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Using Internal Coupling Activities To Enhance The Effectiveness Of Open Innovation

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Abstract

This paper investigates the role of specific intra-organizational mechanisms in analyzing performance implications of openness by addressing two questions: does openness to innovation influence innovation performance? And if so, what organizational activities facilitate increased effectiveness of both inbound and outbound open innovation practices? The paper identifies a set of internal management mechanisms that allows the firm to couple the outside-in and inside-out knowledge flows in support of integrating external knowledge and internal competencies. The empirical basis of the study is a survey carried out in 321 Danish SMEs in manufacturing industries. The paper cannot substantiate the thus far, seemingly positive evidence of openness on innovation performance. Rather, the paper finds that inbound open innovation is related to the introduction of new products, whereas the adoption of outbound open innovation is positively related to innovation profitability. Furthermore, the paper finds that the use of internal coupling activities mediates the relationship between openness and innovation profitability. The main result is that the benefits of open innovation are fully captured only when firms adopt a number of coupling activities that provide employees with time, autonomy and empowerment to conduct their work. The paper therefore contributes to the innovation management literature by developing the concept of internal coupling activities, testing these on a set of open innovation practices, while distinguishing between respectively the effects of inbound and outbound openness on innovation performance. The paper concludes with implications to theory and practice.

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Introduction

Single organizations find it difficult to innovate alone. Albeit not new, this idea has gained prominence in recent years, prompted by an organizing trend towards more porous organizational boundaries in which firms increasingly exchange resources and ideas with external partners (Dahlander and Gann, 2010, Huizingh, 2011, Van De Vrande et al., 2010). Within a short timeframe, this organizing trend known as 'open innovation' (Chesbrough, 2003) has been established as an important, if also contentious, topic for both researchers and practitioners. It can be viewed as an umbrella term, as it encompasses, connects and integrates both the internal and the external execution of a wide range of practices related to knowledge acquisition and commercialization – also known as the inbound and outbound dimensions. Open innovation (OI) has indeed become a popular management concept since it is recognized as a means of achieving increased innovative outcome (Laursen and Salter, 2006, Lilien et al., 2002, Pullen et al., 2012). The evidence is, however, not entirely positive. While Laursen and Salter (2006) identified a limit to the positive effects, Knudsen and Mortensen (2011) found negative effects of openness to NPD results and Czarnitzki and Thorwarth (2012) found no significant influence of design conducted in collaboration with external partners for new product success. Nevertheless, the overall performance expectations around open innovation are undeniably optimistic: higher efficiency, reduced costs and shorter developmental processes are some of the most cited outcomes (Dittrich and Duysters, 2007, Faems et al., 2010, Fu, 2012, Spithoven et al., 2010, Trott and Hartmann, 2009).

Yet, these performance expectations are not always translated into concrete results. While some pioneering firms have attained substantial benefits (Huston and Sakkab, 2006), many others experience difficulties in capturing value from external in- and outflows of knowledge and information (Knott, 2008, Lee et al., 2010). In other words, there is great heterogeneity not only in the extent of adoption but also in the extent to which firms are able to profit from openness. Rather than just focusing on the performance effects of open innovation, it seems more fruitful to investigate the conditions under which its adoption is beneficial. Hence, which conditions may facilitate the effectiveness of openness? While some scholars have suggested that the success of open innovation depends on in-house R&D investments, since they are seen as complementary rather than substitute activities (Cassiman and Veugelers, 2006, Dahlander and Gann, 2010, Hagerdoorn and Wang, 2012), others have stressed the importance of external contingency factors. Strong appropriability regimes and high technology intensity are some of the industrial characteristics associated with higher reliance on external actors (Chesbrough and Crowther, 2006, Huizingh, 2011). However, with regard to organizational context characteristics not much is known beyond traditional features, i.e. how size, age or ownership type affect the likelihood of adopting open innovation (van de Vrande et al, 2009). In other words, contemporary research with a few exceptions (Bianchi et al., 2011, Buganza et al., 2011, Fu, 2012) still understands little about how strategic characteristics, organizational activities, resource endowments and management systems enable or hamper the functioning of the various dimensions of openness.

Understanding the role and effect of specific intra-organizational mechanisms is, however, of critical importance both from an academic and a practical perspective. The development of a more refined theory in which boundary conditions are established is absolutely essential, so that open innovation can be better delimited and hence not applied as an "all-purpose" solution in any setting. Put differently, there is a need not only to elucidate the actual practices that constitute an open innovation approach but also to define the conditions under which performance may be enhanced or hampered. Furthermore, managers ought to know from a practical perspective what in-house activities are needed when aiming at a successful adoption of an open approach to innovation and how they may facilitate the adoption by implementing specific mechanisms. This paper reinforces the notion that the focus on R&D investments and external contingencies needs to be complemented with a focus on internal mechanisms to explain the performance implications of openness.

Our study addresses this topic by posing two related research questions: *1) How does openness to innovation influence innovation performance? 2) What organizational activities* *facilitate increased effectiveness of both inbound and outbound open innovation practices*? Addressing the effectiveness of openness is an important issue in light of two significant shortcomings in the current literature. First, limited efforts have been made to estimate the differential impact of openness on the firm's ability to introduce new products per se and on the firm's ability to generate revenue from new products respectively. Second, although the literature acknowledges the multi-dimensional nature of open innovation, empirical studies have not investigated it simultaneously, nor its (potential) differential influence on innovative performance. Concretely, the paper suggests analyzing internal coupling activities as mediators of open innovation conceptualized as inbound and outbound on two different innovation performance outcomes. Our argument is that supportive organizational mechanisms like the coupling activities that promote autonomy in the form of intrapreneurial initiatives, dedicating time for creativity, and empowerment of employees is necessary to enable firms to benefit from openness. Hence, our study conceptualizes and tests some mechanisms with the firms' management systems that affect the reasons why some gain from the use of purposive in- and outflows of knowledge and others do not.

Theoretical Framework

The Benefits of Open Innovation

"Open Innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2003: xxiv). This definition covers the use of ideas and technologies developed outside the company as well as the use of external paths to market through which firms allow outside partners to exploit ideas and technologies (e.g. via licensing). The literature describes open innovation as an umbrella term encompassing, connecting and integrating both the internal and the external execution of a wide range of practices related to acquisition and commercialization of knowledge and technologies – also known as the inbound and outbound dimensions. Uncovering these dimensions brings forth a myriad of activities which vary in terms of the content of economic transactions (pecuniary vs. non-pecuniary), the types of ownership outcome (public vs. private), the forms of participation (open vs. closed) and the choices of governance modes (flat vs. hierarchical) (Dahlander and Gann, 2010, Huizingh, 2011, Pisano and Verganti, 2008). Research consortia between university and industry, open source software and the lead-user method are all considered manifestations of openness (Henkel, 2006, Perkman and Walsh, 2007, Von Hippel, 2005). As OI integrates a wide range of phenomena, it goes well beyond the involvement of external actors in new product development projects.

In terms of effectiveness, OI is regarded as a means of accelerating internal innovation processes and of allowing organizations to benefit from innovative efforts (Fu, 2012, Van de Vrande et al., 2009). Inbound activities range from Internet searches, which are selected based on the problem at hand and may be fruitful as inspiration for new trends and ideas, to complex practices such as R&D purchases, which may bring entirely new solutions to product development problems. Irrespectively, inbound practices are expected to facilitate access to resources, knowledge and competencies otherwise unavailable to the firm.

Inbound practices benefit innovative activities in a number of important ways. They expand innovation possibilities by complementing the organizational knowledge base, as by its very nature innovation relies on novel combinations of existing pieces of knowledge (Schumpeter, 1934). If a firm depends solely on the internal production of ideas, its ability to introduce new things is naturally limited. Knowledge insourcing may also help firms avoid competency traps triggered by inertia and path dependency (Coombs and Hull, 1998, Leonard-Barton, 1992). Since knowledge is situated, or in another word, contextualized (Tyre and Von Hippel, 1997), the use of external knowledge is likely to challenge an organization's cognitive maps, established routines and technology trajectories, consequently driving adaptation of its processes and structures to new insights and new solutions. Inbound practices are instrumental in keeping firms updated with market and technology-related trends by relying on insights obtained from customers, universities and other key innovation sources. Therefore, the integration and combination of different sources of knowledge can facilitate the discovery of radical new solutions to problems. The study of Von Hippel et al. (1999) uncovers how the involvement of external sources, like lead users, led to the creation of breakthrough products in 3M. Furthermore, by leveraging complementarities with partners, firms can share risks, reduce costs and substantially shorten developmental processes. As an example, Huston and Sakkab (2006) reported that the R&D productivity of their organization increased by nearly 60% with the implementation of an open innovation approach focused on the acquisition of technologies from outside. Hence, the paper posits:

H1: Inbound open innovation practices are positively related to innovation performance.

