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Research Paper

Firms' Eco-innovation Intensity and Sectoral System of Innovation: The Case of French Industry

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The objective of this paper is to analyse the influence of firms' internal organisational structures and different ways of mobilising external resources on their eco-innovative intensity and observe whether, at the firm level, these determinants vary according to sectoral conditions. Using the French CIS 2008 survey, the results reveal that, beyond the classic effect of regulatory pressure, firms' eco-innovation intensity is structured by the firm's internal characteristics, technological opportunities and sectoral conditions.

KEYWORDS: Eco-innovation, sectoral system of innovation, environmental innovation, French industry

JEL Classification: Q55, O33, L60

1. Introduction

An environmental innovation, or eco-innovation, is defined in the literature as a new or modified process, product, technique or management system that avoids or reduces negative impacts on the environment (Horbach 2008; Arundel and Kemp 2009). The first characteristic of an eco-innovation is to give rise to a “double externality”, that is to say, a positive environmental externality, in addition to the classic knowledge spillovers resulting from any innovation. This double externality brings to the fore the need for regulatory mechanisms and environmental policies (“regulatory push-pull effect”, Rennings 2000), and the influence of industrial structures and technological conditions specific to each sector. The second characteristic is that, by definition, an eco-innovation is necessarily based on products or organisational devices and therefore on a firm's internal characteristics and organisational processes. In line with Porter's hypothesis (Porter 1991; Porter and van der Linde 1995a, 1995b), many works on environmental innovation have primarily focused on analysing the interactions between environmental regulations and eco-innovations (Jaffe and Palmer 1997; Brunnermeier and Cohen 2003; Popp

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2006, Johnstone, Haščič, and Popp 2010; Lee, Veloso, and Hounshell 2011). Since the seminal article of Rennings (2000), economics of innovation have shed light three kinds of determinants of eco-innovations: technology push, demand pull and regulatory push–pull effects (Horbach 2008; Horbach, Rammer, and Rennings 2012; Horbach, Oltra, and Belin, 2013; Triguero, Moreno-Mondéjar, and Davia 2013; Ziegler 2013; Cuerva, Triguero-Cano, and Córcoles 2014). However, to eco-innovate, a firm must employ a combination of internal knowledge bases and external information and knowledge. So, the technological conditions and industrial structures that characterise the firm's sector play a decisive role. The approaches in terms of "sectoral system of innovation" (Malerba 2002, 2005) or technological regimes (Malerba and Orsenigo 1993) emphasise not only the technological intensity of the firm's operations and the nature of the knowledge they involve, but also the forms of coordination between the actors and institutional frameworks that support it.

In this context, the objective of this paper is to analyse the influence of firms' internal organisational structures and different ways of mobilising external resources on their eco-innovative intensity and observe whether, at the firm-level, these determinants vary according to sectoral conditions. The objective is to study the respective influence of internal firm's characteristics, external resources and sectoral conditions of innovation on the eco-innovation behaviour of French industrial firms. Beyond a general model that reveals common firm-level determinants of entire French industry, we intend to study how these determinants do vary according to the sectoral context.

To test the hypotheses, this empirical study employs firm-level data derived from the French "Community Innovation Survey 2008" (CIS 2008), conducted by the National Institute for Statistics and Economic Studies (INSEE) in 2008, paired with the French EAE 2007 (Annual Survey of Firms—2007). A zero inflated negative binomial (ZINB) model is used to analyse the determinants of firms' eco-innovation intensity. In addition to the general model, which will reveal the general tendencies, we will test five sub-models for the five sectors that form French manufacturing industry: agribusiness, consumer goods, equipment goods, transport and intermediate goods.

This article is organised into four sections. The following section presents the theoretical framework and derived hypotheses. Section 3 introduces the data, variables and econometric model. The final section presents the results concerning French industry as a whole and those related to its different sectors. These results will enable us to provide suggestions related to public policy.

