

Does openness relate to innovation performance? An empirical analysis of determinants and mediators

or

Openness and innovation performance: an empirical analysis of openness determinants and performance mediators

or

Openness and innovation performance: an empirical analysis of determinants and mediators

1. Introduction

There has been an immense interest in more open modes of innovation among both practitioners and researchers in the past decade. The possibilities of accessing new knowledge and technologies from external partners while at the same time lowering costs, risk and development time have indeed attracted more and more firms to open up for external collaboration on innovation (Cricelli et al., 2016). The research on open innovation (OI) has simultaneously expanded to a number of areas, covering for instance firm-level studies on strategies and modes of openness, performance outcomes of openness, the management of OI and the role of users in OI. Some overviews on OI provide several suggestions for future research endeavours (see overviews in Bogers et al., 2016; Randhawa et al., 2016).

In this paper we set the focus on inbound open innovation and address two research gaps identified in literature. The first gap concerns the need of going beyond previous analysis of isolated relationships between factors, in order to develop models that provide a more comprehensive understanding of OI (Randhawa et al., 2016). Previous studies have specifically asked for empirical studies (Cassiman and Valentini, 2016) that provide a more complete analysis of OI practices that incorporates the interplay between OI strategies, drivers, openness, mediators and performance. In coherence with this, our analysis will include an analysis of what determinants, such as market and technological dynamics, firm size, drivers of collaboration and IP mechanisms, affect firms' openness. Mettiamo solo openness o openness degree? O openness model? Non so...

A second research gap addressed in this paper concerns the need of going more in depth on what different organisational and social contextual factors mediate the performance outcomes of openness. The gap stems from the fact that previous research on performance effects of openness has shown mixed results, which motivates the need of investigating "contingencies of the openness-performance relationship" (Bogers et al., 2016) and to "understand when and how firms can organize their R&D process to exploit the benefits of permeable boundaries" (Cassiman and Valentini, 2016). There are also results from several other studies (e.g. Greco et al., 2016; Lakemond et al., 2016; Crema et al., 2014) stressing that the mediating effect of firms' organisational mechanisms, internal and external social capital on the relationship between openness and innovation performance deserves further investigation. In line with this, Rass et al (2013) call for further empirical analysis of what social capital mediates the outcome of openness.

Thus, the purpose of this paper is to empirically analyse the relationship : i) between some contextual factors and firms' openness messa così sembra che investighiamo comunque variabili singole?; ii) among openness, a set of organisational-managerial and social factors, and open innovation performance outcomes. The purpose will be specified in two research questions presented after the literature review.

The paper main contribution to the OI literature concerns the comprehensive analysis of how firms' openness and the performance outcomes are contingent on a combination of different determinants and mediating factors. As linked result, the comprehensive analysis also allows to provide a more articulated picture of the firms adopting inbound open innovation approaches. Such a picture is characterized by both generic and specific relationships linking the studied variables. For instance, technological trends are relevant to move firms towards external collaborations, with all the types of considered partners (i.e. scientific and business ones) while perché while? Se vogliamo semplicemente mettere un paio di esempi dei risultati possiamo secondo me dirlo esplicitamente: just to make a few example, an aggressive innovation strategy and size are positively

related only to intensity of inbound collaboration with scientific partners. In any considered relationship, external collaborations are positively related to both sides of studied innovation performance (i.e. novelty and efficiency) però non sono state descritte prima, non so se vale la pena di metterle qui, non possiamo dire positively related to performance, tanto dopo spieghiamo come la intendiamo e come la misuriamo?, but the organizational-managerial and social contexts emerge, with only one exception, as relevant mediator variables.

The paper is organized as follows: section 2 defines the theoretical background from which the extant gaps are extracted to define the research questions; section 3 describes the applied methodology; section 4 reports the results; section 5 discusses results and states conclusions and limitations.

2. Theoretical background

possiamo mettere due righe che introducano I tre paragrafi, così uno sa cosa aspettarsi?

2.1 The modes of openness modes? O forms? O degrees? Usiamo un po' tutti I termini, ma forse va bene così?

The most basic research question that empirical research tries to answer is about the existence of open innovation in practice. To this goal, studies started from the general definition of OI as the phenomenon where firms rely increasingly both on the integration of external sources of innovation into the company - inbound OI - and the identification of external paths for commercializing internally sourced innovations – outbound OI (Chesbrough, 2003; Gassmann and Enkel, 2004), but soon researchers began to identify the several specific forms of OI (Huizingh, 2011). One important distinction was made between pecuniary and non-pecuniary modes of open innovation (Dahlander and Gann, 2010). In the so-called non-pecuniary mode, there is no immediate financial reward associated with a knowledge flow across organizational boundaries, while in the pecuniary one there is an immediate compensation related to a knowledge flow. In addition to the original inbound and outbound modes, later studies defined the concept of coupled innovation processes to emphasize the phenomena in which both inbound and outbound coexist by means of partnerships, collaborations, alliances, joint ventures, etc. (Gassmann and Enkel, 2004). While coupled OI was originally considered just a combination of inbound and outbound modes, the concept evolved to describe situations in which organizations cooperate to co-develop product or process innovation (Piller and West, 2014; Cricelli et al., 2016). Whatever the adopted definition, the next step taken by the empirical literature has been that of investigating the adoption rate of the several used forms. For instance, Schroll and Mild (2011) found that inbound cooperation activities are used significantly more than acquisition or outbound activities. Cricelli et al. (2016) presented a large-scale analysis of OI adoption by means of data drawn from the community innovation survey. The results confirmed that the share of companies adopting the OI paradigm has increased, both in terms of inbound and coupled actions.

In addition, most studies agree that openness should be regarded as a continuum between end points of open and closed innovation. However, the degree of openness could differ depending on one's perspective. For example, Lichtenthaler (2008) defined the degree of openness by crossing the inbound and outbound process and identified the extent of external technology acquisition and exploitation. However, the likely most diffused way to study inbound openness degree is that proposed by Laursen and Salter (2006) with their concept of breadth (number of used sources) and depth (intensity of collaboration with each source). The authors also provide a list of the main partners, largely used in the subsequent studies: universities, research centres, customers, suppliers, competitors, companies operating in other industries. Several authors follow a similar approach. For instance, Lazzarotti et al. (2011) identified different types of collaborators depending on the number of phases and partner types ("few" or "many" among those suggested by Laursen and Salter -2006) on which firms collaborate. More recent works (e.g. Du et al., 2014; Bengtsson et al., 2015) reduce partner types in two categories according to the distinctive features of the mentioned partners. Thus, academic/scientific category groups actors such as universities, research centres and innovation intermediaries, while value-chain/business category groups mainly customers and suppliers. Although, on the one hand, categorization could cause loss of details, on the other it allows to simplify the analysis, by focusing on the main distinctive features (Thompson, 2004). Moreover, despite the empirical evidence gathered on partner type (e.g. Belussi et al., 2010; Lee et al., 2010), this remains an interesting construct to be investigated (Schroll and Mild, 2012; Greco and Grimaldi, 2015). Accordingly, among the several possibilities, all theoretically acceptable and also supported by empirical verification, we focus on a specific OI concept, strictly linked to a collaborative behaviour between a focal firm and different types of partners. Following Laursen and Salter (2006) and Lazzarotti et al. (2011), the considered degree of openness reflects how intensively (depth) a firm activates an external relationship to share knowledge and thus to sustain innovation (Drechler and Natter, 2012; Garcia et al., 2014). Depth is considered in terms of intensity of collaboration with external partners and it is limited to two types of partners (Du et al., 2014; Bengtsson et al., 2014): the intensity of collaboration with scientific partners (universities, research centres, etc.) and with business partners (suppliers, customers, etc.). The literature has outlined the need to study separately these two

types of partners because of their different connotations. Indeed, while business partners share the firms' cultural values, expertise and goals, scientific partners show peculiar connotations (Pertuzè et al., 2010). They range from cultural differences to research orientation and reward systems. Researchers at universities have their slow clock-speed in performing activities, which is hard to be influenced by the firms, and they typically have more autonomy, freedom to exchange knowledge and room for improvisation (Aghion et al., 2008). For them scientific reputation is more important than monetary benefits and they are less concerned about unwanted industrial spill-overs. However, although business partners are more similar to firms as concerns the features mentioned above, they are obviously characterised by a specific set of technical capabilities and resources (Croom, 2001).

