Search Strategies for External Knowledge and Environmental Innovation: An Analysis of Large Manufacturing Firms

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Abstract

Although the antecedents of environmental innovation and open innovation strategies have been well studied separately, the impact of a firm's openness on environmental innovation remains largely unknown. This article considers the impact of three dimensions of open inbound innovation search strategies—acquiring, sharing, and information sourcing—on environmental product and process innovations and finds positive impacts in each case. Sharing mainly enhances environmental processes, and inbound innovation sourcing reveals that market sources of information from customers, suppliers, and competitors are positively associated with firms' involvement in product and process environmental innovations at all levels. These findings have significant implications in terms of public policy and managerial insights, highlighting the importance of absorptive capacity as a moderator that stimulates environmental innovation. The results suggest substitution effects between acquiring inbound modes and internal R&D and between R&D cooperation and internal sources, as well as complementary effects between internal R&D and institutional information sources and internal sources and market sources of information.

Keywords: Environmental innovation; Open innovation; Inbound innovation; R&D acquisition; R&D cooperation; Sourcing; Search strategies

1. Introduction

From a traditional technology-push view, technological determinants define innovation (Horbach, 2008) and are essential for environmental innovation, as a particular type of technological innovation. For this study, environmental innovation (EI) refers to the result of a strategy that has been assumed, determined, and implemented by a firm (De Marchi, 2012). That is, we differentiate EI from the more inadvertent or unintended notions of eco-innovation or green innovation. It can encompass new or modified processes, products, or services that reduce environmental harms. Empirical studies (Cleff and Rennings, 1999; Rehfeld et al., 2007; De Marchi, 2012; Triguero et al., 2013; Fleith et al., 2014) emphasize the decisive influence of technological capabilities on EI; other critical success factors include markets, laws and regulations, interfunctional collaboration, and innovation-oriented learning (Fleith et al., 2014). Environmental innovation behavior often correlates with stringent environmental policies (Frondel et al., 2008) and regulatory/institutional frameworks (Porter and van der Linde, 1995; Jaffe et al., 2002; Berrone et al., 2013; Belin et al., 2011; Horbach, 2008; Rennings, 2000; Cainelli et al., 2011).

We propose that firms thus search for external knowledge to boost their EI. A vast stream of literature deals with the impacts of external knowledge and open innovation strategies on technological innovation (e.g., Laursen and Salter, 2006; Leiponen and Helfat, 2010). Because innovation draws on many sources of ideas, information, and knowledge, firms might enhance their chances of innovation success by accessing more knowledge sources, networks of collaboration, or information exchanges (Lundvall, 1992). Wider horizons for accessing external knowledge sources also might be associated with successful innovation (Leiponen and Helfat, 2010).

However, the impact of firm openness on EI remains largely unknown. Ghisetti et al. (2014) test the impacts of knowledge source depth and breadth and the moderating effect of absorptive capacity on firms' EI, arguing that such sourcing reduces cognitive distances to a knowledge base related to EI, though they only consider external information sources. We seek to adopt a more global approach and consider how access to external knowledge might come about not only through sourcing but also through R&D acquisition and sharing strategies (i.e., R&D cooperation). Thus we evaluate the use of three modes of openness—acquiring, sharing, and sourcing—and their influence on EI. For our empirical analysis of the drivers of EI according to the degree of openness, we gather data from large manufacturing firms in the French Community Innovation Survey (CIS) for the period 2006–2008.

With this approach, our study differs from previous research in three important ways. First, we consider the role of external sources of innovation and the influence of the search for this external knowledge according to the degree of openness, from the least to the most open modes (i.e., pecuniary to non-pecuniary). Second, we analyze the moderating role of absorptive capacity and complementarity among the different forms of openness and internal R&D (or internal sources of knowledge). Third, we consider the influence of these external knowledge search strategies (informal and informal) on environmental product and process innovations at the firm and consumer levels. Thus we extend understanding of the impact of various types of external knowledge on various types of EI.

In Section 2, we review literature on EI determinants, with a specific focus on openness modes, before we outline the data set, variables, and methods. Section 4 presents the estimation results. Finally, we conclude in Section 5 with some implications for theory and practice and suggestions for further research.

2. Literature review and theoretical developments

Prior EI literature acknowledges the role of supply- and demand-side factors and regulations, whereas the influence of openness remains largely unclear. We focus on the effects of three modes of openness on different EI types: R&D acquisition, R&D cooperation, and external information sources (e.g., suppliers, customers, competitors, R&D institutes). The underlying hypothesis is that openness through different modes enables firms to develop better knowledge-based capabilities, leveraging their innovation capabilities and competences. The transformation of external knowledge, as reflected in the concept of absorptive capacity (AC; Cohen and Levinthal, 1990), should lead firms to develop EI. We develop our theoretical framework by considering different modes of openness, from less (acquiring) to more (sourcing) open.

2.1. *Supply-side determinants: Search strategies for external knowledge*

Open innovation reflects “how firms make decisions about whether to develop innovations internally or partner with external actors” (Dahlander and Gann, 2010: 700). According to this perspective, firms make two important decisions regarding search strategies for external knowledge. First, they must decide whether to use external knowledge. More open innovation should enable them to leverage external research and complement internal R&D, such that traditional R&D activities get augmented with inbound sourcing of external technologies (Chesbrough, 2006). Boundary-spanning activities thus can speed up innovative processes and improve innovation performance (Laursen and Salter, 2006; Spithoven et al., 2013). Second, when firms search for external knowledge, they choose among different methods. Dahlander and Gann (2010), synthesizing growing literature on open innovation, identify two main forms. “Inbound innovation” is a process of acquiring or sourcing, such that the firm discovers, acquires, and uses information or resources developed by external partners. “Outbound innovation” implies that firms communicate their internal resources or competences to the external environment by revealing, signaling, or commercializing their resources. To investigate the extent to which the use of external knowledge influences firms’ ability to introduce EI, we focus on inbound innovation, the most widely studied type (West et al., 2014), and detail three channels: acquiring, sharing, and sourcing.

2.1.1. Inbound innovation acquiring. This strategy refers to the acquisition of valuable resources or expertise from the marketplace (Dahlander and Gann, 2010). Acquisition (embodied technology purchases) and external R&D enable firms to access resources and knowledge from third parties. Firms have access to an external knowledge base through the marketplace and engage in the acquisition of knowledge from technology markets. From a theoretical perspective, external technology acquisition (or inbound open innovation acquiring) complements the firm’s internal knowledge base, to increase the likely success of exploration and exploitation of new ideas. This complementarity between in-house and external R&D enhances the firm’s AC and innovative performance. Using a productivity approach, Cassiman and Veugelers (2006) confirm firms’ better innovation performance when they combine both types of R&D. External R&D also can enhance internal R&D if firms’ willingness to use external ideas helps them avoid the “not invented here” syndrome (Katz and Allen, 1982; Lichtenthaler and Ernst, 2006) or if they have internal R&D departments, as is common in large firms (Veugelers, 1997). Large firms also tend to have more capital and time to acquire input to their EI processes from the marketplace, whereas small firms lack financing to buy new ideas or licenses from third parties. Empirical evidence of the influence of using external R&D on EI is scarce and inconclusive: De Marchi (2012) uses the Spanish CIS from 2007 and finds no significant effect; Bönte and Dienes (2013), with data from 15,200 manufacturing firms across 14 European countries, gathered in the fourth CIS wave, show that firms engaged in external R&D have a lower probability of introducing energy and material efficiency process innovations. Horbach et al. (2012, 2013) find a slight negative influence, but only in process innovations with environmental benefits in areas such as energy, dangerous materials, and recycling. Although several other empirical studies indicate a negative impact, these results can hardly be extrapolated, because they refer to different countries (Spain De Marchi, 2012; Germany Horbach et al., 2012) and include both large firms and small to medium-sized enterprises (SMEs) in the same analysis. Noting the potential benefits of inbound innovation acquisition for large firms, we predict:

H1: Inbound innovation acquisition has a positive effect on environmental innovation.

