J. of the Acad. Mark. Sci. (2016) 44:166–184
DOI 10.1007/s11747-014-0423-4

ORIGINAL EMPIRICAL RESEARCH

Open innovation, product portfolio innovativeness and firm performance: the dual role of new product development capabilities

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Received: 16 January 2014 / Accepted: 29 December 2014 / Published online: 11 January 2015

Abstract Despite a growing interest in the phenomenon of open innovation (OI), empirical evidence documenting the link between new product development capabilities, OI practices, and new product innovativeness is scarce. Eminent scholars have called for large-scale studies that systematically investigate the OI paradigm. Drawing on the knowledge-based view of the firm, new product development, and NPD capabilities literature streams, we conceptualize a framework in which OI practices are disentangled according to the stage of the new product development process in which they occur (development stage or commercialization stage). We identify two major types of OI practices: development-centric OI (which occurs in the development stage) and commercialization-centric OI (which occurs in the commercialization stage). Specific types of NPD capabilities—R&D, market information management, and launch—are expected to both influence the extent to which each OI practice is implemented and moderate the effect of each OI practice on product portfolio innovativeness and firm performance. The empirical analysis combines primary data from a survey of 239 firms with secondary data on innovation and financial outcomes. Our results support our hypotheses and indicate a need to differentiate among the different kinds of OI practices while elaborating on the complex role played by NPD capabilities in influencing OI practices.

Keywords Open innovation · New product development · Firm capabilities · Firm strategy · Technology and innovation · Knowledge-based view · External knowledge · New-to-the-firm products · Product innovativeness

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Chesbrough (2003) suggests that the traditional innovation model in which the entire innovation process occurs within the boundaries of the firm—with no contact with the external environment until the product is introduced in the marketplace—is no longer sustainable, due to the increased rate at which technology and consumer tastes are evolving, shorter innovation cycles, and escalating R&D costs. This change in marketplace dynamics has led to an increased interest in the "open innovation" paradigm, namely the inflow and outflow of knowledge to accelerate internal innovation and expand the markets for external use of innovation (Chesbrough 2006). Since the marketing domain deals more with the offerings of products to customers than with the outsourcing of technology, we focus on the inbound facet of open innovation.[1]

Open innovation is a fairly pervasive phenomenon in different industries, including low-tech industries (Huston and Sakkab 2006). Despite much interest, our understanding of open innovation is mainly based on case studies, which has caused eminent scholars to call for large-scale studies to systematically investigate the open innovation paradigm (Reibstein et al. 2009; West et al. 2006).

We address three critical gaps in the literature that limit our current understanding of open innovation. First, an external search should lead firms to broaden their knowledge base, escape path-dependency, and enter new areas (Almirall and Casadesus-Masanell 2010; Prabhu et al. 2005). Thus,

[1] From this point on, we use the term "open innovation" to refer to its inbound facet.

the real value of open innovation should not simply lie in increasing the number of new products a firm develops but also—and most importantly—in helping the firm tap into new product categories. In this paper, we examine whether open innovation practices contribute to the development and commercialization of new-to-the-firm products, namely products that "take a firm into a category new to it. New-to-the-firm products are not (or may not be) new to the world, but are new to the firm" (Crawford and DiBenedetto 2011, p. 14). It has been suggested that "newness" in the product development process is most appropriately defined from a firm's perspective, because it is the firm that must allocate resources for a new product's development (Sethi et al. 2012). Hence, we focus on newness from the perspective of the firm that is developing the new product. Our central measure is product portfolio innovativeness, defined as the percentage of new-to-the-firm products, i.e., the number of new-to-the-firm products that a firm introduces in 1 year over the total number of products introduced by the firm in the same year. We propose product portfolio innovativeness to be an intermediate outcome of open innovation that mediates the effect of open innovation on firm performance. In this way, we also shed light on a critical causal mechanism through which open innovation conveys its effect on performance.

Second, the knowledge-based view of the firm suggests that the way external resources are combined with internal capabilities may determine innovative outcomes (e.g., Katila and Ahuja 2002). Using this conceptualization, internal capabilities would seem to moderate the effect of open innovation on performance. However, a closer examination of this literature indicates that internal capabilities also determine the extent to which firms open up their innovation system (Cohen and Levinthal 1990; Todorova and Durisin 2007). Thus, a firm's capabilities may also act as antecedents to open innovation. Accordingly, we analyze the dual impact (antecedents and moderators) of three important NPD capabilities (R&D, market information management, and launch capabilities) on open innovation practices and performance.

Third, we conducted an extensive review of both the academic literature and practitioner-centric articles, which illustrates that, currently, open innovation is used as a generic term to indicate *any* exchange of innovation-related resources between the firm and its external environment. However, open innovation practices may occur at different stages of the new product development process, and they vary in content, risk involved in developing marketable products, and speed of bringing such products to market (Nambisan and Sawhney 2007). Thus, drawing upon the new product development literature, we develop the concepts of product development-centric open innovation (henceforth, development-centric OI) and product commercialization-centric open innovation (henceforth, commercialization-centric OI) as two distinct types of open innovation practices that bring in resources at two different stages of the NPD process: the development stage and the commercialization stage, respectively. We trace the antecedents of these two open innovation practices as well as examine their impact on product portfolio innovativeness and firm performance.

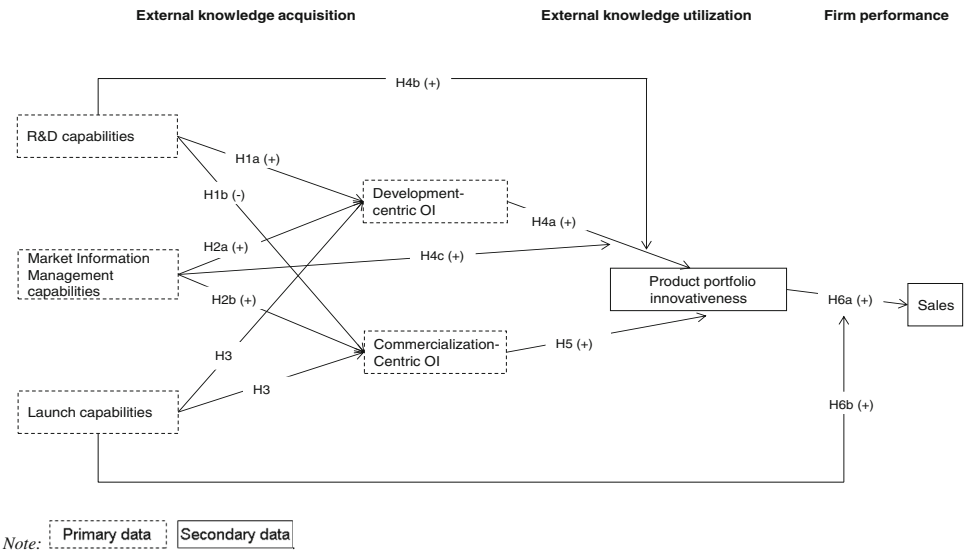
We test our model using longitudinal data for 239 firms operating in the food industry. We make three critical contributions to the existing literature. First, we identify two distinct types of open innovation practices and show that they have different antecedents and consequences. Second, we show that NPD capabilities perform a dual role: they trigger the implementation (i.e., the extent to which a practice is acquired, adopted, enacted, and exercised within an organization) of specific open innovation practices within the organization and shape the impact of each practice on product portfolio innovativeness and firm performance. Third, we show that open innovation is not immediately beneficial for every company, but the value of different practices (especially development-centric OI) is contingent on the level and type of a firm's capabilities. In sum, we show that inter-firm heterogeneity in capability endowment translates into differences in the benefits from otherwise similar levels of open innovation practices.

Conceptual background

We build on the knowledge-based view (KBV) of the firm to describe the logic for the proposed model depicted in Fig. 1. The KBV posits that knowledge is at the core of a firm's competitiveness (Grant 1996; Kogut and Zander 1992; Zander and Kogut 1995). According to the KBV, the way in which firms create, acquire, assimilate, and exploit knowledge leads to the creation of new potential sources of revenue and creates persistent differentials across firms (Foss et al. 2013; Hult et al. 2004; Kogut and Zander 1992; Zahra and George 2002).

