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

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Abstract

Although the antecedents of environmental innovation and the impact of openness on technological innovation have been well studied, the impact of firm?s openness on environmental innovation remains largely unknown. We here study the impact of three main dimensions of openness - R&D acquiring, R&D sharing and external information sourcing ? on four types of environmental innovation. Results provide evidence of a positive impact of inbound innovation acquiring in all types of environmental innovation while R&D cooperation only enhances the adoption of environmental processes, i.e. cleaner technologies in the production stage of the firms. Regarding inbound innovation sourcing, market sources of information stemming from customers, suppliers or competitors, are positively and significantly associated to firms involvement in green innovative products and processes at all levels (production and end user stages) while scientific information sources (institutional) and publicly available information sources do not influence on the introduction of environmental innovations. Furthermore, we find that the combination of inbound innovation acquiring mode and internal R&D disincentives all types of EI considering the moderating role of absorptive capacity leverage at the firm-level. Significant implications can be drawn in terms of public policy, considering the importance of environmental innovation strategies for the sustainable development of our societies.

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Abstract

Although the antecedents of environmental innovation and the impact of openness on technological innovation have been well studied, the impact of firm's openness on environmental innovation remains largely unknown. We here study the impact of three main dimensions of openness - R&D acquiring, R&D sharing and external information sourcing – on four types of environmental innovation. Results provide evidence of a positive impact of inbound innovation acquiring in all types of environmental innovation while R&D cooperation only enhances the adoption of environmental processes, i.e. cleaner technologies in the production stage of the firms. Regarding inbound innovation sourcing, market sources of information stemming from customers, suppliers or competitors, are positively and significantly associated to firms involvement in green innovative products and processes at all levels (production and end user stages) while scientific information sources (institutional) and publicly available information sources do not influence on the introduction of environmental innovations. Furthermore, we find that the combination of inbound innovation acquiring mode and internal R&D disincentives all types of EI considering the moderating role of absorptive capacity leverage at the firm-level. Significant implications can be drawn in terms of public policy, considering the importance of environmental innovation strategies for the sustainable development of our nations.

Key words: Determinants, Environmental innovation, Open Innovation, Inbound Innovation, R&D acquisition, R&D cooperation, Sources of information

1. Introduction

For the traditional technology push view, technological determinants are found to be a key for innovation (Horbach, 2008). Such impact has also been seen as essential for a specific type of technological innovation, namely environmental innovation. Environmental innovation has been defined in various ways. We here see it as a result, an output of the implemented strategy which has been assumed and decided by the firm. In this sense, “environmental innovation” seems to be more suitable to our study that other wordings such as eco-innovation or green innovation, which may be unintended. It encompasses new or modified processes, products, or services that reduce environmental harms (De Marchi, 2012). Most empirical studies (e.g., Cleff and Rennings, 1999; Rehfeld et al., 2007; De Marchi, 2012; Triguero et al., 2013) emphasize that technological capabilities have a decisive influence on environmental innovation. Fleith et al. (2014), in a systematic literature review, found four main critical success factors for environmentally sustainable product innovation: market, law and regulation knowledge, inter-functional collaboration, innovation-oriented learning, and R&D investments. Most authors support the idea that firms’ environmental innovation behavior is mainly correlated with the stringency of environmental policy (Frondel et al., 2008) or the regulatory and institutional framework (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).

In this paper, we focus on how firms may search for external knowledge in order to boost their environmental innovations. A whole stream of literature has concentrated on this impact of external knowledge on innovation. Testing the impact of such open innovation strategies, Leiponen and Helfat (2010) demonstrate that enlarging horizons to access external knowledge sources is associated with successful innovation. Because innovation draws on many sources of ideas, information and knowledge, firms may increase their chances of innovation success by accessing more knowledge sources, networks of collaboration and exchange of information (Lundvall, 1992). Numerous studies focus on the role of openness on firms’ technological innovation performance (e.g., Laursen and Salter, 2006; Leiponen and Helfat, 2010). However, as far as we know, the impact of firm’s openness on environmental innovation remains largely unknown. In this regard, a recent work by Ghisetti et al. (2014) looked at the impact of the ‘depth’ and ‘breadth’ of knowledge sourcing and tested for the moderating role of firm’s absorptive capacity, but they uniquely consider the external information sources but not specifically other modes of openness used by the firms to implement environmental innovation and reduce the cognitive distance to the requirement of knowledge base related to environmental innovation. Our research adds more specific insight to such external search strategies by considering that access to external knowledge may be done through sourcing but also through acquisition and sharing strategies.

The objective of this paper is to empirically study the impact of three main dimensions of openness – acquisition of embodied technology and external acquisition (acquiring), R&D cooperation (sharing) and external information sources (sourcing) on the adoption of environmental innovation. To our knowledge, there has been no attempt in literature to investigate the relationship between these three modes of openness and environmental innovation. Our underlying hypothesis is that open search strategies, which involve the use of alternative modes to access to external knowledge, enhance environmental innovation (EI). We analyze the environmental innovation outcomes according to the degree of openness to external knowledge in large French manufacturing firms. Data was drawn from the Community Innovation Survey (CIS) data for the period 2006-2008

Our paper distinguishes from other contributions by three important points. First, in contrast to other studies on this topic, we investigate the influence of searching practices of external knowledge on environmental innovations from least to most- open modes (from pecuniary to non-pecuniary) instead of analyzing uniquely how firms use a variety of external sources of innovation. Second, we analyze the moderating role of absorptive capacity and how the complementarity or substitution among the different forms of openness and intramural R&D (or internal sources) influences on environmental innovation. Finally, the influence of these external knowledge search strategies and other explanatory variables on environmental product and process innovation at the firm and consumer level are considered. In sum, we try to extend the limited understanding of the influence of different modes of external knowledge search by the firms to cope with diverse environmental innovations.

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The remainder of the article is organized as follows. Section 2 reviews the literature on EI determinants with a specific focus on openness modes. Section 3 outlines the data set, variables and methods. Section 4 presents the estimation results. Section 5 concludes with the implications for theory and practice and suggestions for future research.