Outbound practices refer to outward technology transfer and comprise activities such as out-licensing agreements, provider activities (i.e. that firms are active in providing input and knowledge to other firms' innovation projects) and free revealing. In other words, they are the means that support the external exploitation of technology assets, either exclusively or in addition to their internal application. By establishing mechanisms for the licensing, selling and sharing of technologies, outbound practices enable companies to better realize the monetary and strategic potential of the active commercialization of knowledge (Guilhon et al., 2004, Koruna, 2004). The monetary benefits arise mainly from licensing revenues, which represent the net value of the flow of money ensued to the licensor firm in the form of royalty payments. Yet, as licensing leads to increased competition, the generated revenues must be balanced against the lower price–cost margin and/or the reduced market share it implies (Fosfuri, 2006). Other possible sources of income from outbound OI are the selling of complementary products and/or services (Arora et al., 2001) and compensations from patent infringements.

In addition to generating revenues, firms may use outward technology transfer in a number of strategic ways. It may be employed as a means of entering new markets, particularly foreign markets, thereby expanding the geographical reach of innovations (Lichtenthaler and Ernst, 2007). Paradoxically, it may also be used for gaining access to external knowledge (Dahlander and Gann, 2010, Koruna, 2004). Licensing and cross-licensing agreements are increasingly necessary in order to obtain access to the technology portfolio of other industry participants, considered a core source of competitive advantage in cumulative technology fields (i.e. fields where technologies consist of a number of interconnected components and in which current improvements are tightly related to previous innovations) (Grindley and Teece, 1997, Somaya et al., 2011). The study by Grindley and Teece (1997) of the semiconductor and electronics industries reveals that unless a company is able to develop and present its own patent and license portfolio in cross-licensing negotiations, it will encounter obstacles in its continued product development (due to mutually blocking patents), or alternatively, will have to incur in prohibitively high royalty payments. Besides, technology licensing or sharing may be an approach to speed up the diffusion of innovations, thereby guaranteeing the establishment of industry standards (Gassmann and Enkel, 2004, Guilhon, Attia and Rizoulières, 2004), which ultimately impact firms' ability to profit from its innovations (Teece, 1986). Finally, an entirely strategic path to innovation is engagement in provider activities. For every inbound activity carried out by a firm, a reciprocal outbound activity by another firm must be generated (Huizingh, 2011). Reciprocal outbound activities range from the transfer of knowledge and ideas to solutions to other firms' new product development projects (Tranekjer and Knudsen, 2012). The benefits of providing are especially learning and knowledge creation, which ultimately lead to improved innovation performance (Koruna, 2004, Tranekjer and Knudsen, 2012). Hence, the paper posits:

H2: Outbound open innovation practices are positively related to innovation performance.

The Mediating Role of Internal Coupling Activities

In addition to establishing outward-looking practices that transcend organizational boundaries, open innovation also requires firms to establish internal management practices, so-called coupling activities (Huizingh, 2011). Coupling activities refer to activities that combine the outside-in and inside-out knowledge flows thereby supporting the integration of external knowledge and competencies to the firm's resource base as well as providing the resources and competencies appropriate for externalization of in-house knowledge and competencies that will lead to higher performance (Gassmann and Enkel, 2004). Even though the importance of coupling activities has been mentioned in several studies (Foss et al., 2011, Huizingh, 2011), the literature has not yet fully identified the nature and diversity of these activities. Particularly, coupling activities carried out internally in the organization are an unexplored ground since prior work has focused on coupling activities performed cooperatively with external partners, e.g. via strategic networks (Gassmann and Enkel, 2004).

In particular, internal activities that give employees latitude, information and skills to work independently are expected to support the realization of external knowledge transactions. Realization of external opportunities requires not only that managers strategically facilitate such activities but also that the employees are allowed to exercise freedom and autonomy in the conduct of their work based on their ability to take initiative and find new opportunities in the surrounding environment.

These coupling activities that empower employees to work autonomously are expected to define the performance implications of open innovation in three key ways. First, as research on creativity has revealed (Amabile et al., 1996), individuals produce more creative work when they perceive themselves to have choices as regards how to go about accomplishing the tasks they are given. Because opportunities identified through open innovation channels are often poorly defined and hardly ever ready to be exploited immediately (Huston and Sakkab, 2006), they are intrinsically dependent on the creative act of employees in terms of finding new applications or markets for a given idea or technology. The need for creativity is intensified by the fact that, in open innovation, knowledge must be transferred to contexts where it was not initially meant to be used (Guilhon, Attia and Rizoulières, 2004), and furthermore, is likely not to be well aligned with the existing knowledge base of the company.

Second, when collaborating with external partners, employees must have high levels of autonomy to make decisions in a timely and flexible fashion for the benefit of the collaborative venture. If employees are required to consult upper-echelon managers for every decision, an unproductive collaborative environment marked by a slow pace of progress is the likely outcome, and also employees will tend to follow tight procedures and make uninformed decisions. Foss et al. (2011) found support for this argument indicating that a reallocation of decision rights was necessary to improve the sourcing and use of knowledge held by customers.

Third, when employees work with own ideas in an intrapreneurial fashion, they are likely to be more involved and motivated to champion ideas (Kuratko et al., 1990). Motivation plays a key role in the context of openness because of the high coordination costs that external knowledge transactions imply (Grant, 1996) as well as the inherent imperfections of the markets for technology (Arora, Fosfuri and Gambardella, 2001, Guilhon, Attia and Rizoulières, 2004), which requires individuals to devote extra efforts in completing transactions. The selling of technologies, for instance, is typically a marginal and temporary strategic concern in most companies (Granstrand, 2004), for which there are no well-established structures and processes. It thus depends on employees that are highly motivated to transcend organizational routines and to create new processes that challenge established ways of doing things, e.g. the tradition for selling primarily products and not licenses. It is the sense of ownership towards own ideas that can spur employees to find external markets for ideas and technologies that cannot be implemented within the company, thus supporting/allowing the attainment of performance from e.g. licensing, spin-offs or venture investments. As a result, highly motivated and involved employees are more likely to work outside the existing knowledge, market and technological domains of the company.

All in all, encouraging employees to work autonomously as well as empowering them with the skills and resources to do so is expected to support the ability to fully implement open practices, ultimately leading to higher innovation performance. Coupling activities are thus posited to act as mechanisms of intervention between openness and performance. Hence, the paper posits:

H3: Internal coupling activities mediate the relationship between inbound/outbound open innovation practices and innovation performance.

Insert Figure 1 about here

Methodology

Sample

The empirical analysis of the paper is based on a cross-sectional survey collected in the period from August to November 2010. The data was gathered among a population of Danish firms in the R&D (NACE 72) and manufacturing industries (NACE 10-37) and in the category of small and medium-sized enterprises (SMEs), i.e. with 5-499 employees. The firms were identified in a nationwide database (KOB), considered the most detailed and updated directory of companies in the country. Using the criteria of industry affiliation and firm size, a total of 4,445 firms were identified as our population target. All of them were contacted by phone so that we could introduce the study, identify the right informants (i.e. either the R&D or innovation manager), obtain their e-mail addresses and get their consent for sending the survey. The questionnaire was carried out online and in Danish, since this is the informants' work language. Of the 4,445 companies contacted, 1,051 (40.2%) agreed to participate and therefore received the link to the survey. A total of 345 questionnaires were returned after two reminders. After screening for inconsistent answers, there were 331 usable questionnaires. Due to the peculiarities of the innovative process of firms belonging to the R&D sector (in terms of the intensity of R&D expenditures and outcome), they were excluded from the database (NACE codes 7211 and 7219). As a result, our final sample consists of 321 firms, yielding a response rate of 30.5% (based on the achieved acceptances) or 7.2% (based on the original population).