2.1.2. Inbound innovation sharing. This openness implies that firms enhance their ability to introduce new or improved products or processes by building partnerships with other firms or non-commercial organizations. The argument for the positive influence of this type of openness follows from literature that highlights the growing influence of networking on firms' innovative capabilities. Firms that engage in external relations gain access to complementary partners' knowledge or synergistic skills and capitalize on "incoming spillovers" (Kogut, 1988; Kogut and Zander, 1993; Cassiman and Veugelers, 2002), such that they can reduce the duplication of R&D efforts and the risks and costs associated with innovation projects (Sakakibara, 1997), benefit from economies of scale or scope (Kogut, 1988), and gain access to technology that cannot be acquired on the market (Hagedoorn, 1993). Research on the influence of R&D collaboration on EI, though limited, offers converging results: De Marchi (2012) finds a positive influence of cooperation on EI. European SMEs that collaborate with various actors increase market demand for product EI (Triguero et al., 2013). Collaborative networks with universities and public institutions are essential drivers of all types of EI (Cainelli et al., 2011; Triguero et al., 2013). Horbach et al. (2013) also show a significant influence of R&D cooperation during 2006–2008 in Germany, though only for EI with environmental benefits for the firm (process innovations) related to dangerous substances. We develop the following hypothesis:

H2: Inbound innovation sharing has a positive effect on environmental innovation.

2.1.3. Inbound innovation sourcing. Innovation sourcing describes the extent to which firms can use external information sources for their own innovation activities (Dahlander and Gann, 2010). Growing literature on the role of knowledge inflows and outflows for innovation, spanning a wide range of external knowledge (or information) sources (Amara and Landry, 2005; Huang and Rice, 2012), indicates that the extent to which firms use external sources may signal their degree of openness. Technological network theories of innovation include various informal information sources (Lundvall, 1992; Edquist, 1997), with the assumption that innovative firms connect to highly diversified sets of agents (e.g., consultants, government agencies, university labs, research agencies) through technical networks of collaboration and exchanges of useful information.

Despite considerable research on open innovation, empirical studies of the relationship between information sourcing and EI remain relatively scarce. Belin et al. (2011) find a significant, positive influence of institutional sources (universities) on EI in France but a negative influence of customer sources in Germany. Ghisetti et al. (2014), using CIS 2006–2008 across 11 European countries, reveal that knowledge sourcing has a positive impact on the introduction of an EI and on the diverse types of EI adopted. The systematic, complex, multipurpose nature of EI increases the need to expand the internal knowledge base (De Marchi, 2012; Belin et al., 2011; Ghisetti et al., 2014). Such research highlights the importance of considering different external sources of information to introduce EI, due to the specificities of cleaner technologies with respect to other alternative (or conventional) technologies. In this regard, EI can be more high-tech, complex, and dependent on governmental policy innovation than other technological innovations. Moreover, the high level of uncertainty with respect to impacts along the value chain and to environmental and social concerns (Walz, 2011) suggest that EI firms need a broader scope of external sources.

Similar to Laursen and Salter (2006), we refer to suppliers, users, competitors, research organizations, and universities as external sources that constitute forms of “soft” openness, typically involving knowledge from external parties without entering into legally binding agreements. To investigate their effects, we distinguish market institutional sources from other sources, similar to prior empirical studies of sources of innovation and collaborative networks (Amara and Landry, 2005) and EI (Belin et al., 2011; Bönte and Dienes, 2013). In this regard, market sources enable knowledge-based innovations derived from linkages between actors in markets (suppliers, customers, competitors), whereas institutional sources facilitate knowledge-based innovations derived from science and related more directly to national innovation systems.[1]

[1] Amara and Landry (2005) consider four types of knowledge-based innovations derived from different sources: linkages between actors in markets, science, technological networks, and social networks. Any EI (radical or incremental) implies the creation of technological improvements and social capital around a network, so we consider this traditional classification suitable for our analysis.

Market sources are essential for identifying potential partners to develop new EI projects. They help firms collect and absorb information about the needs and expected demands of clients, as well as better exploit information about the EI programs of their competitors. Strong partnerships with suppliers also can driver EI (Geffen and Rothenberg, 2000). Bönte and Dienes (2013) find that market information, scientific information, and publicly available information sources all enhance introductions of energy and material efficiency innovations. Therefore, we hypothesize:

H3: Inbound innovation sourcing has a positive effect on environmental innovation.