2. Literature review and theoretical development

The literature on environmental innovation has largely acknowledged the role of regulated environmental measures[1] as well as supply and demand side factors on environmental innovation but the influence of openness is a topic that remains understudied. We here focus our analysis on the effects of three various modes of openness on different types of environmental innovations. The underlying hypothesis is that connecting with the external world through R&D acquisition, R&D cooperation and external information sources (e.g. with suppliers, customers, competitors or R&D institutes) enables firms to develop a better knowledge-based capability, hence its innovation capacity. This process of transformation of external knowledge, reflected in the concept of absorptive capacity (Cohen and Levinthal, 1990), should lead firms to engage in EI. We develop our theoretical framework supporting this hypothesis and consider different modes of openness from less to more open model of innovation (from acquiring to sourcing mode).

2.1. Supply side determinants : search strategies for external knowledge

Open innovation can be viewed as "an instance of how firms make decisions whether to develop innovations internally or partner with external actors" (Dahlander and Gann, 2010: 700). According to this perspective, firms have to take two important decisions concerning search strategies for external knowledge. First, firms have to decide whether or not to use external knowledge. Recent empirical literature confirms the potential benefits of external knowledge use in spite of implicit uncertainty assumed in formal and informal external relationships. Increasing the openness of innovation modes facilitates the leverage of external research and complements internal R&D. In other words, traditional R&D activities are augmented with inbound sourcing of external technologies (Chesbrough, 2006). Boundary spanning activities are thus essential to speed up innovative processes and improve innovation performance (Laursen and Salter, 2006; Spithoven et al., 2013). Second, if they decide to search for external knowledge, firms have to choose among different modes to access such external knowledge. Dahlander and Gann (2010), synthesizing the growing literature of open innovation, found two main forms of openness. The first, called "inbound innovation", is defined as the process of acquiring or sourcing through which firm does discover, acquire and made use of information or resources developed by external partners or organizations. The

[1] Indeed, there has been a focus, in past research, on environmental regulation and this variable is the lead determinant to environmental technology innovation/adoption in several papers, neglecting the influence of other variables (Del Rio Gonzalez, 2009)

second, “outbound innovation”, refers to how firm’s internal resources or competences are communicated to the external environment through revealing (signaling) or commercializing the resources developed by the firms.

Since we wonder to what extent the use of external knowledge will influence firms’ ability to introduce environmental innovation, we here focus on “inbound innovation”, the most studied type in the literature (West et al., 2014). Firms can access to external knowledge by three channels: Acquiring, Sharing and Sourcing. Based on Dahlander and Gann (2010), we elaborate our theoretical model on the hypothesis that spanning firms’ boundaries to increase their technology base is crucial for EI (see Figure 1). This model is in line with the stream of literature arguing that the ability to assimilate and exploit external knowledge builds upon firm’s absorptive capacity and becomes a critical component of innovative performance (Cohen and Levinthal, 1990). From this perspective, external R&D and acquisition of embodied technology (pecuniary), R&D collaboration (mixed in pecuniary terms) and sourcing of knowledge (non-pecuniary) will not replace in-house innovation activities (intramural R&D activities) but act as a necessary complement of internal technological capabilities in order to implement environmental innovations[2].

2 Recall however that we do not consider in this paper the synergistic relationship between internal R&D and inbound innovation, but do investigate them in the same model with a systematic way.

