

Assessing the breadth of open innovation practices: the impact on innovation performance

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Abstract

Purpose of the paper: This research has a twofold purpose. First, it aims to identify open innovation practices (OIP) used by empirical studies in the context of the open innovation (OI) field. Second, it aims to test the inverted U-shaped relationship between the breadth of OIP and innovation performance.

Methodology: We followed two steps, conducting: a) a bibliographic analysis to identify the OIP already used in empirical studies; b) an empirical analysis with a sample of 184 Italian firms to test the relationship between the breadth of OIP and innovation performance, and the moderating role of internal R&D over the mentioned relationship.

Findings: The research identifies 16 OIP used by empirical studies and suggests that there is an inverted U-shaped relationship between the breadth of OIP and innovation performance. Furthermore, we did not find a moderating effect of the internal R&D on the above-mentioned relationship.

Research limits: The empirical analysis does not consider the effect of the single OIP. Then, our sample is heterogeneous involving different sectors and firm sizes. We acknowledge that innovation management changes depending of the sector's features. Future studies could focus on specific sectors to further develop our understanding on this topic.

Practical implications: The research helps to understand: a) what are the OIP that firms can exploit to innovate, b) how literature has used these OIP in empirical studies, and, c) if too much openness, in terms of practices, is beneficial for the firm's innovativeness or not.

Originality of the paper: The study offers an original and comprehensive view of openness based on OIP given that most of the empirical studies on OI focused on external sources of knowledge, rather than on practices. As a consequence, the variable breadth of OIP, that is the number of practices established by firms to innovate, is proposed. So, we position our paper within the main inbound OI literature proposing an alternative and complementary view of openness with regard to knowledge acquisition.

Key words: open innovation; innovation performance; Italian firms; open innovation practices; internal R&D.

1. Introduction

Collaborative innovation modes have been considered essential for the renewal of the firms in the last decades (Gulati, 1998; Katila and Ahuja, 2002; Nieto and Santamaria, 2007). Since the seminal work of Chesbrough (2003), collaborative innovation modes have been framed with the term “open innovation” (OI), according to which firms can and should acquire and integrate external knowledge and technologies that are globally dispersed in the external environment. The main idea of this model is that firms improve innovation processes by integrating and leveraging external sources of knowledge (Laursen and Salter, 2006; West and Bogers, 2014; Ferraris and Grieco, 2015). Accordingly, firms explore and exploit external knowledge to enhance their innovation performance since external sourcing might have a mediator effect on firm performance (Chesbrough *et al.*, 2018). In the current globalized world of aggressive competition and fast pace of change, OI strategies become a key element for new product development and firm survival (Enkel *et al.*, 2009; Vrontis *et al.*, 2017; Bresciani *et al.*, 2018). A key aspect in the OI literature regards the measurement of openness. However, the literature presents scattered and inconsistent perspectives about what openness is, how to measure the level of openness of a firm’s innovation process and how to assess whether a firm is open or not and to what extent. In fact, a major critique to the OI phenomenon is about the lack of coherence in the OI theoretical framework and assessment (Trott and Hartmann, 2009).

There are two main mechanisms of OI. The inbound mechanism refers to the acquisition of knowledge, while the outbound mechanism regards the transferring of knowledge. Considering the first mechanism, empirical studies have used different measures and theoretical views about openness. Most of the studies have followed the concepts of search breadth and depth of knowledge sources to measure how open a firm is, from an inbound perspective (Laursen and Salter, 2006; Nieto and Santamaria, 2007; Chiang and Hung, 2010; Ahn *et al.*, 2015). Breadth refers to the extent that firms access different external knowledge sources, such as customers, suppliers, competitors, universities and research centres, while depth regards the intensity of each relationship.

However, these measures fail to provide a comprehensive view of the firm’s innovation process. So, the absence of a comprehensive framework makes it difficult to validate the results about the effects of firms’ openness on performance measures and to assess openness antecedents.

This paper thus aims to identify open innovation practices (OIP) used by empirical studies in the context of the OI field and to test the relationship between the breadth of OIP and innovation performance. In this regard, OIP can be considered as methods applied by firms to acquire new knowledge from external counterparts and sources (van de Vrande *et al.*, 2009; Aquilani *et al.*, 2016), such as licensing-in of external technologies, co-R&D, collaboration with universities and crowdsourcing. The research firstly conducts a bibliographic analysis in order to identify those OIP used by empirical studies on OI. According to this, the variable breadth of OIP, that is the number of practices established by firms to innovate,

is constructed and proposed. So, we position our paper within the main inbound OI literature proposing an alternative and complementary view of openness with regard to knowledge acquisition.