2.2. *Internal and external determinants of openness*

With knowledge about the existence of open innovation adoption, a further question typically addressed by previous studies has been on the reasons why companies are using open innovation. This led to investigations of which were the determinants and the drivers of the phenomenon.

With a deep critical review of the empirical research on open innovation, Schroll and Mild (2012) identified the most commonly studied factors which are pointed as potential determinants of openness. The authors reduce factors in two categories: organizational capabilities and environmental conditions. The first category, named "internal or firm-specific" by other authors (e.g. Lazzarotti et al. 2011; Drechsler and Natter, 2012), includes factors such as goals pursued through collaborations (i.e. drivers of collaborations); a firm's innovation strategy; a firm's R&D investments; a firm's size; a firm's intellectual property strategy. The second category, also named "external" (Lazzarotti et al. 2011), concerns technology-based and market characteristics.

Firm-specific factors

Regarding the drivers of openness, companies open their innovation process to reduce costs, time to market and business risks; to extend skills and creativity, and access advanced technologies to develop breakthrough advancement (Hagedoorn, 1993; Calantone and Stanko, 2007). Accordingly to the specific OI perspective adopted in the paper, i.e. partner-type depth, previous works suggested some interesting associations. For example, the goals of searching for new ideas, or of ways to reduce the uncertainty associated with the market introduction of innovation, seem to encourage collaborations with customers (von Hippel, 1988); cost reduction or input quality improvements seem to favour partnerships with suppliers (Gassmann and Enkel, 2004); universities and research institutes are usually called on to provide advanced technologies and radical product innovations (De Backer, 2008; Tether, 2002; Parida et al., 2012). However, other studies state that such partners are also searched by firms to support the efficiency of the innovation process because they allow not only the experimentation with new technologies, but also the refinement of existing technologies (e.g. Faems et al., 2005; Janeiro et al., 2013). This encourages further investigation on the specific relationship between types of drivers and types of partners.

Drivers of OI are obviously linked to a firm's *innovation and technology strategy*. This is that part of strategy which deals with the growth of an organization through the development of new products, services, processes or business models (Cooper, 2000). Two typical approaches are normally distinguished (Bessant et al., 2005): radical (where the goal of innovation strategy is to develop and bring to the market something which represents breakthrough advancements) versus incremental strategy (where the goal is to develop only a minor improvement over the status quo). Concerning the relationship between innovation strategy and open innovation, literature suggests that when the emphasis is on radical innovation, OI is expected to increase; in fact, firms that emphasise radical innovation are seldom able to develop all knowledge internally, and therefore must strongly rely on complementary external sources (Colarelli O'Connor, 2006). Emphasis on radical innovation is also studied as an element in a more specific construct, i.e. technological aggressiveness (Lichtenthaler and Ernst, 2009) and as a component of the prospector's strategy (Miles and Snow, 1978). As concerns technology aggressiveness, for instance, Lazzarotti et al. (2011) found that open innovators choose and aggressive innovation and technology strategy. Prospectors usually enact in dynamic environments and have a reputation as innovators. They try to continuously find and exploit new product and new market opportunities to be the creators of change and of new technologies. With this regards, Lefebvre et al. (2013) found that firms following a prospector strategy require the expansion of their domains of knowledge and thus they show a higher open innovation breadth than defenders. Crema et al. (2014) studied the influence of different types of business strategy (i.e. innovation, diversification and efficiency) on open innovation propensity and they confirmed that innovation strategy matters to explain open innovation choices. Indeed, they found that firms adopting a competitive strategy of innovation are strongly motivated to open their processes toward the support of information technology instruments and OI practices. However, these open firms do not neglect internal R&D investments, so confirming other studies (Barge-Gil, 2010; Lazzarotti et al., 2011; Podmetina and Vaatanen, 2011) which assert that internal and external sources are used as complements: open innovators spend significantly more on R&D and this higher expense is just required to open up the innovation process (Schroll

and Mild, 2012). By following the original idea of Lazzarotti and Manzini (2009) about clusters of integrated and specialized collaborators, Verbano et al. (2015) also clustered a sample of 105 small and medium firms and, among other firm-specific factors, they indicated technology aggressiveness as a possible determinant of openness *bella questa!!!!!!!!!!!!!!*. Despite these interesting insights, to our best knowledge there is still an empirical lack in connecting innovation strategy to specific types of partners and this also has encouraged our investigation.

Another firm-specific factor, strongly debated in literature, is *intellectual property strategy (IP)*. Legal and contractual mechanisms (patents, design registration, trademarks, copyright, trade secrets, employee agreements, non-disclosure agreements, confidentiality agreements) are commonly distinguished from strategic ones - mainly product and process complexity and lead time advantage (Arundel, 2001; Gallié and Legros, 2012; Laursen and Salter, 2014). Legal mechanisms provide companies with legal rights or contracts that can be used in case of litigation, infringement and counterfeit. Several studies alert firms about the hazards that openness could cause in terms of innovation appropriability (Gulati and Singh, 1998). A tension between protection requirements and knowledge sharing has been brought into evidence (Bogers, 2011), leading firms to face a paradox: on the one hand, in order to capture the value created through innovation firms need to protect their technological competencies; on the other hand, to collaborate with other organizations they have to share knowledge. Studies in this area aim to investigate whether Intellectual Property Protection Mechanisms act as enablers or disablers for openness. For example, the study by Alexy et al. (2009) and the work by Bader (2008) found that IP legal rights, such as patents, can become the 'currency of OI' and facilitate collaboration. Very recently Zobel et al. (2017) provide interesting insights on the relationships between types of mechanisms and openness in terms of the synthetic measures of breadth and depth proposed by Laursen and Salter (2006). In particular, they found that legal or formal mechanisms are positively associated only with breadth, but when a firm is pursuing radical innovation the association is also with depth. However, they do not shape the relationships according to the type of partners. With this regard, pioneer studies by Henttonen et al. (2016) found that high levels of legal and contractual mechanisms were most heavily emphasized in R&D collaborations with scientific partners (e.g. publicly funded research organizations). The authors state that, although much research conducted in research institutes is now tailored to firms' needs, these organizations also need to publish their findings. In this case, legal and contractual mechanisms provide the basis of appropriation for companies: without these safety nets, it might be difficult to collaborate with partners with very different goals with respect to the firm's ones. For other types of partners, especially for collaboration with suppliers an even wider range of protection mechanisms may be required (e.g. patents, contracts, secrecy and lead time too) as they might be prepared to use valuable company knowledge for their own ends, including serving the firm's competitors' interests. The same authors recommend further empirical investigation to enforce their findings with alternative samples and methodologies.

Size is another firm-specific factor that has been investigated by several authors but with still controversial results. On the one hand, it is stated that openness is mainly driven by larger companies: this can be justified by the more systematic approach they have in their innovation processes and by the larger resources they possess with respect to small and medium enterprises (De Backer et al., 2008; Drechsler and Natter, 2012). On the other hand, other contributions emphasize that especially small companies, which often lack resources and competence to innovate by themselves, would benefit greatly by exploiting the OI model; indeed, small and medium enterprises (SMEs) are increasingly adopting OI practices (van de Vrande et al., 2009; Spithoven et al., 2013). Lastly, other authors (Schroll and Mild, 2011) found no correlation between size and openness. The absence of conclusive evidence in general and still the lack in analysing relationships between size and specific types of partners call for further empirical studies.

Environmental factors

As concerns the impact exerted by external factors on openness, the empirical evidence is variegated. It was initially assumed that openness was suitable only in particular industries, but Chesbrough and Crowther (2006) could not find any confirmative evidence. In their critical review, Schroll and Mild (2012) clearly distinguished industry technology features from market ones. Concerning technology characteristics, several constructs have been suggested as openness determinants: for example, technology intensity (De Backer, 2008; Barge-Gil, 2010), technology turbulence (rapidly changing technology conditions: Schweitzer et al., 2011) and technology convergence (high level of interdisciplinary research: Bröring, 2010). Evidence is controversial: De Backer et al. (2008) found that high-tech industries show a higher level of open innovation, but results from Barge-Gil (2010)'s work were unclear as non-high-tech companies were both open and closed. Other authors identified the positive effect of technology turbulence on openness (Gassmann and Enkel, 2004; Lichtenthaler, 2009; Schweitzer et al., 2011) as turbulence emphasizes the importance of innovation, thus stimulating the search of additional external knowledge. Similarly, technology convergence can stimulate firms to collaborate as it requires the integration of different technologies, hardly mastered by a single company (Bröring, 2010).

