications emerge from the analysis of the context where the firms operate (industry and technological complexity) and their features (dimension, technological endowment, etc.). The size of the firms is not a determinant of openness in the innovation process, while the technological complexity of the production process is an important discriminant in crossing the firm's boundaries and searching for new knowledge or better competences that are necessary for developing new products.

2. Open innovation and networks

Several authors focus on the process of opening up the innovation process outside of the firms' boundaries (Henkel, 2009; Herzok and Leker, 2010; Chiaroni *et al.*, 2011; Enkel and Bader, 2013). In fact, open

innovation (OI) has also been analyzed in terms of the degree of openness of firms' innovation process (Huizingh, 2011). Dahlander and Gann (2010) underline that there are several degrees of openness and that openness produces not only benefits but also costs (Laursen and Salter, 2006; 2014; Knudsen and Mortensen, 2011).

Huizing (2011) defines the openness of the innovation process on the basis of either the number and type of partners, or the number and degree of the phases of the innovation process. Dahlander and Gann (2010) introduce a taxonomy of openness linked to the direction of this process (inbound and outbound) and to its nature (*pecuniary* or *non-pecuniary*). Lazzarotti and Manzini (2014) analyze openness on the basis of both the partners' number and type, and the phases of the innovation process by using external sources.

Trot and Hartman (2009) underline that the opening of innovation is not a standard process, but rather develops throughout a continuum of cases depending on the characteristics of the firms and the context where they operate.

Notwithstanding the wide literature exploring this dynamic, what remains under-investigated is how the process of opening develops and whether it is related to specific elements, such as the industrial and technological context where firms operate, or some of their characteristics, for example their dimension (West, 2014).

In analyzing OI implementation, several authors have focused on the study of networks and network dynamics (Capone, 2016). Network dynamics are one of the possible ways of adopting an approach to open innovation, especially in *outbound open innovation* (Dahlander and Gann 2010). External networking is perhaps one of the most significant dimensions of outbound open innovation (Huizing, 2011), either due to the number of studies in this stream of research or the importance of the topic in the context of studies on innovation networks (Powell and Grodal, 2005; etc.).

The literature on innovation networks began to develop in the Nineties (Powell, 1990; Powell *et al.*, 1996) and although its origins precede the birth of Open Innovation, there are several contributions that have tried to integrate these two streams of research since its earliest stages (Chesbrough, 2003; Dittrich and Duysters, 2002; etc.).

However, in the international literature there are few studies that fit in the intersection of these two streams of research (Capone, 2016). One of the first contributions in this regard is Dittrich and Duysters' (2007) study that states that innovation networks can be used to manage the process of technological change in the corporate environment by presenting a longitudinal case-study of an innovation network during its transition from closed to open innovation.

Belussi and Orsi (2016) analyze the inter-connections between networks, innovation and high-tech environment and underline that networks are a means of transition towards a more open approach to innovation, particularly in high technology sectors. Lee *et al.* (2010) study open innovation practices in small and medium firms, confirming the potential of adopting of open innovation practices in SMEs and indicating

networking as one effective way of facilitating innovation among small firms. Wincent *et al.* (2009) underline the role of boards in strategic small-firm networks that employ them to effectively manage joint research-and-development activities.

Enkel (2010) investigates the role of networks in performance and profitability. She studies the personal and organizational attributes that are required to profit from an open innovation. Moreover, she underlines that the attribute of openness and the possibility to equally contribute to influencing the value that individuals receive from open innovation networks.

Finally, Brunswicker and Van de Vrande (2014) explain that a key area in research on open innovation in small firms consists in the importance of different kinds of networks when SMEs engage in open innovation. The two authors underline that as the locus of innovation regularly resides at the network level, open innovation in SMEs is naturally quite specific and different from large firms and it is necessary to explore the unique challenges of leveraging and managing open innovation in SMEs.

In addition, networking in open innovation does not only bring advantages. Jarvenpaa and Wernick (2011) analyze the difficulties of developing networks for open innovation, pointing out that networks in the context of open innovation produce more obstacles than other types of networks.