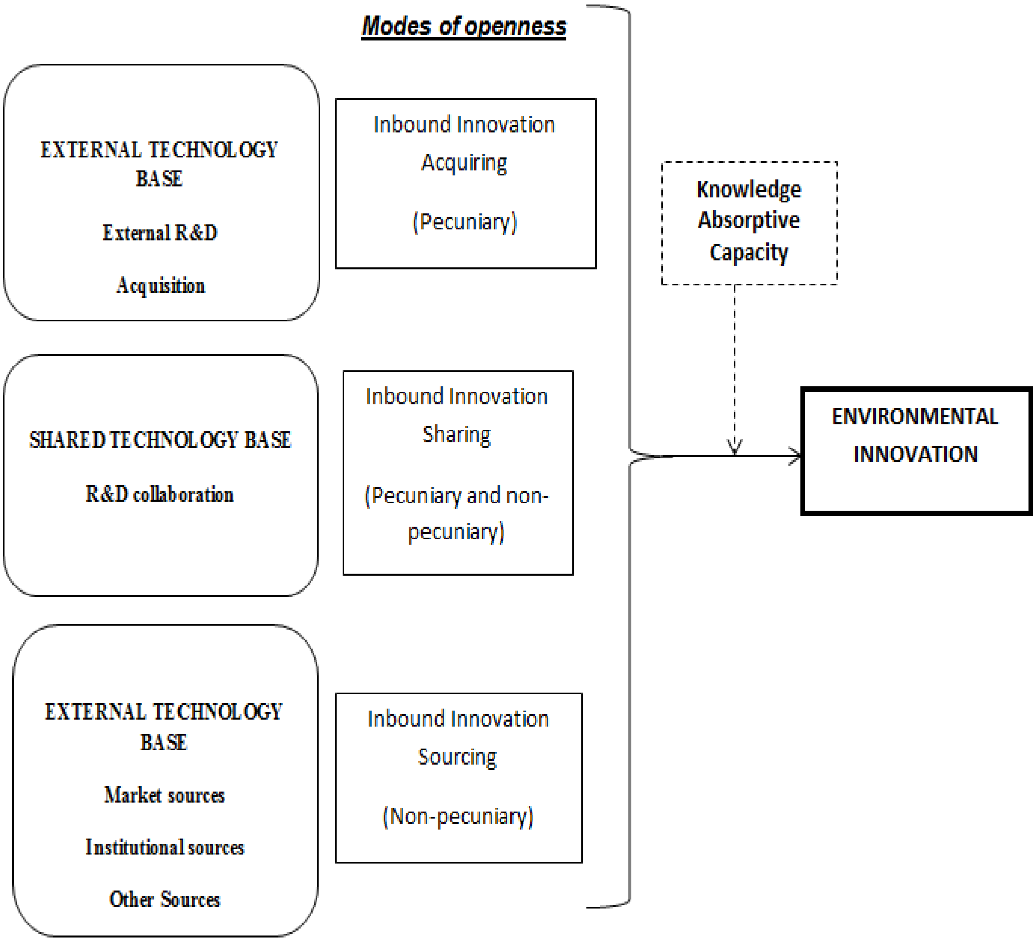

Figure 1. Conceptual framework

Inbound Innovation Acquiring. According to Dahlander and Gann (2010), this type of strategy refers to acquiring valuable resources or expertise from the market place. Acquisition (embodied technology purchases) and external R&D enable firms to access resources and knowledge of third parties. Firms access to external knowledge base through the market place and engage in the acquisition of knowledge on the technology market[3]. Regarding the influence of the use of external R&D on EI, the empirical evidence is rather scarce and inconclusive. Using data of 15200 manufacturing firms from the 4th Community Innovation Survey of 14 European countries, Bönte and Dienes (2013) show that firms doing external R&D have a lower probability of introducing energy and material efficiency process

[3] Dahlander and Gann (2010) consider internal R&D, external technology acquisition and cooperation in R&D but ignored the “purchase of equipment “embodied technology” arguing that most of firms answer positively on this item.

innovations. In a similar way, 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. Other studies do not find any significant effect (De Marchi, 2012). Thus, we believe that:

H1: Inbound Innovation Acquiring has a negative effect on the adoption of environmental innovation.

Inbound Innovation Sharing. This type of openness refers to how firms enhance the ability to introduce new or improved products or processes through building cooperation or partnership with other firms or non-commercial organizations or actors. The argument for the positive influence of this type of openness follows the stream of literature highlighting the growing role of networking in firms' innovative capabilities which is closely linked to the emerging knowledge-based global economy. Because of the tacit and non-transferable character of knowledge and evolutionary and continual character of the learning process, innovative firms have to concentrate on their core-capabilities involving in cooperative arrangements to extent their know-how. Firms also are encouraged to engage in external relations to have access to partners' complementary or synergistic skills and capitalize "incoming spillovers" (Kogut, 1988; Kogut and Zander, 1993; Cassiman and Veugelers, 2002), to reduce the duplication of R&D efforts as well as risks and costs associated to innovation projects (Sakakibara, 1997), to benefit from economies of scale or/and scope (Kogut, 1988) and to facilitate the access to technology that cannot be acquired in the market (Hagedoorn, 1993). The analysis of the influence of R&D collaboration on EI is still limited, providing so far rather converging results. De Marchi (2012) finds a positive influence of cooperation on EI using the Spanish CIS 2007. Collaborative networks with universities and public institutions are founded to be essential to drive all types of eco-innovation (Cainelli et al., 2011; Triguero et al., 2013). Horbach et al. (2013) also show a significant influence of R&D cooperation during the period 2006–2008 in Germany but only on eco-innovations with environmental benefits within the firm (process innovations) in the area of dangerous substances. . Based in the theoretical arguments, we state that:

H2: Inbound innovation Sharing has a positive effect on the adoption of environmental innovation.

Inbound Innovation Sourcing. Innovation sourcing describes to what extent firms can made use of external information sources for their own innovation activities (Dahlander and

Gann, 2010). There is a growing stream of literature on the role of knowledge inflows and outflows for innovation, spanning a wide range of external knowledge (or information) sources, including customers, competitors, suppliers, and research institutions (Amara and Landry, 2005; Huang and Rice, 2012). The extent to which firms use such external sources can also indicate their degree of openness. The Knowledge-Based View (KBV) focuses on how knowledge can be created, assimilated, integrated, and applied by firms (Grant, 1996). A firm's knowledge strategy, which ultimately turns out in competitive advantage, implies identifying which knowledge to seek, and how an upstream open innovation strategy including diverse agents can be implemented. Technological network theories of innovation include a large variety of information sources (Lundvall, 1992, Edquist, 1997). These streams of literature assume that innovative firms are linked to a highly diversified set of agents through technical networks of collaboration and exchange of useful information such as consultants, government agencies, laboratories, university research agencies, etc.

Despite the considerable amount of recent research on open innovation, empirical studies on the relationship between information sourcing and EI remain relatively scarce. Belin et al. (2011) for example find a significant and positive influence of institutional sources (universities) on EI for France and a negative influence of sources stemming from customers for the case of Germany. The most recent piece of work on the impact of such external sources on environmental innovation is that of Ghisetti et al. (2014). Using the Community Innovation Survey (CIS) 2006–2008 in eleven European countries, they found that knowledge sourcing has a positive impact on two firm's probabilities: introducing an EI and extending the number of EI-typologies adopted. They justify the requirement of broad knowledge sources in environmental innovative activities on the basis of the peculiar characteristics of EI. Specifically, the systematic nature of EI and the multipurpose nature of EI near to the lack of the cognitive proximity by the firms increase the need to expand their internal knowledge base by networks (De Marchi, 2012; Ghisetti et al., 2014)The above explanation highlights the importance of considering different types of external sources in explaining the ability to introduce EI. Thus, we attempt to empirically investigate separately their effects.

Market sources are essential for identifying potential partners for developing new projects and R&D cooperation. These sources of information also have been shown to be crucial for technological and organisational innovations (Mothe & Nguyen-Thi, 2013), they lead firms to collect and absorb information about the needs and expected demand of clients, suppliers, as well as to better exploit information about the environmental innovation programs of the main competitors. Similarly, it is argued that strong partnerships with suppliers are important drivers for the development of EI (Geffen and Rothenberg, 2000)). Bönte and Dienes (2013) using a data of manufacturing firms obtained from the fourth Community Innovation Survey covering 14 European countries find that market information sources, scientific information sources and publicly available information sources influence positively on the introduction of energy and material efficiency innovations. Thus, we hypothesize the following:

H3a: Market Sourcing has a positive effect on the adoption of environmental innovation.

H3b: Institutional Sourcing has a positive effect on the adoption of environmental innovation.

