Environmental Benefits of Forms of Innovations in French Manufacturing Firms

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Abstract: This paper aims at studying the benefits of forms of innovations on the environment. Using two waves of Community Innovation Survey - CIS datasets, we are able to investigate the impact of four forms of innovations (Product, Process, Organizational and Marketing) during the 2004-2006 period on two types of environmental benefits (for the firm and for the end user) during the period 2006-2008. Our findings indicate that product innovation as no significant impact on environmental footprint whereas three other forms: process, organizational and marketing innovations have a positive and significant impact. Companies that implement specific procedures dedicated to measure and control their environmental impact are more prone to reduce their negative outcomes on the environment.

Key words: Environmental Innovation; Forms of Innovation; Determinants; Empirical analysis; France.

JEL codes: Q55; D22; C10.

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1. Introduction

Firms have received a lot of pressure from different market actors (*e.g.* customers, stockholders, governments, etc.) to improve their impact on the environment. One of the major components by which firms could act in harmony with the environment is through investment to different kinds of environmental innovations. Currently, environmental innovations seem to have increased in quantity and quality. Many (overlapping) reasons could explain these phenomena such as - increasing consciousness regarding the impact of economic activities on the "ecological" environment, - regulations such as constraints and/or incentives to develop greener innovations, - internal incentives and strategies like cost reductions and/or market opportunities enabling to develop new eco-friendly products and increase sales and revenues. Moreover, investment in environmental innovation is often seen as the fastest and most cost-effective way to achieve competitive advantage on the market (*e.g.* Porter and van der Linde, 1995). Not surprisingly, environmental innovation and its policy implications has become a rich field of investigation.

This previously mentioned literature underlines the importance of environmental innovation investment. However, there are relatively few studies that capture empirically the features that increase a firm's probability to invest in environmental innovation. Our research aims to answer the following questions: Which forms of innovations lead to which kind of environmental benefits? Is there a time lag between forms of innovations and environmental benefits?

It is important to investigate the policies that encourage investment in environmental innovation in order to reduce the impact on the environment since these policies may differ from "traditional" innovations (Horbach, 2008). To answer empirically these questions we include in our analysis those factors that have been recorded in the relevant literature as possible incentives of environmental innovation investment. Then we turned to the literature on forms of

innovations (product, process, organizational, marketing) and their associated environmental benefits for the firm and for the end-users.

This paper contributes to the existing literature in several ways. The limited empirical evidence related to the environmental innovation determinants led us to further investigate their nature and their intensity. What is more, we follow previous theoretical literature to explicitly categorize the factors that contribute to environmental innovation. Finally, we investigate the impact of the four different forms of innovation in period (t) on the introduction of innovation with environmental benefits in period (t+1). This time effect will then permit to study the strategies that aimed to reinforce the environmental outcomes of the firms. To our knowledge, this is also the first paper that examines this topic using a sample of French manufacturing firms.

2. Literature Review

Environmental innovation could be defined as "the introduction of a new or significantly improved product (good or service), process, method of organization or marketing, that generate an environmental benefit, compared to existing solutions" (OECD, Oslo manual, 2005). Environmental benefits can be the principal objective of the innovation or the outcome of an innovation aiming at achieving other objectives. Rennings (2000, p. 322) defined environmental innovation as "… measures of relevant actors (firms, …, private households), which: (i) develop new ideas, behaviour, products and processes, apply or introduce them, and (ii) contribute to a reduction of environmental burdens or to ecologically specified sustainability targets". This kind of innovation is usually characterized as a process encompassing three major stages: invention, innovation and diffusion (Jaffe *et al.*, 2002; del Río, 2009) and different actors, including users, manufacturers, suppliers and policymakers (del Río, 2009).

In order to examine which factors may influence on a firm's decision to invest in environmental innovation, we first review the literature concerning environmental innovation which will help us to theoretically identify four main factors that are associated to environmental innovation investment. (cf. del Rio, 2009 for a literature review)

Benefits and costs of environmental innovation: Environmental innovation would simultaneously be beneficial for the environment and for the firms, as it has been suggested by Porter and van der Linde (1995). However, empirical research shows contrasting conclusion indicating that environmental innovation is too costly which will influence negatively a firm's business performance (Walley and Whitehead 1994; Konar and Cohen, 2001).

