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Barriers to Environmental Innovation in SMEs: Empirical Evidence from French Firms

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Abstract. Recent literature has explored the determinants of environmental innovation (EI) but has rarely addressed obstacles to this innovation. To our knowledge, no previous study accounts for the antecedents of EI to explore the various perceived barriers to EI for small- and medium-sized enterprises (SMEs). Noting the importance of SMEs in European economies, this article identifies the extent to which SMEs perceive there to be barriers to EI and considers their type, number, and intensity. With a merged data set of 435 French SMEs, we investigate different perceptions of environmentally innovative SMEs, compared with those of technologically innovative SMEs and non-innovative ones, using a multiple treatment model that integrates the antecedents. We thereby analyze SME CEOs' perceptions of barriers to EI. The barriers are not only more numerous but also more important for SMEs that engage in EI activity compared with those that introduce only technological innovation (TI) or those that do not undertake any innovation activity (NI – non-innovation).

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In the past decade, concerns about firms' wrongdoing, especially in relation to the environment, have expanded. In response to pressures for a cleaner environment, firms might pursue environmental innovation (EI), which differs from "traditional" innovations in its externalities and drivers. Because regulations for adopting EIs exist, institutional pressures trigger such innovations, especially among polluting firms (e.g., Berrone, Fosfuri, Gelabert, & Gomez-Mejia, 2013; Jaffe, Newell & Stavins, 2005; Porter & van der Linde, 1995; Rennings, 2000). A great deal of literature explores the determinants of EI adoption but we know little about the elements that hinder EI. In particular, we have found limited research into the barriers to EI, which suggests the need for further empirical research on this topic (Del Río González, 2009).

To contribute to current debates on EI, we study EI determinants and barriers, both theoretically and empirically. Noting that the barriers to EI remain largely unexplored, we investigate the possibility of transferring or adapting existing theories and conceptual frameworks to EIs (De Marchi, 2012; Horbach, 2008; Rennings, 2000), which tend to be more complex than other TIs (De Marchi, 2012). Theoretical and empirical research started to investigate the environmental benefits associated with innovations about a decade ago, including their drivers and determinants. However, few studies (cf. De Marchi, 2012; Horbach, 2008) have compared environmental and non-environmental innovations. Even fewer investigations have addressed these issues in relation to small- and medium-sized enterprises (SMEs), even though the 20 million SMEs in the European Union represent 99% of all European firms. Due to their resource constraints, SMEs tend to focus less on environmental questions than their larger

counterparts, even though they account for approximately 64% of all industrial pollution (Calogirou, Sørensen, Bjørn Larsen, & Alexopoulou, 2010). In this sense, SMEs have a major role in global sustainable development issues and represent an important target for public policies aimed at developing a sustainable society. They also face unique challenges, because even if they want to reduce their environmental impacts, they are limited by a relative lack of resources.

This article therefore seeks to identify the extent to which SMEs that innovate in environmental contexts perceive barriers to their innovation, compared with SMEs that introduce TIs only or SMEs that do not innovate. As Mairesse and Mohnen (2010: 8) indicate, "most of the data collected in innovation surveys are qualitative, subjective and censored". Many variables, whether qualitative or quantitative, are subjective in nature, based largely on the personal appreciation and judgment of the respondents. Such perceptions are important in relation to public policy issues, because perceived obstacles to innovation constitute reflections of failed innovation policies, in that "if an obstacle is perceived to be high by a respondent, it means that somewhere there is a deficiency in innovation policy" (Mairesse & Mohnen, 2010: 22).

This subjective approach requires an understanding of subjective visions of business opportunities and the mobilization of resources and capabilities to transform knowledge into business reality (Shepherd & DeTienne, 2005)[1]. We follow subjectivist entrepreneurial theory (Penrose, 1959), which acknowledges the economic importance of an entrepreneur's personal knowledge (Polanyi, 1962), which is intrinsically subjective (Kor, Mahoney, & Michael, 2007). Adopting Kor et al.'s (2007) use of Penrose (1959) to elaborate how entrepreneurs' perceptions and personal knowledge shape firms' subjective, productive opportunity sets (including innovative activities), we assert the importance of understanding perceptions of the factors that hinder or make it difficult for SMEs to innovate environmentally. Such an understanding has major implications in terms of macroeconomic policies to support EI.

Literature on the barriers to EI is very scarce, although two recent working papers testify to a growing interest. First, Marin, Marzucchi, and Zoboli (2014) propose a taxonomy of European SMEs in terms of barriers to eco-innovation. Second, Ghisetti, Mazzanti, Mancinelli, and Zoli (2015) reveal the importance of overcoming financial barriers for SMEs' EI. With this study, we extend this line of research by accounting for the type, number, and intensity of these barriers and thereby answering two main research questions: what are the main barriers to EI, as perceived by SMEs? And are these perceived barriers more numerous or intense for environmentally innovative SMEs than for technologically innovative or non-innovative SMEs? To test our predictions, we use a novel multiple treatment model and a merged sample of 435 SMEs in the French Rhône-Alpes region.

We find that barriers to EI are not only more numerous but also more important for SMEs that engage in environmentally innovative activity, compared with those that do not undertake any innovation activity. This also holds for the comparison with SMEs that have introduced TI only, though to a lesser extent and mainly as a matter of intensity rather than of number.

With this approach, we contribute to the prior literature in several ways. First, in line with Klewitz and Hansen (2014), we seek to develop a more integrated theoretical framework of EI in SMEs that encompasses, for the first time, both antecedents and barriers to EI. Second, we identify specific EI determinants for SMEs and compare the perceptions of barriers to EI across three SME categories (environmentally innovative, technologically innovative, and non-innovative), using an original methodology based on a multinomial logit model with treatment effects. Our findings show that EIs have a more binding character than more classical TIs and that the barriers to EI appear more

1. Such perceptions may be subject to decision-making biases though, especially under uncertainty (Busenitz & Barney, 1997).

numerous and more intense. Third, our novel data set of French SMEs enables us to address conventional questions about innovation while also considering SMEs' specific antecedents and barriers to innovation.

In the next section, we present our theoretical framework and draw hypotheses about barriers to EI. We then present the data and methodology, followed by the main results of our econometric models. Finally, with our discussion and conclusion, we note some limitations of this research and avenues for further research.

ANTECEDENTS OF ENVIRONMENTAL INNOVATION

Environmental innovation has been defined in various ways, including different types of innovation (i.e., technological or non-technological), depending on the researchers' objectives and questions. For example, Kemp (2010: 2) defines EI as the "production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". In contrast, Rennings (2000: 322) views EIs as "measures of relevant actors (firms, […]) which: (i) develop new ideas, behavior, products and processes, (ii) apply or introduce them, and; (iii) contribute to a reduction of environmental burdens or to ecologically specified sustainability targets". The various definitions sometimes refer to EI as "green innovation" or "eco-innovation", which are broader terms that also encompass unintended EIs (Arundel & Kemp, 2009). We prefer the term "environmental innovation", because it aligns with our research perspective, in which EI is the result of a firm's strategy. Moreover, it is the term most often used in innovation literature (Schiederig, Tietze, & Herstatt, 2012).