Also, as concerns market features, different constructs have been defined to grasp the industry competitive intensity (e.g. industry hostility: Drechsler and Natter, 2012; market uncertainty: Acha, 2008). Here the studies share the view that a high competitive intensity (e.g. shorter product life cycles or rapidly changing customer/consumer preferences) forces companies to establish partnerships with external actors. However, even accepting that the mentioned environmental factors may favour a higher openness, to our best knowledge specific relationships between such factors and types of partners have not been studied. Thus, basing on two constructs which represent respectively technological and market dynamics, we carry out further empirical investigation.

Separare dalle sezioni precedenti, dedicare a singoli temi? Serve anche questo se poi fai una sintesi dei gap? Non possiamo metterla una volta sola?

In sum, the analysis of the empirical literature shows that the evidence on the relationships between some commonly identified determinants and openness is not conclusive and thus requires additional studies. But, more importantly, to our best knowledge the potential determinants have not been investigated in connection to specific partner-type depth (scientific and business). This gap promoted our investigation while we were aware that that we could not consider all the factors identified by the literature. For example, Schroll and Mild (2012) identified also some additional determinants, such as geographically proximity (Belussi et al., 2010) or firm age (Drechsler and Natter, 2012), which we ignored in our work. Thus, we focus on the following firm-specific and external factors:

- goals of collaborations
- innovation and technology strategy
- intellectual property mechanisms
- size
- market and technological dynamics.

2.3 Openness and innovation performance: the role of the organizational-managerial and social context

The current competitive environment is characterized by elements such as rapid technological change, shortening of product life cycles, more informed and demanding customers. In such an environment, firms' sustainable competitiveness depends on two innovation outcomes (Alegre et al., 2006): on the one hand, efficiency and, on the other hand, novelty. Efficiency regards things such as the reduction of the innovation risks, the compression of both the costs for the development of new products/processes and the time to market; novelty regards things such as the introduction of new or significantly improved products/services or processes and the opening up new markets. Opening the innovation processes to different types of partners seems to be the right way for improving both sides of the innovation performance. Indeed, if the pursued collaboration goals mentioned above are achieved, both scientific and business partners may contribute to innovation performance? Non ho capito, sembra che sia il raggiungimento degli obiettivi a consentire il coinvolgimento di entrambi i tipi di partner?. However, as well as there is the need of further investigation on the specific relationships between collaboration drivers and type of partners, so the same requirement recurs as concerns the relationships between types of partners and sides of innovation performance, which represent the achievement of the established goals. This is the first aspect we aim to investigate as concerns openness and performance, i.e. the detailed relationships linking scientific and business partners to efficiency and novelty. Indeed, previous works (e.g. Barge-Gil, 2013) studied the relationship between openness strategies and innovation performance, but without distinguishing between different types of partners.

However, one of the most important open issues is that these performance expectations are not always translated into concrete results. While some pioneering firms have attained substantial benefits (Huston and Sakkab, 2006), many others experience difficulties in capturing value from external in-flow of knowledge and information (Burcharth et al., 2013; Lee et al., 2010). In other words, there is great heterogeneity in the extent to which firms are able to profit from openness. Thus, both scholars and practitioners of open innovation began to suggest that, instead focusing on the performance effects of open innovation, it was far more fruitful to investigate the conditions under which its adoption is beneficial (Foss et al., 2011). These conditions act as facilitators and they represent a kind of master capacity to align a firm's external knowledge sourcing activities with a firm's innovation objectives (Cohen and Levinthal, 1990; Brunswicker and Vanhaverbeke, 2015). Traditionally measured through R&D intensity (Veugelers, 1997), such conditions are recently identified as a set of contextual organizational, managerial and social capital components acting as absorptive capacity micro-foundations or antecedents (Foss et al., 2011; Volberda et al., 2010). Such antecedents should lead to an understanding of how absorptive capacity is working and thus explain the firm's capacity to learn from external sources. This capacity, in turn, affects a firm's innovation performance (Lane et al., 2006; Lazzarotti et al., 2015). According to this perspective, contributions have rapidly increased. For example, Foss et al. (2011)

studied the relationships among interaction with customers, organizational-managerial context and innovation performance. They found that such context provides a strong mediating effect between customer involvement and innovation. Lewin et al. (2011) provided examples of a broad set of internal routines aimed to favour knowledge sharing, problem solving and autonomy of employees. They, in combination with external routines (i.e. open innovation practices such as collaborating with suppliers, networking with universities, etc.), are proved to result in improvement of innovation performance. Burcharth et al. (2013) found that the use of internal coupling activities (i.e. a number of organizational activities that provide employees with time, autonomy and empowerment to conduct their work) mediates the relationship between openness and innovation performance. Lazzarotti et al. (2015) clustered a sample of Italian companies and identified different modes for companies to open up their innovation process. In addition, some managerial mechanisms were selected consistently with the choices regarding the degree of openness. They were also recognized as facilitators to make firms able to absorb external knowledge. In a similar way, also Brunswicker and Vanhaverbeke (2015) clustered a sample of 1411 SMEs: intensity of collaboration with supply-chain actors (customers and suppliers) on the one hand, and with technology partners (universities, research centers, intellectual property expert), on the other, emerged as crucial factors to cluster firms. In addition, four internal organizational practices are proposed, among which the level of use of project management techniques. Although with different relevance, each cluster benefits to achieve performance if equipped with organizational facilitators. A limit of these works is that individual motivation is overlooked. Lakemond et al. (2016) extended the set of managerial factors acting as facilitators by studying, beyond the effect of project management procedures, also the impact exerted by knowledge integration and knowledge matching mechanisms. As they allow to achieve complementarities and synergies with external partners, they may enhance innovation performance. The limit of this study is that it gave up the relational component among employees and external actors, which could also play a facilitator role. Indeed, other authors assign a mediating role just to the internal and/or external dimension of the relational social capital (respectively the value embedded in internal relationships among employees -Tsai and Ghoshal, 1998; and in external relationships: Inkpen and Tsang, 2005). The supposed rationale is that the quality of the relationships, internal (among employees) and/or external (among employees and external partners), acts as facilitator and thus makes open innovation beneficial. The employees and partners' willingness to cooperate, in a trust-based manner, encourages the exchange of knowledge, the acquisition of tacit knowledge (Nonaka, 1994), the absorptive capacity of new technologies (Cohen and Levinthal, 1990), the joint problem solving and the coordination of complex tasks (Gulati and Singh, 1998), as well as the experimentation with different knowledge combinations (Cuevas-Rodríguez et al., 2014). All these factors likely have positive impact on innovation performance. In this vein, Rass et al. (2013) elaborated a theoretical framework in which they supposed that the implementation of open innovation instruments strengthens an organization's social capital, which, in turn, is positively related to innovation performance. However, the same authors called for empirical verification of their theoretical assumptions. Lazzarotti et al. (2016) focused on the scientific partners and found that both the internal relational social capital dimension (intended as employees' propensity to interact and work in groups) and the external relational social capital dimension (intended as trustful relationships with scientific partners) can mediate the relationship between intensity of collaboration (depth) and innovation performance. Lazzarotti et al. (2017) focused on the internal relational social capital dimension (intended as employees' propensity to interact and work in groups) and found that it mediates the relationships between intensity of collaboration with both types of partners (scientific and business) and innovation performance.

Despite these relevant contributions, several needs of further empirical investigation emerge on how the context influences the relationship between open innovation and innovation performance. Indeed, the previous mentioned studies show limitations that open the call for additional work: some of them provide theoretical contributions (e.g. Rass et al., 2013), but lack empirical verification; many studies often focus only on single types of partners (e.g. Foss et al., 2011; Lazzarotti et al., 2016) and even when they consider more than one type of partners (Lazzarotti et al., 2017) they are focused on a single type of context (e.g. social); furthermore, most studies neglect different types of innovation performance. In synthesis, there is the need of further empirical investigation that is both more detailed on specific relationships and more comprehensive in order to deal with a larger set of variables.

