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Virgile CHASSAGNON et Naciba HANED

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ESDES - Université catholique de Lyon
23, rue Carnot
69286 Lyon Cedex 02

Tél : 04.72.32.58.96
Fax : 04.72.32.51.58
www.esdes-recherche.net
esdes.recherche@univ-catholyon.fr

ENVIRONMENTAL INNOVATION AND TECHNOLOGICAL LEADERSHIP: A FIRM-LEVEL EMPIRICAL ANALYSIS

Virgile CHASSAGNON (Director of Research and Associate Professor in Economics, Esdes school of management, catholic university of Lyon)

Naciba HANED (Associate Professor in Economics, Esdes school of management, catholic university of Lyon)

Abstract. Environmental and climate change concerns have come to be ranked very highly on the competitive, political and socio-technical agendas of market economies over the last two decades, as demonstrated by the 2009 Copenhagen summit. This context appears to be an opportunity to reconcile economic imperatives and ethico-ecological requirements. This paper seeks to contribute to the green building debate in economics and innovation management by focusing on environmental innovation and innovation leadership–the latter is the dynamic capability of an innovative firm to seize new innovation opportunities as a result of a proactive investment policy and enhanced innovativeness. The paper defends the thesis according to which firms that are consistently “innovation leaders” are those that encourage environmental innovations in both integrated technologies and end-of-pipe technologies. We use French CIS Surveys and employ a binary probit model using a sample of 1180 firms to study which different forms of innovation leadership increase the propensity to develop environmental innovations. We find a strong impact of innovation leadership that is measured in a novel way, using innovation persistence, with a greater effect on cleaner production technologies.

Keywords. French CIS surveys, environmental innovation, innovation leadership, innovation persistence, end-of-pipe technology, cleaner integrated technology innovations

1. Introduction

The year 1972 is notable for economists due to the famous work by Meadows et al., who raised the question of the limits and the (un)sustainability of growth regarding the intensive use of energy in industrial activities. This issue has also cast doubt on the use of strictly market measures and shed light on regulatory imperatives (see, e.g., Dosi and Grazzi, 2006). Environmental and climate change concerns have thus come to be ranked highly on the competitive, political and socio-technical agendas of market economies over the last two decades, as demonstrated by the 2009 Copenhagen summit. This context appears to be an opportunity to reconcile economic imperatives and ethico-ecological requirements.

Porter (1991) explains that environmental regulation could constitute a competitive advantage between countries (see also Jaffe and Palmer, 1997). In a 1995 seminal paper, Porter and van der Linde wrote: “companies must start to recognize the environment as a competitive opportunity – not as an annoying cost or a postponable threat” (ibid., p. 115). Their argument is consistent with the notion that environmental regulation and competiveness can be positively related. From this perspective, regulation and environmental concerns in a way induce innovation. These innovations are often specific to an institutional and industrial context (and thus to a category of countries) and appear to be profitable in response to specific regulations (see, e.g., Rennings, 2000; Rennings and Beise, 2003). Such practices contribute to a new regime of growth sometimes called a “sustainable socio-technical regime” (see Debref, 2012).

However, regulatory imperatives imply a clear definition of what is or can be an environmental innovation (also later called an eco-innovation). There are a number of complementary definitions in the literature. In the spirit of Kemp and Arundel (1998), Rennings (2000) and Rennings and Zwick (2002), environmental innovations can be defined as new or modified processes, systems, techniques or products that aim to reduce or eliminate environmental harms. Environmental innovations must be analyzed in the context of the current environment where new models of firm performance are evaluated on the basis of green performance and global ecological preservation. Nevertheless, what are the characteristics of the firms implementing environmental innovations?

This paper seeks to contribute to the green building debate in economics and innovation management by focusing on environmental innovations and innovation leadership. This paper defends a thesis according to which firms that are consistently innovation leaders” are those that encourage environmental innovations in both integrated (later called “cleaner”) and end-of-pipe technologies. Here, we define innovation leadership as the dynamic capability of an innovative firm to seize new innovation opportunities due to a proactive investment policy and enhanced innovativeness. For Tuominen et al. (2004, p. 497), “innovativeness refers to an organization’s capacity to innovate”.

Innovation leadership can explain why certain firms can more easily simultaneously enhance industrial and environmental performance. They are able to respond to the evolution of the competitive environment by seizing new innovation opportunities. This joint objective currently seems to be crucial for success in a strong selection environment. We use French CIS Surveys and employ a binary probit model to determine which different forms of innovation leadership increase the propensity to develop environmental innovations.

The paper intends to discuss the potential contribution of innovation leadership to approach eco-innovations implementation and so the corporate environmental responsibility movement through the relationship between industrial performance and ethico-ecological concerns. The crucial question is whether the firms that are “innovation leaders” are those that implement environmental innovations. The paper is organized as follows: section 2 presents a theoretical background on environmental innovation and innovation leadership and describes the hypotheses we tested. Section 3 describes the data from the French CIS survey, the variables and the empirical method we employed to conduct our empirical study. Section 4 analyzes and discusses the results. Section 5 concludes the paper and sheds light on the limitations that could be addressed in future research.

2. Environmental innovation and innovation leadership: background and hypotheses

The recent development of eco-innovations should be seen as a means of achieving environmental sustainability in the economy as a whole (Rave, Goetzke and Larch, 2011). This is why the theoretical and empirical analysis of the determinants of environmental innovations has recently (since the end of the 1990’s) become a research subject. This section provides a brief overview of the main theoretical arguments on environmental innovation and innovation leadership with the aim of clearly deriving the empirically testable hypotheses we selected in our study on the impact of innovation leadership on the firms’ capacity to implement environmental innovations.

2.1. Environmental innovation: definition and theoretical insights

Environmental innovation is a fuzzy concept because the absolute environmental impacts of products are very difficult to measure. It is commonly accepted that environmental innovations are alternative technologies. In this sense, studies made by OECD apply the definition of innovations provided in the latest version of the OSLO manual to eco-innovations and include two additional characteristics. The first considers products, process innovations and other forms of non-technological innovation that have reduced environmental impacts–even if such an effect was not intended. The second includes changes related to social and institutional structures. This means that the environmental benefits of a given innovation can generate changes in the societal context through changes in social norms, cultural values and institutional structures.

This definition therefore goes far beyond the conventional organizational boundaries of the innovator because it also captures the environmental benefits of goods: “the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)” (OECD report on eco-innovations, 2009). The OECD aligns its definition with what is suggested in the 2010 MEI report: “eco-innovation is innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle” (See Kemp, 2011).

A crucial point concerning environmental innovation relates to the externality issue. Indeed, this specific type of innovation aims to introduce new processes or products reducing (globally) or avoiding environmental harms, as the academic literature has explained (see *supra*). In this view, environmental innovation is, to a certain degree, similar to a (global) public good. Because they produce positive spillovers both in the innovation and the diffusion phases, eco-innovations imply “double externality problems” (Rennings, 2000) that could lead to a reduction in the incentives of firms to invest in environmental innovations. However, owing to the existence of regulation, such innovations also share, to a certain extent, the characteristics of a private good in the sense that firms often have to pay for environmental harms (see Porter and van der Linde, 1995).