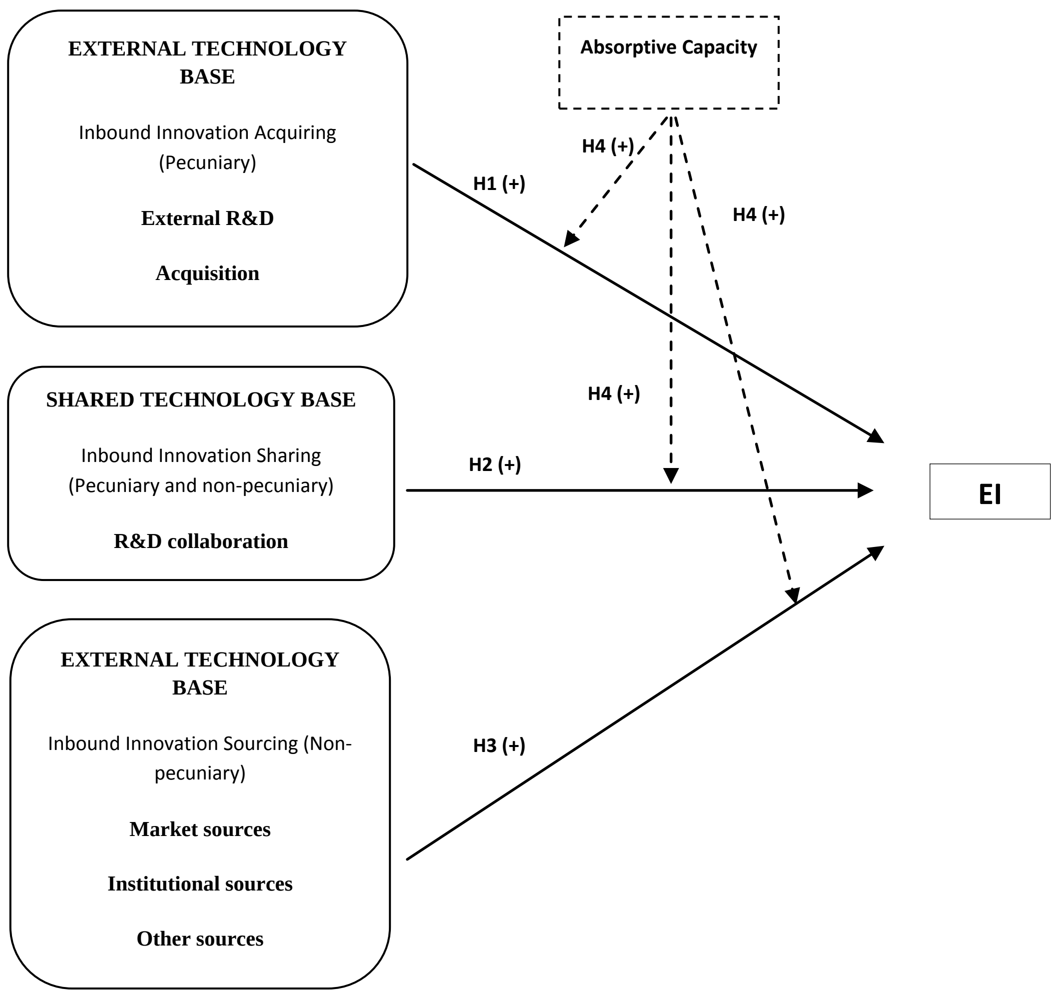
2.2. Absorptive capacity as a moderator between open search strategies and EI

Absorptive capacity (AC) fosters the recognition, assimilation, and application of external knowledge (Cohen and Levinthal, 1990). It "helps a firm to link external and internal technology sourcing, and thereby to benefit from ambidexterity in technology sourcing" (Rothaermel and Alexandre, 2009: 764), and it facilitates the assimilation of new technologies developed elsewhere. Essential for knowledge sharing and sourcing (Liao et al., 2007) and serving a pivotal function in terms of accessing knowledge from external partners (Koch and Strotmann, 2008), AC is a key link between knowledge sharing and innovation capability (Muller and Zenker, 2001). Various studies focus on the factors on which AC depends, such as internal R&D, which increases the intelligibility of external knowledge related to EI by reducing the cognitive distance between the firm and external providers (Ghisetti et al., 2014). But AC also embodies a firm's ability to handle knowledge internally and constitutes a "second face" of R&D (Cohen and Levinthal, 1989). It enables the acquisition, assimilation, transformation, and exploitation of knowledge related to natural environmental protections through proactive environmental strategies. Moreover, AC combined with management support facilitates the adoption of successful environmental strategies and competitive advantages (Delmas et al., 2011; Lenox and King, 2004). We therefore hypothesize:

H4: Absorptive capacity positively moderates the impact of the three search strategies on EI.

We elaborate our theoretical model, in which firms must move past their boundaries to increase their technology base for EI (see Figure 1), in line with literature that shows that the ability to assimilate and exploit external knowledge builds on a firm's AC and is a critical component of innovative performance. From this perspective, external R&D and the acquisition of embodied technology (pecuniary form), R&D collaboration (mixed in pecuniary terms), and sourcing of knowledge (non-pecuniary form) do not replace in-house innovation activities (intramural R&D activities) but rather act as necessary complements of internal technological capabilities for implementing EI.[2]

Figure 1. Conceptual framework



2.3. *Other drivers of environmental innovation*

2.3.1. Regulation. Suitable regulations can favor EI and compensate for related costs (Porter and van der Linde, 1995). Two main elements differentiate EI from other innovations: the double externality problem and the regulatory push/pull effect (Rennings, 2000). Just as

2 We do not consider the synergistic relationship between internal R&D and inbound innovation but investigate them in the same model, with a systematic approach.

innovation and R&D activities are characterized by positive externalities, environmental innovators produce an environmentally positive externality (De Marchi, 2012). Because part of the value created is appropriated by society, in the form of reduced environmental damage, there is a disincentive for firms to invest in products or processes that reduce environmental impacts (Rennings, 2000; Jaffe et al., 2005). This positive externality may prompt a lack of investment or interest by firms, because the direct returns are difficult for them to reap. This market failure induces a greater need for policy interventions to drive EI (Rennings, 2000). Empirical research also shows a positive correlation between regulation and environmental innovations (Gonzalez, 2009; Horbach et al., 2012, 2013). Antonioli et al. (2013), in a comparative analysis, find that polluting sector firms tend to innovate more environmentally than firms outside a polluting sector. This effect of more stringent environmental regulations exists for innovation in general too (Ford et al., 2014), such that some firms over-comply to gain competitive advantages and improved social images, and the costs associated with reduced pollution might be balanced by realized gains (Ambec and Lanoie, 2008). Chen and Chang (2013) examine how institutional pressures affect the adoption of green information systems and information technologies across organizations, showing that both coercive (regulations, policies, contracts, formal programs) and mimetic pressures significantly drive green technological innovation. Kammerer (2009) and Cai and Zhou (2014) also show that external pressures from environmental regulations positively affect EI.

2.3.2. Demand side. There is a strong incentive for firms to engage in EI that are congruent with the customer benefits (Kammerer, 2009). Firms often initiate EI to satisfy minimum customer and societal requirements (Kesidou and Demirel, 2012). Market share has a significant, positive influence on product EI. Moreover, on the demand side, environmental consciousness by consumers and other public or private actors is a relevant parameter to consider by firms that innovate (Horbach, 2008). Customers' environmental demands affect firms' EI (Cai and Zhu, 2014).

3. Data and methodology

3.1. Data

Firm-level data were drawn from the French CIS for 2006–2008. This survey collects general information about the firms (activity sector, group, number of employees, sales, geographic market), technological and non-technological innovations, perceptions of factors that may hamper innovative activities, and subjective evaluations of innovation outcomes. The survey also provides information about strategies pursued by the firm to search external knowledge and other variables related to the innovation process (R&D, internal sources of knowledge information, cost reduction motives). We focus on large firms with at least 250 employees that operate in the manufacturing sector. The resulting sample of 1,292 firms helps ensure the robustness of our analysis.

3.2. Dependent variables

We distinguished four dichotomous variables to determine if the firm produced an EI during the focal period. *Ecoproduct_firm* (*Ecoprocess_firm)* is a binary variable, equal to 1 if the firm introduces a product (process) innovation with environmental benefits for the stage in which it produces goods or services (e.g., reduced material use per unit of output, recycled waste, water, or materials), and 0 otherwise. This EI usually implies so-called clean technologies that reduce waste or pollution generated through the production process or during the product's life cycle. *Ecoproduct_market* (*Ecoprocess_market)* equals 1 if the firm introduces product (process) innovation with environmental benefits for the customers, at the stage of after-sales use of a good or service by end users (e.g., reduced air, water, soil, or noise pollution; reduced energy use; improved recycling of product after use), and 0 otherwise. We thus define EI as an innovation in products and processes that can deliver more value to producers (*_firm)* or consumers *(_market)*.