The KBV conceptualizes the successful integration of external resources as the outcome of two processes: acquisition and utilization (Zahra and George 2002). Since different levels of a firm's capabilities cause heterogeneity in the firm's propensity to scan the external environment and look for innovation-related resources (Todorova and Durisin 2007), inter-firm differences in the implementation of open innovation practices are likely determined by different capability levels. Similarly, different levels of firm capabilities likely cause heterogeneity in the utilization of external resources (Cohen and Levinthal 1990; Sorescu et al. 2003). Accordingly, we investigate how capabilities influence the way in which firms open their innovation system in search of external resources to bring inside and implement within, as well as how firms combine the externally acquired resources with their

Fig. 1 Theoretical model



Note: H3 states that the strength of the positive relationship between launch capabilities and implementation of commercialization-centric OI will be greater than the strength of the positive relationship between launch capabilities and implementation of development-centric OI.

own capabilities in an effort to enter new product categories.[2] We next identify the relevant capabilities that determine the effects of open innovation and propose a typology of open innovation.

New product development process: stages and relevant capabilities

NPD is considered an organizational learning process (Leonard-Barton 1992) during which firms deploy resources by the means of capabilities in order to develop new products. The NPD process is articulated in two macro-stages: development and commercialization (Yli-Renko and Janakiraman 2008).

The development stage includes idea generation, concept design, prototype development, and testing. This stage utilizes two resources: ideas about how to satisfy consumer needs and technology, namely the means by which to embody these ideas into physical products or services that consumer may want to buy. There is vast agreement in the innovation literature that, in order to develop unique and successful products, firms need insight into the needs of their customers, together with the technical capability to act on those insights (Danneels 2002; Rubera et al. 2012). As new product development is a process of linking technology and customer needs (Dougherty 1992), it requires bringing together the knowledge related to both technology and customers. Accordingly, we identify in market information management capabilities and R&D capabilities the two focal capabilities that—in the development stage—allow firms to deploy resources and turn them into products. We define market information management capabilities as the skills and organizational routines that enable a firm to develop and use market knowledge through the management of relationships with customers and the monitoring of competitors' activities (Vorhies and Morgan 2005). Market knowledge is "the firm's knowledge of its customers' behaviors and needs as well as its competitors' behavior" (De Luca and Atuahene-Gima 2007, p. 97). Such knowledge determines if and in which areas opportunities are discovered (Narasimhan et al. 2006). We define R&D capabilities as the skills and organizational routines that enable firms to develop and exploit investments in technology and know-how to physically develop new products and services (Krasnikov and Jayachandran 2008; Vorhies and Morgan 2005). Thus, the exercise of market information management capabilities leads firms to accumulate market knowledge (Moorman 1995) while the use of R&D capabilities leads firms to accumulate technological knowledge (Cohen and Levinthal 1990).

The outcomes of the development process are market-ready products, namely products that are physically ready to be introduced in the marketplace. We view these products as resources that do not automatically lead to performance unless a firm actively deploys them in the commercialization stage. The commercialization stage encompasses market launch, product training, and sales support (Ernst et al. 2010). It is characterized by a firm's attempts to reduce customer barriers to new product adoption. The deployment of the firm's product portfolio occurs through launch capabilities, which we define as the firm's skill and organizational routines that facilitate the products' diffusion in the marketplace (Talke and Hultink 2010).

[2] We acknowledge that open innovation also involves collaboration with external sources. However, we consider such collaboration a prerequisite that culminates with the acquisition of resources that the firm considers valuable, thereby making acquisition a broader term that contains such collaboration.

Open innovation typology

The resources (i.e., ideas and technology in the development stage and market-ready products in the commercialization stage) that firms deploy throughout the NPD process can already exist within the firm or can be acquired externally by collaborating with outside sources. In the latter case, we have open innovation. While open innovation has become a popular term in common parlance, and as currently used in the literature embodies *every* form of innovation-related exchange, we propose a typology of open innovation. It is our hope that this typology will shed light on the complex web of relationships linking a firm's capabilities, open innovation, and performance.

Specifically, we propose to distinguish open innovation depending on whether it provides resources to be deployed, either in the development stage or in the commercialization stage. We refer to open innovation practices that provide resources for the development stage as *development-centric OI* and open innovation practices that provide resources for the commercialization stage as *commercialization-centric OI*.

Development-centric open innovation We define development-centric OI as the acquisition, from external sources, of ideas or technologies to use in the development stage of the NPD process. Firms may own technologies or patents but lack a product concept to embody them. Searching for outside ideas may represent a valuable strategy to turn patents or technologies into final products. The literature has identified several external sources of ideas. For instance, customer co-creation (Prahalad and Ramaswamy 2000) represents a firm's efforts to obtain new ideas directly from their customers. Many firms have developed websites or competitions where customers can suggest new ideas. Suppliers, consultants, or even competitors (Huston and Sakkab 2006) may all represent sources of ideas.

Alternatively, firms may be aware of market needs but may lack the technological knowledge to satisfy these needs in a short time frame. Rather than waiting to develop the necessary new knowledge internally, firms can solicit solutions from inventors outside the company. The last decade witnessed a flourishing of innovation marketplaces (e.g., InnoCentive, Nine Sigma, YourEncore, Eureka Café): websites where firms post their technological needs to a community of "solvers" who submit their technologies, and then firms select the most promising ones (Terwiesch and Xu 2008). Other, more traditional forms of obtaining technologies include suppliers (Yeniyurt et al. 2014) or relationships with universities and private research labs (Iansiti and West 1997).

Commercialization-centric open innovation We define commercialization-centric OI as the acquisition, from external sources, of market-ready products that a firm can introduce in the market without further physical development. We borrow the term "market-ready products" from Nambisan and Sawhney (2007), who use it to indicate the acquisition of products that have been fully developed and tested—and hence are physically ready to be introduced—but which are still missing critical marketing elements, such as the packaging or a name. These market-ready products provide firms with a quick opportunity to launch new products (for instance, P&G's Crest SpinBrush or Krafts' Bagel-ful) at reduced time-to-market, risk, and cost (Nambisan and Sawhney 2007).

Firms often use lead users or innovation toolkits to acquire products that are almost ready to be launched (Franke et al. 2010; VonHippel 2005). Acquiring products that have already been demonstrated to be responsive to some consumer needs may give manufacturers a quicker and more accurate estimate of the size of a potential new market (VonHippel 2005). The open question is whether commercialization-centric open innovation enhances product portfolio innovativeness. This is the question that we address.

External validation of our typology of open innovation

In an effort to validate our novel typology of open innovation, we conducted an abstract search for the term "open innovation" in three top business magazines (*Businessweek*, *Forbes*, and *The Economist*), two leading newspapers (the *Wall Street Journal* and *New York Times*), and under major world publications in Lexis Nexis for the 5 years immediately prior to the data collection. This search yielded over 500 articles highlighting current open innovation practices. We informed a research assistant of the conceptual definition of development-centric OI (i.e., collaborating with other subjects to acquire ideas or technologies that could potentially lead to the introduction of new products) and commercialization-centric OI (i.e., collaborating with other subjects to acquire products that need no further physical development, but are ready to be introduced in the market). The examples presented in each article were then coded by the research assistant as (a) development-centric OI, (b) commercialization-centric OI, or (c) other. The classification was comprehensively cross-checked by one of the authors. Our classification fits 85% of the open innovation practices that deal with new product development mentioned in these articles. Thus, we are confident that this typology comprehensively captures open innovation practices that deal with new product development. Table 1 summarizes this typology of open innovation and provides some examples of each kind.

Hypotheses

In this section, we first investigate the role played by capabilities in influencing the extent to which firms implement

Table 1 Typology of open innovation

Open innovation practice	Stage in the NPD process	Resources acquired	Capabilities used to deploy the acquired resources	Examples of innovation outcomes in the food industry
Development-centric open innovation	Development	Ideas and technologies	• R&D • Market information management	• Green Giant's snack chips, the first entry in the snack product category for the company. The ideas for the flavors came from Burley Foods, an external partner company • Yoplait Go-GurtFizzix by General Mills, a first-of-its-kind carbonated yogurt that General Mills produced after buying product and process patents from Brigham Young University
Commercialization-centric open innovation	Commercialization	Market-ready products	• Launch	• Kraft Bagel-fuls: first ready-to-heat bagels prefilled with Philadelphia cream cheese. The product had already been fully developed and market tested by a bagel maker

different types of open innovation practices. We then theorize about the effects of open innovation practices on product portfolio innovativeness.

Antecedents of open innovation practices

R&D capabilities Scholars have advanced two different perspectives on the influence of R&D capabilities on a firm's decision to open up its innovation system. On the one hand, the KBV maintains that R&D capabilities help firms screen and recognize the value of external resources (Cohen and Levinthal 1990). Firms with higher R&D capabilities are more receptive to external resources (Zhou and Wu 2010). In the absence of such capabilities, firms cannot recognize the value of external resources and fail to open their innovation system (Todorova and Durisin 2007). Thus, this literature suggests that firms with high internal R&D capabilities are more proactive in looking for external resources than firms with poor R&D capabilities (Rothaermel and Alexandre 2009).