Environmental public policies (Incentives/Regulations) factors: The studies concerning the impact of public policies on environmental innovation are not conclusive. For instance, the results of Hemmelskamp (1999) suggest a negative influence of public policies on environmental innovation while Cleff and Rennings (1999) and Rehfeld *et al.* (2007) find a positive effect. This could be due to *(i)* differences in the variables and indicators used to measure regulations (pressures/ incentives) and their impact (strength/(perceived) stringency), *(ii)* differences in industries and countries' characteristics and *(iii)* differences in the type of environmental issues addressed and benefits associated to these innovations. It can also be argued that companies might postpone the decision to develop environmental innovation because they anticipate new regulations.

Market driven factors: Another set of drivers that would motivate environmental innovation relates to the demand. Firms might develop green innovation that provides environmental benefits for their customers (Wagner, 2007; Praest-Knudsen *et al.*, 2011). As indicated by Reinhardt (1998), firms may invest in environmental innovation to differentiate their products from others and thus gain a competitive advantage. What is more, consumers are ready to pay additional prices for green products.

Internal strategies / environmental management systems (EMS) / capabilities factors: Here we include firm's internal strategies associated with green innovation investment. This covers several dimensions: *(i)* the willingness to reduce (internal) costs (ex: energy consumption, packaging, waste, etc.) (*e.g.* Frondel *et al.*., 2005), *(ii)* the adoption / implementation of environmental (quality) management systems, (*e.g.* EMAS, ISO 14000) (*e.g.* Rennings *et al.*, 2006; Wagner, 2009; Ziegler and Nogadera, 2009), which have been viewed as a facilitator and seem to have a positive impact on environmental process innovations. However, the cau-

sality between these systems and technological environmental innovations is not clear (Ziegler, 2009).

Several authors (Cleff and Rennings, 1999; Horbach, 2008 and Kammerer, 2009) have studied at the same time the three following categories of factors: Environmental public policies (Incentives/Regulations); Market Driven Incentives/motivations; and Internal: strategies / managerial methods EMS/capabilities.

Environmental benefits of forms of innovation

Literature relating environmental innovation' forms (product, process, organizational, marketing) and their benefits is flourishing.

For example Horbach (2008) states *e.g.* that improvements of technological capabilities (Knowledge Capital) by R&D triggers innovations *(R&D) and that* The introduction of new or relevant changes of organizational structures (*organization*) is especially important for environmental innovations. Kammerer (2009) argues that green products, besides their public benefits have private benefits for the customers. Praest Knudsen, Gertsberger, Stampe (2011) show that while market attention is important for new product development, green aspects of innovation and efficiency considerations for innovation are important for the energy efficiency of the production companies. They argue that product innovation and energy efficiency is a balancing act and that focusing on one will have detrimental effects on the other.

This research proposes to extend these papers in the literature studying environmental innovations by examining the incentives related to investment in environmental innovation in French manufacturing firms using CIS 2006 and CIS 2008 survey.

We conclude that all forms of innovation can potentially have a positive impact on environmental benefits for the firm and /or end users. Every form of innovation can lead to specific benefits depending on the specific characteristics of their innovations.

This invited us to further investigate the impact of the four different forms of innovation in period (t) on environmental benefits in period (t+1). This time effect will then permit to study the strategies that aimed to reinforce the environmental outcomes of the firms.

This led us to formulate the four following hypothesis.

H1. Product innovation in period (t) significantly and positively influences environmental benefits for the firm and/or end users in period (t+1)

H2. Process innovation in period (t) significantly and positively influences environmental benefits for the firm and/or end users in period (t+1)

H3. Organization innovation in period (t) significantly and positively influences environmental benefits for the firm and/or end users in period (t+1)

H4. Marketing innovation in period (t) significantly and positively influences environmental benefits for the firm and/or end users in period (t+1)

3. Empirical Analysis

This section presents and discusses the results drawn from the analysis of the behaviors adopted by French manufacturing firms regarding environmental innovations. After having presented the databases used, we present the independent and control variables used in the study as well as descriptive statistics relating to the two types of environmental benefits of innovation: for the firms and for the consumers/users. Finally, we present and discuss the determinants of innovations with environmental benefits related to the different forms of innovation (Product, Process, Organization and Marketing).

3.1. The database: French CIS 2008 and CIS 2006

In order to investigate environmental innovations and related forms of innovation (Product, Process, Organization and Marketing), we use information from two waves, CIS 2008 and

CIS 2006, of the Community Innovation Survey (CIS) – "Enquête Communautaire sur l'Innovation" for France carried out by INSEE (National Institute for Statistics and Economic Studies). CIS data are based on firm-level surveys that ask organizations to provide on their level and form of innovative efforts. These surveys are based on the Oslo Manual drawn up by the OECD, and revised in 1996. Although definitions of innovation and examples are provided to respondents, all the information relies on self-reported information by managers within these organizations (OECD, 2005). This survey focuses on firms with over 10 employees, a stratified sample of firms under 250 employees and census of large firms. These data have the advantage to cover all sectors of the private economy in CIS 2008, whereas CIS 2006 cover all manufacturing sectors, and to capture information on many different aspects of firm's innovative efforts. Overtime, CIS has become a central tool for researchers working on understanding the innovation process, and there have been over 100 papers published in academic journals using the data, including leading economic and management journals (see Smith, 2005 and Mairesse and Mohnen, 2002).

