Technological strategy, open innovation and performance: evidences by a structural- equation-model approach

Structured Abstract

Purpose – Still little is known about the determinants of the openness degree. Examples of investigated determinants are firm-specific or environmental/external factors. However, the role exerted by some of them remains unclear. In particular, it is still debated the influence exerted by the technological strategy, in that evidences on the relationship between the technological strategy and openness are conflicting. The aim of this study is thus to shed further light on the above mentioned relationship in order to give a more conclusive evidence to the debate.

Design/methodology/approach – We elaborate a structural equation model which enriches the state-of-the-art by explicitly testing the interplay among technological strategy, openness (innovatively measured in terms of partner intensity, phases intensity, and variety in terms of partners, phases and content) and innovative performance. Our study relies on data from 415 firms by a survey research developed in Finland, Italy and Sweden.

Originality/value – Findings shows that openness, if measured as partner intensity and phase intensity, fully mediates the relationship between technological strategy and innovative performance, by suggesting that the effectiveness of a firm's technology aggressive behavior is strongly related to the intensification of collaboration with the partners along the innovation funnel. Conversely, openness variety seems to play an opposite role and is differently influenced by partner and phase intensity. This result likely emphasizes the cost-side of an open behavior becoming harder to manage, and thus costly, when involving too many different partners, phases and contents.

Practical implications – Firms, which adopt a technological aggressive strategy, are recommended to deeply open their innovation process in order to foster innovation performance. However, due to the fact that a high openness variety could generate some drawback, managers should be very careful in the management of different phases, sources and contents. Therefore a call to find adequate strategies for effectively managing the collaboration process in order to avoid waste of resources and efforts clearly emerges.

Keywords – Open Innovation, Partner Intensity, Phase Intensity, Openness Variety, Technological strategy, Innovation Performance, SEM

1 Introduction

It is largely recognized by scholars, belonging to several theoretical perspectives (strategic resource-based perspective: von Hippel, 1986; Katila and Ahuja, 2002; innovation management literature: Chesbrough, 2003; Dahlander and Gann, 2010), that cooperative agreements and partnerships aim at creating value and enhancing firm innovativeness. It is also recognized that open innovation (OI) resides on a continuum ranging from closed to thoroughly open approaches (Dahlander and Gann, 2010; Huizing, 2011; Bader and Enkel, 2014) and it is usually measured as openness degree through collaboration breadth - i.e. number of external knowledge sources used in innovation activities - and depth - i.e. intensity of collaboration with each external partner, ranging from surface to deep collaboration as collaborative interactions intensify (Laursen and Salter, 2006; Lazzarotti et al., 2011).

Notwithstanding it is acknowledged that effectiveness of open innovation must be context dependent (Huizing, 2011; Gassman, 2006) and despite relevant exceptions (Sofka and Grimpe, 2010; Drechsler and Natter, 2012), still little is known about the determinants of the openness degree. According to contingency theory, investigated determinants are firm-specific (e.g. innovation-strategy approach and goals pursued with collaborations) or environmental/external factors (e.g. technological and market dynamics) (Drechsler and Natter, 2012). However, the role exerted by some of them remains unclear. In particular, it is still debated the influence by the so-called "technological strategy" construct, intended as the firm orientation in terms of level of specialization and focus on radical rather than incremental innovation (Miles et al., 1978; Brockhoff and Pearson, 1992). As a matter of fact, evidences on the relationships between the technological strategy and openness are conflicting. On the one hand, literature argues that technologically aggressive firms, just because of their specialization and emphasis on radical innovation, are focalized on research activities inside the firm and are reluctant to rely on technologies that are available from external sources (Brockhoff and Pearson, 1992; Lichtenthaler and Ernst, 2009). On the other hand, Colarelli O'Connor (2006) and Lichtenthaler (2008) find that a strong emphasis on radical innovations pushes firms to adopt approaches based on a higher degree of external technology acquisition because they may not be able to internally develop all the relevant knowledge.

Thus the aim of this study is to shed further light on the relationship between technological strategy and openness degree in order to give more conclusive evidence to the debate. To this purpose, we elaborate a structural model which, building on a survey which involved 415 Finnish, Italian and Swedish firms, enriches the state-of-the-art by explicitly testing the interplay among technological strategy, openness and performance.

This study develops and tests a model that links technological strategy, open innovation activities, and innovation performance. It contributes to the literature in the following ways. First, following suggestions that open innovation effectiveness is context dependent (Cheng and Hiuzing, 2014; Huizingh, 2011; Lichtenthaler, 2008), we determine the importance of technological strategy. Second, this study develops an open innovation measurement scale that incorporates a wide range of aspects of open innovation. Third, we systematically investigate the relation between open innovation activities and various innovation performance dimensions, such as new product/process innovativeness and performance in terms of reduction of risks, time and cost: this leads to more generalizable insights regarding open innovation effectiveness.