Martinez-Torres (2014) investigates open innovation communities through social network analysis and interpersonal networks of community members. Results underline how collective intelligence evaluation schemes can be useful to identify users that post ideas that are potentially applicable for the organization. In this same context, Fichter (2009) explores the role of promoters and networks of promoters in Open Innovation communities, underlining the relevance of interpersonal networks for innovation beyond the firm's boundaries.

Finally, it is also important to indicate the different networks that can be formed in the adoption of open innovation practices. For instance, several contributions have been devoted to entrepreneurial networks (Zampi, 1997). Huggins and Thompson (2016) underline the relevance of entrepreneurial networks in Open innovation. The two authors point out that strategic and embedded ties are significantly associated with rates of innovation for entrepreneurial firms. Strategic ties are most strongly linked to product and organizational innovations, while process innovations are more related to embedded network ties.

In this context, many contributions have stressed the important role that the study of networks and social network analysis (Scott, 2012) can play in innovation studies and collaborations for innovation (Sciarelli and Tani, 2014; Van der Valk and Gijssbers, 2010). For instance, Yun *et al.*, (2016) apply social network analysis to investigate open innovation practices. They analyze network structures and features of firms' joint patent applications such as *betweenness* and *degree centrality*, structure holes, and closure. They point out that the structure of collaboration networks has both direct and indirect effects on firms' innovative performance. Lazzeretti and Capone (2016a) stress the importance of network *centrality* and *betweenness* in

inter-organizational collaboration for R&D in a technological district.

Finally, the role of the context or territory where firms operate is also considered increasingly important in facilitating the adoption of OI practices (Cooke, 2005). As networking is particularly fostered in geographical concentrations of firms and institutions (Belussi *et al.*, 2010), Huang and Rice (2013) investigate if open innovation works better in geographical clusters and state that localization in clusters fosters the adoption of OI practices. Lazzeretti and Capone (2016b; Capone and Lazzeretti, 2017) investigate the role of the union of geographical, social, cognitive and institutional proximity in a high technology cluster, thus finding that geographical proximity fosters collaborations among inter-organizational innovation networks. Pucci *et al.* (2017) investigate internal resources and capabilities and external inter-organizational relationships in a cluster. They underline how the local cluster favors the development of companies with a particular focus on social capital and social ties for the development of innovations.

Vanhaverbeke *et al.* (2014) point out that it will be important to analyze the role of geographical concentrations (like clusters and industrial districts) in the future to understand if they can be drivers to promote even more open innovation, in particular for knowledge dissemination and the role of local knowledge networks. Simard and West (2006) also argue that the benefits of OI can be better achieved in clusters of enterprises, research centers, universities and institutions that constitute a favorable environment for knowledge exchange and better collaboration among companies.

All these contributions emphasize the profound changes of the firms' innovation process and stress the importance of networks and networking activities in implementing open innovation practices. Obviously, it is easy to assume that there are connections between these two research topics, given that innovation networks are part of a way in which the opening of the innovative process is carried out. However, only recently have some works started to investigate these aspects.

3. Research design

The present article carries out a multiple case study analysis of 8 Tuscan companies that developed R&D projects in inter-organizational networks during the period under analysis.

Despite the criticism of case study research¹, the case study analysis method has greatly developed in research activities in numerous disciplines and particularly in management studies (Yin, 1994; Guercini, 1996).

In this context, this article carries out a multiple case study analysis. Although the multiple case study is an expensive and time-consuming process, it presents some advantages (Stake, 2013). First of all, a multiple

¹ Case study analysis has been addressed as a research method that is not sufficiently rigorous, often imprecise and leaves too much room for the researcher's subjective interpretation. See Guercini (1996) for a review of the limits and benefits of case study research in management.

case study approach allows data to be analyzed *within* each situation and *across* different situations and similarities and differences between the cases to be understood. Another advantage is that the evidence that is generated from a multiple case study is more reliable than a *single case study* and this helps to evaluate if the findings are relevant or not.

The research started with the selection of the firms under study through the analysis of the Calls for R&D projects launched by the Tuscany Region within the POR-CReO² 2007-2013 program.