Our choice of sampling was motivated by several criteria. First, a multi-industry approach was preferred, because our aim was to investigate the occurrence of open innovation in a wide range of sectors covering low, medium and high-tech, so as to move beyond the focus on high-tech industries that prevail in the literature (Van De Vrande, Vanhaverbeke and Gassman, 2010). Second, SMEs were selected for being a particularly well-suited context for our hypotheses. This is because, on the one hand, to a greater extent they rely on inflows and outflows of knowledge from outside their boundaries to sustain innovation in order to compensate for their resource deficiencies (Bierly III and Daly, 2007). On the other, even though they constitute the large majority of firms in many economies, they have been largely overlooked in this research field, which has mainly investigated openness in the context of large multinational companies (Huizingh, 2011) (see *Table 1*). Third, the R&D or innovation managers were considered the most appropriate informants for our survey, because they are responsible for the technology-related aspects of their companies as well as for the organization of innovation activities both internally and externally. We are confident that they are able to make informed assessments about internal innovative activities as well as about practices related to knowledge in- and out-sourcing. However, in the cases of firms without these job titles/functions, the business owner or general manager was asked to fill in the survey questionnaire. In any case, all informants were requested to have more than three years of work experience in the company to ensure that they possessed sufficient knowledge to reply appropriately to the questions.

The sample of firms contains mainly smaller companies, in that 76.3% of them have fewer than 50 employees. Besides, 78.5% of the firms in the sample introduced new products within the last three years (2007-2009), yielding 252 innovative firms. Compared with the results from the Community Innovation Survey in Denmark, which consistently indicate that nearly half the firms launched new products within the previous three years (these values were 42% in 2008 and 46% in 2007), our sample is considered to be biased toward more innovative firms. This is due to the fact that companies were screened out if they had no innovation-related activities in the three years prior to data collection, as this was considered the maximum timespan respondents could recall when responding to the questionnaire. As *Table 1* indicates, the share of innovative firms increases from 78.5% to 100% for the largest firms (up to 500 employees) suggesting that more firms are innovative when size is taken into account. With respect to industry affiliation, the majority of firms participating in this study belong to the medium to low-tech sector (34.6%). The most innovative companies appear in high-tech industries (90% of high-tech companies), and the lowest level relates to low-tech industries (77%).

Insert Table 1 about here

The data was tested for representativeness comparing the population with the firms that accepted and the ones that actually replied to the survey questions. We applied t-tests to compare our sample, potential respondents and the population means with respect to variables such as industry classification (on the basis of NACE code one digit), firm size (six size groups), and regional distribution (in terms five administrative regions of Denmark). As the comparisons did not reveal any significant differences between any of the three groups (population, accepts and respondents), we accept that the sample is representative of the underlying population with respect to these objective measures.

Measures

*Dependent variables***.** Innovation performance, the dependent variable, is measured both as the output (whether or not a firm has introduced a new product on the market within the years prior to data collection) labelled “product innovation”, and as the percentage of turnover from new products that was launched within the last three years (2007-2009) labelled “innovation profitability”. These proxies have been extensively used in the literature to illustrate innovation performance (Knudsen, 2007, Laursen and Salter, 2006) and are both used to disentangle the effects of openness on different performance outcomes. Whereas product innovation is a binary variable (yes/no), innovation profitability is double censored (as it ranges between 0 and 100 by definition) and highly skewed, as its distribution is truncated around zero (i.e. 46% of the firms have renewed less than 10% of their turnover in the last three years). On average, 22.6% of the turnover of the firms in our sample was achieved from products that were finalized in the last three years.

Independent variables. The paper measures openness according to a set of practices related to knowledge in and outflows, such as purchasing R&D work and actively participating in other companies' innovation process (see *Table 2*). The contention of the paper is that, even though the relationship measure based on the scope and the extent of use of external sources of knowledge (i.e. search breadth and depth) has prevailed in the literature (Laursen and Salter, 2006, Leiponen and Helfat, 2010), it does not fully capture the multifaceted nature of the concept. While recognizing the valuable contributions of these studies, appropriate attention should be given to the fact that external relations constitute a limited proxy of open innovation, since they cover only part of the multitude of practices the concept encompasses. Open innovation may happen, for instance, via other means such as Internet searches (see Pisano and Verganti, 2008 for a description and examples of these practices). Besides, the relationship measure carries a substantial problem as proxy since it does not capture outflows of knowledge, i.e. the outbound dimension. As argued by some of the authors more critical of the 'new paradigm of open innovation', the benefits of external partnerships have been suggested by academics and recognized by industry for decades (Trott and Hartmann, 2009). The question is how these 'old' partnering activities interplay with more recent examples of open innovation practices such as crowdsourcing and outsourcing of R&D. While underscoring the relevance of external partnerships for innovation, this paper argues that it constitutes a particular mechanism rather than a manifestation of openness itself.

As an alternative, a practice-based approach was used to measure openness. The selection of practices was generated from a literature review. After screening research addressing open innovation topics (Bahemia and Squire, 2010, Chesbrough and Garman, 2009, Van de Vrande, Jong, Vanhaverbeke and Rochemont, 2009), a comprehensive list of practices was identified with the aim of building an extensive rather than compressed list of practices. The 11 practices were then divided into two groups following the widely accepted classification (Dahlander and Gann, 2010, Van de Vrande, Jong, Vanhaverbeke and Rochemont, 2009): inbound and outbound open innovation. All practices were measured on a binary scale (yes/no) and the two indicators were calculated as the sum of their respective practices. The average number of practices used for all companies is 4.9 (mode = 6), while the innovative firms (5.1) generally use a higher number of practices as compared to the non-innovative firms (4.3).

Insert Table 2 about here

The most commonly adopted practices are inbound open innovation practices with a mode of 5, as 77 firms use five of the eight practices constituting the inbound dimension (mean = 4.2). Outbound open innovation practices are less used, with the mode of 1, as 167 of the firms in the survey have not implemented any of the outbound activities (mean = 0.67). Due to the reduced amount of categories of these variables, outbound OI has been entered as dummy variables in the regression models (D0 = none; D1 = one practice; D2 = two practices).

Mediator. In this paper, focus is specifically on three aspects of internal coupling activities related to the empowerment, autonomy and freedom of employees, namely: 1) supporting employees to work on their own ideas; 2) providing employees with time for creativity, and 3) initiated intrapreneurial activities. First, *supporting employees to work with own ideas* refers to the practices that empower employees with resources and autonomy to dedicate time to projects they initiated individually, but that do not constitute a specified task in their list of job responsibilities. Second, *time for creativity* refers to the 'loose time' employees are granted where they can engage in exploratory thinking and experiment with novel approaches to solve problems. Earlier research has suggested that, when employees do not experience a high time pressure and receive encouragement for their creative efforts, they are more likely to persist in their idea generation endeavours (Baer and Oldham, 2006). Examples of the first and second set of coupling activities include the use of skunk work and flexible work schedules, in which employees are allowed to spend a certain percentage of work time on own ideas. Google and 3M are examples of companies that allow employees to spend up to 20 per cent of their time on ideas they are passionate about (Bonn, 2001, Finkle, 2012). Whereas the first activity focuses on the content of the idea, i.e. the employee may work on own ideas, the second activity directly awards resources to it. Third, *supporting intrapreneurial activities* means that the company encourages and facilitates a culture of autonomous opportunity searching, also called an entrepreneurial mindset (McGrath and MacMillan, 2000), as well as the creation of new business in existing organizations via corporate entrepreneurship programs (Guth and Ginsberg, 1990).

These three activities were assessed in the form of binary measures (yes/no), which were then summed up to form the final construct used as a mediation variable (*Table 3)*. Mediators can play different roles in the relationship between openness and performance: they may decrease or increase the relationship or they may change the relationship between the independent and dependent variables.

Insert Table 3 about here

The measure 'internal coupling activities' is an ordinal variable that ranges from 0-3 (mean = 1.2; mode = 1). Since it cannot be considered a continuous variable, it was re-coded into dummy variables for estimation purposes according to the number of internal coupling activities employed (D0 = none; D1 = one activity; D2 = two activities; D3 = three activities).

Control variables. For the regression analyses, the paper adopts the following control variables of firm size, firm age, industry affiliation, R&D employees, process innovation and patent application.