H3c: Other Sourcing has a positive effect on the adoption of environmental innovation.

2.2. Role of absorptive capacity in the link between search strategies and EI

Absorptive capacity fosters the recognition of the value, assimilation, and application of external knowledge (Cohen and Levinthal, 1990). Liao et al. (2007) find that absorptive capacity arises between knowledge sharing and innovation capability. Absorptive capacity can help an organization integrate external knowledge and transform it into firm competence. This mediating variable between knowledge sharing and innovation capability acts as a bridge (Muller and Zenker, 2001). If absorptive capacity is inadequate, knowledge sharing in a firm will offer fewer direct benefits for the firm's innovation capability. Koch and Strotmann (2008) confirm the importance of absorptive capacity and the pivotal role of access to knowledge from external partners in innovation. Numerous studies have focused on the understanding of the factors (or those essential "internal resources") on which absorptive capacity depend. The most frequently mentioned is internal R&D as it increases the intelligibility of external knowledge related to EI (Ghisetti et al., 2014) by reducing the cognitive distance between the firm and the external providers. However, absorptive capacity also embodies a firm´s ability to handle knowledge internally. The importance of internal resources enables firms to take advantage of external resources through the development of their absorptive capacity (Koch and Strotmann, 2008). Absorptive capacity "helps a firm to link external and internal technology sourcing, and thereby to benefit from ambidexterity in technology sourcing" (Rothaermel and Alexandre, 2009, p. 764). Absorptive capacity facilitates the assimilation of new technologies developed elsewhere. In word of Cohen and Levinthal (1989) learning or absorptive capacity will be the "second face" of R&D. We therefore hypothesize that:

H4a: The firm's absorptive capacity (internal R&D) positively moderates the impact of the three modes of openness on EI.

H4b: The firm's absorptive capacity (internal sources) positively moderates the impact of the three modes of openness on EI.

2.3. Other drivers of environmental innovation

Institutional and regulatory factors. According to the Porter's hypothesis, a suitable regulation favors environmental innovation and may compensate for related costs (Porter and van der Linde, 1995), environmental regulation providing incentives for innovation, in particular through environmental taxes and certificates. The subsequent literature has focused on two major aspects that differentiate EI from other innovations, linked to their externalities and drivers. Rennings (2000) refers to the "double externality problem" and the "regulatory push/pull effect". Just as innovation and R&D activities are characterized by positive externalities, environmental innovators produce an environmental positive externality (De Marchi, 2012). Because part of the value created is appropriated by society—in the form of reduced environmental damage—rather than just by the investing firms, there is a disincentive for firms to invest in products or processes that reduce environmental impacts (Rennings, 2000; Jaffe et al., 2005). This additional positive externality may prompt a substantial lack of investment or interest on behalf of firms, because direct returns are not easy for them to reap. The additional market failure induces a greater need for policy intervention to drive the introduction of EI (Rennings, 2000). However, there seems to be a positive correlation between regulation and environmental innovations (Horbach et al., 2013) and environmental regulation is seen as the first incitation for firms to develop EI (del Rio Gonzalez, 2009; Horbach et al., 2012, 2013). Antonioli et al. (2013), in their comparative analysis, find that polluting sector firms tend to innovate more environmentally than firms outside a polluting sector. This effect of more stringent environmental regulation exists for innovation in general (Ford et al., 2014), such that some firms even over comply to gain competitive advantages and an improved social image, in which case 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 adoption. Kammerer (2009) and Cai and Zhou (2014) also found that external pressures from environmental regulations affect eco-innovation.

Demand side. There is also a strong incentive for firms to engage in EI which are congruent with the "customer benefits" (Kammerer, 2009). Kesidou and Demirel (2012) indicate that firms initiate EI to satisfy minimum customer and societal requirements. Triguero et al. (2013) show that European SMEs which collaborate with various actors are likely to increase market demand for environmental product innovations. Market share has also a significant positive influence on eco-product innovations. Moreover, on the demand side, environmental consciousness by consumers and other public or private actors is also a relevant parameter to consider by firms which eco-innovate (Horbach, 2008). Customers' green demands thereby affect firms' eco-innovation (Cai and Zhu, 2014).

3. Data and methodology

3.1. Data

For our empirical analysis, we use firm-level data drawn from the French Community Innovation Survey (CIS 2008) during the three-year period 2006-2008. General information about the firm (sector of activity, group, number of employees, sales, geographic market), technological and non-technological innovations, perceptions of the factors that might hamper innovation activities, and subjective evaluations of innovation outcomes are collected. The survey also provides information about strategies pursued by the firm for searching external Knowledge and other variables related with the innovation process (R&D, internal sources of knowledge information, cost reduction motives …). For this study, we focus on large firms with at least 250 employees that operate in the manufacturing sector. The resulting sample of 1292 firms helps to ensure the robustness of our analysis.

2.2. Dependent Variables

We distinguished four main dichotomous variables to measure whether the firm produced an environmental innovation during that period. Ecoproduct_firm

(Ecoprocess_firm) is a binary variable, equal to 1 if the firm introduces product (process) innovation with environmental benefits at the stage of the production of goods or services such as reduced material use per unit of output; recycled waste, water, or materials, etc., 0 otherwise. This type of environmental innovation usually implies the adoption of so called "clean technologies". They reduce the waste generation or pollution generated in the production process or during the life cycle of the product. Ecoproduct_market (Ecoprocess_market) is equal to 1 if the firm introduces product (process) innovation with environmental benefits at the stage of the after sales use of a good or service by the end user such as reduced air, water, soil or noise pollution; reduced energy use or improved recycling of product after use, 0 otherwise. While some research establish a dual category between cleaner and "end of pipe" technologies[4], both types of environmental innovation considered are equally important in terms of reducing environmental harms. We have defined EI as an innovation in products and processes that could deliver more value to producers (_firm or consumers (_market). The first implies that environmental innovation happens inside the firm while the second involves the consumer participation and does not require changes in the production processes. They are devices or plants added at the end of the production processes, aiming at transforming primary emissions into substances easier to handle. We then added two more combined variables: Ecoproduct_tot (Ecoprocess_tot) is equal to 1 if the firm implements at least one of the above-mentioned environmental product/process innovations, 0 otherwise.