Following this, using a unique database result of a survey conducted over Italian firms operating in a wide array of manufacturing and service industries such as ICT, food and beverage, textile, automotive, financial services, and engineering, the paper tests an inverted U-shaped relationship between the breadth of OIP and innovation performance. In addition, the moderating role of internal R&D is assessed given that it is essential to manage external knowledge and previous studies achieved inconsistent results due to the different measures applied to quantify openness (Cohen and Levinthal 1990; Veugelers and Cassiman, 1999; Tsai, 2001; Caloghirou *et al.*, 2004; Laursen and Salter, 2006; Schroll and Mild, 2011). Therefore, this research adopts a mixed methodological approach in order to develop a better understanding of openness in relation to OIP.

Overall, the paper offers several theoretical contributions. First, the study identifies and proposes 16 different OIP that firms can exploit to embrace OI, extending the contribution of previous empirical studies that focused more on identifying external knowledge sources used for innovation (Laursen and Salter, 2006). In fact, most of the previous studies measured OI counting the number of external sources (search breadth of OI sources), thus neglecting the “practices”. In this way, we evaluate whether firms are able to innovate exploiting different practices at the same time and thus exploring whether the organization is able to manage and simultaneously implement those practices. Second, the study proposes the measure breadth of OIP extending our understanding on how to assess OI apart from counting the number of external sources of knowledge (Laursen and Salter, 2006). We contribute to OI and in particular to those studies that suggest fragmented ways to engage in OI proposing a new comprehensive measure taking into account the variety of OIP firms can use. We thus suggest a new measure to evaluate openness based on the “how” to innovate rather than “from whom” to acquire knowledge and theoretically connect this with innovation performances. To sum up, the study proposes the measure “breadth of OIP” extending our understanding on how to measure OI. Third, the study empirically tests the proposed relationship, shedding more light also on the role of internal/external R&D link suggesting a substitution effect between the two variables, in line with the results of previous studies assessing openness in terms of external sources (Laursen and Salter, 2006; Schroll and Mild, 2011).

The remainder of the paper is organised as follows. The next section offers a review of the literature on open innovation and in particular on how to measure openness. In the third section, hypotheses concerning the relationship between the breadth of OIP and innovation performance and the moderating effect of internal R&D are proposed. Then, we present data, methodology, and variables used in our study. Finally, we highlight the results of the analysis, proposing a novel discussion in the light of existing literature as well as recommendations to academics, managers and practitioners.

2. Theoretical background

Studies in the innovation management field have emphasized the relevance of firms engaging in collaborative and networked activities in the last two decades (Gulati, 1998; Katila and Ahuja, 2002; Nieto and Santamaría, 2007). These new models contrast the view of a closed innovation process according to which a firm generates, develops and commercializes its own ideas with a tight control of knowledge (Chandler, 1990; Rothwell, 1992; Chesbrough, 2003). The OI paradigm has been developed in 2003 to extend those theories. In detail, this paradigm describes the inflow and outflow of knowledge and technology between the focal firm and the external entities such as customers, suppliers, governments, partners (Chesbrough, 2003; Santoro *et al.*, 2018b). These external sources can provide firms with different forms of knowledge useful to innovate processes and products. The adoption of an OI model is pursued to improve innovation performance, reduce time to market, sustain competitive advantages and exploit a technology through the proper business model (Bogers *et al.*, 2018).

Two main mechanisms describe the OI model. The inbound OI mechanism regards the leveraging of technological and knowledge capabilities developed outside the boundaries of the organization to integrate those developed internally (Spithoven *et al.*, 2011; Du *et al.*, 2014; Santoro *et al.*, 2018a). In turn, the outbound OI mechanism entails innovation activities aimed at capturing value by transferring knowledge and technologies to other counterparts through, for example, licensing-out (Bianchi *et al.*, 2011; Kutvonen, 2011).

Despite the large amount of theoretical studies on inbound OI, a comprehensive framework to measure the openness of the firm's innovation process with regard to knowledge acquisition is still missing in the literature. This is because each empirical study employs different measures of openness and considers openness in different ways. In fact, a major critique to the OI phenomenon is about the lack of coherence in the OI theoretical framework and assessment (Trott and Hartmann, 2009).