2. The Determinants of Firms' Eco-innovation Intensity: Analytical Framework and Hypotheses

At the firm level, the economics of innovation highlight the cumulative and interactive nature of innovation, the path dependencies of firms and the important role of their technological bases in determining their innovation capacity (Dosi 1988). The existing technological potential of a firm is therefore fundamental in that it is the basis of not only its innovation capacity but also its absorptive capacity (Cohen and Levinthal 1990). The notion of system of innovation is based on the idea that a firm is embedded in various networks and institutions, and innovation processes arise from interactions between the

firm and the diverse actors that constitute its environment (national, regional or sectoral). As noted by Malerba (2005),

sectoral systems of innovation have a knowledge base, technologies, inputs and a (potential or existing) demand. They are composed of a set of agents carrying out market and non-market interactions for the creation, development and dissemination of new sectoral products.

As is the case for National Systems of Innovation (NSI), relationships and networks are the key elements of the innovative processes and products of the SSI. Thus, beyond firms' technology base, the mode of diffusion of information and the ways in which the actors coordinate for innovating constitute the key variables for analysing firms' innovation behaviour. In this context, the eco-innovation intensity should be considered a complex and interactive process, linking the firm's internal characteristics (1) with the external resources (2) and sectoral conditions (3) (see Figure 1).

2.1 The Firm's Internal Characteristics

The literature on innovation attributes a fundamental role to firms' internal characteristics insofar as they constitute the basis of their technological potential and absorptive capacity—i.e. their ability to acquire and assimilate knowledge (Cohen and Levinthal 1990). In other words, a firm possesses a certain amount of internal resources that influence its propensity to innovate and the benefits expected from employing the new technologies (Karshenas and Stoneman 1993). Different authors have shown that the firms that are well endowed with internal resources encounter fewer problems or failures when undertaking innovation projects. Being a large firm, belonging to a group and having high R&D intensity can positively influence the firm's innovation capacity—particularly its absorptive capacity—and thus help it overcome the difficulties encountered during the innovation process (Lhuillery and Pfister 2009). Being a large firm theoretically allows for easier access to finance, scale economies and a more diversified workforce in terms of skills. It also facilitates access to information and permits greater bargaining power vis-à-vis suppliers. In the same vein, being a part of a group implies that its mother company can potentially add to its internal resources. Studies have shown that these factors are particularly significant in the initial stage of the innovation process (Galliano and Roux 2008; Lhuillery and Pfister 2009). However, being a small firm has a positive effect in terms of performance and innovation intensity and is believed to be conducive to more radical innovations because of, among other things, the lower cost of replacing older technologies (Astebro 2004) and greater learning capacity, despite that the latter is often associated with belonging to a technology-intensive industry. Moreover, it is widely acknowledged in the literature that R&D is a major determinant of a firm's innovation capacity (Mairesse and Mohnen 2010) and is fundamental to its absorptive capacity (Nieto and Quevedo 2005). In this respect, having a permanent R&D team within the firm seems more effective than outsourcing R&D or only occasionally undertaking R&D projects. Indeed, an internal R&D team reflects the firm's continuous efforts to develop its absorptive capacity (Veugelers 1997; Becker and Peters 2000).

In the case of the determinants of eco-innovation analysis, most empirical studies observe a positive relationship between firm size and eco-innovation. This positive impact of firm size is found in the case of organisational, product and process eco-innovations (Triguero, Moreno-Mondéjar, and Davia 2013) and for both incremental and radical eco-innovation (Frondel, Horbach, and Rennings 2007). Only Demirel and Kesidou (2011) find a positive relationship between the size of the firm and its propensity to undertake incremental eco-innovation, but no influence on radical eco-innovation. Concerning the role of R&D in the firm's eco-innovation intensity, the literature focused more on studying R&D expenditures than permanent R&D. R&D investments have a positive impact on eco-innovation (Frondel, Horbach, and Rennings 2007; Horbach 2008). Horbach, Rammer, and Rennings (2012) have tested the fact of having an internal R&D team in eco-innovative behaviour. They find a positive effect of internal R&D only on adoption of eco-innovation aiming to reduce air emissions. Horbach, Oltra, and Belin (2013) find a negative effect of internal R&D for French industrial firms.

A firm's eco-innovation behaviour is also heavily dependent on its other internal resources, in line with the notion of complementarity (Milgrom and Roberts 1990, 1995), or of co-evolution, between environmental innovations and other types of innovations, whether they are product, process or organisational innovations (Rennings 2000).