The calls that were mainly taken into consideration are the R&D (BUR&D) Calls that were launched by the Tuscany Region in 2008 and 2012 and financed research & development projects of a maximum length of 2 years. The two regional Calls supported innovation networks in temporary R&D projects and admitted the participation of small and medium sized firms (SMEs) along with large firms. This allows the innovation dynamics in networks composed of both SMEs and large firms to be investigated. All calls addressed manufacturing firms, thus excluding services, agriculture, transport and trade firms. The selection of firms was based on a multistep process. First of all, given that even single enterprises were admitted to participate in the analyzed calls, we only considered those that constituted an innovation partnership as a project leader. Moreover, the selected firms had to participate in at least two R&D projects within the period so as to focus on enterprises that had a high propensity toward (open) innovation in networks.

The second, further selection was based on the availability of firms to participate in the study on open innovation dynamics. In addition, we tried to build up a heterogeneous sample that could represent firms from different industries, of different sizes and in different locations in Tuscany.

Every firm was followed in the course of the development of one or two R&D projects, observing its approach to innovation, the openness of the innovation process, and the dynamics of knowledge management with partners. The case studies were developed through the analysis of internal documents and secondary data provided by the firms (balance sheets, websites, project documents, etc.).

Moreover, several unstructured interviews were carried out during the period in accordance with Chesbrough and Crowther (2006) (see below and Table 1). In the majority of cases, the involved personnel consisted in the executives of the R&D departments, the technical managers of the R&D projects, or - in the case of small and micro-enterprises - the entrepreneurs themselves.

Eight firms were selected in the end. Table 2 presents their main characteristics.

As previously mentioned, during the analysis we closely followed the process of case study research for open innovation realized by Chesbrough and Crowther (2006) and presented in Table 1.

Table 1 presents the key questions that we tried to address and highlight in the course of the multiple case study analysis. The key questions of the analysis aim to explore the innovation process of firms along four pillars:

² Regional Operational Programme on Growth and Employment

strategies and aims, process of technology sourcing, outsourcing, and the integration of these two processes.

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Chesbrough and Crowther (2006) underline that the guidelines of the analysis that were developed in their work could be the basis on which to build a qualitative benchmarking analysis framework on the adoption of the open innovation paradigm in different contexts, industries and businesses.

The first part of Table 1 regards the approach of firms to external knowledge and technologies and to the relative activities of internalization (inbound open innovation). The second part of the table refers to the firms' approach to internal market knowledge and internally developed competence (outbound open innovation). Finally, the last part concerns the role of the network in these processes and the role of financial incentives and public calls for innovation in the networks of firms.

Tab. 1: The focus of the analysis during the case studies

<ol style="list-style-type: none"> 1. To what level of satisfaction are your technology needs met by your internal R&D? Explain. 2. Does your company make a practice of looking to bring in outside IP and technology? Is this done opportunistically or do you have a formal, systematic to doing so? 3. Is looking outside for technology that can be leveraged everyone's job-or is there a distinct group dedicated to doing this? What types of people fulfill this role? 4. What specific goals or objectives do you have regarding bringing in technology? What incentives are tied to these goals? 5. Where do you typically look for outside ideas and technology: e.g.: universities, start-ups, competitors, conferences, or companies in peripheral industries? 6. How would you characterize your efforts to bring in technology: <ol style="list-style-type: none"> a. Would you say that typically when you bring in or jointly develop an outside technology, it is to address an incremental product improvement or a breakthrough product? b. Do you typically work with 'proven' technologies used in other applications, or are you trying to develop something entirely new? c. Do you typically bring in technology that leverages core R&D capabilities, or does it feel more like outsourcing non-core needs? 7. How has bringing in outside technology helped your company? Has the impact been significant? What has the impact been? 8. How would you characterize your efforts to take out technology? <ol style="list-style-type: none"> a. When something is developed internally that doesn't fit with your business model, do you have a practice of taking the IP or technology assets out to the marketplace? b. When something that was initially developed internally is deemed 'dead,' are efforts made to find companies or partners that might be interested in it? Is this done opportunistically or is there a formal mechanism to do this? 9. Are there specific goals around when a technology asset can be taken out to the marketplace? Who or what group has responsibility for doing this? How are they incented? 10. What impact has taking IP or technologies you have chosen not to commercialize out to the market had on the company?