Appendixes 1 and 2 provide variable definitions and descriptive statistics. 56% of French large manufacturing firms have introduced a new or significantly improved environmental product innovation at the firm level while 41% of the firms were environmental product innovators at the market level during the period 2006-2008. Moreover, on average, 38% have introduced a process innovation at the market level and 54% at the firm level with environmental benefits.

2.3. Independent variables

As the objective of this paper is to assess the impact of openness on environmental innovation, we introduced external R&D, acquisition, R&D cooperation as well as different external sources of information as explanatory variables. For controlling for inbound

[4] Although the 'cradle-to-grave' framework considers different levels of eco-efficiency, from the most efficient (cleaner technologies) to to end-of pipe technologies, our dataset does not make this distinction.

innovation acquiring, two binary variables are used: first, External R&D, is used to measure whether firms have had innovation activities during the reference period which were performed by other firms (including other firms or subsidiaries within own firms) or by public or private research organizations and purchased by the firms. The second binary variable is acquisition of advanced machinery, software or purchased licenced patents and non-patents inventions or know-how to produce new or significantly improved products and processes. Both of them (External R&D and Acquisition) are proxies of inbound innovation acquiring mode. R&D cooperation is also a binary variable, measuring whether firms have undertaken cooperation on any of their innovation activities with other firms or institutions during the period 2006- 2008. This variable allows taking into consideration the Inbound innovation Sharing dimension as described in our theoretical framework.

Finally, in order to control for inbound innovation sourcing, different types of sources of information are introduced. Market sources refer to sources stemming from suppliers, clients, competitors or other firms in the sector, consultants, commercial labs or private R&D institutes. Institutional sources are the ones coming from universities, other higher education institutions, government, public research institutes). Other sources of information refer to the use of patents, databases, trade literature or fairs. These variables are equal to 1 if that specific sources inflow is crucial to firm innovation activities and 0 otherwise.

Descriptive statistics are presented in Appendix 2. On average, 47% of firms have had acquisition of knowledge while only 41% of firms made use of external R&D. Nearly 51% of large French manufacturing firms have undertaken R&D cooperation during the reference period. Regarding sources of information, 38% of firms made use of market sources, 14% were users of other sources and only 6% have benefited from institutional sources for their innovation activities[5].

To check get the robustness of our model, we also used new measures of information sources as indicators of openness in terms of variety and intensity of their use. Similar to Laursen and Salter (2006), Leiponen and Helfat (2010) and Ghisetti et al. (2014), the Breadth of openness variable is constructed on the basis of the three latter inbound innovation types: sharing, acquiring and sourcing. For determining the variable Breadth of openness, we

[5] Recall that institutional sources are still the less frequent way of sourcing. On the other hand, this variable is defined as equal to 1 if the use of institutional sources is crucial for firm's innovation activities and 0 otherwise. The restriction is thus very high.

summed up the three variables Sourcing, Sharing and Acquiring to obtain variable varying from 0 when no information inbound is used by the firm to 3 when all 3 modes are used.

In line with the literature, a set of environmental regulation variables are introduced such as existing or expected environmental regulations or taxes on pollution, environmental financial regulations, voluntary codes or agreements for environmental good practice within the activity sector (respectively Existing regulations and Expected regulations). We also added the firm's objective of introducing EI (financial objective such as benefiting from grants, subsidies or other financial incentives, responding to legislation, reducing labor costs or responding to market demand) (Public funding) as well as the existence or not of control procedures to regularly identify and reduce the environmental impacts such as environmental audits, setting environmental performance goals or ISO 14001 certification (Control procedures). As controlling for demand side, we introduced Market demand which is equal to 1 if the firm has introduced an environmental innovation in response to current and expected market demand from the customers for environmental products or services, 0 otherwise. The Market geography is a variable measured on a four-point Likert response scale, ranging from 1 (local market); 2 (national); 3 (European) and to 4 (other countries). Correlations between variables can be found in the Appendix 3.

We also included several traditional control variables which have been shown to have influence on firm's eco-innovative capabilities. Firm size is the natural logarithm of the number of employees. We introduced a dummy variable for group belonging, equal to 1 if the firm belongs to a group and 0 otherwise. This ownership status may be of importance as firms that are part of a group are supposed to have more incentives for innovation activities through their easier access to financing (Love and Roper, 2001) and also apply the innovation strategy adopted by their headquarters. Four sub-sectors of activities were included, according to a two-digit NACE classification of manufacturing industries into categories based on R&D intensities following OECD ISIC Rev.3 technology intensity definition (OECD, 2011): (1) high-tech, (2) medium high-tech, (3) medium low-tech and (4) low-tech (which serves as the reference category).

4. Results and discussion

Table 1 presents the results of the multivariate Probit model on the likelihood to introduce environmental innovation (EI). Results on the impact of openness are very significant, although there is difference among different modes of openness.

Regarding inbound acquiring innovation, the results indicated a significant and strongly positive impact of acquisition of embodied technology on the adoption of eco-product and eco-process for firm and market level. In the same vein, external R&D has a significant influence in any of types of environmental innovations considered. As acquiring modes of openness are important for all types of EI, our results reject hypothesis H1. This finding contrast with some results of previous studies as De Marchi (2012) for Spanish manufacturing firms.

Rather surprisingly, we found R&D cooperation was positively associated only with ecological process innovation at the firm level. No evidence was found for product innovation of both levels neither process innovation at the market level. These results are counter-intuitive contrasting with recent trends in the literature which emphasize that firms actively develop R&D partnership to benefit from "incoming spillovers" (Kogut and Zander, 1993; Triguero et al., 2013). These results could confirm that firms are more reticent to share eco-products than eco-process with their partners, probably due to problems of appropiability rents. Regarding inbound sharing innovation mode, our results partially reject hypothesis H2.