The paper is organized as follows. The next section presents the analysis of the extant literature. The methodological approach - including sample and data collection, constructs and the structural equation modelling - is then described, followed by the presentation of the empirical results. Lastly, we present a discussion of these results, conclusions, as well as academic and managerial implications

2 Theoretical background

Our research framework is depicted in figure 1: it shows the influence of technological strategy on OI choices and the impact of OI choices on innovative performance. In the following sections we will discuss the state-of-the-art of the literature regarding the relationship between technological strategy and OI choices (section 2.1) and soon after the main results of the literature analyzing the impact of OI choices on performance (section 2.2). In section 2.3, hypotheses will be put forward.

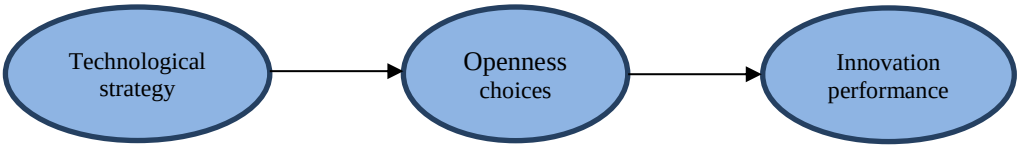

Figure 1 - The research framework

However, being OI a broad concept encompassing different dimensions (Huizing, 2011; Cheng and Huizingh, 2014), before entering the analysis of the literature we clarify the perspective of analysis through which we will investigate OI. More exactly, OI regards both purposive outflows and inflows of knowledge to accelerate internal innovation processes and to better benefit from innovative efforts, respectively (Chesbrough, 2003; Chesbrough and Crowther, 2006; Gassmann and Enkel, 2004; Dahlander and Gann, 2010). Purposive outflows of knowledge (outbound OI) imply innovation activities to leverage existing technological capabilities outside the boundaries of the organization (Hung and Chou, 2013) and entail activities such as, for instance by licensing out, selling of knowledge, and divestment of parts of the firm, such as spinning off innovation projects into new create innovative firms (Cheng and Huizing, 2014). Instead purposive inflows, usually referred to as inbound OI, mainly relate to innovation activities aiming at capturing and benefiting from external sources of knowledge in order to enhance current technological developments (Huizing, 2011). While referring specifically to the inbound OI, this articles investigates the firm's degree of openness by a three-fold perspective: first, the number of partners with whom collaborating (Dilk et al., 2008) as well as the level of intensity of the collaboration with them (Laursen and Salter, 2006; Keupp and Gassmann, 2009); second, the number and type of phases of the innovation process to be opened to external partners in order to collaborate and, hopefully, co-create along the innovation funnel (Lazzarotti and Manzini, 2009; Chiaroni et al., 2009); third, the contents the partners should contribute with along the funnel (Huizingh, 2011; Bengtsson et al., 2013).

2.1 Technological strategy and OI choices

Miles et al. (1978), in their framework of adaptive cycle, depict the process of adaptation of the major decisions needed by an organization to maintain an effective alignment with its own environment; such decisions pertain to the entrepreneurial domain - i.e. relating to how the organization orients itself to the marketplace - the engineering domain - i.e. the technology used to produce the organization's products and services - and the administrative domain – i.e. how the organization attempts to coordinate and implement its strategies in terms of structure and processes. On the basis of such domains, they portray three successful (or proactive) patterns of adaptive behavior, in which each unique strategy in terms of product-market is associated with a configuration of

technology, structure, and processes. Namely, they are: prospectors, defenders, and analyzers, being prospectors and defenders situated at either end of the continuum of adjustment strategies. Although such three patterns have not been explicitly analyzed by Miles et al. (1978) in terms of OI, following the suggestions by Lefebvre et al. (2013) and Bader and Enkel (2014) it is possible to infer some implications in terms of open innovation choices. Indeed, prospectors seem to emphasize a more opened approach (Bader and Enkel, 2014) than the firms belonging to the other two patterns (Lefebvre, 2013): while not limiting the choice of products-markets to those which fall within the range of their organization's present technological capability, prospectors require expanding their domains of knowledge and this, on its turn, requires monitoring a wide range of environmental conditions, trends, and events (Shortell and Zajac, 1990), as well as tapping into a broad range of knowledge bases provided by different types of partners. Defenders, because of their emphasis on technical efficiency and protection of their base business, are generally more narrowly focused (Shortell and Zajac, 1990) and therefore expected to intensely open their funnel to a limited set of partners, usually current customers or universities for reasons of efficiency and risk reduction (Bader and Enkel, 2014). Analyzers, who use components of both the prospector and defender strategies, should adopt in between OI choices. Also Dittrich et al. (2007) find that exploration networks make relatively more use of non-equity alliances with an increasing number of new partners mostly operating outside the existing competencies of the focal firm.

Nevertheless evidences on the relationship between technological strategy and openness are rather scant and, most importantly, conflicting. For instance, Lefebvre et al. (2013), investigating the food industry, do not find any significant relationship between the firm's strategy (operationalized in terms of prospector, analyzer and defender) and firm's openness. Instead, Lichtenthaler and Ernst (2009) show that technological aggressiveness is negatively related to the extent of external technology acquisition (i.e. inbound OI). While focusing the attention on only one of the aspects which characterize the technological strategy – i.e. only on the firm's emphasis on radical rather than on incremental innovations – Lichtenthaler himself (2008) finds that, radical innovation exerts a strong positive impact on technology acquisition in that firms which emphasize radical innovation are not able to develop all knowledge internally, but rather have to strongly rely on complementary external sources (Lichtenthaler, 2008). This result, in particular, deserves further analysis because the impact of the emphasis on radical

innovation is controversial. Indeed, when analyzed as an item within the technology aggressiveness construct, it seems to have a negative impact on the degree of external technology acquisition (Lichtenthaler and Ernst, 2009), but, if analyzed individually it shows the opposite influence, i.e. a positive influence on openness, interpreted as an inbound process (Lichtenthaler, 2008).