Partially contradicting this perspective, the open innovation literature has evidenced that firms with high R&D capabilities may be reluctant to tap into external resources due to the so-called Not-Invented-Here (NIH) syndrome. NIH refers to the tendency of a group to be biased against ideas from outsiders, with a view that ideas from inside the organization are superior to external ideas (Laursen and Salter 2006; Menon and Pfeffer 2003; Katz and Allen 1982). Research has shown that the NIH syndrome emerges only when employees are not involved in the NPD process, while it is less likely to occur when employees are even partially involved in the further refinement of external resources (Menon and Pfeffer 2003). The NIH syndrome would then strongly emerge in the case of commercialization-centric OI, where much of the NPD process is skipped, compared to development-centric OI, where R&D capabilities are still needed to move the NPD process along.

The combination of these two perspectives lead us to hypothesize that—consistent with the KBV literature—high R&D capabilities facilitate the implementation of development-centric OI, while hampering the implementation of commercialization-centric OI—consistent with the studies on NIH. Formally:

H1a: R&D capabilities will be positively related to the implementation of development-centric OI.

H1b: R&D capabilities will be negatively related to the implementation of commercialization-centric OI.

Market information management capabilities We define market information management capabilities as the skills used to develop and use market knowledge. We contend that these capabilities foster the implementation of both development- and commercialization-centric open innovation. First, these capabilities augment a firm's ability to scan the environment and identify new market opportunities (Iansiti and West 1997; Narasimhan et al. 2006). Thus, firms with high market information management capabilities should be more able to access and evaluate ideas, technologies, and products, as compared to firms with low market information management capabilities. Second, firms with higher market information management capabilities are also more likely to value the need for reducing time to market, as they have a clear understanding of rapidly changing consumer needs, technologies, and competitors' actions, as compared to firms with limited market information management capabilities (Joshi and Sharma 2004). To the extent that both open innovation practices reduce the lead time of the NPD process (Chesbrough 2003), we maintain that the incentives to implement these practices increase at increasing levels of market information management capabilities. Thus:

H2a: Market information management capabilities will be positively related to the implementation of development-centric OI.

H2b: Market information management capabilities will be positively related to the implementation of commercialization-centric OI.

Launch capabilities Firms tend to prefer strategic options that allow them to immediately use their capabilities, while they tend to disregard those options that do not allow immediate use (Grant 1991). Because launch capabilities are used during the commercialization stage, we maintain that they would lead firms to favor the implementation of those open innovation practices that require an immediate use of launch capabilities. For this reason, the acquisition of market-ready products may be emphasized more than ideas and/or technologies when firms have high launch capabilities because market-ready products provide an immediate opportunity to use launch capabilities. On the other hand, the use of launch capabilities may be delayed or disregarded in the case of development-centric OI as it brings in resources that must still undergo development before ultimately being turned into final products that can be commercialized. Hence, high launch capabilities may lead to a prioritization of commercialization-centric OI over development-centric OI. Thus, we hypothesize:

H3: The strength of the positive relationship between launch capabilities and implementation of commercialization-centric OI will be greater than the strength of the positive relationship between launch capabilities and implementation of development-centric OI.

Effects of open innovation practices on product portfolio innovativeness

Development-centric OI Development-centric OI enables a firm to broaden its knowledge base with new ideas or technological knowledge. A central tenet of the KBV is that firms with broad knowledge are less likely to incur core rigidities and hence be less likely to keep developing new products in the same areas (Leonard-Barton 1992). On the contrary, firms that do not search for resources outside of their organizational boundaries show a path-dependency tendency in their innovation activities, which forces firms to keep innovating along the same trajectory (Rosenkopf and Nerkar 2001). Hence, opening up the innovation system in order to acquire external resources (either ideas or technologies) helps firms enter a new innovation path and new product categories without remaining locked in the same innovation area (e.g., Ahuja and Katila 2001; Almirall and Casadesus-Masanell 2010; Laursen and Salter 2006; Prabhu et al. 2005). By acquiring new ideas, firms can identify new areas that might become commercially important in the future (Prabhu et al. 2005). By acquiring new technologies, firms may discover new combinations of product features that would otherwise be hard to foresee (Almirall and Casadesus-Masanell 2010). Hence, we hypothesize that:

H4a: Development-centric OI will be positively related to product portfolio innovativeness.

Moderating role of firm's capabilities The development of new-to-the-firm products requires firms to combine existing pieces of market and technological knowledge in novel ways (Ahuja and Katila 2001; Kogut and Zander 1992). External resources are more likely to be converted into innovative products when they can draw upon a vast knowledge base (Ahuja and Katila 2001; Katila and Ahuja 2002). Thus, both R&D and market information management capabilities play a critical role in the transformation of the resources acquired through development-centric OI into new-to-the-firm products, as these capabilities lead to the accumulation of technological and market knowledge, respectively.

R&D capabilities A central tenet in the KBV literature is that firms with high R&D capabilities possess the cognitive structure necessary to make sense of and use external technologies and ideas. Conversely, firms with poor R&D capabilities are less capable of transforming externally acquired resources into products (Todorova and Durisin 2007; Sorescu et al. 2003). Increased R&D capabilities provide firms with heterogeneous information that allows them to develop connections and combine different ideas and technologies in novel ways (Katila and Ahuja 2002). As a result, firms can quickly identify new technological trends, experiment with emerging consumer needs, and engage in product innovations beyond a firm's current boundaries (Rosenkopf and Nerkar 2001; Zhou and Wu 2010). On the contrary, firms with low R&D capabilities have restricted knowledge bases to draw upon, and thus fewer chances of converting ideas and technologies brought in from development-centric OI into new-to-the-firm products. Thus, firms with high R&D capabilities are better equipped to convert the resources acquired through development-centric OI into new-to-the-firm products than firms with low R&D capabilities. Hence, we hypothesize that:

H4b: R&D capabilities will positively moderate the relationship between development-centric OI and product portfolio innovativeness.

Market information management capabilities Since entering new fields requires knowledge about the consumer needs in that field, the market knowledge accumulated through market information management capabilities is a critical component in the development of new-to-the-firm products. A traditional criticism is that market knowledge may entrench firms in existing product categories, causing them to only develop products that serve existing markets (Christensen and Bower 1996). However, more recent studies have shown that acquiring external ideas or technologies help expand the scope of information search beyond existing categories (Zhou and Li 2012), thus avoiding the risk that firms remain locked outside of new areas of commercial interest (Prabhu et al. 2005). The

infusion of new information from emerging categories/technologies acquired through development-centric OI, combined with a deep understanding of current segments, enables firms with high market information management capabilities to detect future market trends and develop innovations to capitalize on them (Zhou and Li 2012).

Further, firms with greater market knowledge have a greater potential to recombine different elements of their knowledge to improve opportunity recognition and creative potential (Ahuja and Katila 2001; De Luca and Atuahene-Gima 2007). Specifically, market knowledge helps firms recognize market opportunities for novel products (Todd et al. 2011) and flexibly adapt to emerging customer needs. In other words, market information management capabilities guide the use of technology to develop novel opportunities in that market (Dutta et al. 1999). Further, market information management capabilities enhance the chances of "happy accidents," whereby ideas from one field are applied to another field in unexpected ways, which leads to a greater number of radical products (Prabhu et al. 2005). Corroborating this logic, Sorescu et al. (2003) show that firms with higher market knowledge develop more radical innovations. Thus, we hypothesize that:

H4c: Market information management capabilities will positively moderate the relationship between development-centric OI and product portfolio innovativeness.

Commercialization-centric OI We have defined commercialization-centric OI as the acquisition, from external sources, of market-ready products that a firm can introduce in the market without further physical development. Firms with low commercialization-centric OI tend to focus more exclusively on internal development and deployment, which is riskier, given that in most competitive markets, there is a distribution of innovative product ideas outside the boundaries of any one firm. Such a focus is also likely to lead to slower development, given the resource and capacity constraints of a single organization or product development team. Such firms are also more likely to be constrained by organizational inertia, routines, and momentum of past successes (Nelson and Winter 1982)—issues that result in local search patterns in the quest for new knowledge.