Interestingly, what seems clear is that this global regulatory perspective can also be seen as an opportunity for firms to gain a competitive first mover advantage. In other words, it is possible to argue for a positive relationship between environmental regulations and firms' competitiveness (Frondel et al., 2007). The issue that the different definitions proposed (see Oltra, 2008 for an exhaustive survey) raise regards what precisely leads a firm to have the incentives to produce environmentally friendly products.

The question of the determinants of environmental innovations has been discussed for a decade (see, e.g., Brunnermeier and Cohen, 2003 for an analysis based on environmental patents). According to Reenings (2000), regulatory incentives constitute a major factor behind the production of what we have defined as environmental innovations. Additionally, several theoretical and empirical studies have emphasized the role of regulatory or policy stringency on firm incentives to produce environmental innovations. The literature often purports that innovation behavior is correlated with the stringency of environmental policy (see, e.g., Frondel et al., 2008).

The objective of this type of innovation is hence twofold: it becomes a way for firms to overcome environmental pressures and adapt to a more competitive environment (see Frondel et al., 2007 for a specific survey on the perceptions of regulated firms). Interestingly, a set of studies have found a positive relationship between the costs related to regulatory and policy environmental stringency and environmental innovations as measured by patents (Brunnermeier and Cohen, 2003; Lanjouw and Mody, 1996), in particular, end-of-pipe technologies driven by costs savings (Frondel et al., 2007). Environmental innovation has become critical in the creation and evolution of firms' competitive advantages. It appears to be a means for coping with strong competition. In this regard, Brunnermeieir and Cohen (2003) have empirically demonstrated that environmental innovation seems to be more likely to occur in competitive environments.

Nevertheless, environmental innovation does not only respond to regulatory requirements. Rennings (2000) linked eco-innovation to technology pushes, regulatory pushes and market pulls. Global demand considerations also have an impact on the development of new forms of ecological innovation. As Aversi et al. (1999) remind us, demand patterns are based on preferences shaped by "the cognitive structures of consumers and evolve in socially embedded fashions" (ibid., p. 353). In worldwide public opinion, climate change concerns have become critical and are increasingly included in consumption decisions (of both consumers and firms). All of these tendencies explain why firms have recently invested in environmental innovations; consumer pressure plays an increasingly crucial role in the firms' incentives to invest in eco-innovations (Florida, 1996; Popp et al., 2011). Based on French and German experience, Belin et al. (2009) have demonstrated that the regulatory push-pull advanced by Rennings (2000) and cost savings (market determinant) are highly relevant in triggering environmental innovations. On the supply side, it is hence important to remember that elements such as cost cutting devices (Frondel et al., 2007; Horbach, 2008; Belin et al., 2009) or the complementarity between organizational innovations and environmental innovations constitute real sources of incentives for innovative firms (Rehfeld et al., 2007).

Regarding the previous arguments, it appears that there is a large and heterogeneous set of innovations that could correspond to the definition that we employ. This is why the theoretical and empirical literature encourages the categorization of environmental innovations. Generally, there is specific differentiation among process innovators. Just as technological innovation is classified into product, process, and organizational innovations, so are eco-innovations. However, the principle categorization of these innovations is the differentiation among process innovations between "end-of-pipe" technologies and "cleaner production technologies (integrated technologies)" (Oltra, 2008, p. 6).

To analyze environmental innovations, it is important to distinguish between those that include pollution abatement—end-of-pipe innovation—and those that constitute new technologies that avoid or reduce environmental harms (see Lanjouw and Mody, 1996). In this regard, we refer to the work of Pavitt (1984), who argued that both market-pull and technology-push arguments could be invoked to explain why technological innovation can also be relevant for analyzing end-of-pipe and integrated technology eco-innovations. As Frondel et al. (2007) wrote, these factors are expected to be more critical for cleaner products and processes than for end-of-pipe technologies.

2.2. Innovation leadership and eco-innovation: the hypotheses

We have explained that the industrial and institutional context encourages the development of an alternative model of value creation based on what we can call "green leadership" that rests on a win-win strategy combining ecological preservation and firm performance. The question that should be raised at this point is what can explain the firms' investments and success in environmental innovations. We defend the thesis that innovation leadership–the notion that a firm acquires a dynamic capability based on specific investment programs and/or strong innovativeness that allow it to seize new innovation opportunities–leads firms to implement eco-innovations. This is what we will explain in this sub-section. We depart from the notion that the continuity of innovative activity depends on the incentives provided by new innovations and value creation opportunities. Thus environmental requirements constitute a strong innovation opportunity. In this context, firms' specific innovation capabilities are a successful means of seizing new opportunities (see van der Panne et al., 2003) and improving environmental performance (see Carillo-Hermosilla et al., 2010).

Studying the environmental behavior of different large multinational firms, Laperche and Lefebvre (2012) have explained that the implementation of environmental strategies goes hand in hand with the production of new knowledge and capabilities that raise new issues in economics and innovation management. In line with this conclusion, the relationship between eco-innovation and innovation leadership has not been the object of investigation by academic scholars. Some organizational authors have shown that individuals' (transformational) leadership influences creativity and innovation in the knowledge economy (see, e.g., Cummings and O'Connell, 1978; Walumbwa, Christensen and Hailey, 2011; Gumusluoglu and Ilsev, 2009). Other works have explained that leadership considerations are crucial for firm performance (Smith, Carson and Alexander, 1984) and are lacking in the organizational economics literature (see Witt, 1998; Foss, 2001).

However, there are no studies in the economics and management literature on the role of what we call innovation leadership (analyzed at a firm level) and the implementation of new innovation opportunities. In a similar, recent work, Fontana and Nesta (2009) explained that technological leadership can explain firms' survival. More recently, Fontana and Moriniello (2011) have shown that there is a positive relationship between technological leadership and persistence in product innovation. Moreover, in the same way that industrial leadership must be linked to innovation dynamics (see Robertson and Langlois, 1995), environmental innovations must not be isolated from innovation leadership considerations, because the most innovative firms develop a "sustainable integrated innovation strategy" (Glazer, 2007, p. 120) that creates a "culture of innovation" (ibid.), allowing them to seize new innovation opportunities that could be incremental, radical or rather different in nature.

Underlying this notion is an argument that a firm's technological and organizational innovation leadership could help it to become a leader in another innovation sector. In a 1996 paper, Florida sheds light on the link between manufacturing process innovations and environmentally conscious manufacturing strategies. Innovation leadership is a key driver of environmental manufacturing strategy, particularly because it allows, in the spirit of March (1991), for the exploitation of innovations and the ability to engage in innovation exploration.

Florida (1996), using a cluster analysis, finds that there is a class of firms that are able both to implement technological and organizational innovations and to produce environmental innovations. In terms of innovation leadership, technological innovation is also a key factor in improving the environmental performance of firms. It can be a way to succeed in acquiring new market segments. From a similar perspective, Rennings and Beise (2003) have explained that environmental regulations have created "lead markets". Innovation leadership could be understood as a means of creating lead markets, particularly in countries where there are national environmental regulations.

Horbach (2008) has shown that there is a positive relationship between technological R&D capabilities and what he calls "knowledge capital" and environmental damage. This argument confirms the famous hypothesis that innovation breeds innovation. As Horbach notes, "to be innovative in the past increases the probability for the realization of present or future innovations" (ibid., p. 170). Such a conclusion is in line with the notion that innovative firms that occupy a position of "innovation leadership" can more easily benefit from first movers advantages and higher future profits when new sources of innovation such as eco-innovations appear.