Firms answer questions primarily concerned with the nature of technological innovations, innovation performance, the supervision of these innovations (*i.e.* innovation projects), the internal and external sources of R&D, the objectives of technological innovation, the main sources of information, the cooperation to innovate and finally the innovation with environmental benefits in CIS 2008. This last part of CIS 2008 replaces the obstacles to innovation related questions available in CIS 2006.

CIS 2008 covers the 2006-2008 period and include for the first time specific information on environmental benefits for the firms[1]. This survey was the 6th wave of Community Innovation Survey in France carried out in 2009. The survey population included 25,000 firms, drawn manufacturing, services and construction sectors. It was a mandatory survey and it received a response rate of 86 percent, including 7,389 firms from manufacturing sector. As expected with such high a response rate, the sample closely mirrored the original population.

[1] As far as we know, only two papers (De Marchi, 2012b and Galliano and Nadel, 2012) investigate specifically environmental innovation using CIS 2008. However, De Marchi (2012a) use Spanish CIS 2006 and Belin *et al.* (2009) use French and German CIS 2004. These last two papers follows the approach of Horbach (2008) using a question on the effect of innovation about "the importance of reduced environmental impacts or improved health and safety".

The last part of the CIS 2008 dedicated to environmental innovations concerned 4,412 innovative firms. Innovative firms are defined as firms that introduced at least one innovation among the four forms of innovation: Product, Process, Organization and Marketing[2].

CIS 2006 covers the 2004-2006 period for 4,821 manufacturing firms. This survey was carried out in 2007 as the 5th wave of Community Innovation Survey in France. CIS 2006 is used to define all independent and controls variables in 2004 in order to avoid reverse causality with dependent variables. The originality of the paper is that using both waves of CIS we are able to investigate the impact of the four different forms of innovation in period (t) on the introduction of innovation with environmental benefits in period (t+1). This time effect will then permit to study the strategies that aimed to reinforce the environmental outcomes of the firms. Merging CIS 2008 and CIS 2006, 1,361 innovative firms are used to analyze the characteristics of firms introducing environmental innovations related to the different forms of innovation (Product, Process, Organization and Marketing).

Dependent Variables

Using CIS 2008, this study investigate the determinants of introduction of environmental innovations. We use information from Questions 11.1a and 11.1b respectively related to the environmental benefits for the firms (6 types of individual benefits) and the environmental benefits for the end-user (3 types of individual benefits). The definition of an environmental innovation used in CIS 2008 is the definition of OECD (Oslo manual, 2005): "the introduction of a new or significantly improved product (good or service), process, method of organization or marketing, that generate an environmental benefit, compared to existing solutions". Environmental benefits can be the principal objective of the innovation or the outcome of an innovation aiming at achieving other objectives. CIS 2008 differentiate two types of environmental innovations benefits: for the firms and for the end-users. Compared to De Marchi 2012b and

[2] Non-innovative firms (firms that did not introduced any innovation among Product, Process, Organization or Marketing) do not respond to the last part of the CIS 2008 survey dedicated to the environmental innovations (questions 11.1 to 11.3) Therefore, it was not possible to identify any pattern for these non-responded firms, we assumed that no selection bias for our sample.

Galliano and Nadel, 2012, we investigate separately these two types of environmental innovations as we consider them as different.

Innovations with environmental benefits for the firms are detailed by the following 6 different benefits: Reduced material use per unit of output; Reduced energy use per unit of output; Reduced CO2 'footprint' (total CO2 production) by the firm; Replaced materials with less polluting or hazardous substitutes; Reduced soil, water, noise, or air pollution; and Recycled waste, water, or materials. Each innovation with environmental benefits for the firm is a dichotomous variable equal to 1 if firm reported the associated benefits; 0 otherwise. We perform an intensity of environmental innovation for the firm from 0 to 6 defined as the number of environmental innovation benefits for the firms. This intensity index is similar to the one used by Laursen and Salter (2006) in order to measure how open is the innovation strategy of the firm. Therefore, we are able to investigate such variable as a measure of the breadth of the firm's environmental innovation strategy and may be interpreted as a proxy of how much the environment concerns are strategic for the firm.