Scholars have used the concept of openness degree in order to explain the weight of collaborations in the innovation process. In particular, a stream of studies considers the number of external sources of knowledge involved in the innovation process to measure openness (Laursen and Salter, 2006; Tether and Tajar, 2008; Chiang and Hung, 2010; Gronum *et al.*, 2012; Lasagni, 2012; Ahn *et al.*, 2013, 2015). Specifically, Laursen and Salter's seminal work proposed the concept of search breadth and depth to describe the number of the external sources of knowledge exploited to innovate and the intensity of the relationship with each source. Other authors have followed the same logic (Ahn *et al.*, 2015; Aloini *et al.*, 2015; Bengtsson *et al.* 2015; Chen *et al.*, 2016).

Other studies consider openness as the leveraging of different OIP (van der Meer, 2007; Petroni *et al.*, 2012; Michelino *et al.*, 2015). Van de Vrande *et al.* (2009), for example, propose technology exploitation in terms of venturing, licensing-out, and employee involvement, whilst technology exploration in terms of customer involvement, networks, external

participation, outsourcing R&D and licensing-in. Parida *et al.* (2012) assess the openness in terms of technology scouting, vertical collaboration, horizontal collaboration and technology sourcing. Spithoven *et al.* (2013) focused on both sources and practices. First, they evaluate openness considering cooperation with several external sources. Second, they investigate several modes for accessing external knowledge. Also Ahn *et al.* (2015) used a mixed approach by considering several practices such as licensing-in, co-R&D, M&A, alliances, user involvement, spin-off and open sourcing.

Overall, most of the empirical studies on OI have followed the concept of search breadth and depth of knowledge sources to measure how open is a firm (Laursen and Salter, 2006; Nieto and Santamaria, 2007; Chiang and Hung, 2010; Ahn *et al.*, 2015), while some studies have considered the OIP but incoherently.

The next table (tab. 1) sums up a framework of the studies that focused on open innovation sources (OIS) or OIP.

Tab. 1: Studies focusing on open innovation sources or open innovation practices

How openness is assessed/measured	Explanation	Sources	Implications
Open innovation sources	Open innovation is measured as the number and the intensity of external sources of knowledge involved in innovation process	Laursen and Salter, 2006; Nieto and Santamaria, 2007; Tether and Tajar, 2008; Chiang and Hung, 2010; Gronum <i>et al.</i> , 2012; Lasagni, 2012; Ahn <i>et al.</i> , 2013; Aloini <i>et al.</i> , 2015; Bengtsson <i>et al.</i> 2015; Chen <i>et al.</i> , 2016	Firms should evaluate and decide “from whom” to acquire knowledge in terms of how many sources and to what extent (breadth and depth)
Open innovation practices	Open innovation is assessed considering the impact/effect of specific open innovation practices exploited to innovate. However, each study considers different practices and no studies consider the breadth of OIP	van der Meer, 2007; Van de Vrande <i>et al.</i> , 2009; Parida <i>et al.</i> , 2012; Petroni <i>et al.</i> , 2012; Spithoven <i>et al.</i> , 2013; Michelino <i>et al.</i> , 2015	Firms should evaluate and decide “how” to acquire knowledge from external sources

Source: own elaboration

The methodology section will present all the OIP used by empirical studies in order to develop a measure that counts the number of OIP practices used by firms to innovate. Therefore, this paper is positioned in the stream of studies that consider OIP as a form of engaging in open innovation.

3. Hypothesis development

Overall, firms establish alliances, join networks and seek external knowledge to enhance the strategic position and legitimacy (Eisenhardt and Schoonhoven, 1996), acquire resources and assets (Marx and Hsu, 2015), expand the internal knowledge base (Scuotto *et al.*, 2017) and develop innovations with lower risks, time and costs (Chesbrough, 2003).

Many previous studies found a positive relationship between the number of external sources of knowledge involved in the innovation process and innovation performance (Ahuja, 2000; Caloghirou *et al.*, 2004; Laursen and Salter, 2006; Gronum *et al.*, 2012; Ahn *et al.* 2013, 2015; Fernandes and Ferreira, 2013). In addition, some studies indicate that a wide OI strategy involving different external sources is beneficial for incremental innovation (Garriga *et al.*, 2013). By increasing the openness of the innovation process, a firm can burgeon its competitiveness through mixing and exploiting various sources and knowledge bases (Laursen and Salter, 2006; Hung and Chou, 2013). Integrating diverse knowledge inputs increases the opportunities for new knowledge combinations (Salge *et al.*, 2012). In this guise, involving different sources of knowledge provides firms with a pool of heterogeneous knowledge bases useful to recombine existing products or develop new ones following technological and market trends. As a consequence, firms that invest in broader search may have a greater ability to adapt to change and therefore to innovate (Laursen and Salter, 2006). As a consequence of that, the innovations developed through the acquisition of different types of knowledge will ultimately have higher chances to be appreciated by the target segments, thus increasing sales from new products and services (Berchicci, 2013).