The urgency of such a call is revived also by other authors in very recent contributions, all in line with the need of analyzing the mediation role of the context. For instance, Cassiman and Valentini (2016) call for the need of understanding how firms may organize their R&D process to exploit the benefits of permeable boundaries. Bogers et al. (2016), in a deep work written by several open innovation experts in order to identify avenues for future studies, stresses the need of investigating "contingencies" of the openness-performance relationship. The authors suggest that these contingencies are very variegated and placed at different levels (e.g. organizational and individual). As concerns for example the individual level, the authors state that the effectiveness of firms' OI strategies strongly depends on the individuals tasked to bring those strategies to fruition. So "how do individual-level attributes (e.g. motivation) influence inter-organizational knowledge flows with OI stakeholders" remains a key question which provides clear arguments for social capital analysis as mediator

factor. Greco et al. (2016) in their large analysis of open innovation effect on innovation performance claims that they could not control for unobserved heterogeneity of firms. Again, such heterogeneity may be recognized in a firm's capabilities to manage openness.

We aim to answer this call by empirically analyzing how firms' context mediates the relationship between each partner type (scientific and business) and each side of innovation performance (novelty and efficiency). To this goal, we rely on three types of contextual variables supposed as mediators, in similar vein to Lazzarotti et al. (2015) and Lazzarotti et al. (2016):

1. a set of organizational-managerial factors to manage collaborations
2. internal relational social capital as the value embedded in internal relationships among employees. The attention is focused on employees' knowledge exchange habits, propensity to interact and work in groups, as well as on firms' practices which encourage their entrepreneurial initiative and professional development with regards innovation topics
3. external relational social capital as the value embedded in external linkages among employees and external partners, which concerns the partners' intention and willingness to cooperate and exchange knowledge at the inter-organizational level and it depends on factors such as commitment and trust.

2.4 Summary of the gaps and the research questions in detail

From the analysis of the literature it emerges that previous research verified the adoption of OI according to different modes (Dahlander and Gann, 2010). In particular the main types of partners have been identified, as well as the main single determinants of openness (Schroll and Mild, 2012). Some studies have also identified typical emerging clusters in terms of partner types and managerial mechanisms and social context (Brunswicker and Vanhaverbeke, 2015). Moreover, there are many studies on open innovation and innovation performance, but without reaching uniform results (e.g. Pertuzè et al. 2010; Lee et al., 2010); therefore, the context has been recognized as a potential factor able to facilitate OI (or make OI profitable). Io non ripeterei questa prima parte. However, empirical studies, which provide a detailed analysis of the relationships among the identified variables, are still few. More specifically, this knowledge gap concerns the need of identifying specific relationships among the considered variables (e.g. types of contextual determinants and types of partners; types of partners and types of innovation performance). Furthermore, the impact of a firm's managerial-organizational and social context is empirically under-studied. Instead, it could exert a relevant role in the relationship between open innovation, in our conception of partner-type depth, and the double sides of innovation performance. In few words, despite the variety of the literature contribution, a comprehensive framework, through which detailed relationships have been empirically verified, is still lacking: "comprehensive" in the sense that it comprises a larger set of variables – openness determinants; partner types; organizational-managerial and social context; innovation performance types; "detailed" in the sense that specific relationships among the considered variables are analyzed.

A second research gap concerns the need of studying more in depth what different contextual factors affect the performance outcomes of openness. In this paper, we limit us to the mediating role of organizational-managerial mechanisms, as well as of internal and external social capital.

These gaps generate our following detailed RQs:

1. What are the relationships between the considered? Considered da chi? non è meglio dettagliarle nella RQ anziché dire genericamente considered? Oppure togliere il termine considered? determinants and partner-type depth (scientific and business)? In other words, are emerging any specific openness determinants in connection to the types of partners?
2. What are the relationships between partner-type depth and types of innovation performance? Do organizational-managerial mechanisms and internal and external social capital mediates the outcome? Is this role specific in connection to a type of partners? Is this role specific in connection to a type of performance?

The following picture (fig. 1) represents our empirical investigation framework.

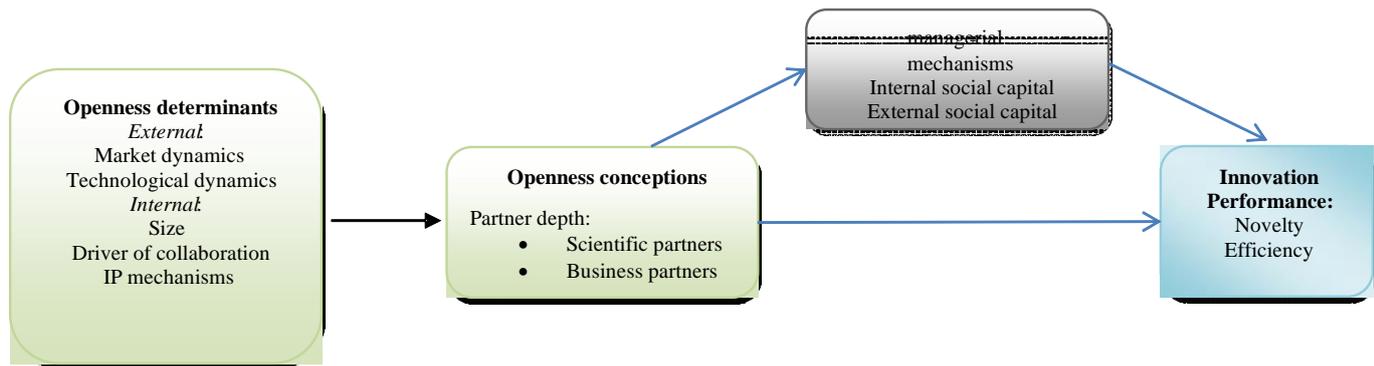


Figure 1. The empirical investigation framework quali sono le RQ in questo schema?

3. Methodology

3.1. Field research

As the constructs of the framework are already well understood and measured in the literature, which also provides the main expectations in terms of the relationships among constructs (determinants and openness; openness and innovation performance, mediated by the context), the main conditions to develop a confirmatory (or theory testing or explanatory) survey research are respected (Malhotra and Grover, 1998; Forza, 2002). More specifically, we carried out an international survey on open innovation which was considered a suitable research method to test the adequacy of both the constructs depicted above, and of the linkages among them.

The data were collected during 2012 and 2013 by universities in Italy, Sweden, Finland and UK. In order to ensure comparable results across the nations, common guidelines were used for the survey design and the data collection process in accordance with Forza (2002). The target and frame population is manufacturing industry firms (codes 10-32 and 98 in NACE Rev. 2) with no fewer than 10 employees. From this population a representative and randomized sample of firms (N=4000) was drawn to ensure representativeness of the sample and, hence, the generalizability of the results.

The data was collected by means of questionnaires distributed by email to the participants. The respondents are R&D managers or similar persons knowledgeable about open innovation. After three reminders, we finally gathered in total 477 complete answers (response rate of about 12%) from firms that state they have collaborated with external partners in innovation (i.e. development of new products, services or processes) during the past five years. Of the 477 answers used in the current analysis, 152 come from Italy, 176 from Sweden, 87 from Finland and 62 from UK. Table 1 in the Appendix shows sample statistics (country and size) where some missing data on UK companies' size lead to a usable number of 459 cases. The complete questionnaire covers questions on strategy, context (size, industry, etc.), openness, organizational-managerial mechanisms, relational factors (internal and external social capital) and innovation performance.

In order to improve the quality of the instrument, a pilot test of the questionnaire was conducted on two groups: colleagues and target respondents in selected firms.