On the other end of the spectrum, firms that extensively use OI as an avenue for product commercialization are able to achieve a much higher throughput of innovative products as they are not capacity constrained within organizational boundaries, and are able to draw from a larger pool of often ready-to-market innovative products. Such firms are also able to break free from inertial mindsets and truly engage in an exploratory search for novel products across individuals and organizations. Indeed, prior research suggests that organizational boundary spanning, or exploration beyond organizational boundaries, is instrumental in impactful innovations whereas local search is more likely to lead to development of incremental innovations (e.g., Martin and Mitchell 1998; Rosenkopf and Nerkar 2001). Thus we hypothesize that:

H5: Commercialization-centric OI will be positively related to product portfolio innovativeness.

The relationship between product portfolio innovativeness and firm performance

There is widespread agreement in the literature that new-to-the-firm products create opportunities for growth and sustained competitive advantage (Andrews and Smith 1996; Sethi et al. 2012). Hence, new-to-the-firm products are expected to be positively correlated to firm performance. However, new-to-the-firm products are more difficult to market, as their launch may involve the development of a new sales and service infrastructure that is different from the one the firm currently has (Sethi et al. 2012). Being new to the firm, they may diffuse more slowly due to potential lower support from the salesforce or the distributors, (Talke and Hultink 2010). The importance of launch capabilities becomes particularly significant for new-to-the-firm products in order to overcome diffusion barriers related to the salesforce or distributors (Talke and Hultink 2010). Specifically, to enter new categories, firms must gain credibility in those categories by more effectively communicating to the frontline employees the significant benefits offered by the new product, as well as the product details, and by engaging in targeted communication with dealers (Talke and Hultink 2010). Hence, launch capabilities are crucial to help translate product innovativeness into performance. Thus:

H6a: Product portfolio innovativeness will be positively related to firm performance.

H6b: Launch capabilities will positively moderate the relationship between product portfolio innovativeness and firm performance.

Method

Sample and survey data

We examine our research questions in the context of the food industry as this is an attractive context to study open innovation practices. First, there are several different players involved in the food supply faced with the common challenge of meeting

heterogeneous requirements of intermediates, final consumers, and legislators (Sarkar and Costa 2008). Firms like P&G or Kraft now routinely rely on open innovation to access external ideas, technologies, and market-ready products (Huston and Sakkab 2006; Sarkar and Costa 2008). Second, innovation in the food industry has always required technological knowledge, but in recent years, the rising worldwide diffusion of functional foods requires rapid acquisition of advanced technical know-how (Lee and Chen 2009). For these reasons, many recent studies on innovation have used the food industry as their setting (e.g., Faems et al. 2005; Knudsen 2007; Salomo et al. 2008; Sorescu and Spanjol 2008).

We examine the use of open innovation practices through a survey of Italian firms. In this way, we answer the explicit call for open innovation research in a non-U.S. context (West et al. 2006). We used the following procedure to identify the firms in our sample. First, we identified all the Italian firms that have introduced at least one product in the 2005–2008 time period, anywhere in the world, through the Mintel Global New Products Database (GNPD). Mintel GNPD is a proprietary database that monitors new product introductions worldwide in the consumer packaged goods industry and is updated each month. We identified a total of 762 firms. Second, we contacted these firms by phone in order to identify the top executives, obtain collaboration, and schedule an appointment with them. We also mailed a letter with a brief description of the research to each informant. To increase participation, we let informants know that they would receive a report of the research outcomes. Third, in late 2008, we collected primary data from firms that accepted the invitation to participate. At the end of this process, we collected a total of 239 completed questionnaires, with a response rate of 31.3%.

In the surveys, we questioned the firms about their OI practices pertaining to the 2007–2008 time period and measured the impact of such practices on product portfolio innovativeness and overall sales for the year 2009. We considered a 1-year time lag between the independent variables and our key dependent variable to avoid endogeneity issues. Further, a 1-year time lag may be considered sufficient to consider the impact of innovation in the food industry, as revealed in our exploratory interviews with managers, and other studies in the food industry (e.g., Sorescu and Spanjol 2008).

To check for potential non-response bias, we conducted F-tests for key variables. There were no significant differences in firm performance, size, or number of new products introduced in the 2005–2008 period. We also checked for early versus late respondents (Armstrong and Overton 1977) but did not find significant differences.

Archival data

We supplemented the survey data on open innovation practices with data from multiple archival sources. Rather than using self-reported measures of product portfolio innovativeness and performance, we used objective, external sources. The use of primary data for independent variables and secondary data for dependent variables avoids the problems of common method bias and increases the face validity of the measures (Podsakoff et al. 2003).

We collected data on the product portfolio innovativeness for the 239 firms in our sample through Mintel GNPD (described earlier). One advantage of our dataset is that it contains the list of new products introduced in the market, regardless of their eventual success. A second advantage is that product introductions are recorded contemporaneously (rather than subsequently to introduction), ensuring that a potential memory bias does not affect which products are included in the sample (Sorescu and Spanjol 2008). Most importantly, this database distinguishes between products that are new to the company and products that are just improvements on a company's existing products. This information is vital to measure the innovativeness of the company's product portfolio.

Measures

We use both reflective (i.e., R&D, market information management, and launch capabilities) and formative (i.e., development-centric OI and commercialization-centric OI) constructs. We describe these measures below and more fully in Appendix A.

Development-centric OI Development-centric OI occurs during the development stage of the NPD process to acquire two resources: ideas and technology. Since acquiring ideas does not necessarily imply acquiring technology, development-centric OI appears to be a combination of these two practices rather than the underlying construct which causes a firm to externally acquire both ideas and technology at the same time. Hence, we conceptualize it as a second-order formative construct (rather than reflective) made up of two first-order formative constructs, which refer to the acquisition of external ideas (i.e., idea-centric OI) and technologies (i.e., tech-centric OI), respectively. We conceptualize these two first-order constructs as formative because firms may acquire external resources from one specific source (e.g., customers) but not from others (e.g., suppliers). Thus, also in this case, the acquisition of external resources from one source causes (rather than being caused by) an increase in the firm's idea- or tech-centric OI.

For idea-centric OI, we asked firms to indicate on a 5-point scale how frequently they collaborated with each subject to acquire new ideas to possibly include in new products from each source in 2007–2008. For tech-centric OI, we asked firms to indicate on a 5-point scale how frequently they collaborated with each subject to acquire the technology

necessary to develop new products from each source in 2007–2008. We excluded final consumers from the sources of technology because—according to our pretest—they do not provide technological solutions in the food industry.

Commercialization-centric OI We asked firms to indicate on a 5-point scale how often they collaborated in 2007–2008 with each subject to buy new products almost ready to be launched in the market from five different sources (the same identified for the acquisition of technology). In the questionnaire we specified that "almost ready" means that the product is physically ready to be introduced, but it is still missing critical marketing elements (e.g., package, name). For the same reasons described above, we also conceptualize commercialization-centric OI as a formative construct.

In the case of formative constructs, researchers must pay particular attention to define a comprehensive list of indicators that can tap the entire content of the construct (Diamantopoulos and Winklhofer 2001). We achieve this object in three steps. First, we rely on previous scales used in past studies on open innovation (e.g., EU's community innovation survey: Laursen and Salter 2006; Leiponen and Helfat 2010; Mol and Birkinshaw 2009). The review of these studies led to identification of the following possible sources of external resources: suppliers, customers, retailers, competitors, consultants, universities or research labs, patents, scientific publications, databases, trade fairs, government research organizations, regulations, and professional or industry associations. This list is extensive and the sources are not mutually exclusive (Laursen and Salter 2006). Second, we conducted in-depth interviews with a group of 15 food managers, during which we asked if these are really the sources that they use or if there are others that we missed. The interviews led to the exclusion of some sources, which our managers indicated were totally irrelevant to the food industry. Eventually, we ended up with the following sources of ideas and technologies: suppliers, competitors, consultants, universities or research labs, professional or industry associations, and clients (just for ideas). Also, none of the managers mentioned any other source of external resources. Thus, we are confident that the sources identified above cover the entire scope of the constructs.

R&D capabilities (α=.85) We adopt Vorhies and Morgan's (2005) scale to assess R&D capabilities. We excluded one item, "Successfully launching new products/services," because we believe that this item more properly refers to launch capabilities. Our scale focuses on a firm's capability to develop new products, exploit R&D investments to develop new products, and test market the new products. Consistent with Dierickx and Cool (1989), we assume that capabilities are built over time and hence tend to remain stable over a 2-year time period.

Market information management capabilities (α=.85) We use the Vorhies and Morgan (2005) five-item scale to capture market information management capabilities. The items capture a firm's ability to gather information about customers and competitors, use market research skills to develop existing marketing programs, track customer wants and needs, make full use of marketing research information, and analyze market information.