We control for *firm size*, since the literature has suggested that this is a key characteristic negatively affecting the innovative performance of companies (i.e. large firms are generally considered less innovative than small ones) (Ahuja et al., 2008). *Firm age* is also included in the analysis because older firms are expected to be less likely to introduce new products and less likely to introduce radically new products that yield the highest returns (Ahuja, Lampert and Tandon, 2008). In our sample, the age of the firms ranged from 1 to 312 years with a mean of 41.1 years. As the distribution is skewed towards younger firms (with very few firms above 100 years of age), the variable was corrected using the logarithmic function. *Industry affiliation* is used as a means of controlling for external contingencies, once a multi-industry approach was employed in our data collection. We include industry controls with respect to their technology intensity, as defined by the OECD sectors, because high-tech industries have been related to higher innovative performance (Gassman et al., 2010, Pavitt, 1984). Precisely, two dummies are introduced (i.e. high-tech and low-tech sectors) having medium-tech as the basis level. As to control for internal sources of innovation, we take into account whether the firm had staff engaged specifically in R&D activities. The variable *R&D employees* is included as dummy variable (1= one or more R&D employees; 0 = none), because internal and external sources are considered complementary in the innovation process (Cassiman and Veugelers, 2006). In addition, we use a control for *process innovation* (dummy variable 1 = yes the firm has implemented new production methods or processes that are new to the firm in the last three years; 0 = no). This control was entered to accommodate the observations of Pisano and Wheelwright (1995), who argue that the simultaneous development of product and process is necessary. According to these authors, process innovation smooths the launch of new products and ensures a faster market penetration. Finally, *patent application* is included as a dummy variable to account for the firms that have applied (once or several times) for the formal protection of its inventions in the period from 2007 to 2009 (1= yes; 0 = no). Formal protection mechanisms such as patents are added to the analysis because they are considered important instruments in increasing the profitability of innovations (Teece, 1986).

Common method bias. In order to address concerns related to common method variance, we applied the Harman's single factor test in which all variables of our study were loaded into one exploratory factor analysis. As the un-rotated solution of this analysis resulted in four factors with Eigen values greater than one (each single factor accounted for no more than 20% of total variance), common method bias is not considered a serious issue for our study (Podsakoff et al., 2003).

Results and Discussion

Besides the descriptive facts (see *Table A* in the appendix), the paper employs logistic, Tobit and ordinal regression techniques to test the hypotheses, using the software SPSS version 19.

The Differential Impact of Inbound and Outbound Practices on Innovation Performance

The investigation starts with the focus on the main effects of openness on innovation performance, thus addressing the effectiveness of inbound and outbound practices.

The first part of the analysis relies on product innovation (i.e. the introduction of new products) as a proxy for performance. Since the dependent variable is binary, the logistic regression technique was employed. As expected, the results of *model 1* (*Table 4*) reveal that three controls are positive and significant: process innovation ($p<0.05$), R&D employees ($p<0.001$), and patent application ($p<0.05$). This implies that companies, which develop new processes, carry out internal R&D activities and protect inventions, have a higher chance of introducing novel products in the market. In contrast, none of the controls related to structural characteristics (firm size, age, and industry affiliation) are found to be significant. Furthermore, model 1 shows that inbound open innovation positively increases the likelihood of a firm to launch new products ($p<0.05$), while outbound open innovation has no significant effect. Hence, *hypothesis 1* is verified by these results, whereas *hypothesis 2* is rejected.

Insert Table 4 about here

The second part of the analysis is based on the measure of innovation profitability (i.e. the share of turnover from new products). A Tobit regression analysis was employed, since the dependent variable is double censored and truncated around zero (see *Table 5*) (Wooldridge, 2009). Out of the controls included in *model 3*, firm age was found to be significant and negative ($p<0.05$), whereas the high-tech sector dummy ($p<0.10$), process innovation ($p<0.001$) and R&D employees ($p<0.05$) were found to be positively significant. In other words, young companies belonging to high-tech sectors and companies that implement novel processes and internal R&D arrangements yield a higher turnover from innovative products. Interestingly, with regard to the openness measures, the opposite effect is found in *model 3* (compared to model 1). Inbound open innovation[1] is not significant in explaining turnover from new products, while outbound open innovation is (although only for dummy 2), which means that companies using two or more outbound practices experience higher turnover from new products. Thus, *hypothesis 1* is not supported in this model, whereas *hypothesis 2* is verified.

Insert Table 5 about here

Internal Coupling Activities Mediating the Effectiveness of Openness

In order to test the mediation effect of internal coupling activities, as postulated in hypothesis 3, we apply the method described by Frazier, Tix and Barron (2004) and MacKinnon (2008). The method consists of four estimation steps assessing: 1) the predictor–outcome relation; 2) the predictor–mediator relation, 3) the mediator–outcome relation, controlling for the effects of the predictor and 4) the significance test for the mediated effects. Regression techniques have been preferred over SEM due to the use of single indicator variables (versus a model with latent variables) and to the possibility of including control variables.

The first step of the mediation analysis is to establish that there is a significant relation between the predictor and the outcome variable. The results of this step were discussed in the previous sub-section (*models 1 and 3*, see *Tables 4 and 5*). Contrary to our expectations they reveal limited evidence of the effect of openness on innovation performance. Only the inbound dimension is positively related to product innovation, whereas solely the outbound dimension is positively related to innovation profitability. Even though a mediational study is typically grounded on the existence of the predictor–outcome relation, its absence does not inevitably hamper the

[1] Inbound open innovation was automatically converted into dummy variables for the operationalization of the estimations.

identification of mediator effects (MacKinnon, 2008). According to Frazier et al. (2004), this first step may not be necessary nor required if there is a convincing theoretical rationale for examining mediation. For instance, a situation in which treatment does not appear to be effective, albeit the theoretical conjectures. On the basis of earlier research, which has insisted on a positive causal relation between openness and performance (Chesbrough and Garman, 2009, Dahlander and Gann, 2010, Huizingh, 2011), we argue that this is the case in our model. Even in the absence of strong direct effects, it is useful to examine the mediation effect as it may elucidate the boundary conditions of open innovation, which have so far been much neglected in the literature.

In the second step, the mediator is regressed on the predictor variable. *Table 6* presents the results for this step, which was carried out with ordinal regression methods given the ordinal nature of the dependent variable (i.e. the internal coupling activities).

Insert Table 6 about here

The results of *model 5* reveal that both inbound and outbound open innovation are significantly related to internal coupling activities ($p<0.001$ and $p<0.05$ (D1 and D2) respectively). The outbound measure presents negative coefficients, because it was inserted in the regression as dummy variables on the basis of a zero value (D1; D2 =0). As a result, they imply that the both the lack of knowledge about and implementation of outbound activities has a negative relation with internal coupling activities.

It is worth mentioning that three control variables, low-tech sector ($p<0.05$), process innovation ($p<0.001$), and R&D employees ($p<0.1$) are significant (*model 5*) meaning that there is an association between the presence of low-tech sector companies, R&D employees and the mediator, and a negative association between the use of patent applications and the mediator. In addition, the test of parallel lines is insignificant ($p=0.71$) indicating that the impact from the dependent variable is the same on the probability of moving from one category to the next, irrespective of the considered category.

Insert Figure 2 about here

In the third step, the outcome variable is regressed on both the predictor and the mediator. Models 2 and 4 (in *Tables 4 and 5* respectively) present the results of this step. Internal coupling activities have no effect on product innovation (*model 2*), however presenting significant positive effects on innovation profitability (*model 4*, $p<0.05$). In both cases, the same controls remain significant as in the base models (*models 1 and 3*).

Insert Figure 3 about here

Since no relation was verified between *inbound* open innovation and innovation *profitability* in the first step, coupling activities fully mediate this relationship by acting as a distorter variable (MacKinnon, 2008). Conversely, as the direct impact of *outbound* open innovation on profitability is reduced in *model 4* ($p<0.05$) in comparison with *model 3*, coupling activities act as a partial mediator (Frazier, Tix and Barron, 2004) in this case functioning as a suppressor variable (MacKinnon, 2008). Hence, *hypothesis 3* can be verified with respect to innovation profitability.

In the final step, the significance of the mediated effect was examined using the formula of standard error derived by Sobel. On the basis of the estimates and standard errors calculated in *models 4 and 5*, the z-scores (the estimate of the mediated effect divided by its standard error) and the confidence intervals were computed for the mediated effect of both inbound and outbound practices. As the z-scores were greater than 1.96 and the confidence intervals were outside zero (see Appendix, Table 2), it can be concluded that the mediated effect is significant at the 0.05 level (Frazier, Tix and Barron, 2004, MacKinnon, 2008). Our results thus suggest that internal activities designed to provide employees with autonomy and empowerment are found to be critical for the effectiveness of openness for firms aiming at increasing the turnover from new products.

Table 7 summarizes our findings with respect to the test of the hypotheses:

Insert Table 7 about here

Robustness Analysis

With a view to verifying the robustness of the results presented above, we ran sensitivity tests with respect to the predictor variable. Specifically, we computed open innovation into a single measure, i.e. as the sum of all inbound and outbound practices (mean = 4.9; mode = 6; std. dev. = 1.86). The results reveal no direct effect of open innovation on performance assessed in terms of both output and profitability (step 1). Nevertheless, they confirm the positive and significant relation between openness and internal coupling activities (step 2) as well as between internal coupling activities and innovation profitability (yet not for product innovation), when controlling for openness (step 3). In this way, the mediation effect was again confirmed with respect to innovation profitability, suggesting robustness in our results.