Appendixes 1 and 2 contain the variable definitions and descriptive statistics, showing that 56% of firms in our sample introduced a new or significantly improved product EI at the firm level, and 41% at the market level; 54% introduced a process EI at the firm level, and 38% at the market level.

3.3. Independent variables

To assess the impact of openness on environmental innovation, we use external R&D acquisition, R&D cooperation, and different external sources of information as proxies for openness, classified as three modes: inbound acquiring, inbound sharing, and inbound sourcing.

For *inbound acquiring*, we used two binary variables: external R&D, which measures whether firms' innovation activities during the reference period were performed by other firms or public or private research organizations and then purchased by the focal firm; and acquisition of advanced machinery, software, or licensed patents and non-patent inventions or know-how to produce new or significantly improved products and processes. Regarding *inbound sharing*, R&D cooperation is a binary variable that measures whether firms have cooperated in any of their innovation activities with other firms or institutions during 2006–2008. For *inbound sourcing*, we introduced different types of sources of information. Market sources refer to suppliers, clients, competitors, or other firms in the sector, as well as consultants, commercial labs, or private R&D institutes. Institutional sources are universities, other higher education institutions, government, and public research institutes. Finally, other sources of information include the use of patents, databases, trade literature, or fairs. These variables equal 1 if that specific source inflow is crucial to firm innovation activities and 0 otherwise.

We find that 47% of firms acquired knowledge, 41% used external R&D, and nearly 51% undertook R&D cooperation. Regarding sources of information, 38% relied on market sources, 14% used other sources, and only 6% benefited from institutional sources[3] (see Appendix 2).

As a robustness check, we introduced a new measure to assess the intensity of search strategies. Similar to Laursen and Salter (2006), Leiponen and Helfat (2010), and Ghisetti et al. (2014), this variable reflects three inbound innovation types. That is, we summed the three variables, *Sourcing*, *Sharing*, and *Acquiring*, to obtain *Intensity*, which varies from 0 when the firm uses no inbound information, to 3 when all three modes are employed.

Researchers have measured AC with various indicators. Cohen and Levinthal (1990) use R&D intensity, but internal R&D is a more general measure. The convenience of measuring diverse internal sources of knowledge justifies the inclusion of an alternative variable, to check the robustness of our results. We therefore use two proxies of AC: internal R&D and internal sources of knowledge (see Appendix 1).

In line with prior literature, we also introduced a set of environmental regulation variables, including existing or expected environmental regulations, taxes on pollution, environmental financial regulations, voluntary codes, and agreements for environmental good practices within the sector (*Existing regulations* and *Expected regulations*). We also added the firm's objective for introducing EI: financial, such as benefiting from grants, subsidies, or other financial incentives; as a response to legislation; reduced labor costs; as a response to

[3] Institutional sources are still an infrequent method, though this variable equals 1 if the use of institutional sources is crucial for firm's innovation activities and 0 otherwise. The restriction is thus very high.

market demand; or due to control procedures for regularly identifying and reducing environmental impacts, such as environmental audits, environmental performance goals, or ISO 14001 certifications (*Control procedures*). To account for market-pull determinants, we introduced the variable *Market demand,* equal to 1 if the firm introduced an EI in response to current and expected market demand from customers for environmental products or services, and 0 otherwise. The *Market geography* variable used a four-point Likert response scale, with 1 = local market, 2 = national, 3 = European, and 4 = global market. The correlations across these variables are in Appendix 3.

Finally, we included traditional control variables that should influence firms' EI capabilities. *Firm size* is the natural logarithm of the number of employees. *Group belonging* equals to 1 if the firm belongs to a group and 0 otherwise. Firms that are members of a group tend to have more incentives for innovation activities, because of their easier access to financing (Love and Roper, 2001) and ability to apply an innovation strategy adopted by their headquarters. Four *subsectors of activities* reflect a two-digit NACE classification of manufacturing industries based on R&D intensity (OECD, 2011): (1) high-tech, (2) medium high-tech, (3) medium low-tech, and (4) low-tech (reference category).

4. Results and discussion

Table 1 presents the results of the multivariate Probit model regarding the likelihood of introducing EI. The results on the impact of openness are significant, though we also find some differences across the various modes.

Regarding inbound acquisition, the results indicate a significant, strongly positive impact of the acquisition of embodied technology on environmental products and processes for firm and market levels. In the same vein, external R&D has a significant influence on all types of EI we consider, in support of H1. This finding contrasts with previous findings (e.g., De Marchi, 2012; Horbach et al., 2012), though as we noted, these results are not totally comparable, because previous studies included a high proportion of small firms.

Inbound sharing (R&D cooperation) was positively associated only with process EI at the firm level. These results are counterintuitive and conflict with recent results that indicate firms actively develop R&D partnerships to benefit from incoming spillovers (Kogut and Zander, 1993; Triguero et al., 2013). Our results thus suggest that firms are more reticent to share product EI than process EI with their partners, probably due to appropriability concerns. Regarding the inbound sharing innovation mode, our results partially reject H2. Product innovation usually generates more value creation than process innovation. Moreover, product EI often are more radical than process EI. Thus, firms attempt to be open but can capture returns from their innovative efforts. In this sense, Laursen and Salter (2014) affirm that non-pecuniary inbound open innovation is strongly influenced by a firm's "pecuniary" logic, manifested by its capability to appropriate innovative returns. The problems of appropriability associated with product innovation could explain our findings. This finding is related to the paradox of openness: The creation of innovations often requires openness, but the commercialization of innovations requires protection.

The results for inbound sourcing vary with the type of information source. Market sources of information are positively and significantly associated with firms' involvement in product and process EI at all levels (production and end-user stages), partly in support of H3. However, the intensive use of institutional sources instead has a negative, significant impact on the likelihood of product EI at the firm level, whereas other sources, such as conferences, scientific journals, and professional associations, have no influence on any type of EI. Thus, we must partly reject H3 and H3. This finding also could be explained by the greater challenges for appropriability returns on product EI (more radical innovations) than process EI. Companies use their collaborations with universities to explore new knowledge that is far from the market, not for the direct achievement of new products and processes (Feller et al., 2002). A successful collaboration with universities demands prior ties, certain technological similarities, and geographic closeness (Petruzzelli, 2011).

Testing for the impact of AC, we consider the direct influence of internal R&D and internal sources and their indirect role for each mode of openness (Table 1). The likelihood of EI increases for firms that invest in internal R&D and have internal knowledge sources (i.e., intramural R&D and internal sources are both significant and positive). Previous studies similarly highlight the direct role of a firm's AC (Koch and Strotman, 2008) and social integration mechanisms for external knowledge (Zahra and George, 2002), which we capture as the existence of intensive internal information sources. With regard to their moderating role, we find that in-house R&D negatively moderates the impact of acquiring inbound innovation. The interaction terms *Acquisition×R&D* and *ExtR&D×R&D* have significant, negative effects on all types of EI, after we account for the other explanatory and control variables. The combination of an external acquisition of embodied technology and R&D with internal R&D disincentives all types of EI, so we must reject H4. However, these results affirm Ghisetti et al.'s (2014) proposition that interactions with external knowledge sources increase the chance of mismatches between external and internal R&D programs and generate problems for distributing decision makers' attention across the two.