Launch capabilities (α=.86) We use a three-item scale that refers to a firm's capability to successfully introduce new products, ensure that the launch of the new products is consistent with consumer needs, and support the sales force.

Product portfolio innovativeness We measure product portfolio innovativeness as the percentage of new-to-the-firm products, i.e., the number of new-to-the-firm products that a firm introduced in 2009 over the total number of products introduced in 2009. Data were drawn from the Mintel GNPD database, which distinguishes between products that are new to a firm and products that are just improvements on the firm's existing products.

Firm performance We measure performance in terms of total sales (in Euros) as of 2009. We collected data on annual total sales for each firm included in the analysis from the AIDA Bureau Van Dijck database.

Control variables We use several control variables in our analysis. First, we control for the effect on a firm's channel management capabilities (α=.89) on the extent to which firms implement open innovation practices. The relationship literature clearly shows that the capability to create and manage durable relationships with customers and channel members facilitates access to external resources (Rindfleisch and Moorman 2001). Second, we control for the effects on performance of marketing capabilities that the previous literature showed to improve firm performance (Vorhies and Morgan 2005): marketing planning (α=.86), marketing implementation (α=.88), pricing (α=.86), marketing communication (α=.87), and selling (α=.84). We use the Vorhies and Morgan (2005) scale to measure all of these capabilities. We also control for the effect of firm size, measured as the logarithm of the number of employees. Finally, we control for the average innovativeness of a firm's product portfolio over the last 5 years, measured as the percentage of the number of new-to-the-firm products introduced in the last 5 years over the total number of products introduced in the same time period. This control variable accounts for the fact that firms may differ in their ability to introduce new-to-the-firm products, regardless of their use of open innovation.

Results

Descriptive statistics

Table 2 reports the correlations between variables in our sample. 67% of the firms introduced at least one new-to-the-firm product in 2009. Suppliers and customers seem to be the dominant sources for idea-centric OI, with 45% of firms in our sample stating that they frequently acquire ideas from suppliers, while 32% stated that they frequently collaborate with customers to acquire new market ideas. A majority of the firms stated that they acquired ideas only a few times from competitors or from professional or industry associations. Suppliers and industry associations seem to be dominant sources for technology-centric OI, with 50% of firms reporting they frequently acquire technologies from suppliers and 21% reporting they frequently acquire technologies from industry associations, respectively. Finally, 40% of the companies in our sample declared that they often collaborate with consultants, research labs, and industry associations to acquire market-ready products.

Measure assessment

Because we have a mix of reflective and formative constructs, the commonly used covariance-based structural equation modeling (SEM) techniques could potentially lead to "identification problems, the occurrence of implied co-variances of zero among some measured variable, and the existence of equivalent models" (MacCallum and Browne 1993, p. 540). To avoid these problems, we use a partial least squares (PLS) technique, which allows us to manage both formative and reflective constructs (Chin 1998; Hair et al. 2012). Specifically, we use SmartPLS (Ringle et al. 2005). Although the measurement and causal models are estimated simultaneously in PLS, Hulland (1999) recommends analyzing and interpreting the two models separately. We start with the measurement model and the reliability and validity of our constructs.

For reflective constructs (i.e., capabilities), we factored construct items to assess whether they correctly measure their intended constructs. All item loadings are significant ($p<0.01$) and greater than 0.60. We, therefore, could keep our initial set of items (Fornell and Larcker 1981). Composite reliabilities are higher than 0.8, and the average variances extracted are greater than 0.5, thus indicating that these measures have good convergent validity. We followed Fornell and Larcker's (1981) recommended test to assess discriminant validity. On the basis of this test, we found that the correlation between any pair of constructs was not larger than the respective square root of the average variance extracted for each of the constructs, in support of discriminant validity (Table 3).

For formative constructs (i.e., open innovation practices), we report in Appendix A the weights for the individual items, even though "there is no reason that a specific pattern of signs (i.e., positive versus negative) or magnitude (i.e., high versus moderate versus low) should characterize the correlation among formative indicators" (Diamantopoulos and Winklhofer 2001, p. 271). In the case of formative constructs, the concepts of reliability and construct validity are not appropriate (Diamantopoulos and Winklhofer 2001). Two other statistical tests are relevant in this case. First, there should be low multicollinearity among the formative indicators (Diamantopoulos and Winklhofer 2001). The highest variance inflation factor (VIF) is 1.36 for development-centric OI and 1.35 for commercialization-centric OI. The small values of VIFs indicate that there is no multicollinearity among the formative indicators of the three constructs, thus validating our measures as formative constructs. Second, following Diamantopoulos and Winklhofer's (2001), we included a reflective indicator to test the formative constructs for external validity. The relationships between the formative constructs and their reflective indicators are strong and significant ($p<0.01$). Finally, an essential characteristic of formative constructs is the fact that the items used as indicators must cover the entire scope of the latent variable (Diamantopoulos and Winklhofer 2001). The inclusion of all the possible sources of

Table 2 Correlation matrix among the main variables

	Mean	Std. dev.	1	2	3	4	5	6	7	8
1.Sales (€ 000)	53,954	92,608	1							
2. Product portfolio innovativeness	0.38	0.37	0.26*	1						
3. Development-centric OI	0.29	0.79	0.08	0.22*	1					
4. Commercialization-centric OI	0.29	0.80	0.22*	0.31*	0.45*	1				
5. R&D capabilities	0.50	0.51	0.01	0.18	0.34*	0.30*	1			
6. Market info management capabilities	0.18	0.88	0.08	0.06	0.20*	0.36*	0.26	1		
7. Launch capabilities	0.14	0.91	0.06	0.03	0.03	0.08	0.31*	0.41*	1	
8. Firm age	61.38	44.68	0.04	−0.08	−0.07	−0.08	0.08	0.06	0.08	1
9. Firm size (ln employees)	5.31	5.55	−0.03	0.06	0.08	−0.01	0.14*	0.04	0.01	0.02

* $p<.05$

Table 3 Discriminant validity

	1	2	3	4	5	6	7	8	9
1. R&D capabilities	0.82								
2. Market info management capabilities	0.26	0.72							
3. Launch capabilities	0.31	0.41	0.75						
4. Channel management capabilities	0.21	0.27	0.10	0.81					
5. Marketing communication capabilities	0.04	0.23	0.02	−0.01	0.90				
6. Selling capabilities	0.22	0.41	0.25	0.26	0.21	0.80			
7. Market planning capabilities	0.33	0.21	0.31	0.10	0.30	0.34	0.84		
8. Marketing implementation capabilities	0.28	0.25	0.25	0.26	0.28	0.10	0.31	0.84	
9. Pricing capabilities	0.07	0.31	0.23	0.18	0.18	−0.10	0.25	0.29	0.74

Correlation between latent variables (off diagonal) and square root of average variance extracted (diagonal)

ideas, technologies, and market-ready products in our scales of development-centric OI and commercialization-centric OI respectively satisfies this requirement.

Results of the PLS analysis

PLS allows us to specify endogenous constructs in a system of equations that are jointly estimated.

We conceptualize development-centric OI as a second-order formative construct made up of two first-order formative constructs: idea-centric OI and tech-centric OI. We follow the two-stage approach described in Ringle et al. (2012) to build the measurement model. First, we use repeated indicators to obtain the latent variable scores for the two first-order constructs (Lohmöller 1989). Then, we used these latent variable scores as manifest variables to measure our formative-formative construct of development-centric OI.

Because we have interaction effects that involve both formative and reflective constructs, we adopt a two-step process to test for our hypotheses (Henseler and Fassott 2010). In the first step, we tested a model with only the direct effects (Model 1 in Table 4), and used this model to obtain the estimates for the latent variable scores of capabilities, OI practices, innovativeness, and sales. In the second step, we created the interaction terms as the multiplication of the latent variable scores of the two variables of interest (e.g., we multiplied the latent variable score of R&D capabilities and that of development-centric OI to obtain the interaction term between the two variables). We then regressed the latent variable score of product portfolio innovativeness on the latent variable scores of capabilities, open innovation practices, and the interaction terms (Model 2 in Table 4).

Direct effects: drivers of open innovation practices and product portfolio innovativeness

We assessed the significance of the paths through a bootstrapping procedure with 500 samples of the same size (n=239). We find that R&D capabilities have a positive effect on the implementation of development-centric OI (b=0.23, $p<.01$), but no effect on the implementation of commercialization-centric OI (b=0.05, $p>0.05$). Market information management capabilities positively influence the implementation of development-centric OI (b=0.24, $p<0.01$), while having no effect on the implementation of commercialization-centric OI (b=0.09, $p>0.05$). Thus, we find support for H1a and H2a but have to reject H1b and H2b. Launch capabilities negatively influence the implementation of development-centric OI (b=−0.16, $p<0.05$) but positively influence the implementation of commercialization-centric OI (b=0.21, $p<0.01$). Supporting H3, we find that this difference is significant ($p<0.05$), thus suggesting that higher launch capabilities cause firms to emphasize commercialization-centric OI over development-centric OI.