Accordingly, we focus on technological EIs, which we regard as new or modified processes, products, or services that reduce environmental harms (Beise & Rennings, 2005; De Marchi, 2012). This definition includes changes to products and production processes that generate environmental benefits, whether those benefits accrue to final customers (i.e., products and services) or firms themselves (i.e., processes). Note that this definition "is based on the effect of the innovation activities independent of the initial intent and includes both incremental and radical improvements" (De Marchi, 2012: 615). Because EI holds increasing interest for both firms and scholars, a question arises: does it require specific theory and public policy? This question is particularly pertinent for SMEs (Cuerva, Triguero-Cano, & Córcoles, 2014; Del Río González, 2009), for which the frontier between the determinants and barriers of EI remains tenuous.

Prior EI literature has discussed whether EI is triggered by supply-push factors, demand-pull factors, or both (Costantini, Crespi, Martini & Pennacchio, 2015; Di Stefano, Gambardella & Verona, 2012; Peters, Schneider, Griesshaber & Hoffmann, 2012). Beyond such technology-push and market-pull factors, regulation is another important driving force (e.g., Ghisetti et al., 2015; Horbach, 2008; Horbach, Rammer & Rennings, 2012; Rennings & Rammer, 2009). Some authors also introduce firm-specific factors (Ghisetti et al., 2015; Horbach et al., 2012). We adopt a classification[2] of four types of antecedents, in line with Horbach et al. (2012) and Ghisetti et al. (2015): regulation, technology-push factors, demand-pull factors, and firms' characteristics.

2. This classification is now well accepted, but it raises some challenges, because regulation may support both supply (by improving infrastructure and/or public R&D) and market forces, such as through public procurement (Rennings & Rammer, 2009).

REGULATION

Similarly to most other studies of firms' EI antecedents, we do not adopt a standard "policy-oriented" approach. We instead prefer the Porter hypothesis, which stresses that regulation can drive innovation in certain circumstances. This hypothesis has been formulated twice (Porter, 1991; Porter & van der Linde, 1995) and indicates that well-designed regulations can enhance firms' innovation and competitiveness. In contrast, a standard view considers environmental regulation solely an additional cost for firms.

With this reliance on the Porter hypothesis, we consider environmental policy a main potential driver of EI (Horbach, 2008). For example, environmental regulations incentivize innovation through environmental taxes or certificates (Wagner, 2003). Two key points differentiate EIs from other innovations: externalities and drivers, which Rennings (2000) refers to as the "double externality problem" and the "regulatory push/pull effect", respectively. That is, just as innovation and R&D activities induce positive externalities, green innovators can produce positive environmental externalities (De Marchi, 2012). Part of this created value gets appropriated by society – in the form of reduced environmental damage – so there are some disincentives for firms to invest in products or processes that reduce their environmental impacts (Jaffe et al., 2005; Rennings, 2000). This additional externality may prompt a lack of investment or interest among firms, because direct returns from investments in EI are difficult to reap. The potential for market failure also induces a greater need for policy intervention to drive EI (Rennings, 2000).

In this vein, recent studies have indicated a positive correlation between regulation and EIs (Horbach, Oltra & Belin, 2013); environmental regulation offers the initial incentive for firms to develop EI processes (Del Río González, 2009). Antonioli, Mancinelli, and Mazzanti (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, Steen & Verreynne, 2014), such that some firms even overcomply to gain competitive advantages and an improved social image, in which case the costs associated with reduced pollution may be balanced by realized gains (Ambec & Lanoie, 2008).

For SMEs, though regulation is a powerful driver of EI, meeting environmental regulations is arduous (Brammer, Hoejmose, & Marchant, 2012), especially when the regulatory system is complex (involving numerous certifications, policies, or institutions). With a sample of Chinese SMEs, Zhu, Wittmann, and Peng (2012) find that unclear laws or regulations, together with excessive taxation, have hampering effects on small firms. Thus, well-designed regulation must be adequate and appropriate to support SMEs' EI processes.

TECHNOLOGY-PUSH FACTORS

Literature on the determinants of EI that adopts a technology-push (supply-side) view generally has suggested that improving organizational, strategic, and technological capabilities triggers EI (Horbach, 2008). Using a novel data set of 1566 UK firms, Kesidou and Demirel (2012) emphasize the importance of allocating organizational capabilities and resources to EI. A strong positive relationship emerges between technological capabilities and EI (Cuerva et al., 2014); in addition, environmental management systems (EMS; e.g., ISO norms) favor the EI process (Horbach, 2008; Kammerer, 2009; Wagner, 2007). The ISO 14001 norm has a positive influence on R&D activities, and a more mature EMS increases environmental R&D investments (Inoue, Arimura, & Nakano, 2013). Kesidou and Demirel (2012) also find that cost savings, especially on material and energy, are important incentives for EI. Horbach et al. (2013) confirm this

result among French and German firms and show that savings on energy and material enhance EI. In addition, SMEs with an external acquisition strategy likely innovate less, because both acquisition and innovation strategies incur important costs (Hitt, Hoskisson, Johnson, & Moesel, 1996). By contrast, an internally focused strategy should enhance a firm's propensity to innovate environmentally (De Marchi, 2012).

Cooperation in R&D also appears to drive EI by enabling economies of scale, especially for firms in the same sector (Cainelli, Mazzanti & Zoboli, 2011). An important characteristic is that EI may require knowledge and competences that do not belong to a firm's core competences (Horbach et al., 2012; Rennings & Rammer, 2009). In this sense, Cainelli, Mazzanti, and Montresor (2012) not only show that interfirm network relationships are the most important EI drivers for firms located in a local production system, but also that EI is stimulated by firms' interactions with "qualified partners" (e.g., universities and suppliers, but not customers or competing firms). Other authors demonstrate that cluster policies could leverage EI, in both clean-tech sectors and other industries (Barsoumian, Severin, & van der Spek, 2011). Wagner (2007) emphasizes the need to collaborate with environmentally concerned stakeholders, especially for SMEs. In one of the rare studies dedicated to SMEs, Del Río González (2009) asserts that other actors, such as industrial associations or public and private entities, can engage in cooperative processes to support innovation. Research into EI determinants also highlights the crucial importance of interactions between firms, and between SMEs and various actors (Marin et al., 2014), which implies a link to open innovation considerations since SMEs with EI are generally seen as more open for innovation than other firms. Open innovation is key for EI (De Marchi, 2012), especially for SMEs (Klewitz & Hansen, 2014; Worthington & Patton, 2005), and in their systematic review of the sustainability-oriented innovation of SMEs, Klewitz and Hansen (2014) argue that interactions with external actors (e.g., authorities and research institutes) can ultimately increase the innovative capacity of SMEs for EIs. As Triguero, Moreno-Mondéjar, and Davia (2013) suggest, on the basis of their analysis of the drivers of different types of EI in European SMEs, supply-side factors thus appear more important for environmentally oriented innovations than for more traditional product innovations.

DEMAND-PULL FACTORS

Firms have strong incentives to engage in EIs that are congruent with customer benefits (Kammerer, 2009). Kesidou and Demirel (2012) argue that firms initiate EI to satisfy minimum customer and societal requirements. Environmental consciousness is thus a relevant parameter for innovative firms (Horbach, 2008), especially in environmentally sensitive industries. In the pulp paper industry for example, public pressure is the strongest determinant of EI, even more so than regulation (Popp, Hafner, & Johnstone, 2011). Although some SMEs likely are reluctant to implement EI, out of a concern that most of their customers are not willing to pay more for green products or services (Bianchi & Noci, 1998), their investment in EI can represent a means to develop their markets (Brammer et al., 2012). Moreover, close proximity between a firm and its customers can help it implement an EI strategy (Madrid-Guijarro, Garcia, & van Auken, 2009). As Triguero et al. (2013) show, European SMEs that collaborate with various actors (including consumers) increase market demand for green products, and market share in turn has a significant positive influence on EI.