Innovations with environmental benefits for the end-user are detailed by the following three different benefits: Reduced energy use; Reduced air, water, soil or noise pollution; and Improved recycling of product after use. Each environmental benefits is a dichotomous variable equal to 1 if firm reported the associated benefits for the end-user; 0 otherwise. An intensity of environmental innovation for the end-user is performed from 0 to 3 defined as the number of environmental innovation benefits for the end-user.

Therefore, we are able to investigate individually the six environmental benefits for the firms and the three environmental innovation benefits for the end-user using Probit models.

Independent Variables

We will focus on the impact on environmental innovations of four forms of innovation: Product, Process, Organizational and Marketing innovation taken from CIS 2006 (see Table 1 for definition of variables).

Product innovation was taken from two questions from CIS 2006 to whether the firm had developed a product and/or a service. These questions defined product innovation as introduction of a new good or service or significantly improved good or service respective to 'functionalities'. *Product innovation* is a binary variable equal to 1 if the firm had introduced a new or significantly improved product and/or service during the period 2004-2006, 0 otherwise.

Process innovation was defined as the use of new or significantly improved method for the production or supply of goods or services. The associated question includes techniques, technology and new knowledge leading to development of new processes or production methods. Respondents were provided with a detailed list of activities pertaining to process innovation, with several examples. *Process innovation* is a binary variable equal to 1 if the firm had introduced a new or significantly improved method for the production or supply of goods or services during the period 2004-2006, 0 otherwise.

Organizational innovation was measured by using questions from the French CIS 2006. *Organizational innovation* is a binary variable equal to 1 if the firm had introduced one of the four following action: 'introduction of new modes to organize the production procedures', 'new or significantly improved system of knowledge management', 'important modifications of work organization within the firm' and 'introduction of new method of organizing the external relations of the firm' during the period 2004-2006, 0 otherwise.

Marketing innovation was defined as 1 if the firm introduces one of the four following action: 'significant change of design or packaging', 'use of new techniques for product promotion', 'new methods of sales or distribution' and 'new strategies of product pricing'.

Control Variables

In order to explore sources of environmental innovation and critical factors that might explain innovativeness more generally, we have introduced a number of control variables mainly from CIS 2006 into the models.

Firm performance

First, our measure of firm performance is based on the sales per employee in 2004 (in Euro and logs), the first year covered by the CIS 2006 survey. Although highly imperfect as a measure of performance, it has been used in many other studies of the performance effects of innovation using CIS data (Crépon, Duguet, & Mairesse, 1998; Griffith *et al.*, 2006; Roper *et al.*, 2008). Since this measure of firm performance is taken in a different time as our environmental innovation data, it reduces the difficult questions about the timing of the effects of innovation.

Size

Second, as size is a critical variable in determining innovative outcomes (Cohen, 1995), we have controlled for firm size by using number of employees in 2004 (full time employees in logs) from CIS 2006.

R&D

Third, since investments in R&D are often a forerunner to innovative outcomes and they help firms more successful absorb knowledge from outside their firm (Cohen & Levinthal, 1990), we have included the amount of internal R&D expenditures per employee in 2006 (in Euros and logs) from CIS 2006.

Environmental procedures

Fourth, we have included a dummy variable (0,1) from CIS 2008 for firms that implemented environmental procedures before January 2006 for measuring regularly and reducing the environmental impact of the firm: preparing environmental audits, fixing environmental impacts objectives, ISO 14001 certification.

Moreover, we have also included two variables to capture the structural features of the firm, including whether it is involved in international markets and whether it was a member of a wider group. Both variables have been found in previous research to shape innovative performance (MacGarvie, 2006).

International market is a dummy variable (0,1) for firms operating in 'European' or 'International' markets from CIS 2006.

Group is a dummy variable for firms belonging to a group (0,1) from CIS 2006.

Sectors. Finally, as patterns of innovation may differ across industry, we have included 16 industry dummies from CIS 2008 for the following associated sectors: Food, Textile, Wood and Paper, Coke and refined petroleum, Chemical, Pharmaceutical, Rubber and Plastics, Basic metals and Fabricated metal, Computer and Electronic, Electric equipments, Machinery, Transport equipment, Other manufacturing, Electricity and gas, Water supply, and Construction.

3.2. Descriptive Statistics

Table 1 and Table 2 provide variables' definitions and associated descriptive analysis. Innovation performance is investigated by four main types: *product innovation*, *process innovation*, *organizational innovation* and *marketing innovation*. The most introduced innovation is *organizational innovation* (70%). *Product innovation* and *Process innovation* are introduced by six out of ten firms (respectively 67% and 61%). *Marketing innovations* concerns four firms out of ten (44%). A third of firms (33%) implement procedures that aimed at measuring and reducing their environmental impact. 86% of firms are operating in international markets and 81% of firms belong to a group.