An environmental innovation rests, by definition, on a technological or organisational innovation that has the particularity of generating an environmental benefit. The types and specifics forms of complementarity between technical and/or organisational innovations and environmental innovations is highlighted in a number of studies on different sectors (the German printing industry by Rothenberg and Zyglidopoulos 2007) and on entire national industries (Rehfeld, Rennings, and Ziegler 2007; Wagner 2007; Horbach, Oltra, and Belin 2013). The introduction, for example, of environmental management systems (EMS) such as the ISO 14001 standard, environmental audits and balances, is referred to in many studies as a particularly positive factor for environmental innovation (Frondel, Horbach, and Rennings 2007; Rehfeld, Rennings, and Ziegler 2007; Wagner 2008). Antonioli, Mancinelli, and Mazzanti (2013) find a complementarity between changes in the organisation of production and eco-innovation, but only if eco-innovation aims to reduce CO₂ emissions among firms belonging to polluting industries, where regulatory pressure is high.

Finally, the firms' internal characteristics are a set of factors that shape the foundations of innovative behaviour of firms and their absorptive capacity. The hypothesis here is that factors such as size, belonging to a group as well as the innovative profile of the firm (R&D, performances in technical or organisational innovations such as the adoption of an EMS etc.), are factors that favour firm's eco-innovation intensity.

2.2. External Resources: Information and Cooperation

External resources refer to the concept of technological opportunities. The nature and forms of technological opportunities are decisive factors to analyse R&D intensity and innovation performance, at the firm and sectoral levels (Chesbrough 2003; Castellacci 2008). Different sources of technological opportunities are highlighted in empirical analyses. Klevorick, Nelson, and Winter (1995) define three sources: scientific advances, technological advances external to the firm's sector (other industries, research organisations,

etc.) and returns from previous technological advances in the firm's own sector. This has led to the finding that the level of opportunity increases as the sources become more varied. Becker and Peters (2000) argue that the firm's stock of knowledge is a function of the stock of external knowledge accumulated by the firm, and they distinguish industrial from non-industrial sources of information and knowledge. Industrial sources refer to actors in the sector to which the firm belongs, such as clients, suppliers or competitors. The non-industrial sources refer more specifically to sources from scientific institutions and universities. These authors show that the more sources there are, the higher the level of technological opportunities (see also Cohen 2010).

Empirical studies on eco-innovation determinants highlight the key role played by sources of information in the development of eco-innovations. Horbach, Oltra, and Belin's (2013) article on French and German industries show that, in the case of France, informal knowledge (trade shows, professional associations, etc.) or information originating within the group or universities have a positive effect on eco-innovation; while German industrial firms are negatively sensitive to internal information and not influenced by the flow of informal information or knowledge originating from universities. Horbach, Rammer, and Rennings (2012) observe, in the case of German industry, a various effect of technological opportunities according to the type of environmental innovation. Information sources from universities have a positive effect on eco-innovation aiming to reduce material and energy, but no influence on pollution reduction. Internal sources only have a positive effect on noise pollution reduction. Montresor, Ghisetti, and Marzucchi (2013) distinguish the influence of the breadth and the length of external information sources in the study of an "open environmental innovation mode". The breadth is the number of different external sources and has a positive effect on eco-innovation. However, they show an "inverted U shape" relationship between the depth of information sources and the propensity to eco-innovate. Indeed, above six different sources, the marginal return tends to decrease towards being negative when the firm uses nine different sources. Thus, they suggest that the firm can not be "too much open". Indeed, they find a relation of substitutability between knowledge and competencies building among the firm, throughout R&D, and the openness to external knowledge to eco-innovate (2013). However, we note that few authors distinguish between whether these sources originate from a cooperation project or from a simple process of information diffusion. Becker and Peters (2000) do make that distinction but only for universities. We hypothesise that cooperation is more conducive to the diffusion of tacit and locally based knowledge than to the diffusion of codified information (Cowan, David, and Foray 2000; Cowan, Jonard, and Zimmermann 2006). Empirical studies highlight the key role played by cooperation and sources of information in the development of eco-innovations. According to Horbach, Oltra, and Belin (2013), innovation-oriented cooperation has a particularly significant and positive effect on eco-innovation, in comparison to other forms of innovation. Rave, Goetzke, and Larch (2011) find, on the basis of patent data, that cooperating with a university for the development of environmental innovations is more strongly associated with radical eco-innovations than incremental innovations. Cooperation with suppliers is given particular attention in the empirical literature (see the survey by De Marchi 2012), and especially in the case of the automobile industry (Geffen and Rothenberg (2005) for the USA and Simpson, Power, and Samson (2007) for Australia).