The inconclusiveness of the debate increases if we add in the analysis the contribution of Laursen and Salter (2006) who indeed find that only one dimension of openness - search depth (but not breadth) - is associated with radical innovation: in early stages of the product life cycle it is necessary to draw deeply from a small number of key sources of innovation in that only a few actors may have knowledge of the key technologies underlying the evolution of the product. Differently, when technology and market mature, more and more actors retain specialist knowledge, so that, in order to access the variety of knowledge sources in these networks, innovative firms need to scan across a wide number of search channels. In doing so, they seek to find new combinations of existing technologies to enable them to make significant improvements in their existing products.

Thus what emerges, therefore, is that literature, on the one hand, claims that "*[o]pen innovation is a matter of firm strategy*" (Bader and Enkel, 2014; 158), but, on the other hand, is characterized by very few contributions investigating the influence exerted by technological strategy on openness (Cheng and Huizing, 2014), and, most importantly, by an inconsistency of the obtained results, which is partly due to the different operationalization of both OI choices and technological strategy. This is the reason underpinning Huizing (2011)'s call for more extensive empirical research on this topic.

2.2 OI choices and performance

Rarely in the OI literature, a financial appreciation of firms' performance has been attempted; exceptions are those of Hung and Chou (2013), who show that inbound innovation is positively and significantly related to Tobin's q, and of Lichtenthaler (2009) who finds that inside-out open innovation activities have a positive effect on financial firm performance. Also Cheng and Huizing (2014) develop multiple performance measures to assess different aspects of innovation performance also including financial items and find that open innovation activities enhance innovation performance.

Rather, most contributions have concentrated on the analysis of the impact of the OI choices on performance in terms of company's competence base, development costs and time to market of new products/processes, as well as the level of innovativeness of the new products/processes.

Literature is unidirectional in showing the impact of the outside-in process on the access and integration of internal company capabilities with new and complementary knowledge of external firms (Chesbrough, 2003; Gassmann and Enkel, 2004; Hung and Chou, 2013). Instead, results are conflicting as far as the reduction of development time is considered: for instance, if on the one hand Gassmann and Enkel (2004) state that the benefits of co-operation are seen in an improvement in the competitive position and in a risk minimisation, but not in a reduction of development time, on the other hand, according to Kolk and Puüümann (2008), firms not concentrating on Open Innovation strategies fail, as rising development costs and shorter product life cycles make it increasingly difficult to justify investments in innovation.

Also, many contributions in the literature support the impact of open innovation on the level of innovativeness. Lichtenthaler (2008), Fernandes and Ferreira (2013), Dahlander and Gann (2007) and Dilk et al. (2008) underpin the effect of open innovation on firms' innovativeness and hence competitive position; similarly, show that the relationships with other actors help firms to increase innovativeness. Laursen and Salter (2006) quote many studies that point to the importance of open behavior in explaining performance differences between organizations and suppose that those organizations that invest in broader (breadth) and deeper (depth) search of external partners may have a greater ability to adapt to change and therefore to innovate. Their results also show that there are tipping points after which openness—in terms of breadth and depth—can negatively affect innovative performance. This negative impact on innovation performance is due to the high costs implied by over-search (Laursen and Salter, 2006), by increased complexity (Mintzberg, 1983), by over-collaboration (Ahuja, 2000; Katila and Ahuja, 2002), by exponential growth of management attention (Duysters and De Man, 2003) and by the difficulty in integrate external knowledge (Berchicci, 2013; Knudsen and Mortensen, 2011). To put it differently, a firm can suffer from information overload and diseconomies of scale once it is involved in too many partnerships at the same time

(Dittrich et al., 2007) and this may outweigh the benefits coming from the opening of the innovation process. The above curvilinear relationship between breadth and depth and innovation performance has been confirmed in more recent studies, reporting that beyond a certain threshold, a greater share of external R&D activities reduces firm's innovation performance (Berchicci, 2013; Garriga et al., 2013). These insights are important as they indicate that not all activities are beneficial and that their relationship with effectiveness may be nonlinear.

What comes out, therefore, is a rather fragmented and limited understanding of the open innovation–performance relationship, mostly due to the fact that literature often concentrates on only one aspect of OI or one aspect of performance (Cheng and Huizing, 2014). Therefore, according to Huizing (2011), it emerges a plea for more empirical research in order to overcome our limited understanding of the costs of openness (Dahlander and Gann, 2010).