The question of innovation persistency has recently become very important in the literature (see, e.g., Cefis and Orsenigo, 2001; Geroski et al., 1997; Roper and Hewitt-Dundas, 2008; Metcalf, 2011) and can be linked to the issue of innovation leadership. These works are interested in explaining the length and sustainability of innovative periods. In this regard, Fontana and Moriniello (2011) have explained that technological leaders are systematically more persistent innovators than laggards. Thus we believe that innovation leaders that have persistent innovation behavior have a greater capacity to introduce any type of environmental innovation

H1. Firms that have the capacity to persistently introduce (product or process) innovations in the market are more likely to introduce any type of environmental innovation.

On the one hand, the theoretical literature describes a successful innovation as the introduction of a technological advance that leads to profit generation. Moreover, it suggests that innovative firms benefit from increasing returns in innovation (Nelson and Winter, 1982) that provide successful innovators with locked-in effects advantages over other firms in the long term. These firms take advantage of the knowledge that has been mobilized to produce past innovations to develop current innovations (Duguet and Manjon, 2002). Other works suggest the existence of a positive relationship between R&D expenditures and innovative activity. According to this view, innovation is persistent because of the continuity of R&D investments (Cohen and Klepper, 1996). Engaging in R&D involves some irretrievable costs (the acquisition of specific assets, hiring or training a specialized workforce, etc.), which are expenditures that few firms can afford. Therefore, these investments may prevent firms that do not engage in R&D to enter certain markets. By contrast, firms that can support these types of investments continuously, meaning those that can afford the sunk costs of R&D, are those that can innovate persistently. Additionally, firms that can afford R&D investments continuously are those that can innovate persistently (Sutton, 1991). Scherer (1965) has explained there are increasing returns to R&D that consolidate a firm's innovation leadership.

H2. Firms with higher and continuous R&D efforts are prone to introduce any type of environmental innovation.

In contrast to some economic arguments suggesting that firms with high market power have no incentive to continuously engage in innovation, we believe that market shares accruing due to successful innovations contribute to the innovation leadership of firms (from a dynamic point of view). The commercial success of an innovation increases the incentive to innovate because of the monopoly power it provides to firms. The monopoly rents associated with an innovation reduce the risk of failure of innovation projects linked to rivals. Additionally, monopoly rents provide firms with additional resources with which to fund innovation projects. A large number of the empirical studies based on CIS data show that innovation performance measured by the amount of sales due to innovations has a positive impact on the propensity to innovate in the long run (Raymond et al., 2010; Peters, 2008) because of the feedback effects they have.

H3. Innovation leaders that have higher and persistent market shares due to successful innovations have a greater capacity to introduce any type of environmental innovation.

Innovation capabilities seem to be decisive determinants of firm capacity to implement both integrated and end-of-pipe environmental innovations. Arguably, integrated technology environmental innovations are less connected with regulations than end-of-pipe environmental innovations, which often correspond with ecological requirements and regulatory policy. Conversely, market forces constitute a real motivation for cleaner production innovations. Frondel et al. (2007) have shown that an increasing number of firms invest in cleaner production technologies (here also called integrated technology) rather than in end-of-pipe technology, although some differences between OECD countries remain as a function of past policy choices. However, we can observe a gap in the literature on empirical innovation research concerning a comparison between end-of-pipe and integrated technologies. Thanks to French CIS surveys, we have the opportunity to fill this gap. We want to examine the positive relationship between innovation leadership and eco-innovative firms by using and respecting this crucial distinction to which we add environmental procedures (such as audits) and certification. The latter can be considered innovations in the sense that their introduction constitutes an innovation for the firm concerned. We thus believe that cleaner production technologies require a great deal of additional reorganization than end of pipe technologies or certification.

H4. Firms that have a greater capacity to be innovation leaders (regarding the previous arguments) are more prone to introduce cleaner production technologies.

In line with the Schumpeterian view of innovation dynamics, we expect that the incentive to innovate should increase, along with R&D investments, when the company is larger. Larger firms may have more funds available to be dedicated to innovation compared to smaller ones. This is because large firms have easier access to financial resources or more generally to capital markets. This means that these firms will tend to produce more significant volumes of all types of innovations because their size increases the stability of their internal funding. Additionally, there may be economies of scale for firms that are endowed with high levels of R&D activity. Scherer (1965) underlined that innovation and technological opportunities depend on firm size, and empirical studies often find a positive relationship between firm size and a firm’s ability to seize new innovation opportunities (see, e.g., Becheikh et al., 2006). This is why this argument remains valid at the environmental innovation level.

H5. The size of the firm has a positive influence on the introduction of environmental innovations in the market

3. Data and descriptive statistics

3.1. Data collection

This study draws upon the merger of the three successive waves of French Community innovation surveys (CIS) beginning with CIS4 (2002-2004) for statistical consistency. More precisely, this study draws upon CIS4 (2002-2004), CIS6 (2004-2006) and CIS8 (2006-2008), provided by the French Institute of Statistics (Institut National de la Statistique et des Études Économiques, INSEE) and collected by the Industrial Studies and Statistics Office (Service des Etudes et des Statistiques Industrielles, SESSI).

As CIS combine methods of census and stratified sampling for each wave, we only retained firms that responded to the three last waves in our data set by excluding firms that entered or exited midway through 2002-2008. As a result, we obtained a balanced panel of 1180 manufacturing firms (each identified as a legal unit) with 20 or more employees[1]. For each period covered by the surveys[2] that we merged, we could gather information on innovation products and processes that were placed on the market over the three years prior to the year the survey was conducted. In the last wave of CIS, questions were added on the use of eco-innovations by French firms, which we exploited to measure the intensity of environmental innovations for our study. We restrict our analysis to the sample that resulted from the merger.

The description of the balanced data set for the year 2006, provided by table 1, shows that the panel is mainly composed of firms that operate in sectors such as food, rubber and plastic products and metals (respectively, 16%, 12% and 11%). These firms operate in areas that can be considered to have low or medium-low technological intensity; the sample includes high and medium high-technology firms (representing approximately 40% of the total sample) operating in sectors such as electronics, instruments and chemicals. The size distribution of our sample shows that it contains small and medium-sized firms (approximately 18% of the total sample), but large firms with more than 250 employees are more numerous (82% of the total sample).

INSERT TABLE 1 ABOUT HERE

[1] For instance, we could identify the same questions as far as environmental, product, process, and non-technological innovations were concerned, which was not the case for CIS prior to the year 2005.

[2] The data set covers three consecutive periods: the information provided on innovations is available for the periods 2002-2004; 2004-2006 and finally 2006-2008.

3.2. Description of the variables

3.2.1. Dependent variables: environmental innovations

To distinguish between the different aspects of the environmental innovations used by the firms in our sample, we have collected information on innovation in CIS2008 that enables us to construct three different endogenous variables (see table 2 for a detailed description of the variables used in the model) accounting for environmental innovation practices between 2006 and 2008 (that is considered the present period, t). Consequently, we intend to test the three following models estimating the probability that a firm will introduce each of the environmental innovations as a function of its ability to be an innovation leader:[3]

In model 1, we use the dependent variable **ECP** that equals 1 if firms have used any environmental innovations that are considered cleaner production technologies. In CIS2008, there are six items to identify this type of environmental innovation that measure whether the firm has reduced its material or energy footprint, or has more generally reduced air pollution and waste in its production process.