The interaction term *SoInsti×R&D* instead is significant and positive, suggesting that internal R&D positively moderates the impact of the use of institutional knowledge sources, particularly on product EI. We found no evidence for environmental processes. This result provides strong support for the moderating role of AC in the relationship between institutional information sourcing and environmental product innovation at the firm and market levels. In other words, the intensive use of institutional sources of information, stemming from public or private R&D institutes or universities, has a beneficial effect on product EI, but only for firms that have invested in internal R&D. Information stemming from research institutes may be academic or scientific in nature, so the firm needs the internal skills, knowledge, and competences to translate information into innovative products. Thus, H4 is partly supported.

With regard to the moderating role of our second measure of AC (internal sources), we ran regressions with our main explanatory variables (sourcing, acquiring, and sharing) using internal knowledge sources as a proxy (Table 2). The interaction term *SoMarket×InternalSources* is significant and positive, in partial support of H4. The more firms have social integration mechanisms through efficient systems of internal information transfers, the greater their capabilities to assimilate and exploit information from the market, and the greater the probability that they introduce EI. In contrast, *Cooperation×InternalSources* is significant and negative; cooperation in R&D has positive and direct effects on EI. Internal sources of information thus exert negative impacts on the positive relation between cooperation and EI. These findings suggest that for high levels of internal sources, a substitution effect arises between cooperation and internal sources of knowledge. Although R&D cooperation enhances EI, its influence is stronger in firms with fewer rather than many internal knowledge sources. This finding confirms substitution between R&D from collaboration and the firm's internal sources.

As a robustness check, we tested our hypotheses using a measure of the *intensity* of search strategies for external knowledge, instead of individual modes of inbound innovation (Table 3). This new specification enables us to include the interactions with our two proxies of absorptive capacity (*Intensity×InternalR&D* and *Intensity×InternalSources*). First, external search intensity has a positive, significant impact on EI in all models, which reinforces our previous findings (Table 1) and confirms the general hypothesis that openness drives EI. Second, the parameter for $Intensity^2$ is negative and strongly significant in all models, indicating the decreasing returns of information sources when firms make use of too many search strategies. This result tends to indicate a curvilinear, inverted U-shaped relationship between the intensity of openness and EI. Although intensive search strategies for external knowledge might enhance the probability of EI, deepening this search beyond a certain level may be adverse for EI. A possible explanation is that the implementation and use of inbound information sourcing has potential disadvantages, related to the difficulty of choosing and combining too many alternatives and aligning them with existing knowledge (Petruzzelli, 2011). Overly deep search strategies thus could have negative effects on firms' profitability and ability to introduce EI. Despite the positive effect of deep search strategies, exaggerating this search above a certain level may create problems related to the allocation of human and financial resources, such as to develop/manage internal knowledge within the firm or search for/manage/assimilate external information. Such allocation challenges in turn might create a conflict-laden, adverse environment that hampers EI.

With regard to the moderating role of AC, we find a negative, significant influence of *Intensity×InternalR&D*. Internal R&D seems to mitigate the positive effect of intensive open search strategies in EI, confirming our results related to the indirect role of internal R&D. However, the intensity of search strategies and internal sources has no influence on EI.[4]

For the other explanatory variables, we find that reducing labor costs can help explain EI, in line with Kesidou and Demirel (2012) and Horbach et al. (2012, 2013), in that cost savings, especially in terms of material and energy, are important incentives for EI. Among the demand factors, the geographic market variable is positively and significantly associated to EI as a clean technology (firm level); the coefficient of product EI as end-of-pipe technologies (market level) is insignificant. Therefore, firms that function in a global market could face more competition and exhibit a higher capacity to develop product EI. As expected, we found positive, significant coefficients of market demand in all models. Firms that report current or expected demand from customers for environmentally friendly products have a higher capacity to generate this type of innovation, in line with former studies (Kammerer, 2009; Horbach, 2008; Triguero et al., 2013).

[4] Using the CIS 2006–2008 for 11 European countries, Ghisetti et al. (2014) find different effects of the depth and breadth of knowledge sourcing (positive and negative, respectively) on firms' EI. These results are not directly comparable with ours, because their breadth variable measures the number of external information sources the firm relies on, whereas our intensity variable is the number of search strategies the firm uses. Their breadth ranges from 0 to 9; our intensity varies from 0 to 3 (acquisition, sharing, and sourcing). We cannot introduce the depth of innovation inbound modes, because the French CIS data do not enable us to do so.

Both demand and supply factors affect both product and process EI. Previous studies (e.g., Rave et al., 2011) instead suggested that the introduction of eco products was guided mainly by demand factors and market opportunities, while green processes stemmed from supply factors. Our results do not support this distinction but are in line with other studies that adopt a more holistic, systematic view (Horbach et al., 2012; De Marchi, 2012; Triguero et al., 2013).

Environmental regulation has an important role, as a motivator that triggers environmental innovation. Some differences arise in terms of the nature of the regulation though. Existing regulations exert a significant, positive impact on both types of EI (Horbach et al., 2012, 2013). Expected regulations have positive, strongly significant effects on product EI, but no evidence arises for process EI, in line with the Porter hypothesis but in contrast with previous empirical results that found no effect of expected regulation on the likelihood of green innovative products (Kammerer, 2009; Triguero et al., 2013). Voluntary environmental codes for good practices within a sector also enhance EI of any type. Firms that have implemented environmental management systems are, perhaps not surprisingly, more likely to engage in environmental products and processes in the production and end-user stages (Wagner, 2007).[5] Subsidies and other public financial incentives do not have any significant impact, a finding that contrasts with Horbach's (2008) indication of an important role of subsidies in motivating firms to introduce EI but in line with other studies (Belin et al., 2011; Triguero et al., 2013; Cuerva et al., 2014). This result might reflect the inadequacy or inefficacy of subsidies as environmental policy instruments to enhance EI. Finally, as we expected, firm size exerts a significant and positive impact on EI.

[5] The presence of this positive association should be interpreted with caution though; it does not explicate the causal relationship between the two variables. Firms with many environmental projects likely have regular control procedures over their environmental impacts.