Source: Chesbrough and Crowther (2006, p. 232)

Of course, the methodological approach developed in this study has some limits. First of all, the article focuses on the study of temporary partnerships for innovation, therefore without taking all the external innovation activities of the analyzed firms into account. Nonetheless, the longitudinal analysis of the firms also enables the investigation of

the network of informal relationships and the firms' global approach to innovation. Finally, it should be noted that the two projects financed by the Tuscany Region were the largest R&D projects in which almost all of the analyzed enterprises were involved, which underlines the relevance of these activities for the studied firms.

4. The characteristics of the analyzed firms

Table 2 presents the overall characteristics of the analyzed firms. As previously mentioned, the sample is heterogeneous and allows the analysis of a wide-ranging spectrum of firms, both in terms of industries and dimensions.

Tab. 2: Characteristics of the analyzed firms and case study results

ID	No. employees	Size	Revenues (M€)	Industry	Location	Average of project partners	Approach to open Innovation
1	250+	Large	>50	Aeronautics	Arezzo	4	In transition
2	250+	Large	>50	Bio-medics	Florence	6	Open
3	100+	Medium	2-10	Textile-clothing	Arezzo	3	In transition
4	10	Micro	<2	Giftware	Florence	3	In transition
5	10	Micro	<2	Ceramics	Lucca	3	Limited
6	5	Micro	<2	Giftware	Lucca	3	Limited
7	25	Small	2-10	Medical devices	Florence	5	Born open
8	250+	Large	>50	Glass	Siena	5	Limited

Source: our elaboration

The analyzed firms include two large companies, one medium-sized enterprise, one small business and three micro-enterprises. The sectors in which they operate are varied, including both high-tech sectors, such as aeronautics, bio-medics or medical devices and low-tech sectors, which are typical of the Made in Italy sectors, such as textiles and clothing, ceramics, glass, etc. All companies are manufacturing firms as required by the attended R&D calls.

With reference to the number of employees, the sample of analyzed firms is quite mixed. There are three large companies with over 250 employees, a medium enterprise with over 100 employees, and four SMEs with less than 50 employees.

Almost all of the companies are established and have been operating in the business for more than ten years, apart from a recent spin-off that had been active for less than five years at the time of the analysis (n. 7).

The firms are located throughout the entire region: three companies were situated in the province of Florence, two in the province of Arezzo, two in the province of Lucca and one in the province of Siena.

The heterogeneous composition of the sample allows us to investigate whether the dynamics of open innovation take place in high or low-tech sectors, and whether in large enterprises or SMEs. Also, the involvement of firms operating in different sectors was helpful in focussing on different

contexts that might lead an enterprise to develop a greater or lesser propensity to OI.

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5. The analysis of firms' approach to open innovation

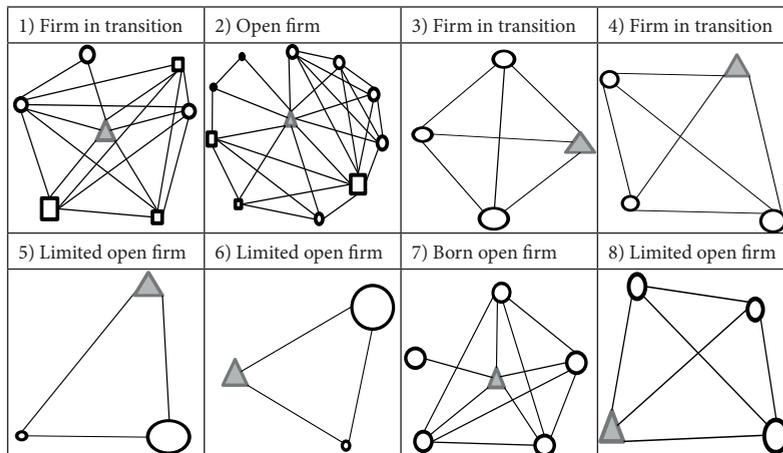
5.1 The ego-networks of the analyzed firms

This section presents the analysis of the R&D networks that was carried out by the interviewed companies through the construction of their *ego-networks*. An ego-network is a network constituted by a focal node (“ego”), the nodes to which it is directly connected (called “alter”) and the bonds, if any, between the ego and alter. These networks are also known as personal networks or ego-centric networks (Freeman, 1982; Everett and Borgatti, 2005). Ego-network can be obtained by extracting a sub-network from a full network and allows us to focus on the relationships of a single firm instead of an entire network.