In model 2, we use a different dependent variable, **EOP,** that equals 1 if the firm uses end-of-pipe technologies. In the CIS2008 survey, the three items that measure this type of environmental innovation reduce unsafe substances in the after-sales use of a good or service by the end user.

In model 3, we use the dependent variable **ENVID** that equals 1 if the firm has implemented procedures to regularly identify and reduce its environmental impacts, for instance, if it has used environmental audits or other certification procedures.

The descriptive statistics on these variables show that cleaner production technologies are the most common in the sample (see table 3: approximately 68%). This aspect is in line with European statistics that show that these types of environmental innovations are more common in European firms, which is rather logical. In the long term, cleaner technologies are more advantageous because they can be resource and production efficient (OECD report, 2009a). Regarding end-of pipe technologies, they are less common for French firms between 2006 and 2008 (47% of the total sample), but more firms have engaged in an environmental certification procedure (59%).

[3] We also use another variable that expresses the intensity of environmental innovation practices. We display these results in appendix N°B.

3.2.2. Explanatory variables

3.2.2.1. Innovation leadership

The main aim of our study is to focus on the effect of "innovation leadership" on a firm's capacity to produce innovations with environmental benefits. The measures of innovation leadership, hence, must be translated into a measure of long-term innovation performance because products that appear to be differentiated in the market are based on core technologies generated from previous innovation efforts. Innovation leaders should then have strategies based on the search for core technologies and the innovation procedures surrounding them. We wish to acknowledge several dimensions of innovation leadership; this is why we use three alternative measures:

- the first accounts for innovation persistence throughout the three waves of CIS (**$PERSINO_t$**), the second for the continuity of R&D expenses (**lRD_{t-1}**, **lRD_{t-2}**) and the third is the increase in sales due to innovation goods or services (**$INOSALF_{t-1}$** and **$INOSALF_{t-1}$**). Although these variables measure innovation capacity, they do not reflect the same type of innovation effort.

Therefore, for the first measure of innovation leadership, we include a binary variable, **$PERSINO_t$**, that equals 1 if the firm was a product or process innovator in at least the three studied periods consecutively. The probability of the success of future innovations should be higher for these firms because they benefit from dynamic increasing returns (Malerba et al., 1997).

The second alternative variable of innovation leadership is measured with two lagged measures of R&D intensity. We use the logarithm of total R&D expenses, **lRD**. R&D is the most established measure used by several empirical studies to explore the sources of innovation (Mairesse and Mohnen, 2010). The measure of R&D available in CIS provides total firm R&D expenditures. It comprises in-house and contracted R&D. The first amount (in-house R&D) includes formal expenditures on R&D activities inside laboratories within the firm, whereas contracted R&D is provided by external organizations that are not affiliated with the enterprise. Both of these sources of innovation are seen by firms as an investment to gain market share or more generally to be more productive. We include two lags for this variable, the first for the year 2006 and the second for the year 2004 (respectively **lRD_{t-1}** and **lRD_{t-2}**).

The third alternative measure of innovation leadership is measured using the proportion of sales caused by the commercialization of new products, **lINOSALF**. This variable is measured with the log transformed value of the amount of sales due to innovations new to the firm, in thousands of Euros.[4] This proxy is used in lieu of the available ratio "innovative sales" in CIS to avoid extreme values (for instance, small firms that dedicate essentially all of their turnover to innovative products).[5] We include two lags of this variable in our models that account for innovation performance for the years 2006 and 2004 (respectively **INOSALF$_{t-1}$** and **INOSALF$_{t-1}$)**. It expresses innovation performance, as well as the commercial success of goods and services that are new to the firm.

The descriptive statistics on these variables show that persistent firms constitute more than half of the sample (see table 3, approximately 59%) and that the two lags of the other variables (R&D and the share of innovation products in the turnover) are approximately the same from one period to another.

3.2.2.2. Other explanatory variables: non-technological innovations and firm characteristics

The other explanatory variables estimate the impact of non-technological innovations and firm characteristics on eco-innovations.

It is important to consider not only innovation capacity but also the impact of organizational innovations and marketing innovations on the production of environmental innovations that are increasingly included in empirical works. The management literature shows that the combination of several innovation modes in a single innovation process helps to transform goods or services into successful new goods and services for the market. This demonstrates that technological innovations and new organizational changes are complementary because they produce higher returns and performance (Cozzarin and Percival, 2006).

We account for organizational innovations with the binary variable **Inorg**, which equals 1 if the firm has implemented at least one new organizational method in its business practices between 2006 and 2008 (including knowledge management, workplace organization or external relations that have not been previously used). This variable is particularly important because the training and educational programs that are pursued by firms who commit to environmentally responsible practices are necessary in the long run (Arundel et al., 2007).

[4] In alternative estimations, we examine innovative sales under even stronger conditions: we define a variable that measures innovative sales that are new to the market. Cf. the results in the appendix.

[5] To arrive at this, we have multiplied the proportion of the share of new products (goods or services) new to the market in the turnover (which is initially an ordered value, based on a ten-point scale) by the amount of the turnover in the same year. Then, we normalize the result by adding 1 to the final value before we transform it with a logarithmic function.

The second binary variable **Mkt** accounts for marketing innovations. It equals 1 if the firm has implemented new marketing concepts or strategies that differ significantly from the enterprise's existing marketing methods and have not been used before. This variable is also considered as a market pull indicator because it measures the impacts of customers' preferences in the process of environmental innovation (Horbach et al., 2011).

Finally, we include other variables that account for ownership structure, size and activity. Empirical studies demonstrate the importance of market power and firm size for the absorptive capacity of firms (Cohen, 1995; Cohen and Levinthal, 1990). In line with the Schumpeterian view of innovation dynamics, we expect that the incentive to innovate should increase, along with R&D investments, when the company is larger. Larger firms may have more funds available to dedicate to innovation than smaller ones. This is because large firms have easier access to financial resources or more generally to capital markets. This means that these firms will tend to produce more significant volumes of all types of innovations because their size increases the stability of their internal funds. Additionally, there may be economies of scale for firms that are endowed with high levels of R&D activity.

To measure these features, we first use the logarithmic transformation of the total size of the firm in 2006 ($\mathbf{lsize_{t-1}}$). We also use the binary variable **GP** to account for the ownership structure of the firm in the present period. This binary variable takes the value of 1 if the firm is part of a group. The firm's ownership structure may have an impact on the incentive to conduct innovation activities. Firms that are part of a group may have easier access to external capital to finance innovation activities.

The last group of variables includes a set of three dummies related to the technological intensity of a firm's activities according to the NACE[6] classification. We use **DLT** as a reference variable that equals 1 if the firm has a low-technological activity, which includes food, textiles wood, paper, furniture, printing and the reproduction of recorded media. We differentiate three sets of binary variables: **DHT** for firms that engage in high-technological activities, **DMHT** for medium-high technological activities and **DML** for medium-low technological activities.