FIRM CHARACTERISTICS

Firm size has a positive effect on EI, such that larger SMEs, which enjoy greater access to financial and human resources (Rehfeld, Rennings & Ziegler, 2007), are more likely to engage in EI processes (Cuerva et al., 2014; De Marchi, 2012; Galliano & Nadel, 2013). Older firms tend to have acquired more competences, knowledge, and resources to support an EI strategy, whereas younger ones tend to seek an understanding of their market first, then search for venture capital funding (Mazzarol, Reboud, & Volery, 2010). In addition, international firms are more conscious of environmental pressures (Del Río González, 2009) and more likely to elaborate and adopt a proactive environmental strategy (Aguilera-Caracuel, Hurtado-Torres, & Aragón-Correa, 2012). Finally, SMEs have more flexibility than large firms, due to their structure and size, which increases their reactivity (Aragón-Correa, Hurtado-Torres, Sharma, & García-Morales, 2008). Madrid-Guijarro et al. (2009) also note that less bureaucracy has a positive effect on EI.

Overall, SMEs appear generally less likely to introduce EIs than large firms, because of their lack of resources. Of the various explanatory factors for SMEs' EI, those related to the demand side seem to have the smallest impact. Examining barriers to EI offers another path of interest, which may provide a better understanding of SMEs' decisions related to EI.

BARRIERS TO ENVIRONMENTAL INNOVATION

Because of the scarcity of studies on the drivers of or barriers to EI, we rely on the literature on the barriers to TI. This analogy between EI and other types of TI requires consideration of two main elements: first, some studies based on large samples demonstrate that EIs are more complex and costly, such that they require knowledge and competences that are not necessarily among a firm's core competences (Horbach et al., 2012; Rennings & Rammer, 2009). Second, Ghisetti et al. (2015) show that EI is not always a question of financial resources but rather reflects organizations and managers' perceptions. Consequently, EI often requires more transverse process activities than traditional, "dirty" TIs (which mainly emerge from R&D departments).

Previous studies of the barriers to (technological) innovation do not address EI specifically but rather seek to explicate the impact of these barriers on firms' attitudes toward R&D activities (Blanchard, Huiban, Musolesi, & Sevestre, 2013; Hyytinen & Toivanen, 2005; Mohnen, Palm, van der Loeff, & Tiwari, 2008; Mohnen & Röller, 2005; Savignac, 2008; Segarra-Blasco, Garcia-Quevedo, & Teruel Carrizosa, 2008)[3]. For example, research carried out for the Commission of European Communities, featuring contributions from researchers across eight European countries, has revealed that major barriers relate to the education system, skilled labor, venture capital and bank financing, norms, legislation, and public bureaucracy (European Commission, 2004). In Canada, Baldwin and Lin (2002) study barriers to advanced technology adoption by manufacturing firms and identify five classes: cost, institution, labor, organization, and information. Galia and Legros (2004), investigating the complementarities among barriers to innovation for French manufacturing firms, show that firms that postpone projects are more prone to economic risk, lack of skilled personnel, innovation costs, lack of customer responsiveness, lack of information about technologies, and organizational rigidities. In contrast, firms that abandon projects tend to face economic barriers rather than technological or organizational ones. Mohnen and Röller (2005) also assess complementarities among barriers to innovation in a sample of firms from Ireland, Denmark, Germany, and Italy. They cite four groups

3. A discussion of the determinants of obstacles to innovation is beyond the scope of this study (see Baldwin & Lin, 2002; D'Este, Iammarino, Savona, & von Tunzelmann 2012; Galia & Legros, 2004; Iammarino, Sanna-Randaccio, & Savona, 2009; Schneider & Veugelers, 2010; Tourigny & Le, 2004).

of barriers – risk and finance, knowledge, knowledge skills outside the enterprise, and regulation – and assert that a lack of internal human capital complements all other barriers in almost all industries. In the Netherlands, Mohnen et al. (2008) show that financial barriers significantly affect firms' decisions to abandon, prematurely stop, slow down, or not start innovative projects; in addition, these financial constraints depend on firms' sizes and economic situations.

As these studies show, many firms are constrained by financial barriers. However, when barriers to innovation serve as an explanatory variable for R&D activity or innovation output, a non-significant or even significantly positive coefficient often results (Baldwin & Lin, 2002; D'Este et al., 2012; Galia & Legros, 2004; Hölzl & Friesenbichler, 2010; Hölzl & Janger, 2014; Iammarino et al., 2009; Mohnen et al., 2008; Mohnen & Röller, 2005; Mohnen & Rosa, 2002), such that firms facing stronger barriers appear more likely to innovate, all else being equal. The positive correlation of innovation with perceived obstacles is, at first sight, a typically counterintuitive result. However, most studies of innovation obstacles, especially those using Community Innovation Surveys (CIS) that are based on perceptions (e.g., Galia & Legros, 2004; Ghisetti et al., 2015; Mohnen & Röller, 2005; Rennings & Rammer, 2009), indicate that barriers to innovation are perceived as stronger by those firms that actually are innovating. Therefore, closer inspection suggests "that innovating firms are more likely than non-innovating firms to perceive the various obstacles that stand in their way" (Mohnen et al., 2008, p. 208). In other words, the perception of hampering factors is itself endogenous and co-determined by some of the same factors that condition innovation. Clausen (2008) provides an original, additional explanation: the key variable is not actual barriers but their perception by managers. In that sense, those who wish to innovate are more inclined to perceive barriers, and this perception relates positively to the will to innovate. Obstacles to innovation should be interpreted as a measure of how firms overcome them, rather than as preventers of innovation (Baldwin & Lin, 2002; Tourigny & Le, 2004). The definitions of barriers to innovation applied in innovation surveys in turn might indicate how successfully a firm has overcome those barriers. D'Este et al. (2012) similarly propose a distinction between "deterring" and "revealed" barriers: the former prevent firms from engaging in innovation activities, whereas the latter invoke a positive effect, such that firms can overcome barriers and innovate. Ghisetti et al. (2015) offer support for the deterrent barrier hypothesis for financial constraints, which deter innovative strategies.

In line with these previous studies, we analyze three major sets of perceived barriers to EI: cost, knowledge, and the market. First, cost barriers reflect a firm's difficulties in financing its innovation projects. During the innovation process, available financial resources might not be sufficient to cover the investments required, so high costs and a lack of financial resources (internal and external sources) constitute important barriers to innovation. Second, knowledge barriers pertain to limited access to information about technology and skilled labor. Managers and employees who can incorporate and support innovation as a business strategy thus attain a competitive advantage. That is, EIs require specific information and knowledge, so qualified personnel and associated skills are important for exploring new environmental technologies. Third, an ability to connect a technical opportunity to a market opportunity encourages successful innovations, but technology-push- and demand-pull-related barriers may constrain innovative activity. The technology and markets linked to EI tend to be complex and evolve rapidly, so firms that pursue EI must address these two issues even more intensively than firms that innovate in other realms. The market barriers thus reflect market structures and pull technology derived from demand.