The effect of development-centric OI on product portfolio innovativeness is not significant (b=0.10, $p>0.05$), while commercialization-centric OI has a significant impact on product portfolio innovativeness (b=0.18, $p<0.05$). Thus, we find no support for H4a, but for H5 only, indicating a direct impact of commercialization-centric OI, rather than development-centric OI, on product portfolio innovativeness. We discuss the theoretical implications of this finding in the discussion section.

R&D capabilities (b=0.03, $p>0.05$) and market information management capabilities (b=−0.01, $p>0.05$), 5-year average innovativeness (b=0.01, $p>0.05$), and firm size (b=−0.02, $p>0.05$) do not influence product portfolio innovativeness

Product portfolio innovativeness has a positive effect on performance (b=0.20, $p<0.01$), supporting H6a. We also investigated the existence of a possible curvilinear effect of product portfolio innovativeness on performance, but failed to find support for it (b=0.09, $p>0.05$).

Further, in a separate analysis, we empirically checked for the existence of a direct effect from commercialization-centric OI to performance. We find that when we do not include product portfolio innovativeness in the model, commercialization-centric has a direct effect on performance (b=0.10, $p<0.05$).

Table 4 Results of the partial least square analysis

	Relationship	Model 1	Model 2
H1a	R&D capabilities –> Development-centric OI	0.23 (2.97)***	0.23 (3.16)***
H1b	R&D capabilities–> Commercialization-centric OI	0.05 (0.84)	0.05 (0.84)
H2a	MIM capabilities –> Development-centric OI	0.24 (2.59)**	0.24 (2.68)**
H2b	MIM capabilities –> Commercialization-centric OI	0.09 (1.17)	0.09 (1.20)
H3	Launch capabilities –> Development-centric OI	−0.16 (2.12)*	−0.16 (2.08)*
	Launch capabilities –> Commercialization-centric OI	0.21 (2.71)**	0.21 (2.74)**
H4a	Development-centric OI –> Innovativeness	0.10 (1.03)	0.08 (0.90)
H5	Commercialization-centric OI –> Innovativeness	0.18 (2.41)*	0.18 (2.09)*
	R&D capabilities –> Innovativeness	0.03 (0.23)	0.09 (1.28)
	MIM capabilities –> Innovativeness	−0.01 (0.09)	−0.02 (0.31)
	Five-year average Innovativeness –> Innovativeness	0.01 (0.39)	0.01 (0.03)
	Firm size –> Innovativeness	−0.02 (0.26)	−0.02 (0.42)
H4b	Develop.-centric OI* R&D capabilities–> Innovativ.		0.23 (2.88)**
H4c	Develop.-centric OI* MIM capabilities–> Innovativ.		0.16 (2.00)*
	Commercial.-centric OI * R&D capabilities–> Innovativ.		−0.11 (1.39)
	Commercial.-centric OI * MIM capabilities–> Innovativ.		−0.03 (0.45)
H6a	Innovativeness –> Sales	0.20 (3.74)**	0.20 (3.75)**
	Launch capabilities –> Sales	0.08 (1.47)	0.08 (1.47)
H6b	Launch capabilities * Innovativeness –> Sales		0.10 (2.12)*
	Control variables		
	Channel management–> Development-centric OI	0.02 (0.27)	0.02 (0.26)
	Channel management –> Commercialization-centric OI	0.07 (1.01)	0.07 (0.88)
	Marketing communication capabilities –> Sales	0.05 (1.01)	0.05 (0.97)
	Selling capabilities –> Sales	−0.09 (1.06)	−0.09 (1.02)
	Marketing planning capabilities –> Sales	0.13 (2.47)*	0.13 (2.58)**
	Marketing implementation capabilities –> Sales	0.11 (1.01)	0.11 (1.01)
	Pricing capabilities –> Sales	−0.10 (1.80)	−0.10 (1.81)
	Firm performance t-1 → Sales	0.41 (2.50)*	0.41 (2.60)**
	Firm size → Sales	− 0.05 (1.24)	− 0.05 (1.20)
	Firm age → Sales	0.05 (0.87)	0.04 (0.85)
	R^2 Development-centric OI	0.12	0.12
	R^2 Commercialization-centric OI	0.11	0.11
	R^2 Innovativeness	0.06	0.15
	R^2 Sales	0.28	0.29

t values are in parentheses

MIM Market information management

* $p<.05$, ** $p<.01$

However, when we include product portfolio innovativeness in the model, the path from commercialization-centric OI to performance is not significant ($b=0.04$, $p>0.05$), while the paths from commercialization-centric OI to product portfolio innovativeness (i.e., the mediator) and from product portfolio innovativeness to performance both remain significant. Thus, according to Baron and Kenny (1986), product portfolio innovativeness fully mediates the effect of commercialization-centric OI on firm performance. We discuss the theoretical implications of this finding in the discussion section.

The direct effects model explains 0.12 and 0.11 of the variance in a firm's implementation of development-centric OI and commercialization-centric OI, respectively. It also explains 0.06 and 0.30 of the variance in product portfolio innovativeness and performance, respectively.

Moderation effects

Model 2 in Table 4 adds the interaction effects (calculated as described above). We find that the combination of

development-centric OI with R&D capabilities (b=0.23, p<.01) and development-centric OI with market information management capabilities (b=0.16, p<.05) increases product portfolio innovativeness. These findings support H4b and H4c. We note here that, consistent with our assumptions, commercialization-centric OI does not interact with R&D capabilities (b=−0.11, p>.05) or market information management capabilities (b=–0.03, p>.05) to influence product portfolio innovativeness. Launch capabilities interact positively with product portfolio innovativeness (b=0.10, p<.05) to influence sales, supporting H6b.

Robustness analysis

We tested the robustness of our analysis in three ways.

Different time lags for innovation outcomes We re-estimated our analysis by considering the number of new products introduced in the second half of 2009, rather than during the entire year. This allows for the possibility that perhaps open innovation activities take a little longer than 1 year to materialize into novel products (even though the food industry has a very rapid NPD processes). We find that the signs of the various coefficients and the substantive results remain the same as our prior results, demonstrating robustness to the specification of time lags.

Different time lags for control variables We re-estimated the model by controlling for the average number of new products that the firm introduced in the last 3 years rather than in the last 5 years. In results not reported here, but available from the authors, we find the substantive results from this analysis to be identical to those reported here.

Different measure of firm performance We re-estimated the model with three different measures of performance: (1) return on sales, (2) sales and return on sales as two separate measures of performance, (3) sales and return on sales as two dimensions of the construct "performance." The results—available from the authors upon request—do not change, even though the magnitude of the effects is smaller when return on sales, rather than sales is used as the final dependent variable. This reduced magnitude is due to the fact that return on sales accounts for the cost of the innovation activities, while sales do not (Rubera and Kirca 2012). The only notable exception is the moderation effect of launch capabilities in the product portfolio innovativeness- return on sales relationship, which is not significant.

Further analysis

Moderation effect of R&D and market information management capabilities The analysis revealed that R&D and market information management capabilities moderate the relationship between development-centric OI and product portfolio innovativeness. It is hence important to quantify the minimum level of these capabilities that a firm must own in order to reap the benefits of development-centric OI.

In Fig. 2a, we plot the effect of development-centric OI on product portfolio innovativeness at different levels of R&D capabilities. Figure 2a indicates that development-centric OI has a positive effect when R&D capabilities are high (mean plus one standard deviation in Fig. 2a). However, when R&D capabilities are low (mean minus one standard deviation in Fig. 2a), development-centric OI negatively influences product portfolio innovativeness. To get a precise estimate of the level of R&D capabilities at which the effect of development-centric OI on product portfolio innovativeness turns from positive to negative, we estimate $\theta = -\frac{\widehat{\beta}_1}{\widehat{\beta}_2}$ where $\widehat{\beta}_1$ is the estimated effect of development-centric OI on product portfolio innovativeness and $\widehat{\beta}_2$ is the estimated moderation effect of R&D capabilities (Schoonhoven 1981). Negative values of θ indicate the values of R&D capabilities for which development-centric OI negatively influences product portfolio innovativeness. We find that this effect is negative when R&D capabilities are lower than −0.34,[3] namely for 32% of the firms in our sample.