Table 1

Multivariate Probit regressions with different categories of openness

	(1) Ecoproduct_firm	(2) Ecoproduct_market	(3) Ecoprocess_firm	(4) Ecoprocess_market
Acquiring				
Acquisition	1.207***	0.909*	0.784***	1.425***
	(0.247)	(0.305)	(0.010)	(0.255)
External R&D	0.926***	0.817***	0.803**	0.922***
	(0.285)	(0.266)	(0.385)	(0.275)
Sharing				
R&D cooperation	0.135	0.101	0.302***	0.129
	(0.109)	(0.103)	(0.103)	(0.101)
Sourcing				
Market sources	0.540***	0.255***	0.205***	0.145*
	(0.094)	(0.108)	(0.026)	(0.798)
Institutional sources	-0.391**	-0.400	-0.451	-0.788
	(0.278)	(0.875)	(0.452)	(0.255)
Other sources	0.055	0.254	0.193	0.887
	(0.140)	(0.155)	(0.186)	(0.174)
Moderating role of absorptive capacity (intramural R&D)				
Acquisition×R&D	-0.835***	-0.855***	-1.645***	-1.140***
	(0.285)	(0.244)	(0.310)	(0.262)
ExtR&D×R&D	-0.989***	-0.425***	-0.812***	-0.930***
	(0.305)	(0.285)	(0.395)	(0.244)
Cooperation×R&D	-0.049	-0.146	-0.789	0.028
	(0.337)	(0.309)	(0.351)	(0.311)
SoMarket×R&D	0.085	-0.241	0.221	-0.325
	(0.321)	(0.306)	(0.371)	(0.296)
SoInsti×R&D	1.852***	0.095**	0.285	-0.421
	(0.333)	(0.890)	(-0.452)	(-0.452)
SoOther×R&D	-0.752	-0.352	-0.478	-0.782
	(0.952)	(0.451)	(0.781)	(0.251)
Other supply factors				
Intramural R&D	1.714***	1.513***	1.458***	1.253**
	(0.123)	(0.124)	(0.210)	(0.119)
Cost reduction	0.752***	0.886***	0.498***	0.114
	(0.102)	(0.095)	(0.095)	(0.072)
Internal sources	0.483***	0.442***	0.316**	0.325
	(0.091)	(0.055)	(0.104)	(0.090)
Environmental policy factors				
Existing regulations	0.248**	0.129	0.369***	0.282***
	(0.111)	(0.105)	(0.106)	(0.105)
Expected regulations	0.247**	0.282***	0.0937	0.163
	(0.123)	(0.109)	(0.116)	(0.109)
Environmental codes	0.229**	0.205**	0.184*	0.335***
	(0.111)	(0.101)	(0.106)	(0.094)
Control procedures	0.386***	0.218**	0.400***	0.246**
	(0.103)	(0.105)	(0.0988)	(0.104)

Public funding	0.051	0.762	-0.031	0.134
	(0.169)	(0.146)	(0.154)	(0.139)
Demand factors				
Market demand	0.392***	0.778***	0.284***	0.685***
	(0.112)	(0.0992)	(0.105)	(0.0962)
Market geography	0.166**	-0.0103	0.0158	-0.111
	(0.0683)	(0.0649)	(0.0613)	(0.0619)
Control variables				
Size	0.255***	0.246**	0.840**	0.456***
	(0.043)	(0.040)	(0.096)	(0.116)
Belonging to group	-0.214	-0.049	0.474	0.494
	(0.162)	(0.151)	(0.111)	(0.146)
Sector dummies	Yes	Yes	Yes	Yes
Constant	-2.204***	-2.540***	-2.789***	-2.857***
	(0.573)	(0.454)	(0.487)	(0.444)
Observations	1,292	1,292	1,292	1,292
Pseudo R-squared	0.447	0.381	0.389	0.31-45
Log Likelihood	-455.3	-578.2	-585.2	-599.4

Notes. Standard errors are in parentheses. ***$p < .01$. **$p < .05$. *$p < .1$.

Table 2

Multivariate Probit regressions with different categories of openness

	(1) Ecoproduct_firm	(2) Ecoproduct_market	(3) Ecoprocess_firm	(4) Ecoprocess_market
Acquiring				
Acquisition	0.217***	0.459**	0.254***	1.455***
	(0.047)	(0.545)	(0.140)	(0.125)
External R&D	0.926***	0.817**	0.453*	0.922*
	(0.245)	(0.156)	(0.545)	(0.205)
Sharing				
R&D cooperation	0.154**	0.112***	0.345***	0.199**
	(0.192)	(0.145)	(0.187)	(0.148)
Sourcing				
Market sources	0.440***	0.855***	0.215***	0.545*
	(0.194)	(0.102)	(0.046)	(0.998)
Institutional sources	-0.392	-0.401	-0.471	-0.988
	(0.228)	(0.885)	(0.472)	(0.215)
Other sources	0.085	0.274	0.194	0.888
	(0.170)	(0.195)	(0.186)	(0.144)
Moderating role of absorptive capacity (internal sources)				
Acquisition×InternalSources	-0.825	-0.875	-1.655	-1.110
	(0.212)	(0.278)	(0.356)	(0.452)
ExtRD×InternalSources	-0.919	-0.475	-0.212	-0.040
	(0.385)	(0.245)	(0.385)	(0.144)
Cooperation×InternalSources	-0.049*	-0.146**	-0.789**	-0.028**
	(0.337)	(0.309)	(0.351)	(0.311)
SoMarket×InternalSources	0.379*	0.660***	0.254*	0.875**
	(0.341)	(0.376)	(0.171)	(0.286)
SoInsti×InternalSources	0.850	0.045	0.125	0.254
	(0.333)	(0.890)	(-0.452)	(-0.452)
SoOther×InternalSources	-0.782	-0.392	-0.778	-0.792
	(0.052)	(0.751)	(0.780)	(0.151)
Observations	1,292	1,292	1,292	1,292
Pseudo R-squared	0.547	0.391	0.349	0.314
Log Likelihood	-545.3	-458.2	-585.2	-590.4

Notes. Standard errors are in parentheses. ***$p < .01$. **$p < .05$. *$p < .1$.

Table 3

Multivariate Probit regressions with intensity of search strategies

VARIABLES	(1) Ecoproduct_firm	(2) Ecoproduct_market	(3) Ecoprocess_firm	(4) Ecoprocess_market
Intensity	0.635***	0.500***	1.149***	0.839***
	(0.162)	(0.171)	(0.167)	(0.178)
Intensity^2	-0.101**	-0.085***	-0.224***	-0.170***
	(0.047)	(0.048)	(0.049)	(0.045)
Intensity×InternalRD	-0.187*	-0.103**	-0.058**	-0.141**
	(0.983)	(0.089)	(0.073)	(0.029)
Intensity×InternalSources	0.012	0.123	-0.001	0.145
	(0.197)	(0.125)	(0.174)	(0.119)
Observations	1,292	1,292	1,292	1,292
Pseudo R-squared	0.464	0.356	0.408	0.324
Log Likelihood	-537.4	-584.5	-552.8	-525.5

Notes: Standard errors are in parentheses. ***p < .01. **p < .05. *p < .1.

5. Conclusions

This paper analyzes the relevance of search strategies for external knowledge as they relate to environmental innovation. We have explored the role of different modes of openness on EI, considering the influences of acquisition and external R&D (inbound innovation acquiring), R&D cooperation (inbound innovation sharing), and external information sources (inbound innovation sourcing) to explain environmentally friendly product and process innovations at the firm level (business value to the firm) and consumer level (value to customer). Accordingly, we estimated a multivariate probit and further sensitivity and robustness checks using data from the French CIS 2008.