With a similar logic, it is reasonable to infer that leveraging various OIP may enhance a firm's innovation processes. Using different OIP increases the knowledge base of the firm and helps in developing both incremental and radical innovation (van de Vrande *et al.* 2009; Parida *et al.*, 2012). Specifically, Spithoven *et al.* (2013) found that OIP improve performance of both SMEs and large enterprises, and that SMEs are more able to apply several practices at the same time. Ahn *et al.* (2015) indicate that the quantity of both external sources and practices are beneficial for a firm's innovation performance.

However, the benefits of openness are subject to decreasing returns, indicating that there is a point where additional search decreases innovation performance (Laursen and Salter, 2006; Berchicci, 2013). This is due to the increasing complexity that firms cope with along with the increasing open approach to innovation. In fact, over-searching can lead to too many ideas and knowledge to consider and firms risk choosing the wrong innovative projects (Koput, 1997).

Moreover, too many OIP can lead to high transaction costs due to the efforts to control and manage the relationships (Faems *et al.*, 2008; Gulati and Singh, 1998), poor allocation of managerial attention (Laursen and Salter, 2006; Ocasio, 1997), and difficulties in managing and absorbing the external ideas (Koput, 1997; Laursen and Salter, 2006).

For the above reasons, we hypothesized that:

HP. 1: The breadth of open innovation practices is positively related to innovation performance, but with an inverted U-shaped relationship.

Internal R&D has been for a long time considered an essential source of innovation for firms (Cohen and Levinthal 1990; Veugelers and Cassiman, 1999). In addition, internal R&D can be deemed vital for integrating external R&D. A strategically balanced mix of internal and external sources of knowledge can prevent not only from over- or under-investing in R&D, but can also help in exploiting efficiently business opportunities (Ahn *et al.*, 2016; Capone and Lazzetti, 2017; Ferraris *et al.* 2018).

However, the role of internal R&D to improve the performance of an OI approach is still unclear in literature. In fact, although many studies have attempted to understand the reasons behind a firm's choice between external and internal technological development, it still remains unknown whether high levels of openness to external sources of knowledge in combination with a high-level internal R&D lead to higher performance. Additionally, studies analyzed the role of external knowledge without investigating the nature of the sources, the characteristics of R&D collaborations and even less, the OIP established.

Despite the contradictions in literature, most of the scholars have found complementarity between internal R&D and external knowledge sourcing in terms of external sources of knowledge (Tsai, 2001; Rigby and Zook, 2002; Caloghirou *et al.* 2004; Cassiman and Veugelers, 2006; Chesbrough and Crowther, 2006; Escribano *et al.*, 2009; Berchicci, 2013; Chen *et al.*, 2016), because internal R&D stimulates the absorptive capacity. Cohen and Levinthal (1990, p. 128) defined the absorptive capacity as '*the ability to recognize the value of new information, assimilate it, and apply it to commercial ends*'.

Hence, absorptive capacity has a potential value for inbound OI activities. However, in order to absorb external knowledge, firms need a prior related knowledge base to assimilate that knowledge (Zahra and George, 2002).

Concluding, although other studies found that openness in innovation is substitute of internal R&D (Pisano, 1990; Laursen and Salter, 2006; Schroll and Mild, 2011), our view here is that internal R&D is necessary to manage different OIP and at the same time improve innovation performance. Therefore, our hypothesis is that internal R&D helps firms in improving the effects of higher level of openness in terms of OIP on innovation performance.

HP. 2: The inverted U-shaped relationship between the breadth of open innovation practices and innovation performance is moderated by internal R&D.

4. Research design

As anticipated, this research has a twofold purpose. First, it aims to identify OIP practices used by empirical studies within the OI field to provide a comprehensive and alternative view of openness. Second, it aims to test the relationship between the breadth of OIP and innovation performance to understand whether too much openness, in terms of practices, is beneficial or not for firms. To achieve these goals, we followed two steps:

1. a bibliographic analysis to identify the OIP found in empirical studies;
2. an empirical analysis to test the relationship between the breadth of OIP and innovation performance.