In the same way, we plot the interaction effect of market information management capabilities and development-centric OI on product portfolio innovativeness in Fig. 2b. By adopting the same procedure detailed above, we find that development-centric OI has a negative effect on product portfolio innovativeness when market information management capabilities are lower than −0.5, namely for 15% of the firms in our sample.

The findings of this analysis highlight the existence of a contingency role for development-centric OI: development-centric OI may have a null or even a negative effect on product portfolio innovativeness if the firm does not possess sufficient R&D or market information management capabilities.

Moderation effect of launch capabilities The main analysis revealed that commercialization-centric OI has a mediated effect on sales via product portfolio innovativeness. This mediated effect is in turn moderated by launch capabilities. In other words, the effect of commercialization-centric OI varies at different levels of launch capabilities. We run a moderated-mediation analysis to identify the minimum level of launch capabilities that a firm must own to reap the benefit of commercialization-centric OI. The effect of commercialization-centric OI can be expressed as:

$$f\left(\widehat{\theta}\middle|\text{Launch capabilities}\right) = \widehat{a}_1\left(\widehat{b}_1 + \widehat{b}_2\,\text{Launch capabilities}\right)$$

[3] We have negative values because we use the latent scores from the PLS analysis.

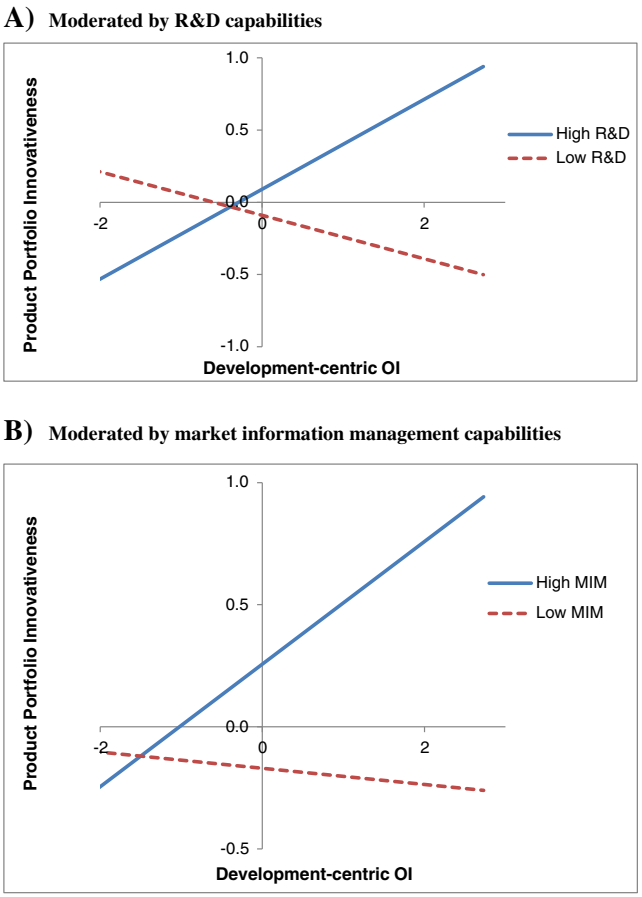


Fig. 2 The Relationship between development-centric OI and product portfolio innovativeness. **a** Moderated by R&D capabilities. **b** Moderated by market information management capabilities

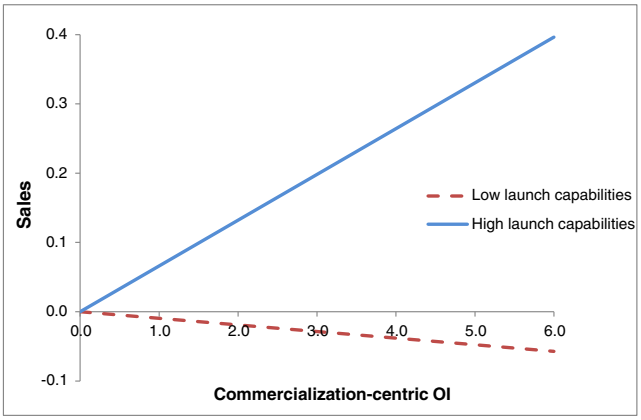


Fig. 3 Moderated mediated effect of commercialization-centric OI on sales (mediated via product portfolio innovativeness and moderated by launch capabilities)

where $\hat{a}_1$ is the estimated effect of commercialization-centric OI on product portfolio innovativeness, $\widehat{b}_1$ is the estimated effect of product portfolio innovativeness on sales and $\widehat{b}_2$ is the interaction between product portfolio innovativeness and launch capabilities on sales. We plot the mediated effect of commercialization-centric OI on sales via product portfolio innovativeness at high and low levels of launch capabilities in Fig. 3. We test the significance of the effect of commercialization-centric OI on sales with a bootstrap procedure (Preacher et al. 2007). We find that commercialization-centric OI has no effect on sales when launch capabilities are lower than −2.00, namely for 6% of the firms in our sample.

Discussion

The increased rate at which both consumer tastes and technology are evolving, shorter innovation cycles, and escalating R&D costs make the traditional, closed innovation model no longer sustainable (Chesbrough 2003). A new paradigm—open innovation—has been offered as an alternate model to sustain a firm's innovation rates. Open innovation envisions firms as porous systems that exchange their ideas, technology, and products with other companies in an effort to maximize commercialization returns. This study provides valuable insights into the effects of open innovation on innovation outcomes and firm performance, and it enriches the ongoing debate about the value of open innovation and its relationship with a firm's internal capabilities.

This research makes three important contributions to the innovation literature. First, we propose a typology of open innovation practices to classify the variety of open innovation activities in which firms are involved. This typology is valuable in that our findings show that different NPD capabilities influence the implementation of different types of open innovation practices and that each open innovation practice has a unique effect on product portfolio innovativeness. Second, we develop a causal model to explain how open innovation and capabilities interact to influence a firm's innovation activities and its performance. We show that NPD capabilities play a dual role in the context of open innovation, by triggering the implementation of open innovation practices as well as by shaping the impact of these practices on product portfolio innovativeness and sales. Third, we investigate when firms can take an advantage of open innovation practices. We show that the value of different practices is strictly contingent on the level of NPD capabilities that a firm owns. These results have important implications.

Theoretical implications

This study offers four critical theoretical implications.

Mediating role of product portfolio innovativeness Over the last few years, the innovation literature has extensively focused on the relationship between open innovation and firm performance. However, there is little research on *how* open

innovation imparts its effects on firm performance. In this study, we identify a route through which open innovation influences firm performance. Our significant results pertaining to the open innovation → product portfolio innovativeness→ firm performance causal chain suggest that the value of open innovation resides in its contribution to the development of a critical resource that increases firm performance.

From a theoretical perspective, this mediating role of product portfolio innovativeness is important for two reasons: First, this finding extends the innovation literature by establishing the link between two critical outcomes of open innovation, namely product portfolio innovativeness and firm performance. Although prior work has demonstrated that open innovation affects the number of new products introduced (Leiponen and Helfat 2010), product innovativeness (Garriga et al. 2013), or performance (Laursen and Salter 2006), the role of product portfolio innovativeness has not yet been explicitly acknowledged and examined as the missing link between open innovation and firm performance. To the best of our knowledge, our study is the first to examine this issue empirically. Second, by using product portfolio innovativeness as an intermediate outcome, we highlight one of the critical roles of open innovation that has not been adequately investigated in the past literature, namely the fact that open innovation contributes to the creation of a valuable resource, such as product portfolio innovativeness, which leads into the firm's entry into new categories. Thus, we bring to the forefront one of the underlying routes through which the performance potential of open innovation is realized and capitalized upon.

The value of open innovation practices A strong result of this research is the fact that the value of development-centric OI is strictly dependent on the level of NPD capabilities. In fact, we find no significant direct effect of development-centric OI practices on product portfolio innovativeness. Specifically, development-centric OI positively influences the number of new-to-the-firm products that firms introduce only when coupled with high R&D and market information management capabilities. These findings indicate that the higher the level of these two capabilities, the higher the benefits of development-centric OI. Thus, development-centric OI acts like a mechanism for the rich to become richer and provides evidence for a complementary relationship between open innovation practices and capabilities. On the contrary, commercialization-centric OI directly affects product portfolio innovativeness. Hence, commercialization-centric OI may act like a substitution mechanism that enable firms to introduce new-to-the-firm products without having to perfect the capabilities necessary to advance to the development stage. This complements the finding of Laursen and Salter (2006) who also allude to a substitution relationship between R&D intensity and open innovation search, but we add to this research by pointing out that not all types of OI practices may substitute for internal NPD capabilities.