The descriptive statistics in table 3 show that in the final sample, marketing innovators were less numerous than firms that introduced organizational innovations between 2006 and 2008 (Respectively 38% and 62%). Additionally, medium and large firms and firms that are

[6] NACE is the "statistical classification of economic activities in the European Community" used uniformly within all the member states. We have classified manufacturing industries according to their global technological intensity using the eurostat classification.

part of a group are more numerous (84% and 62%, respectively). These firms engage in activities that are largely classified as low and medium-low technologies (57%).

INSERT TABLE 2 ABOUT HERE

3.3. The empirical model

We use a simple probit model to determine the probability that a firm introduces one of the three types of environmental innovations that we described in the previous section. First, we wish to determine whether the overall model fits our data and then determine the impact of innovation leadership on several environmental innovation practices.

The objective is to test a firm's probability of introducing environmental innovations in period t as a function of its capacity to be an innovation leader, non-technological innovation achievements and firm characteristics. As the dependent variables are binary, the evaluation of our models can be obtained with a binary probit regression.

First, model 1 estimates the probability that firm i introduces a cleaner production technology environmental innovation in the present period as a latent function of the innovation leadership variables and firm characteristics:

$$ECP_{i,t} = \begin{cases} 1 & \text{if} \quad p_i = \Phi\,(A_i\ \alpha) \\ 0 & \text{if} \quad 1 - p_i = 1 - \Phi\,(A_i\ \alpha) \end{cases} \quad (1)$$

where Φ ($ECP_{i,t}$=1) is the probability of introducing cleaner production technologies at time t. The parameter A_i includes a set of alternative explanatory variables that account for innovation leadership and dummy variables that control for firm characteristics.

Second, model 2 determines the probability that firm i introduces an end-of-pipe environmental innovation as a latent function of the innovation leadership variables and firm characteristics:

$$EOP_{i,t} = \begin{cases} 1 & \text{if} \quad p_i = \Phi\,(A_i\ \alpha) \\ 0 & \text{if} \quad 1 - p_i = 1 - \Phi\,(A_i\ \alpha) \end{cases} \quad (2)$$

where Φ ($EOP_{i,t}$=1) is the probability of introducing end-of-pipe technologies at time t. The parameter A_i includes a set of alternative explanatory variables that account for innovation leadership and dummy variables that control for firm characteristics.

Third, model 3 tests the probability that firm i implements environmental certifications as a latent function of innovation leadership variables and firm characteristics:

$$ENVIDP_{i,t} = \begin{cases} 1 & \text{if} \quad p_i = \Phi(A_i\ \alpha) \\ 0 & \text{if} \quad 1 - p_i = 1 - \Phi(A_i\ \alpha) \end{cases} \quad (3)$$

where Φ ($ENVID_{i,t}$=1) is the probability of implementing any certification procedure at time t. The parameter A_i includes a set of alternative explanatory variables that account for innovation leadership and dummy variables that control for firm characteristics.

4. Results and discussion

Robustness checks of the results demonstrate that the estimations are satisfactory with respect to the assumptions of autocorrelation between variables and the specification. None of the models exhibit inflation in the coefficients while testing for autocorrelated errors (Durbin Watson test) and colinearity (full rank estimation matrix hypothesis). However, even the percent concordant prediction shows that the number of predicted cases is higher for model 1 (between 31% and 34%) than for models 2 and 3 (approximately 20%). The results demonstrate that the overall model is significant at the 1 % level according to the model chi-square statistics for all models. The Hosmer-Lemeshow procedure tests the null hypothesis that the explanatory variables do not fill the model. In this case, there is no difference between the observed and predicted values. In our models, the test is not significant in all cases.

Regarding the results, we have tested the three models presented in the previous section. The goal of this study is to link several types of environmental innovation practices and innovation leadership. In general, the results of our estimations reveal that all of the variables that measure innovation leadership have a positive and significant effect on all of the types of environmental innovations in the present period, which is line with hypotheses that we have formulated in section 2. However, there are some differences between the three models with respect to the values of the coefficients, the likelihoods and the coefficient values of other explanatory variables:

(1) The three sets of exogenous variables that we have used to measure innovation leadership have a positive but not consistently significant effect on the probability of producing eco-innovations (tables 4, 5 and 6):

- First, the variable **PERSINO** is strongly significant and positive in all of the models that we have tested, which is in line with hypothesis H1. This means that the firms that have the capacity to persistently produce innovations during the three periods that we study (in this case products or processes) are more likely to introduce environmental innovations than firms that innovate sporadically or those that are non-innovators. This result confirms the “success breeds success” hypothesis in the case of environmental innovations. Innovative firms benefiting from increasing returns to innovation (Nelson and Winter, 1982) provide successful innovators with locked-in effects advantages over other firms. The leadership of these firms comes from the advantage gained from knowledge that has been mobilized to produce past innovations when developing current innovations.

- Second, the results are less consistent for the two other variables measuring innovation leadership: the two lagged variables accounting for R&D expenses (**lRD_{t-1}**; **lRD_{t-2}**) and the amount of sales due to innovations new to the firm (measured with **$lINOSALF_{t-1}$; $lINOSALF_{t-2}$**). On the one hand, the coefficient is higher for t-1 than t-2, which means that investments are cumulative in the long run; hence, it is understandable to register a decrease in the coefficient in period t-2. On the other hand, the coefficients are higher and more significant for the 2 variables (**lRD** and **lINOSALF**) in model 1 (table 4).

INSERT TABLE 4 ABOUT HERE

These results suggest that firms that invest systematically in R&D are more likely to display higher rates of environmental innovations than sporadic or weak innovators display. These results are in line with other studies showing that permanent R&D and cooperation on R&D projects raise the incentive for firms to innovate (Horbach, 2008). Additionally, the firms that can afford R&D investments continuously are those that can innovate persistently (Sutton, 1991). This stream of the literature suggests that past innovations provide supplementary resources for current innovation activities. Additionally, firms that innovate continuously benefit from the accumulation of knowledge generated by these past innovations. Other findings also reveal a consistent relationship between the growth of sales and higher rates of innovation (Klomp and Van Leeuwen, 2001). Firms with more intense innovation activity in the long run enhance their ability to invest in innovation continuously, regardless of external market conditions (Geroski et al., 1997).

This first set of results demonstrates that there has been a significant positive environmental response on the part of French firms these past last years. The following point will allow us to examine the depth of these environmental innovations.

(2) The comparisons of models 1, 2 and 3 (using respectively **ECP**, **EOP** and **ENVID** as dependent variables) show that model 1 is more consistent and provides stronger and more

efficient coefficients. For instance, the Pseudo R2 is approximately 5 to 10 % higher for model 1 than in models 2 and 3. All of the coefficients of the exogenous variables measuring innovation leadership display higher results for model 1 that estimates the relationship between innovation leadership and the production of cleaner production technologies (table 1). This result is in line with hypothesis H4 that argues for the importance of innovation leadership for the implementation of cleaner production technologies. This means that these firms have made major changes to production procedures to acquire environmental innovations. In fact, they not only have to invest continuously—as innovation persistent firms would do from a classical perspective—but also profoundly and intensively reorganize their production structures. This implies not only the need to finance innovation projects, which is confirmed by the positive and significant coefficients of R&D and the commercial success of innovation, but also a profound reorganization of work and sales procedures. Similarly, we can shed light on the stronger effect of organizational innovations in this case that imply more important changes in the workplaces of these firms (knowledge management, training, etc.). Marketing innovations appear to have a strong effect on all of the types of environmental innovations, except for certification procedures.[7] These figures are quite similar to the description of proactive environmental strategies for which continuous improvement and antecedents in the improvement of organizational capabilities are necessary (Lee and Rhee, 2007).