4.1 Methods for the bibliographic analysis

The main purpose of this phase is to identify the frequencies of OIP occurred in empirical studies. The findings presented in this section are thus part of a broader study where systematic searches of the OI literature have been carried out in several sequential studies covering a time period from 2003 up until 2017. We restricted the timeframe to articles published from 2003 onwards, as the term “open innovation” was originally coined in 2003 by Prof. Henry Chesbrough. The searches were made in three selected sources, namely ISI Web of Knowledge, Google Scholar and Scopus, which cover the field of social sciences. Only papers explicitly using the term “open innovation” were included in the search range. Naturally, there are publications closely related to OI without using the term, but this lies outside the scope. The search was also limited to social sciences publications. Only peer-reviewed material was included in the analysis, and thus materials, such as pure interviews, industry reports and book reviews, were excluded. We chose to also exclude conference papers, as some conferences are not peer-reviewed, and we did not have the capacity to make a distinction among conferences that are peer-reviewed and those that are not. In total, 486 publications in English were found. Then, we have analysed the abstracts in order to verify whether the articles had an empirical nature, or was simply citing other empirical articles. In the latter case, we discarded the article from our research. Whenever the abstracts were too ambiguous to understand the subject of the respective articles, we extended the preliminary analysis of the abstract to the entire article in order to avoid undesirable exclusions.

We have read the abstract trying to understand whether the paper addressed in some way the issue concerning the measurement of openness with particular regard to the acquisition of knowledge or technology. Therefore, the transfer of knowledge/technology (outbound OI) is not considered in our study. Furthermore, we just considered quantitative papers because they clearly measured openness. This procedure led us to 42 papers published between 2006 and 2017.

By reading these papers we identified 16 OIP. The following table shows the OIP and how many times they have been found in empirical studies.

Tab. 2: OIP found in empirical studies

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OIP	Frequency
Licensing in/Technology purchase	20
Partnering/R&D alliances/Co-patent	10
Customer engagement	6
Equity investment/M&A/JV	6
Outsourcing R&D	6
Vertical technology collaboration	5
Networking	5
University collaboration and grants	5
Technology scouting	4
Horizontal technology collaboration	3
National public funding	2
E-collaboration tools/social media	2
Patent search	1
Government collaboration	1
Idea and start-up competition	1
Crowdsourcing (unknown problem solvers)	1

Source: own elaboration

4.2 Methods for empirical analysis

An empirical research was carried out with a sample of Italian firms and data were assessed through quantitative methods. The quantitative methodology has been chosen due to the nature of the topic, which calls for more fine-grained approaches to explore relationships among variables. Moreover, the quantitative approach is widely used in this field of research (Laursen and Salter, 2006; van de Vrande *et al.*, 2009; Parida *et al.*, 2012; Spithoven *et al.*, 2013). As a first step, 1000 Italian firms from different sectors of both the manufacturing and service industry have been selected from the Italian *database AIDA-Bureau van Dijk*, which contains comprehensive information on companies in Italy, with up to ten years of history, such as standardised annual accounts, financial ratios, sectoral activities and ownership data.

Second, we sent a questionnaire along with a brief introduction of the research scope by using their direct email address. If the email address was not available, the firm was approached by phone, requesting an email address and then the questionnaire was sent. The questionnaire, composed of several questions (open and closed), was answered and returned by 184 CEOs or owners. All the respondents had more than 5 years of tenure in their firm. This expertise further supports the validity of both informants for reporting data about their organization (Cruz-González *et al.*, 2015).

In detail, firms within the sample belong to a wide array of manufacturing and service industries such as ICT, food and beverage, textile, automotive, financial services and engineering (table 3). 84 firms are small (less than 50 employees), 89 are medium sized (less than 250 employees), while 11 firms are large (more than 249 employees).

Tab. 3: Sectors

Sectors	%
Automotive	10,9
Beverage	7,6
Electronics	4,3
Energy	3,8
Engineering	2,7
Financial services	3,8
Food	4,9
Human Resources	2,2
IT hardware	2,2
IT services	34,8
Machinery	5,4
Metals	6,5
Retail	7,1
Textiles	3,8

Source: own elaboration

The questionnaire was developed according to the previously discussed literature. It is divided in two parts, with both open and closed questions. The first part investigates general information about the firm, such as industry, number of employees, age and performance. The second part investigates specifically approaches to innovation, OIP established, knowledge sources and internal R&D capacity.

The single questions have been separated in order to reduce the risk of rationalising the answers of the respondents. We also assessed potential non-response bias by looking for differences between early and late respondents (Kanuk and Berenson, 1975). To do so, the order of responses to the survey was recorded and it was revealed to be non-significantly correlated with both firm age and firm size, suggesting that concern regarding non response bias is minimal (Hawes and Crittenden, 1984). We also found no substantial differences in either firm age or firm size across industries. This result is important given the heterogeneity of our sample. Firms are distributed across Italy, though the majority operates in the north of the country.