2.3 Research hypotheses

The discussion above puts in evidence the existence of an important gap in the extant literature, which concerns the lack of a framework that, while considering concurrently technological strategy, OI choices and innovation performance, helps the readership to understand if openness (intended as outside-in process) plays a role in the relationship between technological strategy and innovation performance. Indeed, with the exception of Laursen and Salter (2006) and Cheng and Huizing (2014), to our best knowledge no work has been carried out on the relationship between the technological strategy, the OI choices and performance. While analyzing OI choices not only in terms of partners from which ideas and technological opportunities can be drawn, but also in terms of contents they provide and phases of the innovation funnel which are porous to knowledge flows from the outside toward the inside, we expect that the aggressive firms that intensely focus on radical innovation are likely to draw more deeply from few external sources of innovation than firms that are not aggressive (Laursen and Salter, 2006); we also expect that they open their innovation process in very few phases of the innovation funnel, specifically the early phases of the innovation process, to absorb external knowledge (Tushman and O'Really, 1996; Abernathy and Utterback, 1975). This is underpinned by those contributions that show that in the early phases of the product life-cycle, innovations come from a narrow range of sources, in many cases from universities and research

centers (De Backer et al. 2008; Perkmann and Walsh, 2007), or, as it happens in the bio-pharmaceutical industry, from firms which have already started the process of development of the new product in order to reduce risk of the development process (Chiaroni et al., 2009). Therefore the following hypothesis can be put forward:

HP1: The more is the firm's aggressiveness in technological strategy, the higher is the openness intensity (in terms of phases and partners) and in turn the impact on innovation performance

Also, the above literature suggests that when the collaboration is intense with few partners along few phases of the innovation process, then such an high intensity (in terms of phases and partners) implies a lower variety in terms of phases, partners and also contents in that few partners may bring in the collaboration relatively few contributions in terms of contents. Hence, we put forward the following hypotheses:

HP2a: The more is the openness intensity (in terms of partners), the lower is the variety (in terms of partners, phases and contents) and in turn the higher is the impact on innovation performance
HP2b: The more is the openness intensity (in terms of phases), the lower is the variety (in terms of partners, phases and contents) and in turn the higher is the impact on innovation performance

3 Methodology

3.1 Sample and data collection

We relied on a survey research developed in 2012 by a group of researchers from three different countries: Finland, Italy and UK. In order to ensure comparable results across nations, before each country began conducting the survey within their respective countries, guidelines regarding the design phase where distributed. We followed different steps for the survey development (Forza, 2002); the following describes the details of each of these steps.

Sample

Concerning sample, three main concerns were considered: target and frame population, sample design and sample size, as follows:

- Target and frame population: To draw the population frame, it was recommended that each country refer to widely available sources to promote study replicability. Hence, for the selection of the firms the use of the NACE Rev. 2 codes was suggested. In addition, it was recommended concentrating the analysis on the manufacturing industry (though CI also takes place in service industries or public administration), because theory-testing research requires a well-developed body of knowledge, and manufacturing is no doubt the most investigated field in the literature regarding open innovation; hence, the codes 10-32 and 98 in NACE Rev. 2 were chosen.

  Finally, in order to best represent open innovation activities, the recommendation was to include all statistical units with no less than 10 employees.
- Sample design: The choice was to conduct probabilistic sampling in order to ensure representativeness of the sample and, hence, the generalizability of results (Babbie, 1990).
- Sample size: Each country was urged to reach a minimum sample of 70 firms.

Data collection method

The data were collected by means of questionnaires distributed by email to participants. The advantages of such method include low cost, completion at the respondent's convenience, absence of time constraints, guarantee of anonymity and reduction of interviewer bias (Forza, 2002). Its shortcomings, on the other hand, are represented by lower response rate as compared to other methods, longer completion times and greater effects due to the lack of both interviewer involvement and open-ended questions.

Measurement instrument

The survey was conducted as a questionnaire whose items regarded company characteristics (in particular size and industry), the OI choices in terms of partners, phases and content, and the effects of OI on performance. Details about the measured items can be found in appendix A1.

Answers are measured by perceptive 7 point Likert scales, ranging from 1 = "not at all"/"strongly disagree" to 7 = "to a very high extent" /"strongly agree". In addition, respondents could choose "I do not know".

The measurement instrument was developed with guidelines in terms of wording, respondent identification and rules of questionnaire design. With regard to wording, closed questions were used (except for those regarding the company's name, number of employees, and the previous fiscal year's turnover). Regarding respondent identification, participating countries were urged to identify people who were knowledgeable about OI, in particular R&D managers or similar. The questionnaire was supplemented with a clear, but concise introduction providing an explanation of the aims of the survey, filling instructions and the guarantee of confidentiality.

Pilot testing the questionnaire

A test of the resulting questionnaire was conducted on two groups of subjects: colleagues and target respondents.

As for colleagues, the questionnaire was distributed to a group of colleagues to check whether the questionnaire accomplished its objectives. For target respondents, after the questionnaire was translated into the native language, each country had to involve a number of firms in order to gather feedback on anything that might affect the answers. These two tests were conducted independently.

Data sample

We could rely on a database of 415 firms spread across the three countries (87 firms in Finland, 152 firms in Italy and 176 firms in Sweden). Such firms can be taken as representative of manufacturing firms in their respective countries.