Conclusions

The main result of our study is that the benefits of open innovation are fully captured only when firms adopt a number of internal coupling activities that provide employees with time, autonomy and empowerment to conduct their work. The paper contributes to the innovation management literature by developing the concept of internal coupling activities and testing it on a set of open innovation practices, while distinguishing between the effects of inbound and outbound openness on innovation performance. These findings were identified by analyzing two related research questions: 1) How does openness to innovation influence innovation performance? 2) Which organizational activities facilitate increased effectiveness of both inbound and outbound open innovation practices?

To answer the first question, the paper investigated the direct outcomes of the two dimensions of open innovation. We found that whereas inbound practices positively increase the likelihood of a firm introducing new products, outbound practices were found to positively increase innovation profitability. Opening up the innovation process to external knowledge input thus enhances firms' ability to market new products. Put differently, firms that spend resources on keeping up-to-date with trends and technologies (i.e. via trade magazines and fairs), insourcing ideas and information extra-organizationally (i.e. from lead users) or in acquiring external knowledge (i.e. via R&D purchases) are able to increase the likelihood of actually introducing new products on the market. External commercialization of technologies and active involvement in other actors' innovation process, in turn, are positively related to the economic returns of the new products. Hence, our findings partially confirm the theoretical expectations related to the positive outcome of openness, evidencing that the direction of openness is crucial for the realization of positive performance expectations.

Our contribution in terms of measurement is also worth mentioning. Compared to existing literature on performance expectations of openness, this paper adds a practice-based perspective to the study of open innovation. Previous literature investigating the topic has mainly focused on a more general conceptualization of openness and applied a more rough proxy for it. The majority of open innovation studies have also worked with inter-organizational relationships as proxy for openness, see e.g. Laursen and Salter (2006), Knudsen and Mortensen (2011), Leiponen and Helfat (2010), and Lee et al. (2010). This measure is one-dimensional and captures only firms' inbound activities. Further, our results on both dimensions and on performance measures nuance our understanding of the effects of openness by stressing the importance of considering the direction of openness.

To answer the *second* question, the paper examined the mediation effect of internal coupling activities. These activities are exemplified by intrapreneurial initiatives, supporting employees to work with own ideas, and time for creativity. In combination, these activities were found to be significantly related to innovative profitability (but not product innovation). For outbound open innovation, we found that internal coupling activities partially mediate the relationship (as the main effect on innovation profitability remains significant), whereas for inbound open innovation the coupling activities fully mediate the relationship (as inbound open innovation only affects innovation profitability through the coupling activities). In other words, the findings suggest that the effectiveness of openness depends on the activities that provide employees with autonomy and empowerment to conduct their work. They function as coupling activities in the sense that they facilitate the combination of the outside-in and the inside-out knowledge flows with firms' knowledge base enabling them to profit from openness (in terms of higher economic returns on innovation).

Implications to Research and Practice

In light of the methodology applied, our findings are particularly meaningful for the research agenda in the field because they rely on a large-scale quantitative study that simultaneously integrates the inbound and the outbound dimensions of openness. Prior empirical work in the field has mostly investigated the two dimensions separately and on the basis of distinct proxies, which has limited the comparability of the findings (Dahlander and Gann, 2010). Besides, as different performance measures were applied, a more nuanced view of the effectiveness of openness could be elaborated.

With respect to theory, our findings bear important implications for the advancement of the understanding of openness. The proposed framework contextualizes open innovation in terms of internal activities that explain its effectiveness. This is important for situating the openness construct, a necessary step for identifying the boundary conditions of this influential concept that has been promoted as an "imperative" (Chesbrough, 2003) organizational mode for innovative endeavours. Furthermore, our study links different research streams to the discussion of open innovation, such as the literature on new human resource practices (Laursen and Foss, 2003) and creativity (Amabile, Conti, Coon, Lazenby and Herron, 1996).

Our study provides useful insights for practitioners too. It indicates that inbound open innovation is effective for the companies that either are not launching new products or wish to increase the number of product innovations, whereas outbound open innovation is effective for firms that seek to increase their innovative profitability. Furthermore, it reveals how firms can be better equipped to benefit from openness and especially that managers, apart from explicit efforts to encourage the use of open innovation practices, should simultaneously encourage employees to work independently by granting them a certain autonomy. The paper furthermore suggests that managers may work with three distinct activities to enable the empowerment of employees. All in all, the findings collect evidence about the boundaries of the open innovation approach, and, in particular, identify specific activities that can be adopted by management to improve its outcomes.

Limitations and Future Research

This study has a number of noteworthy shortcomings. First of all, the results are based on a sample of firms mainly from medium-tech industries. Yet, one may question whether these results differ for particular industries. The controls included indicate that there may be more positive effects for high-tech industries. Second, the paper studies the number of open innovation practices at an aggregated level, but does not investigate the specific types of practices and their individual effects on innovation performance. Such analyses should be encouraged in a next step along this line of research. Besides, the data collection pre-defined a range of practices that could be subsumed under the heading of open innovation. However, further tests and validation of the list should be encouraged in forthcoming data collections. Third, only the short-term performance implications of openness are investigated due to the cross-sectional nature of the data. The collection of longitudinal data can enrich the analysis, as it will allow the examination of long-term effects. Finally, a future step in this field of investigation is to study the internal coupling activities individually; as to evaluate whether some activities are more effective than others and under which conditions (i.e. for small firms or large firms; for particular innovation projects, etc.). We encourage such discussions for future research and insights.

References

Ahuja, G., Lampert, C.M. and Tandon, V. (2008). Moving Beyond Schumpeter: Management Research on the Determinants of Technological Innovation. *Academy of Management Annals* 2(1), 1-98.

Amabile, T.M., Conti, R., Coon, H., Lazenby, J. and Herron, M. (1996). Assessing the Work Environment for Creativity. *Academy of Management Journal* 39(5), 1154-1184.

Arora, A., Fosfuri, A. and Gambardella, A. (2001). *Markets for Technology: The Economics of Innovation and Corporate Strategy*: MIT Press.

Baer, M. and Oldham, G.R. (2006). The Curvilinear Relation Between Experienced Creative Time Pressure and Creativity: Moderating Effects of Openness to Experience and Support for Creativity. *Journal of Applied Psychology* 91(4), 963-970.

Bahemia, H. and Squire, B. (2010). A Contingent Perspective of Open Innovation in New Product Development Projects. *International Journal of Innovation Management* 14(4), 603-627.

Bianchi, M., Chiaroni, D., Chiesa, V. and Frattini, F. (2011). Organizing for external technology commercialization: evidence from a multiple case study in the pharmaceutical industry. *R&D Management* 41 (2), 120-137.

Bierly III, P.E. and Daly, P.S. (2007). Sources of External Organisational Learning in Small Manufacturing Firms. *International Journal of Technology Management* 38(1-2), 45-68.

Bonn, I. (2001). Developing Strategic Thinking as a Core Competency. *Management Decision* 39(1), 63-70.

Buganza, T., Chiaroni, D., Colombo, G. and Frattini, F. (2011). Organisational Implications of Open Innovation: An Analysis of Inter-industry Patterns. *International Journal of Innovation Management* 15(2), 423 - 455.

Cassiman, B. and Veugelers, R. (2006). In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. *Management Science* 52, 68-82.

Chesbrough, H. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston, Massachusetts: Harvard Business School Press.

Chesbrough, H. and Crowther, A.K. (2006). Beyond High-tech: Early Adopters of Open Innovation in Other Industries. *R&D Management* 36(3), 229-236.

Chesbrough, H. and Garman, A.R. (2009). How Open Innovation Can Help You Cope in Lean Times. *Harvard Business Review* December 2009, 68-76.

Coombs, R. and Hull, R. (1998). 'Knowledge management practices' and path-dependency in innovation. *Research Policy* 27(3), 237-253.

Czarnitzki, D. and Thorwarth, S. (2012). The Contribution of In-house and External Design Activities to Product Market Performance. *Journal of Product Innovation Management* 29(5), 878-895.

Dahlander, L. and Gann, D.M. (2010). How Open is Innovation? *Research Policy* 39(6), 699-709.