However, these barriers might not be identical or perceived in the same way in relation to EI, especially for SMEs. The European Commission's Environmental Technologies Action Plan (European Commission, 2004) cites

several barriers to EI: economics, inappropriate regulations or standards, insufficient or weak research systems, and lack of market demand. Ashford (1993) also provides a detailed list of barriers to pollution prevention: technological, financial, labor-force-related, regulatory, consumer-related, supplier-related, and managerial. Empirical studies indicate that EI is often costly, because it requires specific procedures to measure, manage, and adapt benefits for the environment, which could hinder an innovative firm's performance (Konar & Cohen, 2001). Market uncertainty also tends to be greater for green products, because of their relative newness and volatile consumer markets. Similarly, access to both skilled personnel and knowledge about markets and technologies is more difficult for goods outside the mainstream.

These barriers get reinforced for SMEs, which lack various resources and are more constrained in their day-to-day operations. At a regional level, Freel (2000) observes barriers to product innovation among a sample of small manufacturing firms and breaks the resource constraints down into four sets: finance, management and marketing, skilled labor, and information. Madrid-Guijarro et al. (2009) consider a lack of financial resources, poor human resources, a weak financial position, and high cost and risk as internal barriers, and consider turbulence, a lack of external partners, a lack of information, and a lack of government support as external barriers. The cost of innovation affects Spanish SMEs more, and barriers' impacts depend on the type of innovation. According to Madrid-Guijarro et al. (2009), costs represent the most significant barriers to innovation, with a disproportionately greater impact on small firms, probably because SMEs suffer more limited financial resources than large firms. In this sense, SMEs are especially subject to barriers linked to the lack of financial resources and costs (Iammarino et al., 2009; Savignac, 2008). Alessandrini, Presbitero, and Zazzaro (2010), considering Italian small firms during 1995-2003, show that their different time patterns cause process and product innovations to be associated with different financial constraints. Del Río González (2009), in a review of empirical studies, indicates that barriers to environmental technological innovation for SMEs are not the same as those encountered by large firms but provides no further details. He only calls for more research and indicates that small firms lack sufficient human, technical, and financial resources, which bars EI.

The two (known) empirical studies on barriers to EI for SMEs (beyond the systematic review by Klewitz and Hansen, 2014) highlight that SMEs have very different profiles in terms of their perceptions of these barriers (Marin et al., 2014) and that perceived financial barriers deter their environmentally innovative activities; that is, they prevent SMEs from adopting EIs (Ghisetti et al., 2015). Two other studies, which include both large and small firms and rely on CIS data related to obstacles to innovation, conclude that legislation and bureaucratic processes (Rennings & Rammer, 2009), as well as lack of knowledge (Horbach et al., 2012), are perceived barriers that hamper EI.

Because SMEs face relatively more, and more intense, barriers to innovation than large firms, due to their inadequate or insufficient internal resources, we explicitly investigate variance in the number and intensity of barriers for SMEs, according to the type of innovation (i.e., environmental versus technological versus no innovation). We hypothesize:

> *H1: Barriers to EI are perceived as more numerous by environmentally innovative SMEs than by (a) technologically innovative SMEs and (b) non-innovating SMEs.*

> *H2: Barriers to EI are perceived as more intense by environmentally innovative SMEs than by (a) technologically innovative and (b) non-innovating SMEs.*

DATA AND METHODS

DATA

We used data from two main sources, both pertaining to French SMEs located in the Rhône-Alpes region. This region exhibits important research and innovation activity; it ranks second in the nation in terms of research potential (after the Paris region). With a specially designed survey[4], conducted in 2012, we asked SMEs' top managers for information about different types of innovation activity (technological, non-technological, and with environmental benefits for the firm or end users). The questions paralleled those included in the 2008 CIS. Moreover, the survey provided detailed information about SMEs' sources of innovation and perceptions of barriers. The focal period was 2009-2011, although questions related to general firm information specified that answers should reflect 2011 values. We obtained 671 completed questionnaires. In addition, we referred to the Orbis database, which gathered balance sheet information for all SMEs located in the Rhône-Alpes region; we used those from 2009-2011. As recommended by Arundel and Kemp (2009), we linked our unique Rhône-Alpes data set to these official data, which included financial information, to ensure higher reliability. After merging the two databases, we obtained a final balanced sample of 435 French SMEs, each of which employed between 10 and 249 people. The final data set is representative of SMEs located in the Rhône-Alpes region, across firm size and sector affiliation, though manufacturing SMEs are slightly overrepresented (see Appendix A).

DEPENDENT VARIABLES

Environmental innovation is generally measured with input, intermediate output, direct output, and indirect impact measures (Arundel & Kemp, 2009). For our sample of SMEs, "objective" measures, such as patents and R&D (i.e., input and intermediate output) are less relevant. Therefore, in line with our theoretical subjectivist perspective, we use perceptual measures and adopt a direct output measure, following the Oslo Manual (OECD, 2005) and CIS 2008. Several authors (e.g., Madrid-Guijarro et al., 2009) assert that subjective measures (e.g., managers' perceptions) are superior to objective measures (Hughes, 2001), as well as highly correlated with objective measures (Frishammar & Horte, 2005; Zahra & Covin, 1993).

We asked the SME CEOs whether, between 2009 and 2011, their firms had introduced significant novelties or improvements in their manufacturing processes or their production of goods or services. A subsidiary question asked if those innovations provided any environmental benefits (e.g., reduced energy consumption, lowered CO2 emissions, or waste recycling) for the firm and/or for customers. We combined these two questions – about technological innovations (yes/no, binary variable) and their environmental benefits (yes/no, binary variable) – to determine if firms were environmentally innovative.

To investigate differences in perceptions of the barriers to EI across SMEs, we used a multiple treatment model (Cattaneo, 2010), which enabled us to compare differentiated perceptions of barriers, according to the SMEs' innovation statuses. That is, we compared the barriers perceived by environmentally innovative SMEs to those perceived by technologically innovative and non-innovative SMEs. Other econometric modeling-based measures (e.g., Böhringer, Moslener, Oberndorfer, & Ziegler, 2012) instead tend to consider only EI firms and therefore measure a global effect among EI firms. Some other studies on TI (Baldwin & Lin, 2002; Galia & Legros, 2004; Hölzl & Friesenbichler, 2010; Iammarino et al., 2009; Mohnen & Röller, 2005; Mohnen & Rosa, 2002) and the

4. Because CIS 2006 only provides information on barriers and CIS 2008 only provides EI information (other CIS surveys do not provide all the necessary information), we conducted this unique survey to gather both pieces of information simultaneously from firms located in the Rhône-Alpes region.

very few studies on EI (Ghisetti et al., 2015) also focus on the perceptions of barriers among innovative firms or treat non-innovative firms as an undifferentiated group. To extend these approaches, we investigate differences among environmentally innovative firms, technologically innovative firms, and non-innovative firms, which provides a better adjusted measure. With these comparisons, we highlight potential specificities of barriers perceived by environmentally innovative SMEs.