3.2 Constructs

The main variables investigated in the paper and validated by the CFA are reported in table 1. Beyond technological strategy and performance, our model includes a multi-faceted measure of openness, through the variables partner intensity (i.e. to what extent firm interacts with the different players of the innovation process); phase intensity (i.e. the firm's level of collaboration with partners at the different phases of the innovation process); and openness variety (i.e. the overall variety of the innovation process

measuring the number of different external players, phases and contents here included). Below details on the constructs are provided (Table 1):

- Technological Strategy: this construct measures the level of technological aggressiveness. Although the operationalization of this construct is newly created, some measures are underpinned by the literature: *i*. We focus on radical rather than incremental innovation is adopted from Lichtenthaler and Ernst (2009); *ii*. We have a broad product/market portfolio: adapted from Lichtenthaler (2008) and *iii*. We have a broad technology portfolio: adapted from Lichtenthaler (2008);
- Innovation Performance: The operationalization of this construct, which is built on Chiang and Hung (2010), has been published in Lazzarotti et al. (2011). Following recommendations in previous research (Cheng and Huizing, 2014), this study applies multiple performance measures to assess different aspects of innovation performance Its items are shown in table 1;
- Partner Intensity: the operationalization has been published in Lazzarotti et al. (2011), which builds on Laursen and Salter (2006). Seven external sources of knowledge and technology for innovation were considered (universities and research centers, innovation intermediaries, government agencies, customers, suppliers, competitors, companies operating in other industries). To compute Partner intensity, firms were asked to indicate on a 7-point Likert scale the intensity of collaboration with each external source;
- Phase Intensity: firms were asked to indicate to what extent they collaborated in the last five years with external sources along the five phases of the innovation process, from idea generation to commercialization (idea generation, experimentation, engineering, manufacturing, commercialization). This construct, which is adopted from Lazzarotti et al. (2011) and Lazzarotti and Manzini (2009), has an explorative nature: it aims to deepen the state of the art literature that, mainly focused on the 'who' question (i.e. the partners to be involved), not rarely has overlooked the 'where' question, i.e. the number and type of phases of the innovation process to be opened to external partners in order to collaborate and, hopefully, co-create along the innovation funnel (Lazzarotti and Manzini, 2009; Ferrero et al., 2013);
- The Content construct specifies the knowledge that partners provide in the open innovation process. The chosen constructs are built on work on supplier innovativeness elaborated by Azadegan and Dooley (2010), Oh and Rhee (2010) and

Wu et al. (2006). We defined eight items, covering access to new products, processes and markets and project and supply chain management (SCM) capabilities (see Table 1)

- Openness Variety aims to measures heterogeneity of sources during the openness innovation process. Specifically, the proposed construct accounts for diversity in partner enrollment, related phases of the innovation process and, finally, contents exchanged. Items which characterize this construct are built in order to measures (1) Partner Variety: the number of different partners actively involved in the innovation processes, (2) Phase Variety: the number of different phases interested by external collaboration and (3) Content Variety: the number of different contents concerning for example access to new technology, process and product innovations, or more broadly capabilities and/or competences (reference items are reported in appendix). The measurement items 1, 2, 3, take into account the number of sources assuming that the specific partner/content/phase is used if the specific answer on the Likert scale is >1, or not used if =1. Finally, the aggregated measures simply add the 1s and 0s.

3.3 SEM

The research model has been evaluated using a Structural Equation Modelling (SEM) approach since it is widely recognized as having substantial advantages over the first-generation techniques such as principal components analysis, factor analysis or multiple regression (Anderson and Gerbing, 1988; Chin, 1998; Shah and Goldstein, 2006). The SEM method in fact allows researchers to model, simultaneously estimate and test complex theories with empirical data.

After the theoretical specification of the research model and the sub-sequent definition of the structural model and the related constructs (see previous sections where hypotheses elicitation and construct operationalization are discussed), the main steps for model testing are reported here following:

a1) Collect data for model testing;

a2) Test reliability of constructs;

a3) Test the structural model;

a4) Evaluate the model fit, and

a5) Interpret the results and eventually refine the model.

4 Analysis and results

As anticipated, we have first tested constructs' reliability; after that, causal relationships were introduced and evaluated by testing the full structural equation model.

4.1 Construct reliability

CFA was assessed to validate reliability of adopted constructs and measures. We have assumed Content Validity to be maintained, since the constructs are mostly well-grounded in the literature. Reliability of constructs was then tested using the internal consistency method that is estimated using Cronbach's alpha (Cronbach, 1951; Nunnally, 1978; Hull and Nie, 1981). Typically, reliability coefficients of 0.70 or higher are considered adequate (Cronbach, 1951; Nunnally, 1978). Nunnally (1978) further states that permissible alpha values can be slightly lower (0.60) for newer scales. As an addition, loadings and their statistical significance (Dunn et al., 1994) for constructs' items were examined as preliminary evidence of convergent validity.

Outputs from the analysis are reported in table 1 and show that all the theoretical constructs exhibited quite acceptable levels of reliability. Results show that all the factor loadings are above the .60 and that the alfa-cronbach indexes respect the selected threshold in order to allow confirming reliability of the constructs. Just a critical point has been evidenced and it is about the Openness Variety construct which present a Cronbach's alpha Index of .55. At the same time, the novelty of the construct proposal support us in maintain Openness Variety into the investigated model with an exploratory connotation.