As theoretically outlined, market sources of information stemming from customers, suppliers or competitors, are positively and significantly associated to firms involvement in green innovative products and processes at all levels (production and end user stages). These results provide support for the fact that accessing such sources enhances the probability of EI. Hypothesis H3a is accepted. On the contrary, the intensive use of source of information stemming from institutional organisations (universities, public and private research centres) has a negative and significant impact on the likelihood of eco-product innovation at the firm level while no evidence was found for environmental process innovation while the role of other sources such conferences, scientific journals, professional associations as sources of information neither influences any type of EI. Thus, hypotheses H3b and H3c are rejected.

We also found that the likelihood of EI is higher for firms that invest heavily in R&D and have knowledge internal sources, thus reflecting the acknowledged role of R&D expenditures and these internal sources as constituting firm's absorptive capacity for green innovation, in line with previous empirical studies. However, the internal R&D negatively moderates the impact of one mode of openness on EI: acquiring inbound innovation. In particular, technological acquisition and external R&D are negatively moderated by internal R&D, suggesting that the combination of external acquisition of embodied technology and R&D and internal R&D disincentives all types of EI. As pointed out by Ghisetti et al (2015), the interaction with external knowledge sources increases the chance of mismatching with internal R&D.

Surprisingly, the contrary effect is found for institutional sourcing. Internal R&D positively moderates the impact of using institutional Knowledge sources on product EI. The combination of internal R&D and use of these institutional sources increase the probability of adoption of Eco-product at firm and market-level (not the adoption of Eco-processes)..

Among the rest of explanatory variables, reducing labour costs per unit appears to be a relevant determinant to explain the barriers to all types of EI. Previous empirical studies show, however, controversial results on the impact of cost savings or increase in revenues. The results are in line with Kesidou and Demirel (2012) and Horbach et al. (2012, 2013) who found that cost savings, especially in terms of material and energy, are important incentives for EI – however focusing here on labor costs instead of costs that are directly linked to EI and, more specifically, to process innovation. Among the demand factors, the geographic market variable is positively and significantly associated to higher probability to adopt EI as clean technologies (at the firm level) while the coefficient of green innovative product as end-of-pipe technologies (at the market level) is insignificant. It suggests that firms which are open to the international market could face more foreign competition and exhibit a higher capacity to engage in green innovative product compared with firms that sell products or services only in local or regional markets. As expected, the results also show positive and significant coefficients of market demand in all models. Thus, firms that report current or expected demand from customers for green products have a higher capacity of adopting this type of innovation, in line with several previous studies (Kammerer, 2009; Horbach, 2008; Triguero et al., 2013).

These results emphasize the fact that both demand and supply factors impact product and process innovations while previous studies (such as Rave et al., 2011) led to think that the introduction of green products was mainly guided by demand factors and market opportunities while that of green processes (to reduce energy and resource costs) was essentially induced by supply factors. Our results do not allow us to make this distinction but are in line with other studies that integrate a more holistic and systematic view (Horbach et al., 2012; De Marchi, 2012; Triguero et al., 2013).

Firms who use departments or firms within the group as intensive source of information seem to be more able to introduce both innovative green products and processes at the production stage of goods and services or at the end user step. This result is in contrast with the other one showing the non-significance of the coefficient of belonging to groups. Previous literature however highlights that multinational firms could have higher financial benefits and higher probability to compensate the costs of EI with a higher competitive advantages (Porter hypothesis) from the introduction of standard environmental strategies across the world, considering the large scale of their operations (Ambec et al., 2008; Rexhäuser and Rennings, 2010). Our results suggest that the international status is not sufficient to spur firms to eco-innovate but those firms belonging to groups who rated intensive knowledge exchange between departments or firms within group might benefit higher incentives to adopt more environmentally sustainable behaviours. This is in line with the analysis of Gulati et al. (2000) highlighting the advantages for domestic firms to enter global networks within which knowledge about green innovation and environmental practices and regulations can circulate.

Concerning the environmental policy influences, our results provide evidence of the important role of regulation as a motivation that triggers environmental innovation, in line with previous literature. Some differences however arise in terms of the nature of regulation. Existing regulations exerts a significant, positive impact on both types of EI (Horbach et al., 2012, 2013). Expected regulations have a positive and strongly significant effect on ecological product innovation while no evidence was found for ecological process innovation. This is in contrast with previous empirical results reported any effect of expected regulation on the likelihood of green innovative product (Triguero et al., 2013; Kammerer, 2009). Among other environmental policy factor, our models show that environmental codes, referring to voluntary codes or agreements for environmental good practices within the sector, also have positive and significant impact on environmental innovation whatever the type. Firms that have environmental management systems such as procedures to regularly identify and reduce the environmental impact (Control procedures) are, not surprisingly, more likely to strongly engage in green products and processes at the production and the end users' stage (Wagner, 2007). The presence of such a positive association should however be interpreted with caution as it does not tell us about the causal relationship between the two variables. Firms with high environmental projects are, of course, also more likely to have regular controlling procedures of their environmental impacts.

Finally, and rather surprisingly, we found that subsidies or other public financial incentives do not have any significant impact on the likelihood of adopting EI. This is in contrast with Horbach (2008) who highlighted the important role of subsidies in motivating firms to introduce EI. However, this surprising result is in line with other former studies, in particular with Belin et al. (2011) on the fourth Community Innovation Survey (CIS) for France and Germany, with Triguero et al. (2013) on a large sample of SMEs in Europe and Cuerva et al. (2014) on firms in the agri-food sector. A potential explanation for this result could be the inadequacy and inefficacy of subsidies among the environmental policy instruments to enhance the environmental innovation.

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 Lik	-455.3	-578.2	-585.2	-599.4

Note. Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1

As expected, firm size exerts a significant and positive impact on EI, very large firms being more likely to adopt EI than smaller firms. Large firms can have the financial, human, technical resources necessary to invest in those green technologies. Given the large scale of their activities, they can also benefit more from creating cooperative network which generates beneficial technological spillovers and stimulates the competitive dynamics.