INDEPENDENT VARIABLES

We introduced a series of variables that prior empirical literature lists as determinants of product and process EI. Public policies and regulation are powerful levers for inciting firms to adopt EI. Because institutional pressures trigger EI even more among highly polluting firms (Berrone et al., 2013), we used this proxy to measure the impact of regulation, with the prediction that SMEs operating in polluting sectors are more prone to adopt EI (Antonioli et al., 2013)[5]. With regard to SMEs' strategy, we anticipated that SMEs engaged in external growth strategies should be more likely to allocate resources to this strategic priority, to the detriment of other activities, such as those linked to innovation (Hitt et al., 1996). In contrast, SMEs engaged in R&D cooperation might be able to compensate for their lack of resources to innovate (Triguero et al., 2013). If SMEs belong to a cluster[6], they also should be more likely to introduce EI, because they can benefit from interfirm network relationships and agglomeration economies (Porter, 2000), though the role of agglomeration economies is not clear-cut (Cainelli et al., 2012). These effects are important in relation to social proximity and processes of collective learning (Mirata & Emtairah, 2005). Cainelli et al. (2012) also confirm the effects of agglomeration economies on EI in areas that have historically rooted specialization patterns in "EI-friendly" sectors, that is, those that have developed a typical social capital.

A firm's implementation of a pollution reduction strategy could also significantly influence its decision to adopt EIs, in the form of products or processes (i.e., environmental monitoring), in line with Wagner's (2007) assertion that implementing an EMS increases the probability that firms pursue innovation in general and EI in particular. Wagner (2007) also notes a positive relationship between cooperation with predominantly environmentally concerned stakeholders and environmental product innovation.

Finally, we introduced variables to control for firms' characteristics. We measured firm age by its logarithm. Because efficient firms are more likely to survive and grow (Bartelsman & Doms, 2000), firm age should have a positive impact on EI. We included firm size, measured by the logarithm of the total number of employees. Medium-sized SMEs seemingly innovate more than the smallest ones (Laforet, 2008), so we expect firm size to have a positive impact on the decision to adopt EI, in that larger SMEs have more resources to innovate. When a SME is part of a group, it can benefit from additional resources necessary to innovate. In contrast, SMEs that face financial constraints (measured for 2010, using the debt-to-equity ratio computed from the Orbis data; Cassar & Holmes, 2003; Michaelas, Chittenden, & Poutziouris, 1999) should be less likely to adopt EI (Madrid-Guijarro et al., 2009). The relationship between innovation and exports has been well demonstrated, so we included a dummy to indicate if the firm engaged in export activity (Basile, 2001; Roper & Love, 2002). Finally, we defined two sector variables (manufacturing versus service). Table 1 provides definitions for the variables in our multinomial logit model.

5. Accounting for government support may introduce an endogeneity bias, because subsidized firms may have characteristics that make them distinct from other firms (Mairesse & Mohnen, 2010), and other firms may not be recipients during the sample period, which would introduce an additional bias. Moreover, SMEs receive only 9% of all public subsidies dedicated to R&D by the French government (Lhuillery, Marino, & Parrotta, 2013). We therefore chose to not include government support for innovation.

6. Here, "belonging to a cluster" means being a dues-paying member. French clusters are unique, in that they are more than just geographic concentrations (cf. Porter, 2000). Created by the French government in 2005, they are led by an organization or formal governance. Even if, geographically speaking, a firm appears in the cluster's territory, it belongs to that cluster only if it pays a membership fee; in return, it benefits from a series of actions determined by the cluster's governance related to innovation, human resource programs, commercial development, and so on. We thank an anonymous reviewer for suggesting this explanation.

Table 1. Variables in the multinomial logit model

Variable	Definition
Innovation	= 0 if the firm has not innovated in the last three years; = 1 if the firm has introduced technological innovation in the last three years; = 2 if the firm has introduced environmental innovation in the last three years.
Polluting sector	= 1 if the firm is part of a polluting sector, 0 otherwise.
Environmental monitoring	= 1 if the firm measures its environmental impact (e.g., environmental audits, ISO 14001), 0 otherwise.
External growth	= 1 if the firm engages in an external growth strategy (mergers and acquisitions), 0 otherwise.
Cluster	= 1 if the firm belongs to a cluster, 0 otherwise.
R&D cooperation	= 1 if the firm cooperates in R&D with other firms, 0 otherwise.
Firm Size	Logarithm of firm size (number of employees) in 2011.
Firm Age	Logarithm of firm age in 2012.
Export	= 1 if the firm exports, 0 otherwise.
Group	= 1 if the firm belongs to a group, 0 otherwise.
Debt ratio	= sum of long-term debts and loans, divided by shareholders' funds and provisions in 2010.
Services	= 1 if the firm is from the services sector, 0 otherwise.
Manufacturing	= 1 if the firm is from the manufacturing sector, 0 otherwise.

SAMPLE

The descriptive statistics refer to the balanced sample, namely the 435 SMEs in Appendix B. When we compare the environmentally innovative and non-innovative SME groups (see Table 2), several differences emerge for variables related to the polluting sector, R&D cooperation, belonging to a cluster, having environmental monitoring, exports, and being from the services sector. We find fewer differences between environmentally and technologically innovative SME groups, and these are related to external growth, environmental monitoring, and age of the firm. We also find several significant differences between the technologically innovative and non-innovative groups, which are quite similar to those between the environmentally innovative and non-innovative SME groups. That is, there is a more important gap between environmentally innovative firms and non-innovative ones, and between technologically innovative firms and non-innovative ones, than between environmentally and technologically innovative SMEs, which exhibit few differences. Appendix B provides the descriptive statistics.

Table 2. Sample composition

	Frequency	Percent
Environmentally innovative SME	142	32.65%
Technologically innovative SME	144	33.10%
Non-innovative SME	149	34.25%
Total	**435**	**100.00%**

METHODS

To analyze possible differences among firms in terms of innovation input, innovation strategies, innovation output, and firm performance, two main methods serve evaluation purposes. First, propensity score matching establishes two groups of firms that are similar in variables that determine a certain feature – here, the introduction of EI – such that one group exhibits this feature (i.e., EI or "treated" firms) and the other does not (i.e., non-innovative or "untreated" firms). Second, multiple treatment-effects models[7] compare not just two groups but several (e.g., environmentally innovative versus technologically innovative versus non-innovative firms). Because this multiple treatment-effects approach provides more accurate and differentiated estimates across groups than propensity score matching, we chose to use it to assess differences in the perceived barriers of environmentally innovative SMEs, compared with those of technologically innovative SMEs and non-innovative ones. Such multiple treatments also are of particular interest and relevance when differential impacts within and across treatments are likely (Cattaneo, 2010). Here, we expect different perceptions of barriers among SMEs, according to their innovation type.

Generally, estimations of innovation decisions are subject to endogeneity biases, because firms perceive innovation obstacles particularly when they are engaged in innovation, with the result that variables are not independent from the phenomenon itself. In cross-sectional data, variables related to R&D and innovation outcomes are generally endogenous (Mairesse & Mohnen, 2010), especially barriers (Mohnen et al., 2008). In contrast, a multiple treatment effect creates proper counterfactuals for the observed data by weighing and subsequently comparing the observed outcomes with the constructed counterfactuals. At the same time, this method overcomes the endogeneity problem: it offers asymptotically unbiased and consistent estimates of treatment effects (Morgan & Harding, 2006; Wooldridge, 2002). The independent variables used to match untreated with treated firms are exogenous and not affected by the treatment, in line with the requirements for matching and related techniques (Imbens, 2004). Thus, to estimate the treatment effect, we apply a doubly robust model[8].