INSERT TABLE 5 ABOUT HERE

INSERT TABLE 6 ABOUT HERE

(3) The effect of size seems to differ according to the type of environmental innovations we use as a dependent variable. It has a stronger and more significant effect on certification procedures; H5 is confirmed. These results are in line with the constraints large firms face: first, we know that these types of procedures are constrained by access to financial resources. This is the case for large firms with endowments that are dedicated to the expenses linked to the environmental strategy of the firm (Table 6). Second, firms with more than 500 employees

[7] There is a secondary result here that we can shed light on. It is the apparent difference between end-of- pipe environmental innovations and certification procedures. The results are different when we examine the variables measuring innovation leadership. When **PERSINO** and **lINOSALF** are used, the impact of innovation leadership is stronger on cleaner production technologies. However, it seems that R&D expenses have a greter impact in model 3, when certification procedures are involved. We can also see from table 6 that the coefficient of the variable **INORG** is also higher in model 3. We can assume that firms that go through certification procedures have to implement “detectable” changes to their organizations.

are required to communicate their social performance in an annual report, which could explain the lack of depth in environmental practices that must me "visible" overall and do not necessary drive important changes in these firms.

(4) The other explanatory variables include non-technological innovations and firm characteristics. The first set of variables is measured using two organizational innovations made by firms between 2006 and 2008 and marketing innovations that occurred during the same period of time. The coefficient of the variable **Inorg** is significant and has a positive effect on all the types of environmental innovations, but the coefficient is significantly higher in the case of cleaner production technologies. This result confirms our past statements according to which firms that produce these types of environmental innovations implement major changes (table 1). Additionally, **Inorg** has a higher coefficient in model 3 than in model 2 (table 5 and table 6). This means that firms that commit to certification procedures have less "superficial" environmental practices compared to firms that use end-of-pipe technologies. Regarding marketing innovations, we can see that **Mkt** has a positive and significant effect in models 1 and 2 but not in model 3, *i.e.,* for certification procedures. Additionally, in model 2, the coefficient of the variable accounting for marketing innovations is larger than the coefficient measuring organizational innovations, which confirms that end of pipe technologies are more market oriented environmental innovations.

The second set of variables includes ownership and control variables to account for the technological intensity of the firm activities in our sample. The variable **Gp** is only significant in model 3. It has a significant and positive effect on certification procedures. This result is in line with the fact that firms with easier access to financial resources or information regarding this type of procedure is more likely to engage in certification procedures.

Finally, we have run additional estimations (cf. appendix A and B), first by changing the nature of persistent innovators (appendix A) and of the type of the dependent variable (appendix B). In the first case we changed the variable measuring persistence. We have considered only firms that are complex innovators (simultaneously innovating in products and processes). The second variable is the share of that is innovation new to the market in terms of sales and includes major innovations. The results are robust to these constraints of our model. Moreover, the effect of size is more significant. This is in line with the characteristics of complex firms that develop the ability to be innovation persistent in both products and process and benefit in the long run form "the first mover's advantage". Considering the change in the dependent variable (appendix B), we have estimated the intensity of environmental innovations in a firm as a function of the same explanatory variables using an ordered probit.

We find that the probability of having proactive (more than one type of practice) environmental innovation behavior increases in innovation leadership and size.

5. Conclusion

The paper aimed to fill a gap in the literature by theoretically and empirically investigating the impact of innovation leadership on the implementation of environmental innovation. In this regard, the paper appears to be novel and completes the abundant recent literature on this subject. The results of our probit models show a strong impact of innovation leadership, measured using innovation persistency, with a higher effect on cleaner production technologies. From a broader perspective, innovation leadership seems to be a means of seizing new innovation opportunities in the knowledge economy. From a Marchian point of view, it also seems to be a means of preventing institutional and global demand changes by combining exploitation and exploration strategies.

The overall results that we have obtained suggest that innovation strategies tend to systematically include environmentally friendly practices with different depths. Therefore, this paper sheds light on the fact the debate should be focused not on the depth of practices but rather on the factors that conduct/drive firms to generate environmental innovations. There also might be another causality explaining the link that we have tested that opens the way for future researches. Environmental friendly practices, as they become more important in firms might be also important determinants for innovation leadership. Very different from the traditional “pull and push” drivers of innovations, environmental friendly products could constitute a new and important reason for firms to engage continuously in innovation projects.

A main limitation of this study is the nature of the data set. We did not use dynamic estimation techniques, because the sample lacks initial conditions. Actually, we included all the measures regarding innovation performances in t, t-1 and t-2; but information on the environmental benefits of innovations is available only in the present period (t). The first step of our research agenda will be to complete the data set thanks to the future CIS surveys to make our model dynamic. These results are a first empirical exploration of the environmental friendly practices French firms have conducted in the few past years. Before that, there have not been any empirical analyses linking environmental products and innovation practices for French firms. This is why the results of CIS surveys should be completed with data on the environmental strategy of firms: we will be able to consider these trends with the analysis of the results of an ongoing survey that we are conducting on French firms. This will be the next step of our research agenda

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TABLES

TABLE 1. DISTRIBUTION OF THE TOTAL SAMPLE BY SECTOR AND SIZE IN 2006

Branches	Nace 2digit level codes : Nace rev 1.1	No	%
Food	15	194	16,44
Rubber and plastic products and other non-metallic mineral products	25-26	144	12,20
Metals	27-28	128	10,85
Machinery and equipment	29	115	9,75
Wood, paper and furniture	20-21 and 36.1	93	7,88
Motor vehicles and transport equipment	34-35 (excluding 35.1 and 35.3)	92	7,80
Chemicals	24 (excluding 24.41 and 24.42)	89	7,54
Electrical machinery	31	63	5,34
Textiles	17-19	60	5,08
Pharmaceuticals	24.41-24.42	47	3,98
Medical, precision, and optical instruments, watches and clocks	33	39	3,31
Computers, office machinery and electronics-communication	30 and 32	34	2,88
Aerospace	35.3	26	2,20
Printing and reproduction of recorded media	22 (excluding 22.3)	24	2,03
Petroleum refining	23	14	1,19
Other manufacturing	36.2-36.6	14	1,19
Shipbuilding	35.1	4	0,34
Size class			
Less than 50		**54**	**4,58**
50-250		**154**	**13,05**
250-1000		**786**	**66,61**
More than 1000		**186**	**15,76**
Totals		**1180**	**100**