--- *Insert Table 1 about here* ---

--- *Insert Table 2 about here* ---

For 79.1% of innovative manufacturing firms, innovation has impact(s) on the environment (for the firm and/or for the end-users). This suggests that environmental issues and concerns are central for the majority of innovative firms. Environmental benefits can be produced in the production process (for 65.2% of innovative firms having developed an innovation with environmental benefit(s) for the firm) as well as during their use by end-users - consumers (42.5%

of innovative firms having developed an innovation with environmental benefit(s) for end-users). This shows that environmental innovations led by French manufacturing firms are much more oriented towards process; they are internally oriented.

Environmental benefits for the firms

Looking in more details at innovations with environmental benefits for the firms (Table 1), the intensity is in average 2.8 out of 6 environmental benefits. We find that more than half of innovative manufacturing firms introduced innovations dedicated to recycled waste, water or materials (58.6%) and that replacing materials with less polluting or hazardous substitutes concerns 50.3% of innovative firms. Reducing materials use per unit of output is introduced by 48.6% of innovative firms. Reducing energy use per unit of output and reducing soil, water, noise or air pollution concerns respectively 48.2% and 47.3% of innovative firms. The last environmental benefit for firms is the reduced CO2 footprint by 35.2% of innovative firms.

Environmental benefits for the firms indicate that recycling comes first and is followed by benefits that are directly associated to cost reductions (energy, packaging/unit). This is in line with the motivations/reasons presented below. Benefits relating to the reduction of gas emissions and pollution - air, water, soils or noise - are less frequently cited. It may be argued that this might be associated to the adoption of codes of good practices and existing environmental regulations and taxations. Finally, the "frequency" of types of benefits is similar (except for recycling, the most frequently mentioned by respondents, and gas emission CO2, the less frequently mentioned).

Environmental benefits for end-users

The intensity of environmental benefits for the end-user is in average 0.9 out of 3. 36.1% of innovative firms introduced innovations for end-users dedicated to reduce energy use. Improving recycling of product after use is introduced by 29.9% of innovative firms. Reducing air, water, soil or noise pollution concerns 29.1% of innovative firms. These three benefits are relatively low (29% to 36% of firms) compared to the benefits for the firms (35% to 58% of firms).

The main environmental benefit for end-users/customers is the reduction of energy use. This result is surprising, because benefits produced during the use of the innovation by customers are present for 61 % of innovative firms having developed an innovation with environmental benefit(s). This could be due to the limited number of items presented in the questionnaire (3 items). Another explanation is that green innovations in French firms would be primarily oriented towards the internal benefits discussed above, and process innovations and/or that their environmental innovations to the benefit of their customers would be limited.

To conclude this section, descriptive statistics indicate that environmental innovations by French innovative manufacturing firms are mainly internally oriented (process innovations) and primarily aim at reducing costs. Firms' behaviors regarding environmental innovations seem to be reactive (external pressures/drivers like existing regulations) rather than proactive.

3.3. Determinants of innovations with environmental benefits

We explain the six environmental benefits for innovative firms and the three environmental benefits for end-users using probit models in Table 3. These nine models include the four innovation types *Product innovation*, *Process innovation*, *Organizational innovation* and *Marketing innovation* as independent variables and the following control variables: *Firm performance*, *Size*, *R&D*, *Environmental procedures*, *International market*, *Group membership* and *Sectors*.

3.3.1. Determinants of innovations with environmental benefits for the firms

Product innovation in 2004-2006 has no impact on the environmental benefits for the firms in 2006-2008 period. We find that firms that introduced *Process innovation* are more likely to introduce all the 6 types of innovation with environmental benefits in the 2006-2008 period except replaced materials with less polluting or hazardous substitutes. This strongly confirms our hypothesis H2 but contradicts hypothesis H1. In other words, firms with new product(s) have no benefits for the environment, whereas firms that changed their way to produce reduce significantly their impact on the environment.

Firms that introduced *Organizational innovation* within 2004 and 2006 impact positively and significantly the benefit associated to the reduced energy use per unit of output in the future period 2006-2008. *Marketing innovation* has a positive and significant influence on the three environmental benefits associated to the reduced CO2 footprint, replaced materials and recycled waste, water and materials. This confirms our hypothesis H3 and H4. This imply that implementing new ways to organize the work within the firm and implementing new ways to design, package and distribute the products will permit to the firm to reduce significantly their impact on the environment in the future.