3.2. Measures

- Although previous contributions clearly provided the empirical foundations of two the categories of partner-types, i.e. scientific and business partners (Du et al., 2014; Bengtsson et al., 2015), we further executed explorative factors analysis (EFA: see Table 2 in the Appendix) in our sample to ensure validity and reliability. Thus, we derived our 7-point measures of *scientific-partner depth* and *business-partner depth*
- Determinants of openness (1. drivers and 2. innovation and technology strategy, called, for sake of brevity, innovation strategy) were also measured through 7-point Likert scale variables taken from the literature (Miles and Snow, 1978; Hagedoorn, 1993; Lichtenthaler and Ernst, 2009; Lazzarotti et al., 2011). Table 3 in Appendix shows how both innovation strategy and drivers were operationalized. Although, similarly to partner-types, they were taken from the literature, determinants of open innovation (both innovation strategy and drivers) were also tested by applying EFA techniques. One factor was obtained for the strategic items (innovation strategy) and one factor synthesized items concerning cost saving, risk reduction, time to market improvement, flexibility increasing (drivers of

risk/cost/time/flexibility: RCTF¹). External determinants of openness, also measured through a 7-point Likert scale, were inspired by Miles and Snow (1978), Lichtenthaler and Ernst (2009), Lazzarotti et al. (2011). Table 3 in the Appendix shows the specific items of each construct, the factor loadings and the values of Cronbach's alpha. We obtained two factors for IP mechanisms (respectively, legal and strategic) and two factors for the environment (respectively, market and technological dynamics)

- As specified in the theoretical background (section 2.2) we also considered the effect of size as it is a potential determinant of openness. We defined it as a dummy variable (1=small; 2=medium and large) based on the number of employees according to European Commission rules (2005)
- As regard the two sides of innovation performance (novelty and efficiency) we relied on the distinction proposed by Alegre et al. (2006) between novelty and efficiency. The specific items used to operationalize both the two constructs followed the work by Lazzarotti et al. (2011) and are reported in Table 4 in Appendix. The items corresponding to novelty outcomes are represented by the introduction of new products, processes and markets, whereas efficiency outcomes deal with lower development risks, costs and time to market
- As concerns organizational-managerial mechanisms, we relied on items drawn from the MINE SURVEY TOOLS 2.1. Attention is focused on the use of formal systems to manage collaborations, to encourage and measure results from collaboration (e.g. project management techniques). Internal relational social capital has got theoretical foundations in Tsai and Ghoshal (1998). The operationalization focused attention on employees' knowledge exchange habits, propensity to interact and work in groups as well as on firm practices which encourage their professional development with regards innovation topics. To measure external social capital we developed items on the basis of Inkpen and Tsang (2005). See Table 4 in Appendix for item details.

3.3. Procedures

Before investigating the relationships as set out in the research questions, we carried out an additional preliminary technical step. Indeed, while factor analysis allowed us to give empirical consistency to the two categories of partners (scientific and business), we then applied cluster analysis to verify whether these types of partners are really viable partners for the companies of our sample, i.e. whether companies, more or less intensively, collaborate with them. Indeed, if not, it would not make sense to base on the "type of partner" variable the following investigation of the relationships. In other words, cluster analysis provides the empirical foundation of the subsequent analysis. Thus, we performed a 2-stage cluster analysis. First, we applied a hierarchical cluster analysis (Ward method) by using scientific-partner depth and business-partner depth as variables to search clusters. The criterion for formation of homogeneous clusters was the relative increase of the merger coefficient: [(merger coefficient at stage k) – (merger coefficient at stage k-1) – 1] (Milligan and Cooper, 1985). A final cluster solution using K-means cluster analysis was then developed using the initial seed points from the Ward's method.

Then, we carried out two types of regressions. The first aims at identifying specific determinants of openness. Thus, independent variables are the main internal and external variables which we selected in paragraph 2.2 on the basis of the literature analysis, while the dependent variables are the two types of partner-depth (scientific and business).

The second type of regression aims at exploring the relationships between the two types of partner-depth (now independent variables) and the two sides of innovation performance (dependent variables), by supposing also a mediating role for the organizational-managerial mechanisms and for the internal and external social context. In addition, we inserted size as control variable as it may be related to innovation performance (Lichtenthaler, 2009).

The regressions are hierarchical because the considered variables are progressively introduced step by step until obtaining a final model which includes all the variables. In addition to Beta coefficients, we report also R² change and its significance through F (ΔR^2), i.e. the incremental contribution provided by each introduced variable to the explanation of the dependent variable.

4. Results

Cluster analysis provides evidence on the fact that the selected two variables measuring openness (scientific-partner depth and business-partner depth) are relevant to describe firms' behaviour.

Table 5 reports descriptive values of each partner-type depth variable for the overall sample as well as cluster analysis results: a four-cluster solution seems to be the most appropriate representation of the data. Scientific-partner depth and business-partner depth are statistically significant to distinguish clusters (see F ration in Table

¹ Drivers indicated by the literature as typically technological (e.g. access to advanced technology) are not explicitly considered because redundant with respect to the construct of innovation and technology strategy.

5). Indeed, a first cluster (CL1 in Table 5) includes companies with a high level of collaboration with the two types of partners; a second cluster (CL2) includes companies that privilege collaborations with business partners whilst relationships with the other type of partners are more limited; a third cluster (CL3) is composed by firms that have a high level of collaborations mainly with scientific partners. Lastly, a fourth cluster (CL4) refers to companies that strongly limit relationships with all the types of partners. To a first exploration by applying cross-tab, no characterization in terms of countries is emerging.

Once it has been found that scientific and business actors emerge as differently selected (i.e. more or less intensively) types of partners, we were ready to investigate more in depth what could explain different partner-type depths (first-type regressions in Table 7) and what was role exerted by different types of partners in contributing to innovation performance, both in terms of novelty and efficiency (Table 8). Table 6 shows descriptive statistics and correlations among all the variables included in the subsequent regressions.

Table 7 reports the results of the first type of hierarchical regressions. The purpose of these regressions is to understand the contribution of the environmental and firm-specific internal factors as explanatory variables of firms' openness choice, both in terms of scientific-partner depth and business-partner depth. " ΔR^2 " (in bold) identifies which factor provides the highest contribution in explaining the variance of the dependent variable.

As concerns collaborations with scientific-partner depth, significant explanatory factors for openness are the following (see in bold ΔR^2):

- technological environment dynamic as the most relevant factor
- size
- goals of reduction/sharing of risks and costs of innovation, reduction of time to market and increasing of flexibility or efficiency goals (RCTF)
- innovation strategy
- use of IP legal rights.

As concern collaborations with business partners, the significance and the explanatory value of the found relationships are too weak to draw inferential considerations, so we limit to report them as purely descriptive results. For collaborations with business-partners it is possible to note that they are slightly related only to:

- technological dynamics
- goals of RCTF.

Table 8 reports the results of the second-type of regressions. Here the purpose is to understand whether partner depth (respectively scientific-partner depth and business-partner) is related to innovation performance, both in terms of novelty and efficiency, and whether the context (organizational-managerial, internal social and external social) exerts a role in influencing such relationships.

The first type of investigated relationship is between scientific-partner depth and both sides of innovation performance (respectively the first ten models at the top of Table 8). Then, the procedure is repeated for business-partners (see the ten models at the bottom of Table 8).

Model "1" always tests the direct relationship between the partner-type depth and the type of innovation performance, with only size inserted as control (always not significant).

Models "2", "3", "4" investigate the direct relationships between each supposed mediator (organizational-managerial: "OM"; internal social capital: "ISC"; external social capital: "ESC") and the selected type of innovation performance by exploring the specific contribution of each mediator to explain performance (ΔR^2). Model "5" considers all the mediators and partner-type depth. Following Baron and Kenny (1986), when a mediating variable is inserted in the model, the contribution of a previously significant independent variable should drop significantly (partial mediation) or even become insignificant (full mediation). Following this procedure, we can find clues on the mediator role exerted by the context.

As concerns scientific-partner depth (SP-depth) and novelty, there is a positive and significant relationship between depth and novelty (model 1). However, when we test the relationship between each mediator and novelty, organizational-managerial mechanisms, internal social capital and external one show respectively a positive and significant relation with it (models 2, 3 and 4). In addition, they contribute to explain most of the variance (OM above all: see $\Delta R^2 = 18\%$, highlighted in bold). Lastly, when all the variables are inserted (model 5), the contribution of scientific-partner depth is very small and it becomes no-significant. These are clues in favour of a (full) mediating role exerted by OM, ISC and ESC. Thus, to obtain novelty-type performance from collaboration with scientific partners, the implementation of formal levers to manage them seems to be important.

As concerns SP-depth and efficiency, we can observe a positive and significant relationship, but the contribution still partially drops when supposed mediators are inserted (clue of partial mediation in model 5). OM and ESC provide the most of the variance explanation (respectively ΔR^2 about 10%, highlighted in bold). Thus, to obtain efficiency-type performance from innovation activities carried out with scientific partners, it is still important to implement organizational-managerial mechanisms to manage collaboration. The quality of external relationships

(ESC) is anyhow relevant, while the quality of the internal relationships provides a very small contribution (see model 3) and it seems even to adversely affect efficiency-type performance (see the negative Beta coefficient in model 5).