Dittrich, K. and Duysters, G. (2007). Networking as a Means to Strategy Change: The Case of Open Innovation in Mobile Telephony. *Journal of Product Innovation Management* 24(6), 510-521.

Faems, D., de Visser, M., Andries, P. and van Looy, B. (2010). Technology Alliance Portfolios and Financial Performance: Value-Enhancing and Cost-Increasing Effects of Open Innovation. *Journal of Product Innovation Management* 27(6), 785-796.

Finkle, T.A. (2012). Corporate Entrepreneurship in Silicon Valley: The Case of Google, Inc. *Entrepreneurship: Theory & Practice* 36(4), 863-884.

Fosfuri, A. (2006). The Licensing Dilemma: Understanding the Determinants of the Rate of Technology Licensing. *Strategic Management Journal* 27(12), 1141-1158.

Foss, N.J., Laursen, K. and Pedersen, T. (2011). Linking Customer Interaction and Innovation: The Mediating Role of New Organizational Practices. *Organization Science* 22(4), 980-999.

Frazier, P.A., Tix, A.P. and Barron, K.E. (2004). Testing Moderator and Mediator Effects in Counseling Psychology Research. *Journal of Counseling Psychology* 51(1), 115-134.

Fu, X. (2012). How Does Openness Affect the Importance of Incentives for Innovation? *Research Policy* 41, 512-523.

Gassman, O., Enkel, E. and Chesbrough, H. (2010). The Future of Open Innovation. *R & D Management* 40, 213-221.

Gassmann, O. and Enkel, E. (2004). Towards a Theory of Open Innovation: Three Core Process Archetypes. In: *Paper presented at the R&D Management Conference*. Lisbon.

Granstrand, O. (2004). The Economics and Management of Technology Trade: Towards a Pro-licensing Era? *International Journal of Technology Management* 27(2/3), 209-239.

Grant, R.M. (1996). Toward a Knowledge-Based Theory of the Firm. *Strategic Management Journal* 17(Winter Special Issue), 109-122.

Grindley, P.C. and Teece, D.J. (1997). Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and electronics. *California Management Review* 39(2), 8-41.

Guilhon, B., Attia, R. and Rizoulières, R. (2004). Markets for Technology and Firms' Strategies: The Case of the Semiconductor Industry. *International Journal of Technology Management* 27(2/3), 123-142.

Guth, W.D. and Ginsberg, A. (1990). Guest editors' introduction: Corporate Entrepreneurship. *Strategic Management Journal* 11(4), 5-15.

Hagerdoorn, J. and Wang, N. (2012). Is There Complementarity or Substitutability Between Internal and External R&D Strategies? *Research Policy* 41, 1072-1083.

Henkel, J. (2006). Selective Revealing in Open Innovation Processes: The Case of Embedded Linux. *Research Policy* 35(7), 953-969.

Huizingh, E.K.R.E. (2011). Open Innovation: State of The Art and Future Perspectives. *Technovation* 31(1), 2-9.

Huston, L. and Sakkab, N. (2006). Connect and Develop: Inside Procter & Gamble's New Model for Innovation. *Harvard Business Review* 84(3), 58-66.

Knott, A.M. (2008). R&D/Returns Causality: Absoprtive Capacity or Organizational IQ. *Management Science* 54(12), 2054-2067.

Knudsen, M.P. (2007). The Relative Importance of Interfirm Relationships and Knowledge Transfer for New Product Development Success. *Journal of Product Innovation Management* 24(2), 117-138.

Koruna, S.M. (2004). External Technology Commercialisation - Policy Guidelines. *International Journal Technology Management* 27(2/3), 241-254.

Kuratko, D.F., Montagno, R.V. and Hornsby, J.S. (1990). Developing an intrapreneurial assessment instrument for an effective corporate entrepreneurial environment. *Strategic Management Journal* 11(4), 49-58.

Laursen, K. and Foss, N.J. (2003). New Human Resource Management Practices, Complementarities and The Impact on Innovation Performance. *Cambridge Journal of Economics* 27(2), 243–263.

Laursen, K. and Salter, A. (2006). Open for Innovation: The Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms. *Strategic Management Journal* 27(2), 131-150.

Lee, S., Park, G., Yoon, B. and Park, J. (2010). Open Innovation in SMEs—An Intermediated Network Model. *Research Policy* 39(2), 290-300.

Leiponen, A. and Helfat, C.E. (2010). Innovation Objectives, Knowledge Sources and Benefits of Breadth. *Strategic Management Journal* 31, 224-236.

Leonard-Barton, D. (1992). Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Management Journal* 13, 111-125.

Lichtenthaler, U. and Ernst, H. (2007). External Technology Commercialization in Large Firms: Results of Quantitative Benchmarking Study. *R&D Management* 37(5), 383-397.

Lilien, G.L., Morrison, P.D., Searls, K., Sonnack, M. and Von Hippel, E. (2002). Performance Assessment of the Lead User Idea–Generation Process for New Product Development. *Management Science* 48(8), 1042-1059.

MacKinnon, D.P. (2008). *Introduction to Statistical Mediation Analysis*. New York: Taylor & Francis Group.

McGrath, R.G. and MacMillan, I. (2000). *The Entrepreneurial Mindset: Strategies for Continuously Creating Opportunity in an Age of Uncertainty*. Cambridge, MA: Harvard Business School Press.

Pavitt, K. (1984). Sectoral Patterns of Technical Change: Towards A Taxonomy and A Theory. *Research Policy* 31, 343-373.

Perkman, M. and Walsh, K. (2007). University-Industry Relationships and Open Innovation: Towards A Research Agenda. *International Journal of Management Reviews* 9(4), 259-280.

Pisano, G.P. and Verganti, R. (2008). What Kind of Collaboration Is Right for You? *Harvard Business Review* 86(12), 78-87.

Pisano, G.P. and Wheelwright, S.C. (1995). The New Logic of High-Tech R&D. *Harvard Business Review* 73(5), 93-105.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y. and Podsakoff, N.P. (2003). Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies. *Journal of Applied Psychology* 88(5), 879-903.

Pullen, A.J.J., Weerd-Nederhof, P.C., Groen, A.J. and Fisscher, O.A.M. (2012). Open Innovation in Practice: Goal Complementarity and Closed NPD Networks to Explain Differences in Innovation Performance for SMEs in the Medical Devices Sector. *Journal of Product Innovation Management* 29(6), 917-934.

Schumpeter, J.A. (1934). *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge: Harvard University Press.

Somaya, D., Teece, D. and Wakeman, S. (2011). Innovation in Multi-Invention Contexts: Mapping Solutions to Technological and Intellectual Property Complexity. *California Management Review* 53(4), 47-79.

Spithoven, A., Clarysse, B. and Knockaert, M. (2010). Building Absorptive Capacity to Organise Inbound Open Innovation in Traditional Industries. *Technovation* 30(2), 130-141.

Teece, D.J. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy* 15(6), 285-305.

Tranekjer, T.L. and Knudsen, M.P. (2012). The (Unknown) Providers to Other Firms' New Product Development: What's in It for Them? *Journal of Product Innovation Management* 29(6), 986-999.

Trott, P. and Hartmann, D. (2009). Why "Open Innovation" is Old Wine in New Bottles. *International Journal of Innovation Management* 13(4), 715-736.

Tyre, M.J. and Von Hippel, E. (1997). The Situated Nature of Adaptive Learning in Organizations. *Organization Science* 8(1), 71-83.

Van de Vrande, V., Jong, J.P.J.D., Vanhaverbeke, W. and Rochemont, M.D. (2009). Open Innovation in SMEs: Trends, Motives and Management Challenges. *Technovation* 29(6-7), 423-437.

Van De Vrande, V., Vanhaverbeke, W. and Gassman, O. (2010). Broadening the Scope of Open Innovation: Past Research, Current State and Future Directions. *International Journal of Technology Management* 52(3/4), 221-235.

Von Hippel, E. (2005). *Democratizing Innovation* Cambridge: The MIT Press.

Von Hippel, E., Thomke, S. and Sonnak, M. (1999). Creating Breakthroughs at 3M. *Harvard Business Review* September-October, 47-57.

Wooldridge, J.M. (2009). *Introductory Econometrics: A Modern Approach*. Scarborough: South Western.