The firms' relationships have been studied through the Social Network Analysis method (Scott, 2012). Through UCINET software it is possible to represent the firm's relationships in a relational graph from the perspective of a central actor (ego) who develops relationships with others (alter).

Figure 1 presents the eight *ego-networks* of the analyzed firms. The “ego” firms are represented by colored triangles, other businesses are represented by white circles, and research centers with white squares. The size of the nodes identifies the importance of the node within the overall network, which is calculated according to its density³.

Fig. 1: The ego-networks of the analyzed firms



Source: our elaboration

³ Since figures are extracted and resized, it is not possible to compare the size of the nodes among different networks, but only within the same figure.

The most complex networks are those in which the ego has a more open approach to innovation. Ego-networks 2 and 7 are those in which the company establishes relationships with a larger group of organizations involving several research centers and universities. Network 1 is also quite complex and extended from the point of view of the number of involved organizations, but according to the interview it can be defined more in transition. All of these networks are inter-organizational networks of firms, universities and research centers, that are coordinated by a technologically advanced firm which therefore coherently fits in with the open innovation paradigm.

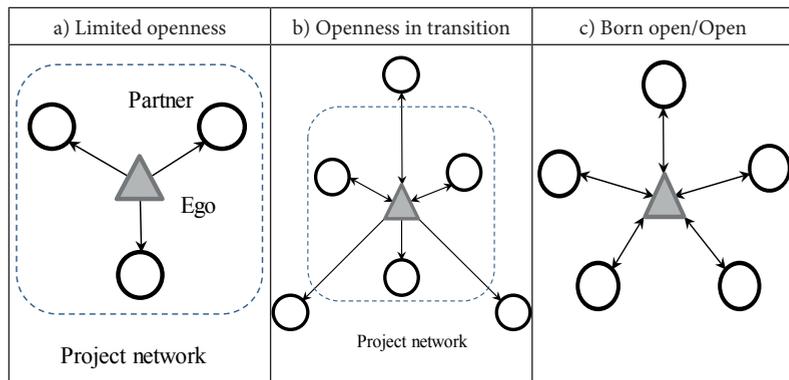
The opposite of this type are limited or partially closed network. These are basically ego-networks 5, 6 and 8, which deal respectively with the networks of two small firms and a large company. Here the structure of the network is hierarchical and mainly based on the company's leader and suppliers. In addition, they all operate in low tech industries or those with a limited level of technological competences (Ceramics, Giftware, Glass).

Finally, the intermediate type between the ideal-types above consists in a firm in transition. It regards ego-networks 3, 4 and 1. Here the networks are mixed and formed by public and private organizations with increasing collaborations with research centers and universities. Network 1, centered on a large company, is the most technologically advanced and, in the course of time, is increasingly opening its innovative process outside.

5.2 Three network configurations of open innovation adoption

The analysis identified three types of open innovation approaches, as shown in Figure 2. The analyzed companies are represented by colored triangles, while white circles indicate the companies with whom they develop innovative relationships. Such a representation of the results aims to model the open innovation approaches of the analyzed ego networks from the perspective of the ego-firm (coordinator of the R&D project).

Fig. 2: Different models of open innovation adoption in R&D networks



Source: our elaboration

The first model (Figure 2a) refers to an enterprise that is still linked to closed innovation dynamics. Its participation in the network through the incentive of an innovation policy is one of the first steps in the journey towards open innovation. In this context, the firm's relationships are mainly developed within the project network and among the actors with whom the company has established more lasting and stable relationships and shares more trust and values.