Also business-partner depth (BP-depth) is positively related to novelty, but again OM, ISC and ESC act as full mediator by explaining the greater portion of variance.

Lastly, as concerns BP-depth and efficiency, the significance of the direct relationship still drops in the presence of OM and ESC, by suggesting that they exert a role to profit from collaboration also with business-partners. Instead, the quality of the internal relationships still seems to adversely affect efficiency-type performance (model 5).

Non vale la pena di mettere la figura con le relazioni che si rivelano essere significative, con il loro segno?

5. Discussion and conclusions

Focusing on some relevant constructs defined by open innovation literature (i.e. determinants of openness; collaboration depth with scientific and business partners; organizational and social context; innovation performance as both sides of novelty and efficiency) the work is aimed to investigate the relationships among such constructs. A preliminary cluster analysis states that the selected two variables measuring openness (scientific-partner depth and business-partner depth) are relevant to describe firms' behaviour.

A first set of regressions takes into evidence some clues on the determinants of both types of collaboration depths. Consistently with previous studies (e.g. Schweitzer et al., 2011), technological dynamics emerge as relevant factor to stimulate firms towards external collaborations. In this regard, we find a positive relationship between technological dynamics and both types of partners depth. Instead, contrary to literature suggestions, we do not find significant relationships between market dynamics and the types of partners depth. È meglio mettere sempre anche depth? O è ridondante?

As concerns innovation and technology strategy, literature suggested a positive relationship between an aggressive innovation strategy and openness (Lazzarotti et al., 2011; Lefebvre et al., 2014; Crema et al., 2014). Our more detailed investigation allows to specify that this positive relationship is only with scientific partners and not with business partners. This seems to confirm the view for which universities and research institutes are usually engaged as partners able to provide advanced technologies and radical product innovations (De Backer, 2008; Tether, 2002; Parida et al., 2012). The investigation on the relationship between the efficiency goals and the types of partners allows to further characterize the possible determinants. Indeed, scientific-partner depth is also positively related to efficiency goals, by fostering the less obvious idea that scientific partners are useful not only to experiment with new technologies, but also to support the efficiency of the innovation process (Janeiro et al., 2013). In sum, while collaboration with business partners is mainly associated to efficiency goals, firms of our sample consider scientific partners as a dual-source partner. However, such a type of partner is not viable for all the firms. The evidence on the role of size seems nurture the conclusions that mainly larger companies intensively collaborate with scientific partners, while no differences in size are emerging between firms which collaborate with business partners. Considering that literature is still controversial on the relationship between size and openness (Drechsler and Natter, 2012; Spithoven et al., 2013), evidence from our detailed investigation reconciles opposite views: size is relevant depending on the type of partner. Larger companies may more easily interact with scientific partners rather than smaller firms thanks to the more systematic approach they have in their innovation processes and the bigger resources they possess, while business partners are accessible by all the companies. Lastly, evidence about the use of IP rights can likely further enrich the picture. In our sample, IP legal rights (e.g. patents and contracts) seem to be relevant in explaining only collaboration with scientific partners. This is partially in line with very recent literature findings (Henttonen et al., 2015), at least as concerns the link between IP legal rights and scientific partners. Although research conducted in collaboration between universities and firms can be tailored to firms' needs, scientific actors also need to publish their findings. In this case, legal mechanisms form the basis of appropriation for companies. Without these protection mechanisms, it might be difficult to collaborate with scientific partners, characterized by very different goals than the firm's own (Pertuzè et al., 2010). However, contrary to Henttonen et al. (2015), we do not find the use of a wider set of mechanisms when firms collaborate with business partners.

A second set of regressions takes into evidence some clues on the relationships between both partner-types depth and both types of innovation performance. To a first inspection, both scientific and business partners are positively related to each type of performance. However, to a more careful investigation, for all the analysed relationships (SP-depth and novelty; SP-depth and efficiency; BP-depth and novelty; BP-depth and efficiency) it emerges that the context is relevant to explain the achieved innovation performance. This evidence nurtures the general view that the context could be the means (the mediator) through which collaboration depths provide benefits in terms of innovation performance (Burchart et al., 2013). In addition, as for the openness determinants, our empirical investigation provides further details, if any, on the specific role of different context factors in connection to the types of partners and the types of innovation performance. First of all, organizational-managerial mechanisms exert the most relevant role in the relationships between both types of

partner depths and both types of innovation performance. This is quite counterintuitive when scientific partners are considered, due to their need of autonomy, improvisation and creativity, not well compatible with formal managerial procedures (Du et al., 2014). However, some other contributions (e.g. Pertuzè et al., 2010) claim that some formal rules may be recommendable also when firms work with scientific actors and our empirical evidence is in line with this last suggestion.

Second, the quality of the external relationships (external relational social capital) is always a relevant factor, again whatever is the type of partner and the type of performance. With respect to the huge literature on social capital and its beneficial effect on innovation performance thanks to partners' willingness to exchange knowledge (e.g. Cuevas-Rodriguez et al., 2014; Lazzarotti et al., 2016), our investigation extends the empirical evidence by detailing such an effect respectively to novelty and efficiency.

Instead, the effect of the internal social capital is not homogeneous and it depends on the type of considered performance. Indeed, on the one hand, our data show that it benefits novelty, while on the other it provides a small contribution in explaining efficiency or it even exerts some negative influence on it. This occurs whatever is the type of partners. Literature has already outlined that external social capital may reduce the effectiveness of the internal social capital on innovation performance. The excessive strength of the external type of capital can reduce the effect of the other because people can lose internal identity with negative effect on innovation performance (Cuevas-Rodriguez et al., 2014). However, our empirical evidence seems quite different. The effect of internal relational social capital is not depending on the level of external relational social capital. Anyway, it generates a sort of trade-off: while it enhances novelty, it reduces efficiency. Perhaps, certain employees' characteristics here considered (e.g. cohesiveness, open mind, etc.) contribute to novelty because they allow creativity, but they somehow slow the innovation process.

Non so se questa parte di sintesi aggiunge valore o semplifica troppo, io non riesco a capirla bene e non vorrei che riducesse troppo il senso n sum, our empirical investigation brings into evidence some interesting associations: on the one hand between determinants and ? intendi single type, ma forse si può omettere single? partner depths, and, on the other hand, between singleidem partner depths, three contextual factors and two sides of innovation performance. The empirical investigation allows to identify different types of relationships among the involved variables:

- i) *specific relationships* when a considered determinant is linked only to a certain type of partners (e.g. size and scientific partners; aggressive innovation and technology strategy and scientific partners; IP legal rights and scientific partners); or when a type of context is linked only to a certain type of performance (e.g. internal relational social capital and novelty; internal relational social capital and efficiency);
- ii) *generic relationships* when the considered determinants are related to both types of partners (e.g. technology dynamics and efficiency goals) or when the types of contexts mediate the relationships between types of partners and types of performance, whatever are the type of partners or the type of performance (e.g. organizational-managerial and external relational social capital).

It is worthy to note that, only two specific relationships emerge as concerns the contextual factors, that are the relationships between the internal relational social capital and the types of performance. The role of the other contextual factors is not depending on the type of partners or on the types of performance. Even the role of the internal relational social capital, that as we said above, is different according to the types of performance (i.e. positive for novelty, negative for efficiency), is not depending on the type of partners. This observation leads to the thinking about the managerial implications of this work. Managers should take care of developing and implementing organizational-managerial mechanisms, whatever is the main type of partner with whom their firm collaborates. Firms of our sample prove that formal procedures to manage collaborations are essential tools to enhance both types of performance, whatever is the type of partner. In addition, they should be aware of the importance of the social capital, in both configurations, external and internal. Novelty seems to benefit from trustful internal and external relationships, as well as from having creative and open-mind employees. However, internal relational social capital generates the trade-off, mentioned above, between novelty and efficiency. How to solve this contrast remains an open issue which could be managed by a balanced set of incentives (creativity-related and cost/time-related).