To verify results' robustness, we ran further regressions with our main explanatory variables(Acquisition, External R&D, Collaboration R&D and information sources), but using knowledge internal sources as proxy of absorptive capacity. The estimation results presented in Table 2 revealed roughly similar estimated coefficients and levels of significance to those we reported Table 1. In this case, hypotheses H1, H2 and H3 are fully accepted. The three modes of openness influence positively to the probability of adoption of all types of EI. The moderating role of absorptive capacity measured by internal sources enable to confirm that the R&D cooperation influence positively on all types of EI, confirming the results found in the former empirical literature. Similarly to the previous specification, market sources of information stemming from customers, suppliers or competitors, are positively and significantly associated to all types of EI (H3a is accepted and H3b and H3c are rejected). Regarding the moderating role of internal sources, the concurrence of R&D cooperation and internal sources also decreases the probability of all types of EI while the use of market information sources and internal sources increase the probability of EI. The effects of regulations and other explanatory variables also were similar across the various models. Therefore, our estimations are robust for regulation and control variables, and we only report the estimated coefficients related to our key variables hereafter.

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*Internal Sources	-0.825	-0.875	-1.655	-1.110
	(0.212)	(0.278)	(0.356)	(0.452)
ExtRD* Internal Sources	-0.919	-0.475	-0.212	-0.040
	(0.385)	(0.245)	(0.385)	(0.144)
Cooperation* Internal Sources	-0.049*	-0.146**	-0.789**	-0.028**
	(0.337)	(0.309)	(0.351)	(0.311)
SoMarket* Internal Sources	0.379*	0.660***	0.254*	0.875**
	(0.341)	(0.376)	(0.171)	(0.286)
SoInsti* Internal Sources	0.850	0.045	0.125	0.254
	(0.333)	(0.890)	(-0.452)	(-0.452)
SoOther* Internal Sources	-0.782	-0.392	-0.778	-0.792

	(0.052)	(0.751)	(0.780)	(0.151)
Constant	-3.204***	-3.580***	-2.029***	-2.897***
	(0.853)	(0.654)	(0.457)	(0.514)
Observations	1,292	1,292	1,292	1,292
Pseudo R-squared	0.547	0.391	0.349	0.314
Log Lik	-545.3	-458.2	-585.2	-590.4

Note. Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1

Table 3

Multivariate Probit regressions with breadth of openness

VARIABLES	(1) Ecoproduct_firm	(2) Ecoproduct_market	(3) Ecoprocess_firm	(4) Ecoprocess_market
Breadth	0.635***	0.500***	1.149***	0.839***
	(0.162)	(0.171)	(0.167)	(0.178)
$Breadth^2$	-0.101**	-0.085***	-0.224***	-0.170***
	(0.047)	(0.048)	(0.049)	(0.045)
Breadth* Internal RD	-0.187*	-0.103**	-0.058**	-0.141**
	(0.983)	(0.089)	(0.073)	(0.029)
Breadth*Internal Sources	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 Lik	-537.4	-584.5	-552.8	-525.5

Note. Standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1

Finally, as a robustness check, we test our hypotheses using a measure of breadth of openness instead of individual modes of inbound innovation. This new specification also enables us to include our two proxies of absorptive capacity (interactions of breadth* Internal R&D and breadth*Internal Sources). First, results show that external search breadth has a positive and significant impact on EI in all models. It strengthens our former results (Table 1) consolidating the hypothesis that the openness for innovation activities is a major driver of EI. Second, we find strong evidence supporting that there is a curvilinear relationship between the breadth of openness and EI, taking an inverted U-shape. The parameter for $Breadth^2$ is negative and strongly significant in all models, showing the decreasing returns of information sources when firms make use of too many modes of openness. Third, our results confirm the absence of complementarity between internal R&D and external knowledge to explain EI. While Ghisetti et al.'s (2014) cannot verify the role of absorptive capacity leverage, we find that the combination of external acquisition of embodied technology and R&D and internal R&D disincentives all types of EI. The influence of breadth*internal R&D is negative and significant. Finally, we find that the combination of different modes of openness (breadth) and internal sources has not influence on EI[6].

5. Conclusions

This paper analyses the relevance of openness for environmental innovation. We explored the role of different modes of openness on environmental innovation, In particular, we consider the role of Acquisition and External R&D (inbound innovation Acquiring), R&D cooperation (inbound innovation Sharing) and external information sources (inbound innovation Sourcing) to explain the adoption of environmentally-friendly product and process innovations at the firm-level (providing business value to the firm) and at the consumer level (providing value to customer). To do this, we estimated a multivariate probit and further sensitivity and robustness checks using data from the French CIS 2008. When analyzing the effects of the three modes of openness in the implementation of environmental innovation for the level of the firm and the customers, we found strong evidence about the influence of each mode of openness.

From least to most- inbound open search strategy, acquisition of embodied technology and external R&D positively influence the adoption of eco-product and eco-process for firm and market level. These results show that incremental environmental innovations are relatively easy to adopt through acquisition of embodied technologies and external R&D (pecuniary) by the firm. Regarding R&D cooperation (pecuniary and non-pecuniary), we achieve a different influence depending on the type of innovation. While the R&D cooperation influences positively on eco-process innovation at the firm level, there is not found a significant influence on any type of environmental product innovation neither on process innovation at the market level. As mentioned, these results confirm that firms are more reserved to share the development of new products with their partners (that can potentially increase their competitive advantage) than novel processes that decrease their production cost and increase their efficiency. Finally, the results show that market sources of information stemming from customers, suppliers or competitors, are positively and

[6] Using the CIS 2006-2008 for eleven European countries, Ghisetti et al. (2014) found a different effect of depth and breadth of knowledge sourcing (positive and negative, respectively) on environmental innovations of firms. As we aforementioned, the results are not directly comparable because their variable `breadth´ measures the number of external information sources the firm rely upon and our variable `breadth´ is define by the number of modes openness the firm rely upon. Their breadth changes from 0 to 9 and our breadth varies from 0 to 3 (acquisition, sharing and sourcing). Unfortunately, we cannot introduce depth of innovation inbound modes because the French data CIS used does not enable us to do this.

significantly associated to all types of environmental innovation – which is not the case of institutional sources and other publicly available information sources. This finding show that market sources information is very important for EI confirming that the demand-pull factors play an essential role in the drivers of any type of EI while other modes of inbound innovation sourcing have not a significant influence. Similarly to the findings of Ghisetti et al. (2014) regarding the breadth of sourcing, we find evidence about the inverted U-shape between the breadth of openness and EI, taking an inverted U-shape.