The hypotheses were tested through hierarchical OLS regression model, which was considered a suitable method in innovation management studies (Benner and Tushman, 2002; Blindenbach-Driessen and Van Den Ende, 2010; Chen *et al.*, 2016), it is appropriate to test moderation effects and it is a proper method for our dependent variable (innovation performance).

The dependent variable is innovation performance (*InnPerf*), and it measures the ability of a firm to develop new products or services (Laursen and Salter, 2006). In particular, it is taken from previous studies in innovation management, and is calculated by using the percentage of sales from new or significantly improved products and services on total sales of the firm (Laursen and Salter, 2006; Brunswicker and Vanhaverbeke, 2015; Chen *et al.*, 2016).

The independent variable is OIP. We built on procedures of Laursen and Salter (2006) followed by Ahn *et al.* (2015), with specific regard to their

variable *search breadth of knowledge* to develop the variable *open innovation practices (OIP)*. In detail, we asked the respondents to select practices used to innovate from a list of 16 practices identified through the bibliographic analysis previously conducted (tab. 1). Respondents had to select 0 if the practice was not used or 1 if the practice was used. Subsequently, the 16 practices are simply added up so that each firm gets a 0 when no practices are used, while the firm gets the value of 16, when all practices are used. In other words, it is assumed that firms that use higher numbers of practices are more 'open', with regard to knowledge acquisition. Seven managers of the firms involved in the survey participated in a pre-test to validate this variable and to discuss about OIP and openness.

The variable *R&D intensity*, used as the moderator, is calculated as the share of investments in R&D to total sales for the year, because it could affect knowledge creation and innovation within firms, and it likely impacts internal capacities for innovation (Cohen and Levinthal, 1990; Tsai, 2001; Blindenbach-Driessen and van den Ende 2014; Ahn *et al.*, 2015; Bresciani *et al.*, 2015).

Finally, we added several control variables. We firstly controlled for the firm's age, that is the number of years since founding, given that it could affect positively or negatively innovation processes (Huergo and Jaumandreu 2004). Then, we controlled for the firm's size, that is the number of employees, because it may affect organisational features and the ability to pursue innovation (Dewar and Dutton, 1986). We added a dummy variable considering the industry being divided between services and manufacturing (Blindenbach-Driessen and van den Ende 2014). Finally, we checked for the environmental dynamism (ED) and technological dynamism (TD) of the sectors, as suggested by previous empirical studies (Jaworski and Kohli, 1993; Jansen *et al.*, 2009).

This study follows the procedure suggested by Friedrich (1982) to reduce or eliminate any bias resulting from multicollinearity because of interaction terms. Before calculating the interaction terms, the variables were mean-centered to avoid multicollinearity issues (Van de Vrande, 2013). In addition, a variance inflation factor (VIF) test is used to evaluate the effect of multicollinearity. Only the VIF for the interaction variable exceed 10, but since it is constructed through the interaction of two standardized variables, we do not believe it contaminates the results; the VIFs for the rest of variables are smaller than 10. Table 4 shows the correlations among variables and descriptive statistics.

Tab. 4: Correlation matrix and descriptive statistics

	Min	Max	Mean	TD	ED	Size	Age	InnPerf	R&D	OIP
TD	1	7	3.83	1	.029	.079	-.072	.259**	.103	.368**
ED	1	7	4.77	.029	1	.043	.001	.055	-.201**	.039
Size	5	1728	143.77	.079	.043	1	.439**	.043	-.070	.233**
Age	3	95	24.81	-.072	.001	.439**	1	-.245**	.181*	-.057
InnPerf	.00	1.00	.3365	.259**	.055	.043	-.245**	1	-.088	.286**
R&D	.000	.480	.09872	.103	-.201**	-.070	.181*	-.088	1	.052
OIP	0	16	4.64	.368**	.039	.233**	-.057	.286**	.052	1

Notes: *p<0.01; **p<0.001

Source: own elaboration

It is noteworthy to consider that firms in the sample are small on average even though micro and large firms are part of the sample alike. On average, firms have good innovation performance (33% of sales come from new products and services), they have established 4.64 out of 16 OIP on average, and they have substantial R&D investments (tab. 4).

5. Findings of the empirical analysis

The results of the hierarchical regressions are presented in table 5. First, we estimate Model 1, which contains the sole control variables. Model 2 contains the direct and linear effect of the breadth of OIP on innovation performance. Model 3 adds the squared term of the breadth of OIP to test the inverted U-shaped relationship. Finally, Model 4 introduces the interaction terms between the breadth of OIP and internal R&D.