Turning to the control variables, we observe that *Firm performance* and *Size* has a positive and significant impact on most of types of benefits. Furthermore, firms implementing *Environmental procedures* in the 2004-2006 period are more likely to introduce all the 6 types of innovation with environmental benefits in the 2006-2008 period. These results indicates that larger firms, with higher performance and that are undertaking environmental strategies are also more likely to impact positively environmental benefits. The amount of *R&D* invested has few impacts on environment benefits. It only influence positively and significantly the replaced materials with less polluting or hazardous substitutes. *Group* membership has no impact on environmental benefits. This confirms previous studies investigating exploring environmental innovations.

3.3.2. Determinants of innovations with environmental benefits for end-users

The two types of technological innovation, *Product innovation* and *Process innovation*, in 2004-2006 have no impact on the environmental benefits for the end-users in 2006-2008 period. This contradicts hypothesis H1 and H2. In that case, firms with new product(s) and/or new way(s) to produce have no environmental benefits for the customer. Technological innovations will not permit to the firm to reduce its environmental footprint in the future.

Firms that introduced *Organizational innovation* within 2004 and 2006 impact positively and significantly the benefit associated to the reduced air, water, soil or noise pollution and the one associated to the recycling of product after use. *Marketing innovation* has a positive and

significant influence on the two benefits for the customer associated to the reduced energy use and the one associated to the recycling of product after use. This confirms our hypothesis H3 and H4: new organizations within the firm and new ways to design, package and distribute the products will permit for the customer in the future to reduce significantly the product's energy used, the product's pollution and will increase the recycling of the products.

Looking to the control variables, we observe that *Size* have a positive and significant impact on environmental benefits for the customer. Furthermore, firms implementing *Environmental procedures* in the 2004-2006 period are more likely to introduce all the 3 types of innovation with environmental benefits in the 2006-2008 period. These results indicate that larger firms and that are undertaking environmental strategies are also more likely to impact positively the environment. The amount of *R&D* reduces the energy use and improves the recycling of the products. *Group* membership has no impact on environmental benefits.

--- *Insert Table 3 about here* ---

4. Discussion

The aim of this paper has been to broaden our understanding of the firm-level innovations that permit to increase benefits for environment.

The three main results of our empirical analysis suggest three main implications.

First, among the four forms of innovation, *Process*, *Marketing* and *Organization* will positively influence future benefits to the environment. *Product innovation* do not impact future environmental footprint.

In other words, firms that change their way to produce and/or change their way to design, package and distribute the products and/or change their organization will have a significant impact on their future environmental outcomes. Knowing the firms innovation profile can then permit to know if the environment will benefits from their innovation. Environmental policies will then be associated to innovation dedicated to improve *Process*, *Marketing* and

Organization.

Second, when firms want to significantly reduce their impact on the environment, they can innovate specifically on *Process* and/or *Marketing* and/or *Organization*. When firms are able to modify their way to produce, their way to market their product and/or their way to organize their work, they will be able in the next period to reduce their environmental impacts.

Third, as firms that use environmental procedures reduce significantly their impact on the environment, firms have to be active and strategically oriented to reduce their footprint. The more the firms are conscious and active in the field of environment (measuring regularly, fixing objectives, auditing and ISO 14001 certification) the more they reduce their impact on environment.

5. Conclusion

This paper has permitted to identify the firm's characteristics that influence the environmental benefits of innovations. Process, organization and/or marketing innovation have a significant and positive impact on the environmental benefits for the firms. Only organizational and marketing innovations have a positive and significant impact on environmental benefits for end-users.

We can conclude that innovation strategies can lead to environmental benefits in the sense that the company should not only focus on environmental policies but also on innovation policies. Companies can reduce their environmental footprint by introducing new ways to produce, new ways to organize and/or new ways to market their products. Furthermore, we found that companies that are proactive in using specific environmental procedures are more prone to master their environmental impact.

These results and main implications open research avenues to further investigate the links between environmental and innovation policies. The objectives of these policies would be to inform and support firms in their effort to reduce their environmental footprint and, at the same time, support innovation in a competitive context. Innovation is an opportunity for firms to be

aware of their environmental footprint and to change their behavior in order to reduce their negative impact on the environment.