Implications for theory include a necessity for researchers to better understand how open search strategies may help environmental innovations. These might even be more crucial for EI than for other types of innovation (De Marchi, 2012). There is an increasingly important empirical literature on the role of openness for firms' innovative performance, focusing however almost exclusively on traditional technological innovation performance. We contribute to the literature on open innovation and EI by proposing a first analysis including various types of openness in order to test the relationship between search strategies of external knowledge and EI. Incorporating in the framework different forms of openness enable us to highlight the role of various forms of openness on EI and to confirm that absorptive capacity measured by intramural R&D moderates negatively the influence of acquiring inbound innovation in all types of EI.

Our work is not exempt from limitations. First, we use cross-sectional data within this paper. Longitudinal studies might offer a better picture on the relationship between openness and EI. Second, we concentrate on large manufacturing firms while small and service firms could be of particular interest to study. This research therefore provides some interesting avenues for further research. In particular, a comparison could be made between small and large firms on one hand, and manufacturing and service firms on the other hand. Besides, other independent variables could be added related to openness such as the belonging to a cluster which is, nowadays, a major channel for information diffusing across firms. It would also be of major interest, especially for public policies, to compare the antecedents for EI to those for technological innovation to identify whether EI requires more or different types of openness modes compared to other type of innovators. Finally, analysing the various complementarities at play between sources of information and between innovation types could be interesting as firms rarely choose to concentrate on one source or innovation type but rather prefer to combine them (Dahlander and Gann, 2010).

Notwithstanding these caveats, the evidence presented in this paper highlights the implications for practice management in the complex combination of internal and external knowledge required to enhance environmental innovative activities. It shows that all types of EI are generally positively correlated with external modes of openness (acquisition, R&D cooperation and sourcing), but considering high absorptive capacity, it becomes necessary to strike a balance between the acquiring mode of openness and intramural R&D. In this regard, managers must consider the nedd of balancing internal and external base knowledge that enhance environmental firm performance. Because the search strategy of external knowledge and the level of intramural R&D is mainly determined by managers, an optimum level of ambidexterity can benefit to configurate and leverage internal and external knowledge resources when looking at the influence of technology sourcing strategy on environmental performance mediated by the firm´s absorptive capacity (Rothaermel and Alexandre, 2009). Furthermore, the influence of market sources of information stemming from customers, suppliers or competitors on all types of environmental innovation give new evidence insights regarding the incorporation of ecological considerations into the process of product design within the firms. In this regard, collaborative efforts and joint development 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)

Implications for public policy for macroeconomic consequences in terms of sustainable development also could be assessed. Our findings have important implications for policy makers to promote measures that increase environmental innovative activities by supporting different search strategies for external knowledge. Thus, a country can promote environmental innovation by enhancing their openness degree in their national innovation system. In this regard, the challenge to the called "open eco-innovation mode" (OEIM) in the Eco-innovation Action Plan, launched by the European Commission in 2011, could move the EU beyond green innovative processes, products and services reinforcing the objective pursued to the transition to a resource-efficient and low-carbon economy. Fostering inbound and outbound innovation process beyond the EU could enable to the development and implementation of policy programs aimed at stimulating or enforcing a more sustainable innovation transferring, translating and transforming knowledge across geographical, sectorial and institutional boundaries (Carlile, 2004).

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Appendix 1. Variable definitions

Variables	Description
Dependent variables	
Ecoproduct_firm	Equal to 1 if the firms has introduced a product innovation with environmental benefits at the stage of production of goods or services (reduced material use per unit of output; recycled waste, water, or materials) within the firm; 0 otherwise
Ecoproduct_market	Equal to 1 if the firms has introduced a product innovation with environmental benefits at the stage of the after sales use of a good or service by the end user (reduced air, water, soil or noise pollution; reduced energy use or improved recycling of product after use); 0 otherwise
Ecoprocess_firm	Equal to 1 if the firms has introduced a process innovation with environmental benefits at the stage of production of goods or services (reduced material use per unit of output; recycled waste, water, or materials) within the firm; 0 otherwise
Ecoprocess_market	Equal to 1 if the firms has introduced a process innovation with environmental benefits at the stage of the after sales use of a good or service by the end user (reduced air, water, soil or noise pollution; reduced energy use or improved recycling of product after use); 0 otherwise
Openness	
Acquisition	Equal to 1 if the firm has acquisition of 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 has R&D activities, but performed by other firms or by public or private research organizations and purchased by the firm, 0 otherwise
R&D Cooperation	Equal to 1 if the firms has R&D cooperation for the innovation activities with other firms or institutions during the three years 2006 to 2008, 0 otherwise
Market sources	Equal to 1 if the score of importance of competitors or suppliers or competitors or consultants, private R&D institutes as sources of information is "crucial" for the firm's innovation process, 0 otherwise
Institutional sources	Equal to 1 if the score of importance of universities or other higher education institutions, government or public research institutes as sources of information is "crucial" for the firm's innovation process, 0 otherwise
Other sources	Equal to 1 if the score of importance of conferences or scientific journals, professional associations or technical standards as sources of information is "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 in response to reduction of labour costs, 0 otherwise
Internal sources	Equal to 1 if the score of importance of departments within the firm or enterprises within the same group as sources of information is "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 expected 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 introduced procedures in place to regularly identify and reduce the environmental impacts such as environmental audits, setting environmental performance goals; ISO 14001 certification, 0 otherwise
Public funding	Equal to 1 if the firm has introduced an environmental innovation in response to availability of government grants, subsidies or other financial incentives for environmental innovation, 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 the customers for environmental innovations , 0 otherwise
Market geography	This variable was measured on a four-point Likert response scale: 1 (local); 2 (national); 3 (European) and 4 (other countries).
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
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