Data confirm an inverted U-shaped relationship between the dependent variable (innovation performance) and the independent variable (the breadth of OIP) with OIP ($\beta=0.396^*$) and OIP² ($\beta=-0.639^*$). Moreover, the moderating effect of internal R&D is positive but non-significant ($\beta=0.311$); therefore, HP. 1 is confirmed while HP. 2 is rejected.

Although Haans *et al.* (2016) justified that testing for moderation in U-shaped relationships should include both the interaction term and its square, some researchers argue that adding the squared terms and later the interaction between the squared terms to the model, would overemphasize the effect of outliers in the estimates. To check that the introduction of the interaction with the squared term does not bias the results, we run the model with and without the squared interaction term and results remain the same.

The findings of the empirical analysis suggest that increasing the openness of the firm's innovation process is beneficial for innovation performance, but there is a point where an additional search is unproductive for firms, confirming the findings of Laursen and Salter (2006) with regard to the breadth of external knowledge sourcing, and Berchicci (2013) with regard to external R&D. This is true also for the number of OIP as this paper advocates. From one side, with diverse OIP firms are able to tap into heterogeneous knowledge types allowing to improve products and find new solutions. From the other side, it is reasonable to understand that firms cannot manage too many OIP because of the complexity they face especially if we consider that, while some OIP are established and carried out informally (technology scouting), others are formally established requiring control, analysis and management with resources (either financial or human).

Evidently, high investments in R&D did not lead to higher innovative products and services for firms of our sample, and therefore our findings hint that R&D does not help in managing the complexity of too many OIP. However, we have to consider that the effects of R&D activities sometimes are time-delayed and therefore not evident in the short run.

If we consider these results together, we can conclude that innovative performances are driven by selected OIP rather than R&D investments.

Tab. 5: Results of regressions

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	INNPFRF	INNPFRF	INNPFRF	INNPFRF
VARIABLES	Model 1	Model 2	Model 3	Model 4
ED	-0.020 (-0.324)	-0.020 (-0.338)	0.024 (0.438)	0.014 (0.209)
TD	0.362 (5.941)***	0.381 (5.982)***	0.410 (7.007)***	0.390 (6.068)***
LOGSIZE	0.476 (7.079)***	0.488 (7.169)***	0.537 (8.607)***	0.544 (8.393)***
LOGAGE	0.085 (1.244)	0.152 (2.054)*	0.094 (1.328)	0.103 (1.447)
R&D	-0.168 (-2.638)**	-0.158 (-2.366)*	-0.145 (-2.306)*	-0.266 (-1.017)
OIP		0.144 (2.234)*	0.396 (2.021)*	0.421 (2.107)*
OIP2			-0.639 (-3.318)**	-0.733 (-3.378)**
OIP*R&D				0.311 (1.103)
R	0.635	0.662	0.739	0.742
R ²	0.403	0.439	0.545	0.551
ADJUSTED R ²	0.358	0.411	0.515	0.512
F-VALUE	22.7000***	16.108***	17.669***	13.943***

Notes: *p <0.1; *p<0.05; **p<0.01; ***p<0.001
 T-values in parentheses

Source: own elaboration

Regarding the control variables, two of the variables employed in the different regressions significantly explain a part of the variance in innovation performance. These are TD and size. In each model these variables have a strong impact on innovation performance. Regarding TD, this is likely due to the fact that dynamism from a technological point of view pushes firms to research new solutions and adjustments to existing products and develop new ones. Regarding firm's size, it seems that larger firms have more capabilities to be innovative or simply they search for introducing new products while smaller firms look to sell more existing products.

6. Discussion and conclusions

6.1 Discussion of findings

This paper has tried to shed light on the OI model clarifying how openness can be measured. In fact, most of the empirical studies on OI have followed the concept of search breadth and depth of the sources of knowledge to measure how open a firm is (Laursen and Salter, 2006). However, these measures fail to provide a comprehensive view of the firm's innovation process. An alternative and complementary view of openness focuses on OIP exploited by firms to innovate (van de Vrande *et al.*, 2009; Parida *et al.*, 2012; Chesbrough and Brunswicker, 2013). Therefore, our paper is positioned among the studies that consider OIP and not the sources to address the issue of openness at firm level.

In line with this, this research has followed two steps. First, through a bibliographic analysis we have identified 16 OIP used by empirical studies on OI. Second, we have developed an empirical analysis assessing

the relationship between OIP and innovation performance, and the moderating role of internal R&D on the above relationship. Findings of this empirical analysis suggest that the breadth of OIP is curvilinearly related to innovation performance, extending and supporting previous studies on the relationship between breadth of sources and innovation performance (Laursen and Salter, 2006; Berchicci, 2013). This means that increasing the number of practices used to innovate, innovation performance increases, but just to a certain point, beyond which additional openness decreases innovation performance.