A typology of open innovation practices Previous research in the open innovation field has largely focused on the depth and breadth of the external source tapped (Laursen and Salter 2006) and Leiponen and Helfat 2010). Differently, we focus on which stage of the NPD process open innovation occurs.

The findings just described reveal a dichotomy between open innovation that is implemented during the development stage (i.e., development-centric OI) and open innovation that is implemented after the development stage (i.e., commercialization-centric OI). Thus, even though open innovation is currently used as a generic term to indicate a vast array of interactions with external sources, this study shows that scholars involved in open innovation research need to distinguish between the resource that open innovation practices aim to acquire, as well as the stage of the NPD process in which they occur.

The typology that we offer in this study helps clarify some animated debates in the innovation literature. In particular, two different theoretical perspectives have been advanced to explain a firm's decision to open up its innovation system. On the one hand, a KBV perspective contends that R&D capabilities enable firms to recognize the necessity and value of acquiring external resources, thus inducing a positive relationship between the availability of R&D capabilities and the implementation of open innovation. On the other hand, the Not Invented Here (NIH) syndrome posits that firms with high R&D capabilities are more likely to reject any input from outsiders, thus inducing a negative relationship between R&D capabilities and the use of open innovation. Our theorizing suggests that both perspectives have their merits, depending on the open innovation practice analyzed: a KBV perspective can explain a firm's decision to implement (or not) development-centric OI; the NIH syndrome can explain a firm's decision to implement (or not) commercialization-centric OI. Our findings suggests a word of caution for scholars involved in open innovation research, where KBV has emerged as the main theoretical underpinning (Laursen and Salter 2006). Our research indicates that the ability of this perspective to explain open innovation is possibly limited to development-centric practices.

The dual role of NPD capabilities A major contribution of this study is the conceptualization of NPD capabilities as both antecedents of open innovation practices and moderators of the effects of these practices on innovation outcomes and firm performance. While the role of capabilities in recognizing the value of external resources has been acknowledged in some studies (e.g., Cohen and Levinthal 1990), it has been largely neglected in subsequent studies (Todorova and Durisin 2007). To the best of our knowledge, this is the first study to

empirically test for a dual role of capabilities in an innovation context. This research clearly indicates that the role of NPD capabilities is more complex than traditionally believed in the innovation literature. NPD capabilities are relevant not only because they enable firms to effectively utilize externally acquired ideas and technologies, but also because they determine the extent to which a firm opens its innovation system to different kinds of external resources.

Furthermore, the prior literature has almost exclusively focused on R&D capabilities as relevant for open innovation (e.g., Laursen and Salter 2006), while the role of market information capabilities has largely been ignored. Our study clearly indicates that the market knowledge that firms build up and utilize through market information management capabilities is also very relevant in influencing the implementation and effects of open innovation practices. Taken collectively, these findings indicate that a deeper understanding of open innovation requires the use of a more comprehensive perspective of the roles of a broader range of capabilities.

Managerial implications

Our research provides clear indications for managers who aim at increasing the number of new-to-the-firm products that their firms introduce and for those who face the classic "make versus buy" dilemma. We propose that firm-specific levels of R&D, market information management, and launch capabilities may help determine the kind of OI practices to pursue.

The role of R&D and market information management capabilities The analysis reveals that firms with high R&D and market information management capabilities benefit from development-centric OI. The good news for managers is that these capabilities also foster the implementation of this practice, thus creating a virtuous cycle with positive consequences on firm performance. On the other hand, the analysis also reveals that development-centric OI has a null or negative effect on product portfolio innovativeness when R&D capabilities are medium or low, and if market information capabilities are low as well. Hence, managers operating in firms with limited R&D or market information management capabilities may need to improve these capabilities before looking outside for ideas or technologies, in order to better capture the benefits of open innovation on product portfolio innovativeness. Of course, our analysis does not preclude the possibility of using development-centric OI to increase *incremental* innovations. However, managers who aim at entering new categories in the short term may be better off opting for commercialization-centric OI. In fact, the introduction of new-to-the-firm products could help managers buy time to perfect the R&D and market information management capabilities necessary to benefit from development-centric OI, while still showing positive innovation outcomes and positive firm performance to their board of directors or investors.

The role of launch capabilities Launch capabilities influence the extent to which firms implement different open innovation practices, and hence they indirectly influence product portfolio innovativeness. Specifically, our analysis reveals that launch capabilities inhibit the acquisition of ideas and technological knowledge (i.e., implementation of development-centric OI), but foster the acquisition of market-ready products (i.e., implementation of commercialization-centric OI). Hence, managers of firms with robust launch capabilities may increase the innovativeness of their portfolio by implementing commercialization-centric OI, as it typically leads to the addition of new-to-the-firm products in their firm's portfolio. The story is more complicated for the implementation of development-centric OI. Here, managers must consider the level of their other key NPD capabilities. Only managers of firms with high R&D and market information management capabilities may be able to reduce the negative impact of launch capabilities on the implementation of development-centric OI.

Limitations and directions for future research

This work presents some limitations that might stimulate future research. First, open innovation may be considered as involving both inward (i.e., alternate paths to acquisition) and outward (i.e., alternate paths to commercialization) flows of resources (Chesbrough 2003). We analyze the inbound facet of open innovation only. Even though this is the most acknowledged and investigated facet, research is needed to understand the potential of the outbound facet. We believe that a typology similar to what we offer here can be used to study outbound open innovation. While the previous literature investigated the effect of technological licensing, it may be interesting to compare it with ideas and/or market-ready product licensing, in an effort to identify what output (i.e., ideas, technological knowledge, market-ready products) is better to offer in the market. Second, our study is in a relatively low-tech industry. We contend that the effects related to tech-centric open innovation found in this study should be stronger in a high-tech industry. For instance, the role of R&D capabilities in turning external technological knowledge into new-to-the-firm products should be even more relevant in contexts where many different technologies must be combined to create breakthrough innovations (Narasimhan et al. 2006). Or, the faster evolution of technologies may strengthen the effect of market information management capabilities on the implementation of development-centric OI. Future research is needed to investigate how the model that we present here works in high-tech industries. Third, we analyze the effect of the capabilities of the focal firm. As companies gain experience with open innovation, future research might investigate the effect of the capabilities of the partner firms in order to generate successful co-development partnerships (Chesbrough and Schwartz 2007).

Acknowledgments The authors thank Ram Ranganathan and Wim Vanhaverbeke for helpful suggestions on earlier versions of the paper.

Appendix A

Primary measures in the survey

Development-centric OI

Please indicate to what extent in 2007–2008 you collaborated with the following subjects to acquire new ideas to possibly include in new products (1=never; 3=sometimes; 5=for every new product development project in the last 2 years).

a. Suppliers .68*
b. Clients .34*
c. Competitors .65*
d. Consultants .23*
e. Universities or research labs .42*
f. Professional or industry associations −.48*

Please indicate to what extent in 2007–2008 you collaborated with the following subjects to acquire the technology necessary to develop new products (1=never; 3=sometimes; 5=for every new product development project in the last 2 years).

a. Suppliers .76*
b. Competitors .19
c. Consultants .40*
d. Universities or research labs −.02
e. Professional or industry associations .33*

Commercialization-centric OI

Please indicate to what extent in 2007–2008 you collaborated with the following subject to buy new products physically ready to be launched in the market from the following subjects (1=never; 3=sometimes; 5=almost for every product that we introduced in the last 2 years).

a. Suppliers .09
b. Competitors −.50*
c. Consultants .49*
d. Universities or research labs −.95*
e. Professional or industry associations .80*

R&D capabilities (α= 0.85)

Please rate your business unit relative to your major competitors in the following areas in 2007–2008 (1=much worse than competitors; 4=the same as competitor; 7=much better than competitors).

a. Ability to develop new products
b. Developing new products to exploit R&D investment
c. Test marketing of new products

Market information management capabilities (α= 0.85)

Please rate your business unit relative to your major competitors in the following areas in 2007–2008 (1=much worse than competitors; 4=the same as competitor; 7=much better than competitors).

a. Gathering information about customers and competitors
b. Using market research skills to develop effective marketing programs
c. Tracking customer wants and needs
d. Making full use of marketing research information
e. Analyzing our market information

Launch capabilities (α= 0.86)

Please rate your business unit relative to your major competitors in the following areas in 2007–2008 (1=much worse than competitors; 4=the same as competitor; 7=much better than competitors).

a. Successfully launching new products
b. Insuring that the launch of new products is consistent with customer needs
c. Providing sales support

$^{*}p<.05$

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