Figures

FIGURE 1
Conceptual Model of the Effectiveness of Open Innovation

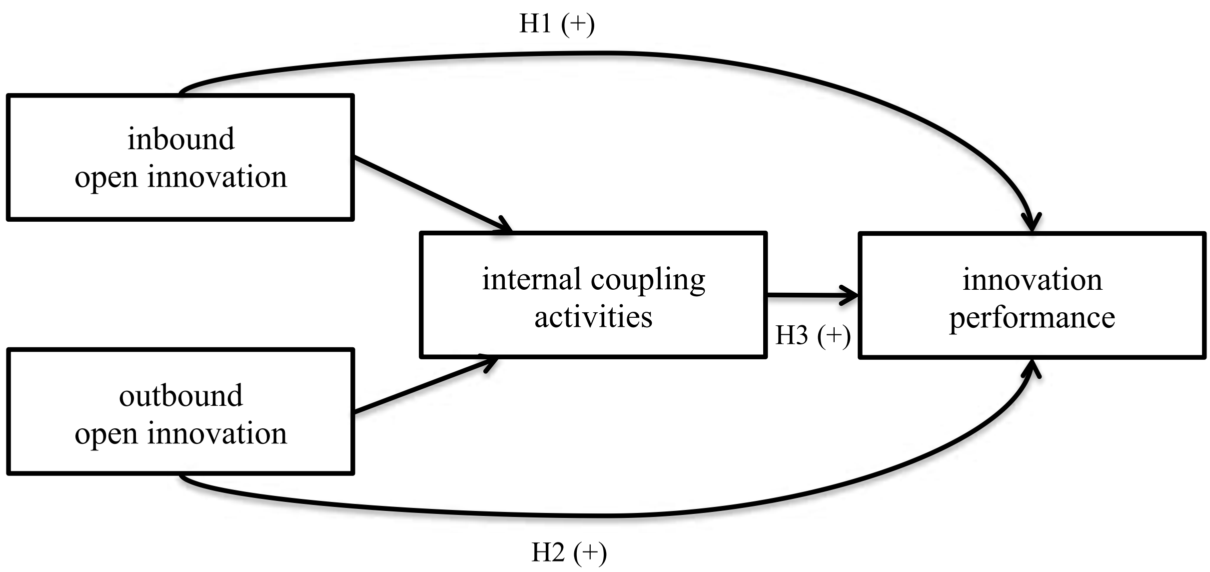
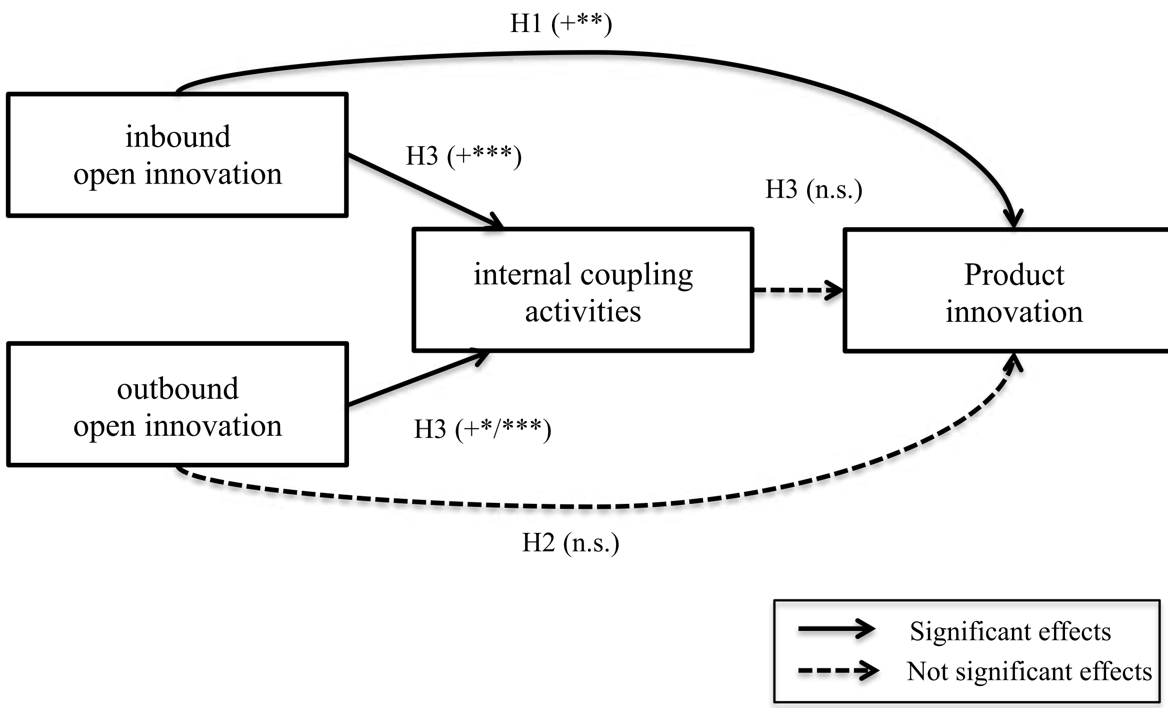
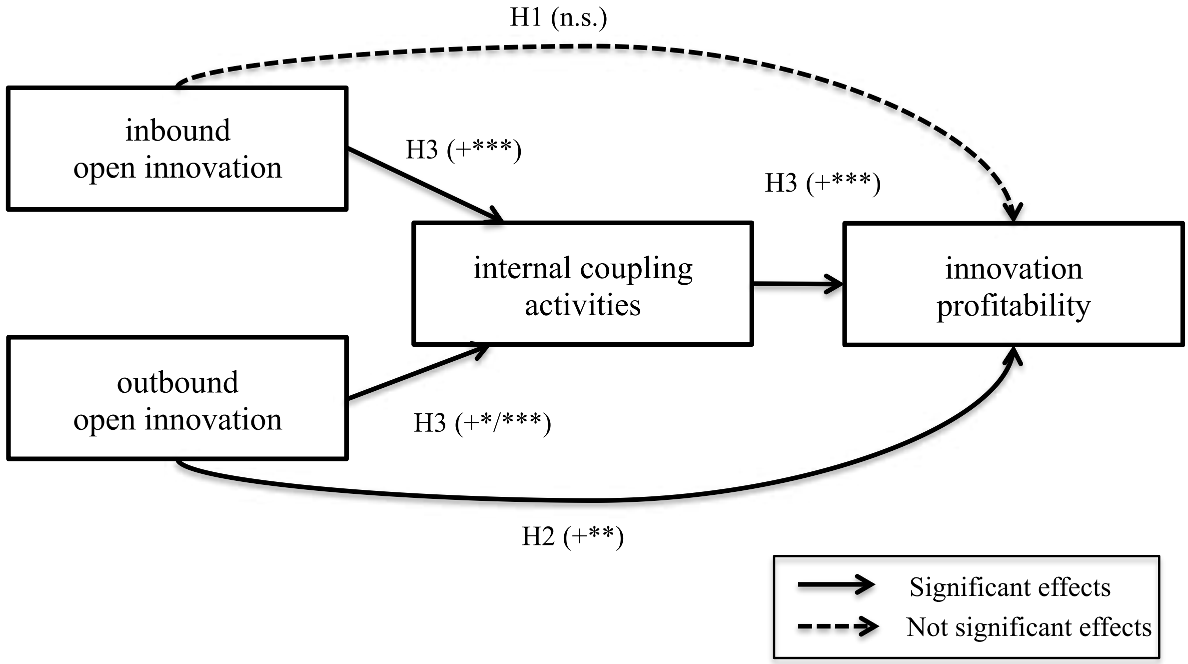


FIGURE 2
Results for Product Innovation



*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

FIGURE 3
Results for Innovation Profitability



*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

Tables

TABLE 1
Distribution of Firms in the Sample according to OECD Technology Sectors and Size (N=321)

	All companies (%)	Innovative companies (%)
Sector		
High-tech	6.2	90.0
Medium high-tech	32.1	83.5
Medium low-tech	34.6	73.0
Low tech	27.1	77.0
Total	**100.0**	**78.5**
Size		
Micro < 10 employees	26.8	76.7
Small < 50 employees	48.0	76.0
Medium < 250 employees	22.1	83.1
Large 250-499 employees	3.1	100.0
Total	**100.0**	**78.5**

TABLE 2
The Use of the Open Innovation Practices among Danish SMEs (N=321)

Construct	Practices	Yes	%
Inbound open innovation practices	Used the internet to search for new trends or technology	274	85%
	Reading technical magazines	266	83%
	Used information from trade organizations	249	78%
	Participated in innovation related fairs or shows	222	69%
	Purchased R&D work from others	189	59%
	Purchased licenses, patents or know-how	80	25%
	Worked with lead users	69	22%
	Used innovation brokers	16	5%
Outbound open innovation practices	Actively participated in other's innovation projects	171	55%
	Sold patents, licenses or know-how	24	8%
	Made own innovations available to others for free	15	5%