In addition, the study indicates that internal R&D does not play a moderating role, contrasting previous studies hinting a complementarity effect between internal and external R&D (Tsai, 2001; Rigby and Zook, 2002; Caloghirou *et al.* 2004; Cassiman and Veugelers, 2006; Chesbrough and Crowther, 2006; Escribano *et al.*, 2009; Berchicci, 2013; Chen *et al.*, 2016).

Finally, TD and firm size impact strongly on innovation performance, suggesting that: a) firms operating in high-tech and dynamic sectors are the most innovative; b) larger firms are more innovative than smaller firms. Considering the first finding, we could suggest an indirect relationship between the breadth of OIP and TD, meaning that the effect of the breadth of OIP on innovation performance (HP. 1) is stronger in the case of high level of TD.

6.2 Theoretical implications

The research findings allow us to provide interesting theoretical implications. First, the study identifies and proposes 16 different OIP that firms can exploit to embrace OI, extending the contribution of previous empirical studies that focused on knowledge sources (Laursen and Salter, 2006), or just few practices (van de Vrande *et al.*, 2009; Parida *et al.*, 2012). Therefore, the major contribution of this paper lies in the measurement of openness, since most of the previous studies measured OI counting the number of external sources (search breadth of OIS), thus neglecting the “practices” (Laursen and Salter, 2006; Nieto and Santamaria, 2007; Tether and Tajar, 2008; Chiang and Hung, 2010; Gronum *et al.*, 2012; Lasagni, 2012; Ahn *et al.*, 2013; Aloini *et al.*, 2015; Bengtsson *et al.* 2015; Chen *et al.*, 2016). In this way, we evaluate whether firms are able to innovate exploiting different practices at the same time and thus exploring whether the organization is able to manage and implement different practices simultaneously.

In this regard, it is important to specify that some OIP have been found more frequently in empirical studies (e.g. licensing-in, partnering/R&D alliances/Co-patent, customer engagement...). This main contribution could be a watershed for future empirical studies on OI focusing on “how” OI can be embraced (practices), whereas most of the previous studies focused on “from whom” to acquire the relevant knowledge (external sources of knowledge). Second, the study proposes the measure “breadth of OIP”, that is the number of practices established by firms to innovate. So, we position our paper within the main inbound OI literature proposing an

alternative and complementary view of openness with regard to knowledge acquisition, based on the breadth of OIP used by firms to innovate. This could provide future studies with a guideline to be followed. Third, the study sheds more light on the internal/external R&D relationship suggesting a substitution effect between the two variables, in line with the results of previous studies assessing openness in terms of external sources (Laursen and Salter, 2006; Schroll and Mild, 2011). As a consequence, we contribute to the literature indicating that higher investments in internal R&D do not enhance the impact of the breadth of OIP on innovation performance.

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6.3 Managerial implications

From a managerial point of view, the study suggests that high performing firms in terms of innovativeness are those who embrace OI increasing but not exaggerating in terms of OIP. This means that R&D units and corporate managers should allocate time and resources (either financial or human) to understand which type of OIP fits better for a firm's innovative projects and with existing business models. Therefore, the study advises managers against the risk of over-searching through too many OIP. Our paper shows that there is an optimal level of OIP exploitation, and that after this point, accessing external knowledge has detrimental effects on innovation performance. Moreover, we stress that firms that want to increase sales from new products and services must not increase internal R&D investments but rather increase the OI approaches, selecting the most appropriate mechanisms and practices.

6.4 Limitations and future research

The paper of course has limitations. First, the empirical analysis does not consider the effect of the single OIP. Future studies could try to understand what are the best performing OIP exploited by firm and what are the different benefits of the OIP. Second, our sample is heterogeneous involving different sectors and sizes. We acknowledge that innovation management changes depending of the sectors' features. Future studies could focus on specific sectors. Finally, it is noteworthy to underline that, regarding the bibliographic analysis, we did not consider publications with terms different from "open innovation" even though they could be closely related to it. However, we truly think that 16 OIP are fully comprehensive of what can be found in literature.

To conclude, OIP regard a key aspect in the OI field, considering that they refer to the modes by which firms embrace OI. In this regard, future studies should deeply explore each practice trying to understand the relative dynamics, barriers and sustaining factors. Future studies could also explore the antecedents and moderators of the relationship between OIP and innovation performance. For example, quantitative studies could explore whether internal R&D investments foster the performances of specific OIP, such as licensing-in and customer engagement. In fact, these two OIP require different extent of efforts by companies.

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