First, the multinomial logit estimate allows us to distinguish the effects of EI antecedents for each group of SMEs (EI, TI, and NI). It contains all dependent and independent variables previously mentioned, as indicated in the following equation[9]:

$$log\frac{\Pr(Y=EI)}{\Pr(Y=non\ innovative)} = \alpha + \beta_1 Cluster + \beta_2 FirmSize + \beta_3 PollutingSector + \beta_4 EnvironmentalMonitoring + \beta_5 R\&DCooperation + \beta_6 ExternalGrowth + \beta_7 FirmAge + \beta_8 DebtRatio + \beta_9 Services + \beta_{10} Group + \beta_{11} Export$$

Second, the results of this regression estimate the population average of the treatment effect on perceived barriers (ATET). This estimator allows us to measure the difference between the perceptions of environmentally innovative SMEs and those of technologically innovative and non-innovative SMEs. More formally, ATET estimates the causal effect of a treatment (having introduced EI) on an outcome (number and intensity of perceived barriers), and thus, it assesses the difference in perceived barriers by comparing treated SMEs (EI) with the control groups (TI or NI). We introduce barrier (outcome) variables that reflect the respondents' answers to a series of questions we designed to identify barriers to innovation, as perceived by SMEs' top managers. Each respondent indicated his or her perception of nine barriers to innovation, related to (1)

7. We thank an anonymous reviewer who suggested the multiple treatment-effects methodology, which allowed us to extend the results that we obtained initially with propensity score matching.

8. We use an inverse probability-weighted regression adjustment (ipwra), because the estimation method models both the impact variable (EI) and the treatment effect (barriers). This model actually combines two models: a regression adjustment model (ra) and an inverse probability-weighted model (ipw). These estimations have a double-robust property, in that if either the outcome model (for estimating barriers' effects) or the treatment model (for EI) is correctly specified, the impacts are consistently estimated. Moreover, inverse-probability weighting is a robust method that leads to efficient estimators (Hirano, Imbens, & Ridder, 2003), and weighting by the inverse of the estimation is more efficient than using population probabilities of the treatment to estimate the average treatment effect (Hirano et al., 2003; Rotnitzky & Robins, 1995; Wooldridge, 2002).

9. The equation is the same for technologically innovative SMEs, except that we substitute "EI" with "TI" in the previous formula.

excessive costs of innovation, (2) lack of external financial sourcing, (3) lack of internal financial sourcing, (4) domination of markets by insiders, (5) demand uncertainty, (6) lack of skilled employees, (7) lack of information about technologies, (8) lack of information or visibility on markets, and (9) difficulties in finding partners with which to innovate. Each barrier measure used a five-point scale, from 0 (very low perception) to 5 (very high perception). The perceptual measures involved two assessments: the perceived intensity of the barrier (barriers' intensity), equal to the sum of all barrier scores by a respondent, and the number of perceived barriers (barriers' number), or the sum of high and very high barriers indicated by the respondent (see Table 3). Finally, we grouped the nine barriers to innovation into three theoretically coherent categories (financial, market, and knowledge) and computed a measure of the intensity of each perceived barrier by category. We also added up the perceived barriers to calculate the number of perceived barriers in each category. The variable definitions are in Table 3.

Table 3. Definitions of barriers (outcomes)

Outcome	Definition
Barriers' intensity	Sum of all barriers' scores by a respondent, ranging from 0 to 45, because for each of the 9 barriers, potential intensity scores range from 1 (very low) to 5 (very high).
Barriers' number	Sum of high or very high barriers perceived by the firm, from 0 to 9.
Knowledge barriers' intensity	Sum of knowledge barrier scores by a respondent, ranging from 0 to 20, because for each barrier (lack of skilled employees, lack of information on technologies, lack of information or visibility on markets, and difficulties in finding partners), potential intensity scores go from 1 (very low) to 5 (very high).
Knowledge barriers' number	Sum of high or very high knowledge barriers perceived by the firm, from 0 to 4.
Financial barriers' intensity	Sum of financial barrier scores by a respondent, ranging from 0 to 15, because for each financial barrier (excessive costs of innovation, lack of external financial sourcing, and lack of internal financial sourcing), potential intensity scores range from 1 (very low) to 5 (very high).
Financial barriers' number	Sum of high or very high financial barriers perceived by the firm, from 0 to 3.
Market-related barriers' intensity	Sum of market-related barrier scores by a respondent, ranging from 0 to 10, because for each market-related barrier (market dominated by insiders and demand uncertainty), potential scores range from 1 (very low) to 5 (very high).
Market-related barriers' number	Sum of high or very high market-related barriers perceived by the firm, from 0 to 2.

FINDINGS

The results of the multinomial logit are in Table 4.

Table 4. Results of the multinomial logit model[10]

Variable	EI - Robust		TI - Robust		differences between EI and TI
	Coefficient	Standard Error	Coefficient	Standard Error	
Polluting sector	0.674	0.384*	0.645	0.398ns	ns
Environmental monitoring	0.735	0.356**	-0.108	0.398ns	significant
External growth	-0.574	0.326*	0.364	0.297ns	significant
Cluster	1.750	0.567***	1.352	0.565**	significant
R&D cooperation	0.479	0.280*	0.268	0.276ns	significant
Firm size	0.471	0.183**	0.455	0.179**	ns
Firm age	0.002	0.151ns	-0.311	0.144**	significant
Export	0.460	0.280ns	0.699	0.278**	significant
Group	-1.046	0.643ns	-0.619	0.561ns	significant
Debt ratio	-0.031	0.131ns	-0.112	0.127ns	significant
Services	-0.088	0.273ns	0.204	0.271ns	significant
_cons	-2.060	0.738***	-1.305	0.714ns	significant
Log likelihood			-436.375		
No. of obs.			435		
Pseudo R^2			0.0867		

The models all pass the test of the independence of irrelevant alternatives (IIA).
***Significant at 1%. **Significant at 5%. *Significant at 10%. ns: non-significant.

As expected, environmental regulation has a positive effect on the probability of adopting EI, such that SMEs from polluting sectors are more likely to innovate environmentally (Antonioli et al., 2013). This effect is not significant for TI. Regulation has a binding effect on SMEs' EI decisions. The influence of environmental monitoring indicates that firms that are conscious of their environmental impact are more proactive in their EI. Quite logically, this variable has no effect on TI. Strategic behaviors also influence the likelihood of EI adoption (Horbach, 2008). Not surprisingly, an external growth strategy through mergers and acquisitions affects EI negatively, because EI and the acquisition strategy both have important costs that make them exclusive (Hitt et al., 1996). In contrast, this strategy neither impedes nor fosters TI. The results also confirm the importance of networks and open innovation for SMEs, especially when EI is concerned. As expected, both joining a cluster and R&D cooperation strongly increase the probability that an SME introduces EI (Cainelli et al. 2012); merely belonging to a cluster favors TI (Baptista & Swann, 1998).

Among the control variables, firm size has a significant positive impact on both EI and TI, but with a larger effect on EI than TI. Large SMEs therefore are more likely to innovate in the environmental field than small ones, regardless of their age (Cuerva et al., 2014; Horbach, 2008).Younger SMEs are more likely to adopt TI, whereas this effect is non-significant for environmentally innovative SMEs. Finally, unlike environmentally innovative SMEs, export is significant for TI and appears to have a positive effect on TI (Roper & Love, 2002).

10. The correlation matrix is available on demand. It has not been included here, because there are no significant or important correlations that could disrupt our models.