Measures	**Factor loadings**
Technological strategy (Alfa-Cronbach .82)	
We prioritise new product and service development and innovation to meet new and changing consumer demands	.67
We aspire to be the technological leader	.74
We focus on radical rather than incremental innovation	.70
We try to hire the best scientists and experts in the market	.66
R&D and marketing are our core competencies	.71
We normally use innovative, flexible and non-routine technologies	.73
We have a broad product/market portfolio	.61
We have a broad technology portfolio	.72
Innovation Performance (Alfa-Cronbach .82)	
Reduce innovation risks	.78
Reduce new product/process development cost	.83
Reduce time to market	.77

Introduce new or significantly improved products or services	.74
Introduce new or significantly improved process of producing our products or services	.68
Partner Intensity (Alfa-Cronbach .67)	
Universities and research centres	.60
Innovation intermediaries	.63
Government agencies	.66
Customers	.61
Suppliers	.60
Consumers	.61
Phase Intensity (Alfa-Cronbach .70)	
Idea generation	.80
Experimentation	.84
Engineering	.73
Openness Variety (Alfa-Cronbach .55)	
Partner Variety	.72
Phase Variety	.77
Content Variety	.72

Table 1 - Measures

4.2 Structural model

The structural model was finally tested. Main results are summarized in figure 2 neglecting for sake of clarity and simplicity the other model parameters (e.g. construct covariance, factor loadings and errors) which can be found in the appendix.

The hypothesized relationships between Technological Strategy and Innovation Performance constructs, as mediated by the Intensity (here measured both in term of Partner and Phase Collaboration) are supported by the data. Standard regression weights are .59 (significant at the .001 level) between Technological Strategy and Partner Intensity constructs and .47 (significant at the .001 level) between Partner Intensity and Innovation Performance. In the case of Phases Intensity their measures are .41 (significant at the 0.001 level) and .19 (significant at the 0.01 level) respectively.

As concerning the construct Openness Variety, instead, it is evident the central role on the final impact on Innovation Performance. Regression weight is negative -.27 (significant at the 0.01 level). The negative impact is in its turn influenced by the constructs Partner Intensity and Phase Intensity. The first positively impacts on Openness Variety: measured regression weight is .40 (significant at the 0.001 level). The second pattern, on the contrary, reveals a negative impact: regression weight is -.29 (significant at the 0.001 level).

Figure 2 and Appendix report details about the estimated impact of Openness factors on the Innovation Performance construct.

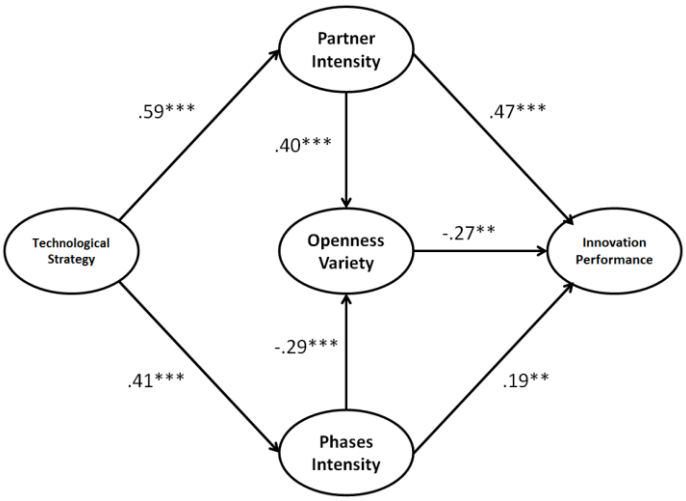

Figure 2 - The structural model

4.3 Model fit

As recommended, a set of multiple fit indexes (see table 3) was used to check the goodness-of-fit of the measurement scale with data. Goodness-of-fit criteria evaluate how well the data fits the proposed model and are generally categorized into three groups representing (absolute) model fit, (incremental) model comparison, and model parsimony (Schumacker and Lomax, 1996). Concluding, these evidences provide an overall good support for the results to be deemed an acceptable representation of the hypothesized constructs.

Index	Value for RI	Recommended values For a good fit	Recommended values for very good fit	Sources
χ^2	607.6	-	-	-
RMSEA	0.06	< .08	< .05	Byrne, 1998
NFI	0.82	>.8	> .9	Byrne, 1998; Zhang et al., 2002
N-NFI or TLI	0.87	>.8	> .9	Byrne, 1998; Zhang et al., 2002
CFI	0.88	>.8	> .9	Byrne, 1998; Zhang et al., 2002
IFI	0.89	>.8	> .9	Byrne, 1998; Zhang et al., 2002
PNFI	0.71	-	> .5	Byrne (1998), Mulaik et al. (1989).
PCFI	0.77	-	> .5	Byrne (1998), Mulaik et al. (1989).