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Table 1: Environmental benefits of innovation for the firm and for the end-users

	Innovative firms	*Eco-innovative firms*
Introduction of any eco-innovation (0,1)	79.1%	100%
Intensity of environmental benefits for the firms (0-9)	3.8 (3.0)	4.8 (2.5)
Intensity of environmental benefits for the firms (0-6)	2.8 (2.2)	3.6 (1.9)
Environmental benefits for the firm		
Reduced material use per unit of output	48.6%	61.5%
Reduced energy use per unit of output	48.2%	60.1%
Reduced CO2 'footprint' (total CO2 production) by the firm	35.2%	44.5%
Replaced materials with less polluting or hazardous substitutes	50.3%	63.6%
Reduced soil, water, noise, or air pollution	47.3%	59.8%
Recycled waste, water, or materials	58.6%	74.1%
Intensity of environmental benefits for the end-user (0-3)	0.9 (1.1)	1.2 (1.1)
Environmental benefits for end-users		
Reduced energy use	36.1%	45.7%
Reduced air, water, soil or noise pollution	29.1%	36.8%
Improved recycling of product after use	29.9%	37.8%
Number of firms	1,361	1,076

Standard deviations are in brackets.

Sources: CIS 2008 and CIS 2006 France.

Table 2: Definition and descriptive statistics of independent and control variables

Variable	*Description*	*Mean*	*Std. Dev.*	*Min*	*Max*
Independent variables					
Product innovation	If the firm introduces a new or significantly improved product and/or service (0,1) [CIS 2006]	0.67	0.46	0	1
Process innovation	If the firm introduces a new or significantly improved process (0,1) [CIS 2006]	0.61	0.48	0	1
Organizational innovation	If the firm introduces one of the following: introduction of new modes to organize the production procedures, new or significantly improved system of knowledge management, important modifications of work organization within the firm and introduction of new method of organizing the external relations of the firm (0,1) [CIS 2006]	0.70	0.45	0	1
Marketing innovation	If the firm introduces one of the following: significant change of design or packaging, use of new techniques for product promotion, new methods of sales or distribution, new strategies of product pricing (0,1) [CIS 2006]	0.44	0.49	0	1
Control variables					
Firm performance	Sales per employee in 2004 (in Euro and logs) [CIS 2006]	2.29	0.28	1.40	4.01
Size	Number of employees in 2004 (full time employees in logs) [CIS 2006]	2.52	0.52	1.27	5.03
R&D	Amount of internal R&D expenditures per employee in 2006 (in Euros and logs) [CIS 2006]	3.00	0.92	0	6.18
Environmental procedures	Dummy for firms implementing procedures before January 2006 for measuring regularly and reducing the environmental impact of the firm: preparing environmental audits, fixing environmental impacts objectives, ISO 14001 certification (0,1) [CIS 2008]	0.33	0.47	0	1
International market	Dummy for firms operating in 'European' or 'International' markets (0,1) [CIS 2006]	0.86	0.34	0	1
Group	Dummy for firms belonging to a group (0,1) [CIS 2006]	0.81	0.38	0	1
Sectors	Dummies for 16 sectors: Food, Textile, Wood and Paper, Coke and refined petroleum, Chemical, Pharmaceutical, Rubber and Plastics, Basic metals and Fabricated metal, Computer and Electronic, Electric equipments, Machinery, Transport equipment, Other manufacturing, Electricity and gas, Water supply, and Construction [CIS 2008]				

Sources: CIS 2008 and CIS 2006 France. 1,361 innovative manufacturing firms with at least one innovation among Product, Process, Organization and/or Marketing.

[CIS 2006] and [CIS 2008] indicates respectively when variables are retrieved from the CIS 2006 and CIS 2008 database.

Table 3: Determinants of innovations with environmental benefits for the firms and for end-users