In addition to defining these EI and TI determinants, we compare barrier perceptions among the different groups of SMEs. Table 5 provides the descriptive statistics of the barriers; the perceived barrier estimation is given in Table 6.

Table 5. Descriptive statistics of barriers

Outcomes	EI Firms, Means (SD)	TI Firms, Means (SD)	NI Firms, Means (SD)
Barriers' intensity	19.894 (9.628)	17.417 (10.225)	14.302 (10.395)
Barriers' number	7.099 (3.032)	6.451 (3.319)	5.497 (3.506)
Knowledge barriers' intensity	8.873 (4.639)	7.688 (4.651)	6.443 (4.483)
Knowledge barriers' number	3.204 (1.366)	2.938 (1.511)	2.523 (1.553)
Financial barriers' intensity	6.697 (4.241)	5.958 (4.455)	4.416 (4.454)
Financial barriers' number	2.324 (1.133)	2.125 (1.234)	1.738 (1.358)
Market-related barriers' intensity	4.324 (2.665)	3.771 (2.944)	3.443 (2.974)
Market-related barriers' number	1.570 (0.766)	1.389 (0.870)	1.235 (0.881)
Number of observations	142	144	149

We calculated the mean of each perceived barrier and compared the scores for EI, TI and NI SMEs. For example, the mean for barriers' intensity (ranging from 0 to 45) is 19.894 for EI SMEs which is higher than for TI and NI ones. T-tests, previously made, indicate that differences are statistically significant (except between TI and NI SMEs for market-related barriers' intensity).

Table 6. Comparison of the perceived barriers (ATET)

	Barriers' intensity	Barrier's number	Knowledge barriers' intensity	Knowledge barriers' number	Financial barriers' intensity	Financial barriers' number	Market-related barriers' intensity	Market-related barriers' number
EI vs. NI	4.686***	1.224***	2.094***	0.543***	1.930***	0.452***	0.662*	0.229**
	(1.497)	(0.469)	(0.683)	(0.208)	(0.659)	(0.173)	(0.403)	(0.114)
EI vs. TI	3.064*	1.164**	1.377*	0.562**	1.017ns	0.337*	0.670ns	0.264**
	(1.649)	(0.514)	(0.724)	(0.226)	(0.686)	(0.189)	(0.418)	(0.129)
TI vs. NI	2.287*	0.556ns	0.921ns	0.275ns	1.290**	0.244ns	0.076ns	0.037ns
	(1.286)	(0.420)	(0.580)	(0.186)	(0.604)	(0.161)	(0.369)	(0.108)

the standard deviations, in brackets, are robust.
***Significant at 1%. **Significant at 5%. *Significant at 10%. ns: non-significant.

Environmentally innovative, technologically innovative, and non-innovative SMEs thus have different perceptions of barriers. Specifically, SMEs that have introduced EI perceive more barriers, with a stronger intensity, than the two other groups of SMEs (technologically innovative and non-innovative firms). Although their effect is significant, the barriers perceived as lesser by environmentally innovative SMEs are those related to the market. This result holds when we investigate perceived barriers in number and intensity too.

In particular, environmentally innovative SMEs perceive more barriers, more intensively, than non-innovative ones do. When comparing environmentally innovative SMEs with technologically innovative ones, the differences in perception are quite similar even though they are less pronounced. The only exceptions are the perception intensity of financial and market-related barriers, the effects of which are not significant. Taken together, these results provide strong support for H1, insofar as barriers are perceived as more numerous by environmentally innovative SMEs than by technologically innovative or non-innovating SMEs. In contrast, we find support for H2 for the aggregate results but only partially, because barriers are not all perceived more intensely by

environmentally innovative SMEs compared with the two other groups of SMEs. That is, environmentally innovative SMEs always perceive barriers more intensely than non-innovative SMEs, but not in comparison with technologically innovative SMEs.

Thus, the results reveal a double specificity of perceived barriers: between environmentally innovative SMEs and technologically innovative SMEs, and between environmentally innovative SMEs and non-innovative SMEs. Differences in the perceptions of environmentally innovative SMEs are a matter of intensity and number compared with those of non-innovative SMEs, but they differ mainly in number compared with technologically innovative SMEs. These results reflect a robust test of ATET estimates, which provide the net average perceptions of barriers by environmentally innovative SMEs compared with two control group SMEs (technologically innovative and non-innovative). With this original methodological approach, we effectively assess perceptions of barriers by environmentally innovative SMEs and their specificities.

DISCUSSION AND CONCLUSION

This study is the first, to the best of our knowledge, to test for perceptions of barriers to EI among SMEs, in line with Ghisetti et al.'s (2015) recent analysis of deterrent financial barriers for SMEs' EI activities. It provides several important results and contributions.

THEORETICAL IMPLICATIONS

First, with regard to perceived barriers, SMEs engaged in EI believe that they face more barriers than other SMEs (those that pursue "dirty" TIs and non-innovators). They also perceive those barriers as more intense than the other two groups of SMEs do. Only the intensities of financial and market-related barriers do not differ between environmentally innovative and technologically innovative SMEs. These results indicate a key distinction of environmentally innovative SMEs: because of the complexity of EI, they must deal with many more dimensions than technologically innovative SMEs. Our research is in line with previous results that show that size affects eco-innovation propensity, emphasizing the difficulties small- and medium-sized enterprises face with regard to the complexity of EIs and the investments needed to switch to greener technologies (Hemmelskamp, 1999).

Among these constraints, the number of financial barriers is critical for SMEs. In line with recent findings, we offer two explanations. On the one hand, without a consistent, predictable policy framework, uncertainties in eco-investment profitability might increase, with new financial risks (Ghisetti et al., 2015). On the other hand, systems failures (Foxon & Pearson, 2008), such as in infrastructure provision and investment, technological transition, lock-in, and restriction of financial credit for SMEs' EI, may contribute to affecting environmentally innovative SMEs' perceptions of financial burdens.

We also note that market barriers are less perceived than any other kind, perhaps because EI for SMEs is less market-driven than other innovations are (Horbach, 2008). However, they remain influential in number for environmentally innovative SMEs, compared with technologically innovative SMEs, which suggests a context of demand uncertainty. Despite predictions about "green" market growth, demand often remains uncertain, because customers are not willing to pay more for environmentally friendly products or services (Bianchi & Noci, 1998; Gabler, Butler & Adams, 2013; Rennings, 2000). Environmental features also are often not easily detectable by end users (De Marchi, 2012).

Moreover, market characteristics may facilitate or hinder the diffusion of EI (Calleja et al., 2004). Due to the complexity and systemic nature of EIs, market and technological uncertainties that characterize many environmental technologies may be perceived as important, because there are no widely accepted standards, in terms of either specific technological solutions or measures, to evaluate the environmental performance of products and processes (De Marchi, 2012). These aspects also explain our results linked to perceptions of knowledge-related barriers.