TABLE 2. VARIABLES DEFINITION

Variables	Type *(1)	Description
		Endogenous variables measuring environmental innovation (present period, t)
ECP	B	Equals 1 for firms that have introduced into the market any innovation with environmental benefits from the production of goods or services: cleaner production technologies (this is the case if the innovation introduced by the firm has either of these six types of environmental benefits : (1) reduced material use per unit of output; (2) reduced energy use per unit of output; (3) reduced CO2 'footprint' by the enterprise; (4) replaced materials with less polluting or hazardous substitutes; (5) reduced soil, water, noise or air pollution; (6) recycled waste, water or materials)
EOP	B	Equals 1 for firms that have introduced into the market any innovation with environmental benefits from the after sales use of a good or service by the end user: end-of-pipe technologies (this is the case if the innovation introduced by the firm has either of these three types of environmental benefits: (1) reduced energy; (2) reduced air, water, soil or noise pollution, (3) improved recycling of product after use)
ENVID	B	Equals 1 for firms that have implemented any procedures to regularly identify and reduce your enterprise's environmental impacts (for example, preparing environmental audits, setting environmental performance goals, ISO 14001 certification, etc)
		Exogenous variables measuring innovation leadership
PERSINO	B	Equals 1 for firms that have persisted in the introduction of product or process innovation during at least 3 periods
lRD_{t-1}	Q	Quantitative variable measured as the log-transformed value of total R&D expenses in 2006
lRD_{t-2}	Q	Quantitative variable measured as the log-transformed value of total R&D expenses in 2004
$lINOSALF_{t-1}$	Q	Quantitative variable measured as the log-transformed value of the amount of sales attributed to innovations new to the firm, in thousands of Euros, compared to the total turnover from new or significantly improved goods or services in 2006
$lINOSALF_{t-2}$	Q	Quantitative variable measured as the log-transformed value of the amount of sales due to innovations new to the firm, in thousands of Euros, compared to the total turnover from new or significantly improved goods or services in 2004

TABLE 2. VARIABLES DEFINITION (CONTINUED)

		Exogenous variables measuring non-technological innovation
Inorg	B	Equals 1 if the firm has introduced an organizational innovation (this is the case if the firm has used either of the following three organizational innovation practices : (1) new business practices for organizing procedures (i.e., supply chain management, knowledge management, quality, etc); (2) new methods for organizing work responsibilities and decision making (employee responsibilities system, education, training, etc…);(3) new methods for organizing external relations with other firms or public institutions (i.e., alliances, outsourcing, etc…).
Mkt	B	Equals 1 if the firms has introduced a marketing innovation (this is the case if the firm has used either of the following four marketing innovations: (1) significant changes to the aesthetic design or packaging of a good or service; (2) new media or techniques for product promotion; (3) new methods for product placement or sales channels; (4) new methods for pricing goods or services).
		Exogenous variables measuring firm characteristics
$lsize_{t-1}$	Q	Quantitative variable that is the log-transformed value of the size of the firm in the year 2006
Gp	B	Equals 1 if the firm is part of a group
DHT	B	Equals 1 if the firm has a high-technology classified sectoral activity. This binary variable equals 1 if the firm's activity is in any of the following industries: pharmaceuticals; computers, office machinery and electronics-communication; medical, precision, and optical instruments, watches and clocks; aerospace.
DMHT	B	Equals 1 if the firm has a medium high-technology classified sectoral activity. This binary variable equals 1 if the firm's activity is in any of the following industries: Chemicals; machinery and equipment; electrical machinery; motor vehicles and transport equipment.
DMMLT	B	Equals 1 if the firm has a medium low-technology classified sectoral activity. This binary variable equals 1 if the firm's activity is in either of the following industries: petroleum refining; rubber and plastic products and other non-metallic mineral products; metals; shipbuilding; other manufacturing activities.
DMLT	B	Reference variable. This binary variable equals 1 if the firm's activity is in any of the following industries: food; textiles; wood paper and furniture or printing and reproduction of recorded media.

** (1) B for binary variables and Q for quantitative*

TABLE 3. SUMMARY STATISTICS

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Dependent variables					
ECP	1180	0,6762	0,4681	0	1
EOP	1180	0,4661	0,4991	0	1
ENVID	1180	0,5915	0,4918	0	1
Alternative explanatory variables measuring innovation leadership					
PERSINO	1180	0,5924	0,4916	0	1
lRD_{t-1}	1180	5,4000	3,6443	0	14,7745
lRD_{t-2}	1180	5,4173	3,5991	0	1
$lINOSALF_{t-1}$	1180	4,4624	4,7948	0	16,3202
$lINOSALF_{t-2}$	1180	4,4260	4,7460	0	16,3202
Exogenous variables measuring non-technological innovation					
Inorg	1180	0,6237	0,4845	0	1
Mkt	1180	0,3845	0,4865	0	1
Explanatory variables measuring firm characteristics					
$lsize_{t-1}$	1180	6,0403	1,0469	2,7081	11,3774
Gp	1180	0,6237	0,4845	0	1
DUMHT	1180	0,1068	0,3089	0	1
DUMMHT	1180	0,3127	0,4638	0	1
DUMMLT	1180	0,2729	0,4456	0	1
DUMLT	1180	0,3076	0,4617	0	1

TABLE 4. RESULTS OF THE PROBIT MODEL: MODEL 1: DEPENDENT VARIABLE ECP (CLEANER PRODUCTION TECHNOLOGIES)

	Results		
Variables			
Alternative exogenous variables for innovation leadership			
PERSINO	**0.8952*** (0.1229)**	/	/
lRD_{t-1}	/	**0.0764*** (0.0188)**	/
lRD_{t-2}	/	**0.0703*** (0.0189)**	/
$lINOSALF_{t-1}$	/	/	**0.042** (0.1201)**
$lINOSALF_{t-2}$	/	/	**0.0362** (0.013)**
Non-technological innovations			
Inorg	**1.0363*** (0.1161)**	**1.0678*** (0.114)**	**1.0796*** (0.1124)**
Mkt	**0.6423*** (0.1385)**	**0.6389*** (0.1345)**	**0.7084*** (0.1349)**
Firm characteristics			
$lsize_{t-1}$	**0.1931** (0.0597)**	0.1083 (0.0682)	**0.2306*** (0.0627)**
Gp	0.2453 (0.1585)	0.2639 (0.1627)	**0.2703* (0.1611)**
DUMHT	YES	YES	YES
DUMMHT	YES	YES	YES
DUMMLT	YES	YES	YES
DUMLT	**Ref.**	**Ref.**	**Ref.**
Cons	-2.2352*** (0.3038)	-1.9868*** (0.3238)	-2.4311*** (0.3078)
Number of observations	1180	1180	1180
Chi^2	287.06	269.41	266.16
Pseudo R^2	0.3455	0.3354	0.3126

Coefficient (Standard error)

**** significant at 10 %, ** significant at 5 %, *** significant at 1 %***

TABLE 5. RESULTS OF THE PROBIT MODEL : MODEL 2 : DEPENDENT VARIABLE EOP (END OF PIPE PROCEDURES)

	Results		
Variables			
Alternative exogenous variables for innovation leadership			
PERSINO	**0.5399*** (0.1174)**	/	/
lRD_{t-1}	/	**0.0348* (0.017)**	/
lRD_{t-2}	/	**0.0489** (0.0178)**	/
$lINOSALF_{t-1}$	/	/	**0.0303** (0.0108)**
$lINOSALF_{t-2}$	/	/	0.0112 (0.0111)
Non technological innovations			
Inorg	**0.5648*** (0.1061)**	**0.5867*** (0.1039)**	**0.603*** (0.1032)**
Mkt	**0.5743*** (0.1111)**	**0.5891*** (0.1098)**	**0.6221*** (0.1106)**
Firm characteristics			
$lsize_{t-1}$	**0.2112*** (0.0563)**	**0.1686** (0.0626)**	**0.2391*** (0.0559)**
Gp	-0.0585 (0.1602)	-0.0302 (0.0626)	-0.02 (0.1585)
DUMHT	YES	YES	YES
DUMMHT	YES	YES	YES
DUMMLT	YES	YES	YES
DUMLT	**Ref.**	**Ref.**	**Ref.**
Cons	-2.4493*** (0.2893)	-2.283*** (0.3034)	-2.5361*** (0.2897)
Number of observations	1180	1180	1180
Chi2	258.62	228.46	232.58
Pseudo R2	0.2073	0.2012	0.1939