	Reduced material use per unit of output (Ecomat (t+1) from [CIS 2008])		Reduced energy use per unit of output (Ecoen (t+1) from [CIS 2008])		Reduced CO2 'footprint' (total CO2 production) by your enterprise (Ecoco (t+1) from [CIS 2008])		Replaced materials with less polluting or hazardous substitutes (Ecosub (t+1) from [CIS 2008])		Reduced soil, water, noise, or air pollution (Ecopol (t+1) from [CIS 2008])		Recycled waste, water, or materials (Ecorec (t+1) from [CIS 2008])		End-user benefits, reduced energy use (Ecoenu (t+1) from [CIS 2008])		End-user benefits, reduced air, water, soil or noise pollution (Ecopos (t+1) from [CIS 2008])		End-user benefits, improved recycling of product after use (Ecorea (t+1) from [CIS 2008])	
	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Independent variables from [CIS 2006]																		
Product innovation (t)	0.219	1.54	0.170	1.21	-0.020	-0.14	-0.019	-0.14	-0.008	-0.06	0.122	0.88	-0.019	-0.14	-0.178	-1.27	-0.015	-0.11
Process innovation (t)	0.302***	2.75	0.218**	1.99	0.385***	3.29	0.089	0.79	0.417***	3.78	0.456***	4.25	0.089	0.79	0.175	1.50	0.079	0.68
Organizational innovation (t)	-0.051	-0.44	0.204*	1.76	0.020	0.17	0.091	0.79	0.079	0.69	0.084	0.74	0.091	0.79	0.195*	1.63	0.206*	1.68
Marketing innovation (t)	0.129	1.38	0.030	0.32	0.188**	2.00	0.258***	2.74	0.140	1.51	0.239***	2.58	0.258***	2.74	0.065	0.68	0.306***	3.28
Control variables from [CIS 2006]																		
Firm performance (t)	0.000***	1.54	0.001*	1.76	0.001***	2.71	0.001	0.84	0.001*	1.85	0.000	0.91	0.001	0.84	0.000	0.37	0.000	0.69
Size (t)	0.483	3.78	0.674***	5.25	0.522***	3.98	0.522***	4.08	0.393***	3.24	0.091	0.76	0.522***	4.08	0.338***	2.65	0.114	0.89
R&D (t)	0.088	1.31	0.042	0.62	0.106	1.53	0.111***	1.64	0.039	0.58	0.096	1.43	0.111***	1.64	0.076	1.09	0.133*	1.89
Environ. procedures (t)	0.413***	4.29	0.420***	4.38	0.334***	3.49	0.183*	1.9	0.360***	3.79	0.356***	3.67	0.183*	1.9	0.297***	3.08	0.187*	1.94
International market (t)	0.202	1.13	0.016	0.09	-0.130	-0.7	-0.487***	-2.74	0.350*	1.91	-0.049	-0.27	-0.487***	-2.74	0.011	0.06	-0.171	-0.97
Group (t)	0.037	0.26	-0.174	-1.22	0.084	0.56	-0.160	-1.07	0.038	0.26	0.137	0.97	-0.160	-1.07	-0.107	-0.7	0.012	0.08
Constant	-2.851***	-4.82	-2.250***	-3.83	-2.010***	-3.33	-2.568***	-4.08	-1.6739***	-2.96	-1.332***	-2.62	-2.568***	-4.08	-1.791***	-3.13	-2.326***	-3.38
Pseudo R2	0.11		0.10		0.13		0.11		0.10		0.07		0.11		0.07		0.06	
Nber of firms	1,361		1,361		1,361		1,361		1,361		1,361		1,3611		1,361		1,361	

Sources: CIS 2008 and CIS 2006 France. 1,361 innovative manufacturing firms with at least one innovation among Product, Process, Organization and/or Marketing.

Industry dummies are not reported

Significance levels at *** 1%, ** 5% and * 10%.

Appendix A: Correlations among independent and control variables

	Product innovation (t)	Process innovation (t)	Organizational innovation (t)	Marketing innovation (t)	Firm performance (t)	Size (t)	R&D (t)	Environmental procedures (t)	International market (t)
Independent variables from [CIS 2006]									
Product innovation (t)	-								
Process innovation (t)	0.248 (0.000)	-							
Organizational innovation (t)	0.157 (0.000)	0.374 (0.000)	-						
Marketing innovation (t)	0.2828 (0.000)	0.2053 (0.000)	0.281 (0.000)	-					
Control variables from [CIS 2006]									
Firm performance (t)	0.09 0.720	-0.026 0.334	-0.006 0.810	0.008 0.759	-				
Size (t)	0.237 (0.000)	0.281 (0.000)	0.165 (0.000)	0.144 (0.000)	0.098 (0.000)	-			
R&D (t)	0.216 (0.000)	0.130 (0.000)	0.103 0.001	0.064 0.048	0.220 (0.000)	0.601 (0.000)	-		
Environmental procedures (t)	0.082 0.002	0.156 (0.000)	0.112 (0.000)	-0.008 0.764	0.116 (0.000)	0.304 (0.000)	0.193 (0.000)	-	
International market (t)	0.180 (0.000)	0.177 (0.000)	0.142 (0.000)	0.085 0.001	-0.013 0.631	0.204 (0.000)	0.138 (0.000)	0.084 0.001	-
Group (t)	0.154 (0.000)	0.174 (0.000)	0.098 (0.000)	0.040 0.139	0.116 (0.000)	0.414 (0.000)	0.222 (0.000)	0.203 (0.000)	0.184 (0.000)

P-values are in brackets.

Sources: CIS 2008 and CIS 2006 France. 1,361 innovative manufacturing firms with at least one innovation among Product, Process, Organization and/or Marketing.