χ^2/df	2.34	>1 and <5	>1 and <3	Bollen (1989); Carmines and McIver (1981); Hair et al. (1998); Jöreskog, 1969

Table 3 - Multiple fit indexes

4.4 Results

Findings show that Technological Strategy construct is positively related with openness if measured as both Partner Intensity and Phase Intensity (relationship with openness variety instead is not significant), which in their turns, are positively related with Innovation Performance. Therefore hypothesis 1 seems to be supported. As an addition, preliminary evidence from the model also seems to suggest full mediation of these two constructs between Technological Strategy and Innovation Performance since the direct relation becomes not significant if analyzed concurrently. Thus effectiveness of a firm's technology aggressive behavior obtaining higher innovation performance seems strongly related to the intensification of collaboration with the partners along the innovation funnel.

Conversely, openness variety seems to play an opposite role which is differently affected by openness Partner Intensity and Phase Intensity. Particularly, when interpreted in terms of Partner Intensity and Variety, the relationship between openness construct and Innovation Performance confirms the pattern evidenced by Laursen and Salter (2006). Increasing intensity with partners is positively related with higher Innovation Performance, but this is also related with a major Variety in terms of partners, phases and contents which has in its turn a negative relation with final Innovation Performance, so limiting the previous positive effect. This result, which does not support HP2a, clearly emphasizes the cost-side of an open behavior becoming harder to be managed, and thus costly, when involving too many different partners, phases and contents; and, it also alerts about the need to find adequate strategies for effectively managing the collaboration process in order to avoid waste of resources and efforts. Possible routes obviously spread from reducing the system complexity e.g. limiting partner, phase and content variety, to trying to manage the increased process complexity e.g. through the identification of adequate managerial levers, and also the definition of criteria for optimal allocation of resources supporting/driving the focalization of efforts depending on context specific factors/needs.

On the contrary, if openness is interpreted as Phase Intensity, i.e. the intensity of external collaboration during the different phases of the innovation process, the model supports

H2b. Indeed, if it is still true that the Phase Intensity construct is positively related to Innovation Performance, Phase Intensity has a negative relationship with Variety (which in its turn is negatively related with Innovation Performance) so suggesting a restrictive effect on Variety. Thus, the higher the intensity during the different stages of the innovation process the lower is likely to be the overall Variety in term of Partners, Phases and Contents. This condition could also limit the negative effect of Variety on Innovation Performance.

The final outcome is that, technologically aggressive firms increase both partner and phase intensity; but, while the former, in increasing variety, negatively impacts on performance, the latter, in reducing variety, positively impacts on performance.

A first interpretation of this evidence may also suggest that phase focalization is a possible candidate (or strategy) in order to manage complexity of the collaboration process and thus a way to deal with the costs and potential inefficiencies of Open Innovation. Keeping collaboration efforts high and focused on specific process phases, avoiding marginal/superficial involvement of resources potentially leading to misuse and dispersion, might help firms in limiting, selecting or managing Openness Variety more effectively and finally obtaining better innovation results.

5 Discussion and Conclusions

Our approach to study open innovation effectiveness (Huizing, 2011) was to investigate the reasons why firms open up their innovation processes, and in particular to contribute on the debate about the relationship linking technological strategy, openness and performance. Specifically, we examined the effects of technological strategy, an organizational characteristic that has often been used in innovation studies, but until now has seldom appeared in open innovation studies (Cheng and Huizing, 2014).

Results show that openness, if measured as Partner Intensity and Phase Intensity, mediates the relationship between Technological Strategy and Innovation Performance. In other words, the direct relation between Technological Strategy and Innovation Performance is not significant, by suggesting that the effectiveness of a firm's technologically aggressive behavior is strongly related with the intensification of collaboration with the partners along the phases of the innovation funnel. Therefore, our results confirm what found by Lichtenthaler (2008) and by Laursen and Salter (2006): firms with an aggressive technological strategy need to draw deeply from partners along

the funnel, and this allows them to increase performance in terms of reduction of risks (Gassman and Enkel, 2004), costs and time (Kolk and Puüümann, 2008) and in terms of innovativeness (Lichtenthaler, 2008; Fernandes and Ferreira, 2013; Dilk et al., 2008; Dahlander and Gann, 2007). However, the positive impact of openness (in terms of Phase and Partner Intensity) on Innovative Performance is influenced by Variety which indeed negatively impacts on Innovation Performance. This result likely emphasizes the cost-side of an open behavior becoming harder to manage, and thus costly, when involving too many different partners, phases and contents (Laursen and Salter, 2006; Knudsen and Mortensen, 2011; Mintzberg, 1983; Ahuja, 2000; Katila and Ahuja, 2002; Duysters and De Man, 2003; Berchicci, 2013; Dittrich et al., 2007). However, our article goes a step forward in that it puts in evidence the key role played by Phase Intensity, which behaves oppositely with respect to Partner Intensity: while this last is positively related with Variety, having Variety a negative effect on Performance, Phase Intensity is negatively related with Variety, which on its turn is negatively related with Innovative Performance. This result is important in that it puts in evidence that technologically aggressive firms can intensely open their innovation funnel in very few phases of the innovation funnel, so limiting the negative effect of Variety on Innovation Performance.
This evidence, however, may be due to the specific features of the collected data (i.e., distribution of observation of the firms' OI choices) in the data sample which may lead to some generalization problems. Most of the firms, in fact, present a high balance between the OI Partner Intensity and OI Phase Intensity. This can overall limit our ability to catch the variance of the OI choices dimension with respect to the performance index and to consider the impact of this component on the measure. Following this limitation, further analyses and tests are needed on different data samples, or on extended versions of the current dataset, in order to provide new evidence and more representative cases in order to explore different firm OI configurations.