This shows, on the one hand, a cohesive and stable network, but probably also presents some criticalities regarding the generation of innovation processes. Knowledge is often redundant and the partnership shares the same knowledge of ego networks. The central enterprise is the strong coordinator of the network partners, who are often subcontractors in the production process, rather than in the technological field. Relationships here are mainly linked to an inbound open innovation, and thus primarily aim to internalize external knowledge within the company, rather than outsource its knowledge and integrate R&D internal processes with external sources. Moreover, there are no structured activities of analysis or search for the most crucial external knowledge from the technological point of view of the company.

Some of the most interesting aspects of this model concern the companies that take on this type of approach to innovation. First of all, companies that adopt this approach are of a varied size, which highlights - as has recently been pointed out - that the dynamics of OI are not only developed in large enterprises (Van de Vrande *et al.*, 2009; Lee *et al.*, 2010; Spithoven *et al.*, 2011; Parida *et al.*, 2012). We find one large company and two micro-enterprises, so the size does not seem to be particularly relevant. An important aspect is however related to the sector they belong to. In fact, all of the companies falling under this category operate in the Made in Italy sector (e.g. ceramics, giftware and glass, etc.). These are all traditionally low-tech sectors, even if the analyzed companies proposed innovations in these areas through their participation in R&D projects.

The second innovation approach has been called "openness in transition" (Figure 2b). Here we find companies that demonstrate a more advanced approach to innovation in comparison to the previous type. It is possible to perceive some typical processes of the OI paradigm. The project network is still very relevant and stable relationships among partners, based on trust and shared goals and visions, continue in time. In addition, the relationships that are established by these companies go beyond the boundaries of the project network and rely on other players. The role of the ego is always very important, but there is a sharing of activities and a more pronounced division of labor compared to the previous model. The relationships that are built in ego networks cover both inbound and outbound processes, the latter are mainly developed within the project-network actors. Knowledge is typically diffused in the project network. However, there are structured OI activities in relation to innovation sourcing activities such as spin-offs or the purchase/sale of patents outside of the firm. Anyway, from time to time individual researchers or R&D employees develop these activities within the enterprise to improve its innovativeness. Finally, relationships

mainly involve subcontractors in the company's production chain, but also highly specialized technology providers on specific aspects.

Here too, the firms' dimension does not seem to be critical: in fact, in this model we find one large enterprise, one medium enterprise and one small business. It is also useful to look at the areas where these businesses operate. They are both from low-tech sectors and high-tech industries, such as the textile and clothing industry, the giftware industry and the aeronautics sector. The latter is especially interesting, since the large company belonging to it underwent a transition from a closed approach to innovation, which is typical of the industry in which it operates (Chesbrough and Crowther, 2006), to a more open position towards innovation. This shift is probably due to many reasons, some of which are related to the sectorial context. An example is the reduction of public funding for innovation and the recent economic crisis (Bianca and Esposito, 2007), which have led companies to favor cooperation and joint research with other companies in order to share risks and costs.

The last model is called "Open" (Figure 2c). Here we find companies whose approach to innovation is closer to the open innovation paradigm. Specifically, this model includes the spin-off that was launched just a few years ago and is known as "Born open".

Companies within this category are based on a reference core network, which is not restricted to this project network, but changes in time. Their approach to innovation is open and develops according both to the logic of the market and that of trust and personal ties with other production and technological suppliers of specific technological solutions related to innovation. As a result, ties are developed even with new technology partners. The coordination of the local network is often in the hands of the central firm but links are bidirectional and greater involvement is required by partners both in relation to technology and the network's future vision.

Relationships are mainly of a technological nature and do not rely on suppliers in the production processes. The development of technological partnerships in the context of the project's objectives is developed by all project partners and coordinated by the leader. The open innovation process refers both to inbound and outbound open innovation. Inbound activities are structured within the company while the same happens only partially for outbound activities.

Another interesting aspect is related to the analysis of the size of the involved firms, which include both large and medium-sized enterprises. The sectors however are mainly high-tech, and from this point of view it seems that the technological complexity of the business in which a company operates can determine of the need for openness in its innovation process.

6. Conclusions

The aim of the present study was to analyze the opening up of innovation processes in time during the R&D project, in order to investigate different adoption behaviors of open innovation practices. We also inquired whether the transition towards an open innovation process changes based

on internal factors such as the firm's size, technological endowment, competences, etc. or on external elements such as the industry where it operates, etc.