Our results provide important evidence about the relationship between search strategies and EI. First, when analyzing the effects of the three modes of search strategies on the implementation of EI for the firm and customers, we found strong support for the influence of each search strategy for external knowledge. Acquisition (embodied technology or external R&D) positively influences environmental products and processes, at the firm and market levels. The impact of sharing through R&D cooperation (pecuniary and non-pecuniary) varies with the type of innovation. Whereas R&D cooperation positively influences process EI at the firm level, it has no significant influence on product EI. As for information sources, market sources of information are positively and significantly associated with all types of EI.

Second, firms' absorptive capacity, captured through internal R&D and internal sources of information, moderate the effect of search strategies for external knowledge on EI. However, this moderating effect shifts, depending on our measure of AC. Regarding internal R&D, we find that indigenous R&D enhances EI but negatively moderates the effect of acquiring embodied technology and R&D from third parties. Internal R&D positively moderates the negative influence of institutional sources, such as universities or research centers. This finding indicates that companies need some minimum level of internal R&D to enable collaborations with universities (i.e., science-based knowledge).

With respect to internal sources of knowledge, the availability of social integration mechanisms, through efficient systems of internal information transfers, enhance firms' capabilities to assimilate and exploit information from the market and thus their EI. In this regard, an intensive use of institutional sources stemming from public or private R&D institutes or universities has a beneficial effect on product EI for firms that have invested in internal R&D. Absorptive capacity, measured by internal sources, is crucial to assimilate and exploit such information. However, internal knowledge sources mitigate the positive relation between R&D cooperation and EI. Thus, the moderating effect of AC on EI varies with the type of search strategies and their characteristics. Finally, we considered the intensity of open search strategies and found a likely curvilinear relationship between the intensity of search strategies and EI. Although intensive search strategies for external knowledge enhance the probability of EI, deepening this search beyond a certain level may be adverse for EI.

We sought to extend existing literature on open innovation and environmental innovation to analyze the influence of different modes of inbound open innovation in the emergence of EI. External search strategies are more relevant for EI than for general innovation, and this type of innovation depends on the strategic interaction between internal knowledge and external knowledge, so the choice of appropriate combinations of openness are critical. To access a wide array of ideas and knowledge to enhance innovation with environmental benefits, companies should acquire outside technology licenses, subcontract their green R&D, cooperate to access partners' knowledge, or rely on non-pecuniary external sources of innovation.

However, our findings also highlight some potential limitations. Companies might over-search in open modes. Despite the benefits of leveraging complementarities with formal and informal partners, a minimum amount of internal R&D and internal sources is required to discover radical new solutions to mitigate environmental problems (not just incremental solutions). In the same sense, AC is essential: Companies must be able to absorb external ideas and integrate them with their own knowledge.

The implications for theory include the need for researchers to investigate more carefully how open search strategies might foster EI; they may be more crucial for EI than for other types of innovation (De Marchi, 2012), considering the macroeconomic consequences of such innovations on sustainable development. Increasing empirical literature on the role of openness for firms' innovative performance focuses almost exclusively on traditional (or dirty) technological innovation. We contribute to literature on open innovation and EI by undertaking the first study to consider the impact of various types of openness and search strategies for external knowledge on EI. Incorporating different forms of openness enables us to highlight their differentiated impacts on EI and differentiated moderating affects of firms' absorptive capacity. For example, when measured by intramural R&D, AC negatively moderates the influence of acquiring inbound innovation on (all types of) EI.

Our work is not exempt from limitations though. We concentrate on large manufacturing firms; small and service firms might be of interest, considering their prominence and important role in modern economies. Other independent variables related to openness also might be added, such as belonging to a cluster, which is a primary channel for diffusing information across firms and gathering knowledge-based social capital to enhance EI. For public policy makers, research should compare the search strategies for EI against those for non-environmental innovations, to identify if EI requires more or different types of openness modes. Finally, assessing the various complementarities among sources of information and across innovation types could be interesting; firms rarely choose to concentrate on one source or innovation type but instead prefer to combine them (Dahlander and Gann, 2010).

Notwithstanding these caveats, the evidence we present highlights the implications for practice management in the complex combination of internal and external knowledge required to enhance EI activities. All types of EI correlate generally positively with external modes of openness (acquisition, R&D cooperation, sourcing); striking a balance between search strategies for external knowledge and intramural R&D might be necessary in certain cases. In this regard, managers must consider the need to balance internal and external knowledge that enhances environmental performance. Because the search strategy for external knowledge and the level of intramural R&D is mainly determined by managers, an optimum level of ambidexterity might allow firms to configure and leverage their internal and external knowledge resources, in terms of the influence of technology sourcing strategies on environmental performance, moderated by absorptive capacity (Rothaermel and Alexandre, 2009). The influence of market sources of information on all types of environmental innovation also indicates new evidence regarding the incorporation of ecological considerations into product design processes. Collaborative efforts and joint developments of green technologies in an open innovation framework can enhance the relationship between environmental collaboration in the supply chain and manufacturing performance, either upstream toward suppliers or downstream toward customers (Vachon and Klassen, 2008).

Finally, implications for public policy, in terms of the macroeconomic consequences for sustainable development, should be assessed. Our findings suggest that policy makers can promote measures to increase EI activities by supporting different search strategies for external knowledge that complements the internal knowledge base. Thus, a country might promote EI by enhancing the openness of its national innovation system, using firm subsidies to encourage collaborations with institutions, such as universities or technology centers. We know little about the influence of informal collaborations with universities. An understanding of this progress could offer greater potential for effective policy measures that can support university–industry collaborations in EI. The challenge to the “open eco-innovation mode,” as detailed in the 2011 Eco-Innovation Action Plan by the European Commission, could be to move beyond green innovative processes, products, and services to reinforce the objectives pursued during the transition to a resource-efficient, low-carbon economy. Fostering inbound and outbound innovation process beyond the EU also could enable the development and implementation of policy programs to stimulate or enforce more sustainable innovations, to transfer, translate, and transform knowledge (Carlile, 2004) across firm, geographical, sectorial, and institutional boundaries.