TABLE 3
The Use of Internal Coupling Activities among Danish SMEs: Descriptive Statistics and Correlations (N=321)

Activities	N (=yes)	Mean	S.d.	1	2	3
Initiated intrapreneurial activities internally in the company	84	0.26	0.44	1		
Supported employees to work on their own with own ideas for the company	176	0.55	0.50	0.23***	1	
Provided time for creativity	115	0.36	0.48	0.23***	0.16***	1

*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

TABLE 4
Logistic Regressions for Product Innovation

	Model 1			Model 2		
Variables	**β**	**S.E.**		**β**	**S.E.**	
Controls						
Constant	-1.10	0.90		-1.13	0.92	
Firm age	-0.19	0.22		-0.18	0.22	
Firm size	-0.05	0.42		-0.02	0.43	
High-tech sector	-0.08	0.87		0.10	0.88	
Low-tech sector	0.43	0.43		0.42	0.46	
Process innovation	0.82	0.36	**	0.76	0.37	**
R&D employees	1.46	0.44	***	1.42	0.45	***
Patent Application	1.55	0.67	**	1.55	0.68	**
Openness						
Inbound OI	0.26	0.13	**	0.25	0.14	*
Outbound OI (D1)	-0.24	0.40		-0.31	0.42	
Outbound OI (D2)	-0.64	0.77		-0.68	0.81	
Mediation						
Int. coupling activities (D1)				0.10	0.45	
Int. coupling activities (D2)				0.60	0.59	
Int. coupling activities (D3)				-0.21	0.67	
Model Statistics						
-2 Log likelihood	204.51			202.66		
Cox & Snell R^2	0.19			0.20		
Nagelkerke R^2	0.28			0.29		

TABLE 5
Tobit Regressions for Innovation Profitability

	Model 3			Model 4		
Variables	**β**	**S.E.**		**β**	**S.E.**	
Controls						
Firm age	-6.24	2.22	**	-5.16	2.16	**
Firm size	3.90	4.01		4.63	3.89	
High-tech sector	12.91	7.21	*	14.04	7.02	**
Low-tech sector	2.39	4.36		5.72	4.33	
Process innovation	13.89	3.94	***	17.16	3.92	***
R&D employees	12.39	5.49	**	9.48	5.33	*
Patent application	6.32	4.19		6.55	4.05	
Openness						
Inbound OI (D0)	9.91	19.21		8.38	18.45	
Inbound OI (D1)	0.26	16.81		0.98	16.14	
Inbound OI (D3)	19.81	12.90		17.88	12.47	
Inbound OI (D4)	17.84	12.61		13.63	12.20	
Inbound OI (D5)	12.56	12.60		8.76	12.20	
Inbound OI (D6)	10.65	12.39		3.87	12.10	
Inbound OI (D7)	10.90	14.67		7.44	14.26	
Outbound OI (D1)	2.75	3.85		1.20	3.74	
Outbound OI (D2)	16.82	6.82	**	13.46	6.68	**
Mediation						
Int. coupling activities (D0)				-14.66	4.86	***
Int. coupling activities (D2)				17.65	5.30	***
Int. coupling activities (D3)				18.82	6.29	***
Model Statistics						
Log likelihood (d.f.)	-675.45	(18)		-671.08	(21)	
Wald statistic (d.f.)	55.12	(16)		72.29	(19)	

*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

TABLE 6
Ordinal Regressions for Internal Coupling Activities

Variables	Model 5 β	S.E.	
Controls			
Firm age	-0.60	0.17	
Firm size	-0.20	0.31	
High-tech sector (D=0)	0.86	0.59	
Low-tech sector (D=0)	-0.68	0.33	**
Process innovation (D=0)	-1.06	0.29	***
R&D employees (D=0)	-0.65	0.37	*
Patent application (D=0)	-0.08	0.34	
Openness			
Inbound OI	0.40	0.11	***
Outbound OI (D1=0)	-0.84	0.31	**
Outbound OI (D2=0)	-1.67	0.55	**
Model Statistics			
Chi-square	68.66	***	
Cox and Snell R^2	0.27		
Nagelkerke R^2	0.30		
McFadden R^2	0.12		

Link function: logistic
*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

TABLE 7
Summary of Empirical Results

Hypothesis	Dependent variable	Result
H1: Inbound open innovation practices are positively related to innovation performance.	Product innovation	Verified
	Innovation profitability	Not verified
H2: Outbound open innovation practices are positively related to innovation performance.	Product innovation	Not verified
	Innovation profitability	Verified
H3: Internal coupling activities mediate the relationship between inbound/outbound open innovation practices and innovation performance.	Product innovation	Not verified
	Innovation profitability	Verified

Appendix

TABLE A
Descriptive Statistics and Correlations among Study Variables

Variables	Mean	S.d.	1	2	3	4	5	6	7	8	9	10	11	12	13
1- Product Innovation	0.79	0.41	1.000												
2- Innovation profitability	22.14	22.31	n.a.	1.000											
3- Inbound OI	4.25	1.61	.190**	.067	1.000										
4- Outbound OI	0.67	0.60	.051	.148*	.240**	1.000									
5- Internal coupling activities	1.17	0.98	.138**	.156**	.340***	.237***	1.000								
6- Firm age (Ln)	3.35	0.91	-.028	-.192**	.087	-.092	-.069	1.000							
7- Firm size (Ln)	1.40	0.50	.101	-.074	.264**	-.035	.080	.367**	1.000						
8- High-tech sector	0.06	0.24	.072	.211**	.048	.101	-.018	-.086	-.076	1.000					
9- Medium-tech sector	0.67	0.47	-.016	-.015	.078	.042	-.024	-.055	.050	-.365**	1.000				
10- Low-tech sector	0.27	0.45	-.022	-.111	-.108	-.100	.067	.105	-.012	-.157**	-.862**	1.000			
11- Process innovation	0.66	0.47	.204**	-.255**	.147*	.089	.291***	.009	.143*	-.083	-.047	.095	1.000		
12- R&D employees	0.76	0.43	.265**	.187**	.377**	.312**	.238***	.029	.182**	.048	.124*	-.157**	.057	1.000	
13- Patent application	0.24	0.43	.223**	.170**	.328**	.115*	.137**	-.007	.314**	.127*	.057	-.129*	.124	.207**	1.000

*Significance levels; * = 0.1; ** = 0.05 and *** = 0.001*

Appendix

TABLE B
Test of Significance of the Mediation Effects Using the Sobel Test

Test	Test version	a	sa	b	sb	Mediated effect	Standard error (Sobel)	z	Lower Confidence Limit	Upper Confidence Limit	Result
Inbound OI on Innovation profitability	Smallest standard error	0,40	0,11	14,66	4,86	5,86	2,53	2.32	0,91	10,81	**
	Largest standard error	0,40	0,11	18,82	6,29	7,53	3,26	2.31	1,14	13,91	**
Outbound OI on Innovation profitability	Smallest standard error	0,84	0,31	14,66	4,86	12,31	6,11	2.02	0,34	24,29	**
	Largest standard error	1,67	0,55	18,82	6,29	31,43	14,75	2.13	2,52	60,33	**

Explanation

Y= i1 + cX + e1 (step 1)

M= i3 + aX + e3 (step 2)

Y= i2 + c'X+ bM + e2 (step 3)

Y= Innovation profitability

X= Inbound OI/ Outbound OI

M= coupling activities

sa= standard error of a, sb= standard error of b

Mediated effect

$$\hat{a} \times \hat{b} = \hat{c} - \hat{c}'$$

Standard error (formula derived by Sobel)

$$s_{\hat{a}\hat{b}} = \sqrt{\hat{a}^2 \times \hat{s}_{\hat{b}}^2 + \hat{b}^2 \times \hat{s}_{\hat{a}}^2}$$

Z-score

$$z = \frac{\hat{a} \times \hat{b}}{s_{\hat{a}\hat{b}}}$$

Confidence Interval (95%)

$$LCL = mediated\ effect - 1.96 \times s_{\hat{a}\hat{b}}$$
$$UCL = mediated\ effect + 1.96 \times s_{\hat{a}\hat{b}}$$

Results

"If the z-score is greater than 1.96, the effect is significant at 0.05 level" (Frazier et al. 2004, p. 128)

"If zero is outside the confidence interval, then the mediated effect is statistically significant" (MacKinnon 2008, p.53)