The analysis dealt with eight case studies of firms that participated in R&D network projects that were financed in public calls. We selected eight firms according to several criteria in order to investigate their transition toward open innovation practices.

The study is based on the analysis of the *ego networks* of the eight firms and on the modelling of some types of innovation process opening. Throughout the analysis of the multiple case studies, three models were depicted: one in transition, one open - and more similar to the open innovation ideal-type described in the literature - and one marginally open.

The results are interesting for several reasons. First of all, the analysis permitted us to underline that the opening of the innovation process, outside of the firm's boundaries, is not standard and that there are several realities and differences in this transition. Therefore the hypothesis described in the literature is confirmed in our cases, where the adoption of open innovation practices is a dynamic process in a continuum of states between two opposite points (one open and one closed), which are perhaps only an ideal-type of a firm that is open and closed to innovation (Dahlander and Gann, 2010; Enkel and Bader, 2013).

Another interesting result emerges from the different models of opening that are influenced neither by the firm's dimension nor the industry where it operates. In this context, small and medium firms, as well as large firms, have adopted open innovation practices (Vanhaverbeke *et al.*, 2018), although for different reasons. Moreover, the industry where the firms operate does not seem to be a fundamental driver of the adoption of open innovation practices. In fact, we found firms that adopt the OI paradigm both in high technology industry and in low technology sectors (Vanhaverbeke *et al.*, 2014).

According to our research, the main determinant for the adoption of open innovation practices consists in the technological complexity in which firms operate.

The study then focuses on the different phases of the open innovation process in which the firms transition from *inbound* to *outbound* open innovation. Firms behave in different manners depending on their size and on the number of phases of the value chain in which they operate. Small firms mainly realize *inbound* open innovation processes related to the final phases of the value chain. The phases of outbound OI instead are mainly developed in an un-structural and autonomous way by employees and supervisors in the R&D department. Besides, large firms operating in high technological complex industries realize inbound and outbound processes in a structured and formalized way, but their importance is not as acknowledged by the firms' management.

Of course, the analysis also presents some limitations. A first limit of the study consists in the fact that it deals with temporary project networks, that therefore only represent the tip of the iceberg of relational innovation processes. However, the selected firms were deeply involved in the analyzed

R&D project and for most of them, it represented their main innovation activity. According to the interview in fact, the analyzed projects were very relevant for the firms and several resources were devoted to these activities.

As concerns further research, it would be interesting to study the innovation process of different networks, such as alliances, joint ventures, etc., in order to overcome the limits of the analysis of temporary project networks, that are sometimes terminated with the end of the public's contribution or financial support.

Moreover, regarding future developments of the OI research, several contributions point out that there is a lack of quantitative large-scale analysis on the firms' opening of innovation process, either in different contexts or industries (high versus low tech for instance) (Chesbrough *et al.*, 2014). Except for a few contributions, such analyses are still missing in the literature of open innovation. A large-scale quantitative analysis on the topics of this paper could help to generalize its results and measure the contribution of different network configurations to the firm's innovation performance.

Despite the above discussed limitations, this study provides interesting implications for the management of technological innovation processes that are of increasing interest for managers and entrepreneurs in the current period where innovation is crucial to stay competitive.

Managers should face the external environment to solve technological problems and criticalities and innovate their products or services. Our results suggest that managers should keep the possible synergies and the need for collaborations in mind. In fact, both small and large firms operating in high technological complex industries only partially realize inbound and outbound processes and their importance is not as acknowledged within the firms' management. Finally, managers should know that there is not a single best way to adopt open innovation practices: instead, the opening of innovation is carried out through a continuum of situations depending on the characteristics of the firms and the context in which they operate. It is however important to take a first step along the path of opening up the innovative process.

In conclusion, the work underlines the importance of the opening of the innovation process outside of the firms' boundaries through the privileged tools of temporary R&D networks financed by public policies. Managers and entrepreneurs should carefully dedicate resources and competences to this process, according to the increasing relevance of open innovation dynamics.

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