Second, environmentally innovative SMEs perceive knowledge barriers as more intense and more numerous than technologically innovative SMEs, possibly due to the higher level of complexity and novelty of the knowledge required to innovate (De Marchi, 2012; Petruzzelli, Dangelico, Rotolo, & Albino, 2011), but also because EI is more knowledge- and information-intensive (Horbach et al., 2013). EI often relies on knowledge and competences that are not core to firms (De Marchi, 2012; Marin et al., 2014). Environmental features also may require sophisticated technical knowledge, such that EI represents a technological frontier on which firms continue to lack experience (De Marchi, 2012) – especially SMEs. In such small firms, CEOs may lack knowledge and expertise about subjects related to EI. This problem is strengthened by the lack of suitable information (Walker, Redmond, Sheridan, Wang, & Goeft, 2008). Our results also align with Horbach et al.'s (2013) assertion that EI relies more on important external sources of knowledge than other innovations do. Firms engaged in collective actions (e.g., R&D cooperation and cluster membership) are more likely to introduce EI, possibly because they enjoy information and knowledge diffusion about the benefits of EI, as well as advice and assistance from partners or other cluster members.

Third, regarding the antecedents of EI, we confirm the effect of regulation, in that firms in polluting sectors tend to introduce more EIs. Beyond these regulatory aspects, firms that have the highest probability of introducing EIs are those that are the most mature in their environmental strategy. Three major antecedents relate to firms' strategies: belonging to a cluster, R&D cooperation, and environmental monitoring. Although the logit estimation shows that EIs are driven by firms' strategic behavior, defensive motives (e.g., decreasing costs and risks or complying with regulation) emerge as being as important motives such as stimulating growth. For example, practices and tools designed to reduce environmental costs favor EI. Similarly, SMEs operating in polluting sectors are more likely to introduce EI. These two results in turn suggest that coercive and mimetic pressures (DiMaggio & Powell, 1983) are crucial levers of SMEs' EI adoption. Regulations represent a significant coercive pressure, and regulatory efforts are effective for guiding green behaviors. These findings also support Porter's (2000) hypothesis, initially developed for large firms, both theoretically and in successive empirical studies with SMEs. Suitable regulation even favors SMEs' EI and may compensate for the related costs (Porter & van der Linde, 1995), through enhanced innovation activities that accord with firms' strategies. Our results thus reaffirm Porter's dynamic vision of the link between public policy, strategic behavior, and innovation.

As in any study, our findings are subject to several caveats. We did not separate product and process EIs, so further research should delineate whether barriers differ with changes in the type of EI (process/product) or its beneficiary (firm/client). Nor did we distinguish incremental from radical innovations; incremental innovation is much less resource- and competency-demanding than radical innovation is, which destroys previous products and skills[11]. It would be interesting to compare our results with findings obtained from a sample of large firms. Market barriers, for example, could have more substantial influences on large firms. Further research could consider the impact of the managers' profiles too, which tend to determine SMEs' strategies. Finally, interactional effects

11. We thank an anonymous reviewer for this remark.

among different categories of barriers could be studied to determine if barriers are interrelated (Ashford, 1993). Such extensions are critical, because of the importance of EI for the sustainable growth of both economies and societies. In the meantime, our study provides interesting insights that may help managers and policy makers.

MANAGERIAL IMPLICATIONS

All SMEs should have strategic goals to facilitate their adoption of EI. Our study reveals that perceptions are as important as objective barriers. Because these perceptions are linked to the experience of the manager, managers must acknowledge the importance of networks and open innovation for SMEs (Chesbrough, 2003; Horbach et al., 2013; Lichtenthaler & Lichtenthaler, 2009). To decrease their perceptions of the number and intensity of barriers to this type of innovation, SMEs should engage in collective actions. By joining a cluster, SMEs enter an innovative environment, which may favor EI (Cainelli et al., 2012). Small firms already face informational and knowledge asymmetries, leaving them under-informed about public subsidies and EI strategies. Public subsidies are also unequally distributed, such that they tend to benefit firms with either very minimal or very intense innovation activities (Blanes & Busom, 2004). Horbach et al. (2013) demonstrate that eco-innovation activities require more information and knowledge than non-environmental innovation. Public bodies should take initiatives to inform non-innovative firms about the opportunities and subsidies associated with EI, to encourage greater adoption.

PUBLIC POLICY IMPLICATIONS

In gathering SMEs' perceptions, we reveal that managers must perceive viable strategic opportunities before they will engage in EI, because overall, SMEs lack knowledge about environmental and sustainability issues and about the specific practices that they could implement. They also lack understanding of environmental problems and risks and about the potential benefits of environmental improvements (Walker et al., 2008). They do not have expertise or knowledge about environmental issues, as confirmed by our results pertaining to the overall perceptions of more numerous and more intense barriers, especially in terms of knowledge. Finally, they see environmental responsibility as too costly (Walker et al., 2008), so financial barriers are deterrents to EI (Ghisetti et al., 2015). Thus, public policies have important roles to play: they must raise firms' awareness, provide necessary information (Porter & van der Linde, 1995), and reduce uncertainties. Such policies should be oriented toward changing perceptions instead of just providing incentives, tools, or instruments. Efforts to support EI might involve information diffusion, technology transfer, or public-private partnerships, because such undertakings can reduce the presence of perceived barriers.

At a more local level, the crucial role of collective engagement, which enables firms to benefit from knowledge externalities, suggests that French competitiveness clusters can effectively support EI. Clusters are not only privileged sites for information diffusion but also places to organize and manage knowledge (Bocquet & Mothe, 2010). The traits that define SMEs suggest that they are not intrinsically aware. They need strong incentives and dedicated support to engage in EI, especially because the market incentives are not as powerful for them.

By supporting the cluster policy, our research demonstrates that public policies should focus less on financial help, subsidies, or concrete and objective measures, and more on shaping and modeling SME CEOs' perceptions of their environment and the potential benefits of EIs. In clusters, they might rely on

experience sharing; entrepreneurial perceptions partly originate from entrepreneurs' experiences in specific business settings, as defined by the industry (Kor et al., 2007). Because of SMEs' importance in the European industry, such an approach could foster macroeconomic sustainable development by emphasizing ecological and environmentally friendly innovations.

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APPENDIX A. DISTRIBUTION BY SECTOR AND SIZE OF 435 RHÔNE-ALPES FIRMS (BALANCED DATABASE)

	Parent population (%)	Balanced sample (%)
Firm size		
10-49 employees	83.79	82.30
50-249 employees	16.21	17.70
Total	100	100
Industry		
Manufacturing	22.25	45.29
Services	77.75	54.71
Total	100	100

APPENDIX B. DESCRIPTIVE STATISTICS OF VARIABLES USED IN THE MULTINOMIAL LOGIT

Variables	Firms with EI, Means and (SD)	Firms with TI, Means and (SD)	Firm with NI, Means and (SD)
Polluting sector	0.246 (0.432)	0.208 (0.408)	0.107 (0.311)
Environmental monitoring	0.211 (0.410)	0.104 (0.307)	0.101 (0.302)
External growth	0.183 (0.388)	0.347 (0.478)	0.215 (0.412)
Cluster	0.190 (0.394)	0.146 (0.354)	0.027 (0.162)
R&D cooperation	0.401 (0.492)	0.375 (0.486)	0.262 (0.441)
Firm size	3.395 (0.769)	3.454 (0.861)	3.126 (0.677)
Firm age	2.888 (0.902)	2.646 (0.868)	2.847 (0.923)
Export	0.472 (0.501)	0.507 (0.502)	0.268 (0.445)
Group	0.042 (0.202)	0.063 (0.243)	0.060 (0.239)
Debt ratio	0.516 (0.993)	0.412 (0.789)	0.488 (1.377)
Services	0.352 (0.479)	0.444 (0.499)	0.456 (0.500)
Number of observations	142	144	149

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