With respect to previous literature, our theory testing survey provides additional and more detailed evidence on two sets of relationships (i.e. determinants and partner depth; partner depth and performance *via* organizational-managerial and social context), which are crucial to empirically understand how companies put into practice open innovation in the conception of collaboration depth. What determinant is linked to a certain partner depth? Are partner depths associated to novelty and efficiency? Does the context exert a role to enhance innovation performance? Are different types of contexts linked to certain types of partners or types of innovation performance? These are the questions to which we give here an empirical answer. However, beyond the usefulness of empirically understanding single relationships, we believe that the value of our work consists just in providing the more comprehensive framework itself, driving an investigation based on several variables. In this regard, some limitations should be brought into evidence: for instance, literature outlined other relevant

variables which we ignored (e.g. openness determinants and mechanisms usable to define the context); partner categorization in two groups could be questionable; other types of partners could be considered and so on. Moreover, the nature of the sample, composed of only four European countries, as well as the very low level of the explanatory values in the regression models, strongly compromise the generalizability of the results. Therefore, these must be considered as very preliminary explorative insights that may be useful to encourage further studies.

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Appendix

| | Small | | Medium and Large | | Total | |
|----------------|-------|----|------------------|----|-------|-----|
| | N. | % | N. | % | N. | % |
| Country | | | | | | |
| Italy | 89 | 61 | 57 | 39 | 146 | 100 |
| Sweden | 82 | 47 | 94 | 53 | 176 | 100 |
| Finland | 32 | 37 | 54 | 63 | 86 | 100 |
| UK | 29 | 57 | 22 | 43 | 51 | 100 |
| Total | 232 | 51 | 227 | 49 | 459 | 100 |

Table 1. Sample statistics

Note: missing data are relative to UK size information (459<477)

| | <i>Scientific partners</i> | <i>Business partners</i> |
|--|----------------------------|--------------------------|
| Please indicate your agreement with each of the following... | | |
| <i>... the extent to which your firm has collaborated with the following stakeholders over the last 5 years (1 = not at all; 7 = to great extent):</i> | | |
| Universities and research centres | .784 | |
| Innovation intermediaries | .637 | |
| Government agencies | .773 | |
| Customers | | .659 |
| Suppliers | | .765 |
| Consumers | | .632 |
| Competitors | | .572 |
| (Companies operating in other industries) | | |
| Variance explained | 25% | 25% |
| Cronbach's alpha | .625 | .609 |
| N=477 | | |

Note: in brackets items which uploading is not univocal and thus are not included in any factor

Table 2. Openness depth (intensity) in terms of partners (exploratory factor analysis)

| | <i>Innovation strategy</i> | <i>Driver cost/risk/time/flex</i> | <i>IP legal</i> | <i>IP strategic</i> | <i>Market Environment</i> | <i>Technological environment</i> |
|---|----------------------------|-----------------------------------|-----------------|---------------------|---------------------------|----------------------------------|
| Please indicate your agreement with each of the following... | | | | | | |
| <i>...statements with respect to your firm's innovation strategy (1 = strongly disagree; 7 = strongly agree):</i> | | | | | | |
| We aspire to be the technological leader | .761 | | | | | |
| We focus on radical rather than incremental innovation | .706 | | | | | |
| We try to hire the best scientists and experts on the market | .694 | | | | | |
| R&D and marketing are our core competencies | .716 | | | | | |
| We normally use innovative, flexible and non-routine technologies | .738 | | | | | |
| We have a broad technology portfolio | .664 | | | | | |
| <i>...drivers of collaboration with external partners in innovation activities (1 = strongly disagree; 7 = strongly agree):</i> | | | | | | |
| Reduce/share the risks of innovation | | .828 | | | | |
| Reduce/share innovation costs | | .855 | | | | |
| Reduce time to market | | .741 | | | | |
| Increase flexibility | | .625 | | | | |
| <i>...the extent to which your company uses the following intellectual property protection mechanisms when collaborating with external partners in innovation activities (1 = strongly disagree; 7 = strongly agree):</i> | | | | | | |
| Patents | | | .774 | | | |
| Designs | | | .719 | | | |
| Trademarks | | | .777 | | | |
| Trade secrets | | | .585 | | | |
| Non-disclosure agreements and other contractual agreements (e.g. joint development agreements) | | | .545 | | | |
| Copyrights | | | .725 | | | |
| Product complexity | | | | .838 | | |
| Lead times | | | | .825 | | |
| <i>...statements with respect to your firm's environmental dynamics (1 = strongly disagree; 7 = strongly agree):</i> | | | | | | |
| Increasing technology development cost | | | | | | .506 |
| Shorter product life cycles | | | | | .599 | |
| Customer/consumer product demands and preferences are highly uncertain | | | | | .854 | |
| It is difficult to predict changes in customer/consumer needs and preferences | | | | | .860 | |
| A large number of new product ideas have been made possible through technological breakthroughs in our industry | | | | | | .695 |
| The technology in our industry is changing rapidly | | | | | | .711 |
| Closing observing the technological development is important for long-term success in our industry | | | | | | .801 |
| In our industry complexity and inter-sector nature of new technologies is increasing | | | | | | .834 |
| In our industry the cross-fertilization of scientific disciplines and fields of technology is high | | | | | | .832 |
| In our industry there is the necessity of monitoring a spectrum of technologies | | | | | | .827 |
| Variance explained | 51% | 31% | 36% | 22% | 40% | 20% |
| Cronbach's alpha | .807 | .819 | .815 | .672 | .694 | .877 |
| N= 477 | | | | | | |

Table 3. Internal and external determinants of openness (exploratory factor analysis)

| | <i>Novelty</i> | <i>Efficiency</i> | <i>Organizational-- managerial mechanisms</i> | <i>Internal social capital</i> | <i>External social capital</i> |
|---|----------------|-------------------|---|------------------------------------|------------------------------------|
| Please indicate your agreement with each of the following... | | | | | |
| <i>...how well collaboration with external partners in innovation activities has performed against the following objectives over the last 3 years (1 = not at all; 7 = to great extent):</i> | | | | | |
| Reduce innovation risks | | .782 | | | |
| Reduce new product/process development cost | | .849 | | | |
| Reduce time to market | | .832 | | | |
| Introduce new or significantly improved products or services | .618 | | | | |
| Introduce new or significantly improved process of producing our products or services | .757 | | | | |
| Opening of new markets | .850 | | | | |
| <i>...statements with respect to your firm's organisational-managerial actions regarding collaboration with external partners in innovation activities (1 = strongly disagree; 7 = strongly agree):</i> | | | | | |
| We formally assess the trade-offs between internal development and external acquisition | | | .666 | | |
| We increasingly rely upon internal search capabilities to scan and assess external knowledge | | | .481 | | |
| We use project management techniques to manage the collaborations | | | .698 | | |
| We formally assess the performance and results of collaborative projects | | | .787 | | |
| We have a reward and incentive system to recognize the benefits of collaborative innovation | | | .673 | | |
| <i>...statements with respect to your firm's staff involved in technological innovation: internal social capital (1 = strongly disagree; 7 = strongly agree):</i> | | | | | |
| We give our staff time and resources to generate new ideas | | | | .739 | |
| Our staff easily adapt to new situations | | | | .675 | |
| We set our staff creative and challenging objectives | | | | .816 | |
| We are open to technologies/knowledge generated outside the company | | | | .553 | |
| We allocate resources for our staff continuous professional development | | | | .700 | |
| There is a high level of collaboration within functional areas to identify and resolve emerging issues in innovation activities | | | | .803 | |
| There is a high level of interaction across different functional areas in innovation activities | | | | .769 | |
| <i>...statements with respect to your firm's experience in collaboration in innovation with external partners: external social capital (1 = strongly disagree; 7 = strongly agree):</i> | | | | | |
| We share a similar management style with our partners | | | | | .472 |
| There is a mutual interest in working collaboratively among partners | | | | | .845 |
| There is a high level of trust among partners | | | | | .857 |
| Partners' technological competences match up | | | | | .800 |
| Access to partners' knowledge resources | | | | | .787 |
| Synergy created by combining knowledge among participating firms | | | | | .812 |
| Variance explained | 39% | 30% | 43% | 53% | 60% |
| Cronbach's alpha | .704 | .811 | .729 | .849 | .856 |
| N=477 | | | | | |