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Appendix 1. Variable definitions

Variables	Description
Dependent variables	
Ecoproduct_firm	Equal to 1 if the firm has introduced a product innovation with environmental benefits at the production stage (reduced material use per unit of output; recycled waste, water, or materials) within the firm; 0 otherwise
Ecoproduct_market	Equal to 1 if the firm has introduced a product innovation with environmental benefits at the after-sales stage (reduced air, water, soil, or noise pollution; reduced energy use; improved recycling of product after use); 0 otherwise
Ecoprocess_firm	Equal to 1 if the firm has introduced a process innovation with environmental benefits at the production stage (reduced material use per unit of output; recycled waste, water, or materials) within the firm; 0 otherwise
Ecoprocess_market	Equal to 1 if the firm has introduced a process innovation with environmental benefits at the after-sales stage (reduced air, water, soil or noise pollution; reduced energy use; improved recycling of product after use); 0 otherwise
Openness	
Intensity	Equal to 1 if the firm has simultaneously experimented with inbound information sharing, inbound information sourcing, and inbound information acquiring, 0 otherwise
Acquisition	Equal to 1 if the firm has acquired advanced machinery, equipment, and computer hardware or software to produce new or significantly improved products and processes, 0 otherwise
External R&D	Equal to 1 if the firm's R&D activities are performed by other firms or public or private research organizations and purchased by the firm, 0 otherwise
R&D Cooperation	Equal to 1 if the firm undertakes R&D cooperation for innovation activities with other firms or institutions during 2006–2008, 0 otherwise
Market sources	Equal to 1 if competitors, suppliers, customers, consultants, and private R&D institutes as sources of information are "crucial" for the firm's innovation process, 0 otherwise
Institutional sources	Equal to 1 if universities, other higher education institutions, government, or public research institutes as sources of information are "crucial" for the firm's innovation process, 0 otherwise
Other sources	Equal to 1 if conferences, scientific journals, professional associations, or technical standards as sources of information are "crucial" for the firm's innovation process, 0 otherwise
Other supply factors	
Intramural R&D	Equal to 1 if the firm undertakes R&D activities within the firm to increase the stock of knowledge
Cost reduction	Equal to 1 if the firm has introduced an environmental innovation to reduce labor costs, 0 otherwise
Internal sources	Equal to 1 if departments within the firm or enterprises within the same group as sources of information are "crucial" for the firm's innovation process, 0 otherwise
Environmental policy factors	
Existing regulations	Equal to 1 if the firm has introduced an environmental innovation in response to existing environmental regulations or taxes on pollution, 0 otherwise
Expected regulations	Equal to 1 if the firm has introduced an environmental innovation in response to environmental regulations or taxes that the firm expects to be introduced in the future, 0 otherwise
Environmental codes	Equal to 1 if the firm has introduced an environmental innovation in response to voluntary codes or agreements for environmental good practices within the sector, 0 otherwise
Control procedures	Equal to 1 if the firm has procedures in place to regularly identify and reduce the environmental impacts, such as environmental audits, environmental performance goals, or ISO 14001

	certification, 0 otherwise
Public funding	Equal to 1 if the firm has introduced an environmental innovation in response to the availability of government grants, subsidies, or other financial incentives, 0 otherwise
Demand factors	
Market demand	Equal to 1 if the firm has introduced an environmental innovation in response to current and expected market demand from customers for environmental innovations, 0 otherwise
Market geography	Four-point Likert response scale: 1 = local, 2 = national, 3 = European, and 4 = global
Control variables	
Belonging to group	Equal to 1 if part of a group; 0 otherwise
Size	Logarithm of the number of employees
High Technology	High-tech manufacturing
Medium High Technology	Medium high-tech manufacturing
Medium Low Technology	Medium low-tech manufacturing
Low Technology	Low-tech manufacturing (reference)

Appendix 2. Summary statistics

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Ecoproduct_firm	1292	0.56	0.49	0	1
Ecoproduct_market	1292	0.41	0.49	0	1
Ecoprocess_firm	1292	0.54	0.47	0	1
Ecoprocess_market	1292	0.38	0.45	0	1
Intensity	1292	0.21	0.42	0	3
R&D cooperation	1292	0.51	0.50	0	1
Acquisition	1292	0.47	0.45	0	1
External R&D	1292	0.41	0.49	0	1
Market sources	1292	0.38	0.48	0	1
Institutional sources	1292	0.06	0.23	0	1
Other sources	1292	0.14	0.34	0	1
Existing regulations	1292	0.46	0.49	0	1
Expected regulations	1292	0.33	0.47	0	1
Environmental codes	1292	0.35	0.46	0	4
Control procedures	1292	0.62	0.48	0	1
Public funding	1292	0.11	0.31	0	1
Cost reduction	1292	0.45	0.49	0	1
Internal sources	1292	0.59	0.49	0	1
Market demand	1292	0.30	0.46	0	3
Market geography	1292	3.60	0.74	0	4
Belonging to group	1292	0.93	0.25	0	1
Size	1292	6.29	0.71	5.52	9.91
High technology	1292	0.14	0.34	0	1
Medium high technology	1292	0.29	0.45	0	1
Medium low technology	1292	0.27	0.44	0	1
Low technology	1292	0.30	0.44	0	1

Appendix 3. Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Ecoproduct_firm (1)	1.00																		
Ecoproduct_market (2)	0.55	1.00																	
Ecoprocess_firm (3)	0.64	0.47	0.61	1.00															
Ecoprocess_market (4)	0.49	0.70	0.51	0.71	1.00														
R&D Cooperation (5)	0.49	0.40	0.51	0.48	0.38	0.49	1.00												
Acquisition (6)	0.43	0.36	0.44	0.54	0.42	0.55	0.47	1.00											
External R&D (7)	0.39	0.33	0.40	0.35	0.29	0.35	0.46	0.34	1.00										
Market sources (8)	0.41	0.33	0.42	0.39	0.31	0.40	0.42	0.40	0.30	1.00									
Institutional sources (9)	0.15	0.13	0.16	0.14	0.11	0.14	0.19	0.10	0.18	0.15	1.00								
Other sources (10)	0.25	0.22	0.26	0.22	0.18	0.23	0.27	0.20	0.19	0.29	0.22	1.00							
Existing regulations (11)	0.40	0.38	0.40	0.41	0.39	0.42	0.28	0.27	0.24	0.23	0.10	0.15	1.0						
Expected regulations (12)	0.36	0.36	0.36	0.36	0.36	0.36	0.26	0.24	0.23	0.19	0.10	0.13	0.59	1.00					
Environmental codes (13)	0.37	0.35	0.36	0.40	0.38	0.39	0.25	0.26	0.20	0.19	0.08	0.13	0.46	0.40	1.00				
Control procedures (14)	0.39	0.35	0.39	0.38	0.34	0.38	0.31	0.26	0.29	0.23	0.12	0.13	0.40	0.35	0.35	1.00			
Public funding (15)	0.20	0.22	0.21	0.20	0.22	0.20	0.16	0.15	0.12	0.12	0.10	0.09	0.32	0.35	0.05	0.22	1.00		
Cost reduction (16)	0.39	0.35	0.39	0.43	0.38	0.43	0.27	0.28	0.20	0.20	0.09	0.13	0.43	0.33	0.51	0.35	0.27	1.00	
Internal sources (17)	0.51	0.40	0.52	0.48	0.38	0.49	0.47	0.47	0.39	0.41	0.14	0.22	0.27	0.23	0.22	0.35	0.10	0.20	1.00
Market demand (18)	0.38	0.41	0.39	0.35	0.38	0.359	0.26	0.24	0.21	0.22	0.09	0.13	0.42	0.48	0.49	0.33	0.36	0.49	0.20 1.00
Market geography (19)	0.29	0.23	0.30	0.23	0.18	0.24	0.29	0.23	0.26	0.23	0.10	0.14	0.15	0.148	0.01	0.29	0.06	0.13	0.13 0220