Beyond the emerged results as concerns the interplay among the investigated variables, the originality and the value of our paper reside also in two methodological connotations:

- A more fine-grained definition of the openness concept, which takes into consideration other facets of openness with respect to those usually analysed in the literature;

- A powerful statistical model, as SEM, offering great advantages and flexibility in order to match the theoretical model with the data, and especially to model complex relations amongst multiple variables, consider unobservable latent variables, evaluate measurement errors for observed variables and constructs. This usually leads to more valid conclusions on the construct level.

This study offers several implications for practitioners. Firms, which adopt an aggressive technological strategy, are recommended to deeply open their innovation process in order to foster innovation performance. However, due to the fact that a high openness variety could generate some downside, managers should be very careful in the management of different sources and contents.

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APPENDIX

Table A1 Constructs and measures in the questionnaire

ID	Constructs and items
	Technological strategy
T1	We prioritise new product and service development and innovation to meet new and changing consumer demands
T2	We aspire to be the technological leader
T3	We focus on radical rather than incremental innovation
T4	We try to hire the best scientists and experts in the market
T5	R&D and marketing are our core competencies
T6	We normally use innovative, flexible and non-routine technologies
T7	We have a broad product/market portfolio
T8	We have a broad technology portfolio
	Innovation Performance
I1	Reduce innovation risks
I2	Reduce new product/process development cost
I3	Reduce time to market
I4	Introduce new or significantly improved products or services
I5	Introduce new or significantly improved process of producing our products or services
I6	Opening of new markets
	Partner Intensity
Pa1	Universities and research centers
Pa2	Innovation intermediaries
Pa3	Government agencies
Pa4	Customers
Pa5	Suppliers
Pa6	Consumers
Pa7	Competitors
Pa8	Companies operating in other industries
	Phase Intensity
Ph1	Idea generation
Ph2	Experimentation
Ph3	Engineering
Ph4	Manufacturing
Ph5	Commercialization
	Content
C1	Advanced technologies
C2	Innovative products
C3	Innovative processes
C4	Access to new markets
C5	Reliable delivery
C6	SCM responsibility
C7	Project management capability
C8	Improvement capability
	Openness Variety

OV1	Partner Variety
OV2	Phase Variety
OV3	Content Variety

Table 1 – Constructs and items

Table A2 Structural model AMOS estimates

			Estimate	S.E.	C.R.	P	Label
Partner Intensity	←	**Technological Strategy**	,868	,127	6,835	***	par_16
Phase Intensity	←	**Technological Strategy**	,429	,081	5,292	***	par_23
Openness Variety	←	**Partner Intensity**	,380	,084	4,517	***	par_19
Openness Variety	←	**Phase Intensity**	-,389	,111	-3,499	***	par_25
Innovation Performance	←	**Partner Intensity**	,399	,073	5,434	***	par_17
Innovation Performance	←	**Openness Variety**	-,239	,076	-3,141	,002	par_18
Innovation Performance	←	**Phase Intensity**	,224	,085	2,643	,008	par_24
Ph3	←	**Phase Intensity**	1,000				
Ph2	←	**Phase Intensity**	1,543	,178	8,663	***	par_1
Ph1	←	**Phase Intensity**	1,314	,153	8,614	***	par_2
I1	←	**Innovation Performance**	1,000				
I2	←	**Innovation Performance**	1,190	,084	14,227	***	par_3
I3	←	**Innovation Performance**	1,047	,080	13,107	***	par_4
I4	←	**Innovation Performance**	,753	,071	10,534	***	par_5
I5	←	**Innovation Performance**	,724	,079	9,218	***	par_6
T8	←	**Technological Strategy**	1,000				
T7	←	**Technological Strategy**	,897	,098	9,190	***	par_7
T6	←	**Technological Strategy**	1,299	,125	10,393	***	par_8
T5	←	**Technological Strategy**	1,263	,146	8,673	***	par_9
T4	←	**Technological Strategy**	1,139	,132	8,641	***	par_10
T3	←	**Technological Strategy**	1,234	,131	9,443	***	par_11
T2	←	**Technological Strategy**	1,482	,141	10,530	***	par_12
T1	←	**Technological Strategy**	1,106	,122	9,054	***	par_13
Partner Variety	←	**Openness Variety**	1,000				
Phase Variety	←	**Openness Variety**	,673	,106	6,347	***	par_14
Content Variety	←	**Openness Variety**	,923	,151	6,120	***	par_15
Pa3	←	**Partner Intensity**	,777	,088	8,815	***	par_26
Pa2	←	**Partner Intensity**	,718	,093	7,711	***	par_27
Pa1	←	**Partner Intensity**	1,000				
Pa6	←	**Partner Intensity**	,517	,082	6,313	***	par_28
Pa5	←	**Partner Intensity**	,560	,092	6,098	***	par_29
Pa4	←	**Partner Intensity**	,541	,088	6,131	***	par_30