Table 4. Innovation performance, organizational-managerial and social moderators (exploratory factor analysis)

| Partner depth | Sample | CL1 | CL2 | CL3 | CL4 | F Ration | Significance |
|--------------------------|--------|------|------|------|------|----------|--------------|
| Scientific-partner depth | 2.81 | 4.89 | 2.73 | 4.77 | 1.94 | 349.03 | .000 |
| Business-partner depth | 3.03 | 4.46 | 3.90 | 2.50 | 2.34 | 242.12 | .000 |
| N of cases | 477 | 56 | 129 | 52 | 240 | | |
| % of firms | 100 | 12 | 27 | 11 | 50 | | |

Table 5. Cluster analysis results (N=477)

| | | Mean (SD) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|----|--------------------------------------|-------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|----|
| 1 | Scientific-partner depth | 2.81 (1.3) | 1 | | | | | | | | | | | | | |
| 2 | Business-partner depth | 3.01 (1.07) | | 1 | | | | | | | | | | | | |
| 3 | Firm size | 1.49 (0.5) | ,239** | ,058 | 1 | | | | | | | | | | | |
| 4 | Market Environment dynamics | 4.30 (1.33) | ,059 | ,108* | -,004 | 1 | | | | | | | | | | |
| 5 | Technological Environment dynamics | 4.16 (1.2) | ,279** | ,221** | ,074 | ,220** | 1 | | | | | | | | | |
| 6 | Driver cost/risk/time | 4.27 (1.38) | ,271** | ,251** | ,038 | ,105* | ,302** | 1 | | | | | | | | |
| 7 | Innovation strategy | 3.77 (1.23) | ,342** | ,240** | ,278** | ,048 | ,518** | ,300** | 1 | | | | | | | |
| 8 | IP legal | 3.70 (1.43) | ,326** | ,152** | ,310** | ,097 | ,307** | ,261** | ,487** | 1 | | | | | | |
| 9 | IP strategic | 3.60 (1.6) | ,126* | ,185** | -,001 | ,122* | ,310** | ,224** | ,414** | ,371** | 1 | | | | | |
| 10 | Novelty | 4.16 (1.26) | ,269** | ,248** | -,019 | ,184** | ,370** | ,338** | ,363** | ,198** | ,252** | 1 | | | | |
| 11 | Efficiency | 3.90 (1.49) | ,273** | ,237** | ,069 | ,104 | ,339** | ,425** | ,315** | ,249** | ,127* | ,496** | 1 | | | |
| 12 | Organizational-managerial mechanisms | 3.52 (1.08) | ,409** | ,296** | ,088 | ,163** | ,395** | ,368** | ,456** | ,382** | ,326** | ,440** | ,335** | 1 | | |
| 13 | Internal social capital | 4.49 (1.11) | ,266** | ,183** | -,006 | ,153* | ,451** | ,302** | ,525** | ,321** | ,352** | ,356** | ,274** | ,542** | 1 | |
| 14 | External social capital | 4.60 (1.09) | ,227** | ,173** | ,115* | ,086 | ,296** | ,301** | ,301** | ,289** | ,251** | ,318** | ,448** | ,308** | | 1 |

Table 6. Descriptive statistics and correlations

Note: Significance levels: ^ p<0.1; * p<0.05; ** p<0.001; N=459

| | <i>Scientific-partner Depth</i> | | | | | |
|------------------------------------|-------------------------------------|-------------|-------------|-------------|-------------|----------|
| | Mod 1 | Mod 2 | Mod 3 | Mod 4 | Mod 5 | Mod 6 |
| Determinants | | | | | | |
| <i>External:</i> | | | | | | |
| Market environment dynamics | -.031 | -.026 | -.036 | -.023 | -.028 | -.026 |
| Technological environment dynamics | .296** | .267** | .211* | .107* | .097^ | .099^ |
| <i>Internal:</i> | | | | | | |
| Size | | .225** | .230** | .194** | .172** | .168** |
| Driver cost/risk/time/flex | | | .191* | .165* | .152* | .154* |
| Innovation strategy | | | | .217** | .161* | .172* |
| IP legal | | | | | .139* | .149* |
| IP strategic | | | | | | -.038 |
| R ² | .084 | .133 | .166 | .199 | .213 | .214 |
| F value | 20.787** | 23.320** | 22.651** | 22.484** | 20.332** | 17.500** |
| ΔR^2 | .084 | .050 | .033 | .032 | .014 | .001 |
| F (ΔR^2) | 20.787** | 26.098* | 18.025** | 18.353** | 7.871* | .608 |
| Determinants | | | | | | |
| | | | | | | |
| <i>External:</i> | | | | | | |
| Market environment dynamics | .026 | .027 | .018 | .028 | .024 | .017 |
| Technological environment dynamics | .195** | .190** | .137* | .058 | .051 | .045 |
| <i>Internal:</i> | | | | | | |
| Size | | .041 | .045 | .018 | .004 | .023 |
| Driver cost/risk/time/flex | | | .181* | .161* | .153* | .147* |
| Innovation strategy | | | | .126 | .128 | .086 |
| IP legal | | | | | .091 | .055 |
| IP strategic | | | | | | .143 |
| R ² | .042 | .043 | .073 | .092 | .098 | .113^ |
| F value | 9.878* | 6.842** | 8.933** | 9.140** | 8.142** | 8.197** |
| ΔR^2 | .042 | .002 | .030 | .019 | .006 | .015 |
| F (ΔR^2) | 9.878** | .779 | 14.593** | 9.311** | 2.958^ | 7.794* |

Table 7. Determinants of scientific and business partner depth
Note: Significance levels: ^ p<0.1; * p<0.05; ** p<0.001; N=459

| | | <i>Novelty</i> | | | | | <i>Efficiency</i> | | | | |
|---------------------------------|---|----------------|------------|-------------|-------------|----------|-------------------|-------------|----------|-------------|----------|
| | | Mod 1 | Mod 2 | Mod 3 | Mod 4 | Mod 5 | Mod 1 | Mod 2 | Mod 3 | Mod 4 | Mod 5 |
| Scientific-partner depth | Size (control) | -.102 | -.069 | -.066 | -.076 | -.098 | -.031 | .006 | .008 | -.011 | -.037 |
| | Scientific-partner depth (SP) | .284** | | | | .098* | .262** | | | .116* | |
| | Organizational-managerial mechanisms (OM) | | .425** | .311** | .293** | .262** | | .330** | .252** | .220** | .182** |
| | Internal social capital (ISC) | | | .212** | .132* | .124* | | | .144* | -.003 | -.013 |
| | External social capital (ESC) | | | | .197** | .191** | | | | .364** | .357** |
| | R ² | .076 | .18 | .212 | .242 | .25 | .066 | .109 | .124 | .228 | .238 |
| | F value | 18.785** | 50.138** | 40.822** | 36.324** | 30.178** | 16.013** | 28.005** | 21.506** | 33.489** | 28.343** |
| | ΔR ² | .076 | .18 | .032 | .030 | .007 | .066 | .109 | .015 | .104 | .010 |
| | F (ΔR ²) | 18.785** | 50.138** | 18.370** | 18.200** | .453 | 16.013** | 28.005** | 7.686** | 60.941** | 6.218* |
| Business-partner depth | Size (control) | -.043 | -.069 | -.066 | -.076 | -.079 | .024 | .006 | .008 | -.011 | -.014 |
| | Business-partner depth (SP) | .206** | | | | .071 | .190** | | | .076 | |
| | Organizational-managerial mechanisms (OM) | | .425** | .311** | .293** | .275** | | .330** | .252** | .220** | .201** |
| | Internal social capital (ISC) | | | .212** | .132* | .130* | | | .144* | -.003 | -.005 |
| | External social capital (ESC) | | | | .197** | .192** | | | | .364** | .358** |
| | R ² | .043 | .18 | .212 | .242 | .247 | .037 | .109 | .124 | .228 | .233 |
| | F value | 10.302** | 50.138** | 40.822** | 36.324** | 29.730** | 8.801** | 28.005** | 21.506** | 33.489** | 27.532** |
| | ΔR ² | .043 | .18 | .032 | .030 | .005 | .037 | .109 | .015 | .104 | .005 |
| | F (ΔR ²) | 10.302** | 50.138** | 18.370** | 18.200** | 2.784 | 8.801** | 28.005** | 7.686* | 60.941** | 3.087 |

Table 8. Scientific and business partner depth and innovation performance

Note: Significance levels: ^ p<0.1; * p<0.05; ** p<0.001; N=459