Coefficient (Standard error)
**** significant at 10 %, ** significant at 5 %, *** significant at 1 %***

TABLE 6. RESULTS OF THE PROBIT MODEL : MODEL 3 : DEPENDENT VARIABLE ENVID (CERTIFICATION PROCEDURES)

	Results		
Variables			
Alternative exogenous variables for innovation leadership			
PERSINO	**0.5273*** (0.1111)**	/	/
lRD_{t-1}	/	**0.041* (0.0165)**	/
lRD_{t-2}	/	**0.0693*** (0.0179)**	/
$lINOSALF_{t-1}$	/	/	**0.0213* (0.0112)**
$lINOSALF_{t-2}$	/	/	**0.0216* (0.0118)**
Non technological innovations			
Inorg	**0.5946*** (0.1069)**	**0.6054*** (0.1028)**	**0.6416*** (0.1038)**
Mkt	0.1341 (0.1202)	0.1318 (0.1199)	0.1875 (0.1178)
Firm characteristics			
$lsize_{t-1}$	**0.41*** (0.0576)**	**0.3253*** (0.0634)**	**0.4287*** (0.0575)**
Gp	**0.4091* (0.1695)**	**0.4334** (0.1665)**	**0.4416** (0.1664)**
DUMHT	YES	YES	YES
DUMMHT	YES	YES	YES
DUMMLT	YES	YES	YES
DUMLT	**Ref.**	**Ref.**	**Ref.**
Cons	-3.5442*** (0.3292)	-3.2941*** (0.3358)	-3.6626*** (0.3284)
Number of observations	1180	1180	1180
Chi2	261.74	284.77	263.98
Pseudo R2	0.2878	0.2948	0.2754

Coefficient (Standard error)
**** significant at 10 %, ** significant at 5 %, *** significant at 1 %***

APPENDIXES.

APPENDIX A. ADDITIONAL ESTIMATIONS OF THE THREE MODELS WITH RESTRICTION ON THE LEADERSHIP EXOGENOUS VARIABLES[8]:

	Model 1 : dependent variable ECP (Cleaner production technologies)		**Model 2 : dependent variable EOP (End of pipe procedures)**		**Model 3 : dependent variable ENVID (Certification procedures)**	
Variables						
Alternative exogenous variables for innovation leadership						
PERSINOB	**0.7324*** (0.1431)**	/	**0.2253* (0.1179)**	/	0.1977 (0.121)	/
lINOSALM $_{t-1}$	/	**0.0259* (0.0139)**	/	**0.0268* (0.0118)**	/	0.0044 (0.0117)
lINOSALM $_{t-2}$	/	**0.0492*** (0.0133)**	/	**0.0272* (0.0122)**	/	**0.0404** (0.0116)**
Non technological innovations						
Inorg	**1.0477*** (0.113)**	**1.07*** (0.1112)**	**0.5959*** (0.1047)**	**0.5927*** (0.1037)**	**0.6409*** (0.1049)**	**0.6335*** (0.1044)**
Mkt	**0.711*** (0.1353)**	**0.6844*** (0.1329)**	**0.6425*** (0.1097)**	**0.5949*** (0.1092)**	**0.2146* (0.1172)**	**0.1809 (0.1163)**
Firm characteristics						
lsize $_{t-1}$	**0.2565*** (0.0612)**	**0.2134** (0.0614)**	**0.2635*** (0.055)**	**0.2142*** (0.0577)**	**0.457*** (0.0562)**	**0.4147*** (0.0578)**
Gp	0.2959* (0.1593)	0.2664* (0.1588)	-0.0018 (0.1569)	-0.035 (0.1583)	0.4535** (0.1664)	0.434** (0.1662)
DUMHT	YES	YES	YES	YES	YES	YES
DUMMHT	YES	YES	YES	YES	YES	YES
DUMMLT	YES	YES	YES	YES	YES	YES
DUMLT	**Ref.**	**Ref.**	**Ref.**	**Ref.**	**Ref.**	**Ref.**
Cons	-2.4262*** (0.3092)	-2.2893*** (0.3083)	-2.5923*** (0.2908)	-2.3952*** (0.2951)	-3.7264*** (0.3279)	-3.557*** (0.3325)
Number of observations	1180	1180	1180	1180	1180	1180
Chi2	242.45	245.19	219.96	231.59	250.9	258.1
Pseudo R2	0.3123	0.3123	0.1885	0.1982	0.2703	0.2785

Coefficient (Standard error)
**** significant at 10 %, ** significant at 5 %, *** significant at 1 %***

[8] The two variables accounting for innovation leadership with persistence and the rate of the commercial success of innovations are restricted: the persistence variable **persinob** is measured on the basis of complex innovators, meaning firms who have introduced product and process innovations at the same time. **Inosalm** is obtained with the log transformed value of the amount of the sales of innovations new to the market instead of innovations new to the firm, in thousands Euros.

APPENDIX B. ADDITIONAL ESTIMATIONS WITH AN ORDERED PROBIT: DEPENDENT VARIABLE EIG: THE INTENSITY OF ENVIRONMENTAL INNOVATION PRACTICES

	Model 4: Dependent variable EIG *(1)		
PERSINO	**0.6952*** (0.1001)**	/	/
lRD_{t-1}	/	**0.0549*** (0.0153)**	/
lRD_{t-2}	/	**0.0693*** (0.0162)**	/
$lINOSALF_{t-1}$	/	/	**0.033*** (0.0235)**
$lINOSALF_{t-2}$	/	/	**0.024* (0.0097)**
Non technological innovations			
Inorg	**0.8007*** (0.0886)**	**0.8372*** (0.0865)**	**0.8495*** (0.0867)**
Mkt	**0.4943*** (0.0936)**	**0.4949*** (0.09)**	**0.5504*** (0.0905)**
Firm characteristics			
lsize $_{\mathbf{t-1}}$	**0.309*** (0.0451)**	**0.2208*** (0.051)**	**0.3274*** (0.0459)**
Gp	**0.2395* (0.1317)**	**0.2665* (0.1301)**	**0.2739* (0.1305)**
DUMHT	YES	YES	YES
DUMMHT	YES	YES	YES
DUMMLT	YES	YES	YES
DUMLT	**Ref.**	**Ref.**	**Ref.**
Number of observations	1180	1180	1180
Chi2	533.01	482.62	478.62
Pseudo R2	0.2160	0.2151	0.2007

*(1) EIG in a qualitative ordered variable taking the value of 1 if the firm has mentioned to practice at least one of the three environmental innovations cited in the above framework, equals 2 if there are 2 practices and 3 if the firm has introduced the three types of environmental innovations.