In this context, the objective is to test the respective role played by the sources of information and cooperation in the development of eco-innovations. The hypothesis is that these technological opportunities globally play an important role in a firm's eco-innovation intensity.

2.3 Sectoral Conditions

The interaction with sectoral conditions is a key factor in innovation processes (Dosi and Marengo 1994). Two specificities of environmental innovation make it highly influenced by external drivers. First, environmental innovation rests necessarily on a product or organisational device, and therefore on sectoral structures. Second, the existence of the environmental externality increases uncertainty and so the role of external forces (Faucheux and Froger 1995; Jaffe, Newell, and Stavins 2005). So the different facets of the sectoral conditions (market, spatial and regulation) play a decisive role in a firm's eco-innovation intensity.

Thus, with respect to the *market's* influence on firms' eco-innovative behaviour, there is no consensus in the literature regarding how the degree of concentration affects eco-innovative activities or the type of market structure that would increase a firm's probability to eco-innovate. Horbach (2008) shows that a monopolistic market structure reduces the risk of an innovation being appropriated, particularly for large firms, which will tend to be less fearful of imitation from rivals. The Porter hypothesis assumes that eco-innovation adoption, by reducing cost, increases a firm's export performance (Porter 1991; Porter et van der Linde 1995a, 1995b). Empirical works tend to validate this hypothesis (Costantini and Crespi 2008; Costantini and Mazzanti 2012). Indeed, market size and international openness are positively associated with eco-innovation adoption. Furthermore, several studies emphasise the influence of market size, in particular the positive effect of international trade on eco-innovation (Horbach, Oltra, and Belin 2013). According to Conceição, Heitor, and Vieira (2006) and Horbach (2008), a high propensity to export has an effect, and being highly exposed to international competition increases the probability of developing environmental innovations. Only Rehfeld, Rennings, and Ziegler (2007) argue that exporting has no influence on the adoption of product eco-innovation.

Regarding firms' *spatial* environment, many studies employ geography of innovation to demonstrate the role of agglomeration externalities and the proximity of the actors to one another in the diffusion of innovations and knowledge (Feldman and Audretsch 1999). The authors highlight different types of spatial agglomeration externalities. Indeed, the geographic proximity of firms from various industries does not have the same benefits as the proximity of firms from the same sector (Jacob's urbanisation economies, 1969 vs Marshall's localisation effects 1890). Rural areas are, conversely, characterised by various disadvantages related, in particular, to the lack of inter-firm relationships and human capital diversity and low levels of knowledge spillovers (Autant-Bernard, Mangematin, and Massard 2006; Magrini and Galliano 2012).

One aim of this study is to test whether it is the urban agglomeration economies that positively influence environmental innovations or whether, on the contrary, environmental innovations, because of their correlation with productive activities, are more sensitive to a spatial division of labour whereby productive activities are primarily located in peripheral

Figure 1 Framework for the analysis of eco-innovation intensity patterns

areas (Ota and Fujita 1993), thus promoting opportunities to develop environmental innovations in those areas. However, the findings of the literature on spatial effects are rarely employed in analyses of the determinants of eco-innovation. Costantini, Mazzanti, and Montini (2013) incorporate a regional variable to compare the environmental performances of various Italian regions. Mirata and Emtairah (2005) draw attention to the possible presence of an “industrial district” effect and suggest that “industrial symbiosis networks” play a role in the diffusion of eco-innovations, as Mazzanti and Zoboli in the case of the industrial district of Emilia-Romagna (2009). This dimension has been little discussed in the literature and has various potential effects (Cainelli, Mazzanti, and Montresor 2012).

The issue of externalities refers more broadly to that of network effects and firms’ processes of adoption and absorption for technologies developed by other firms situated in the same industry. Epidemic models (Mansfield 1968) lead to the hypothesis that a potential user can become an actual user through contact with an adopter. Thus, the higher the number of adopters, the greater the probability that a non-adopter will be in contact with an adopter and the higher the former’s probability of being “contaminated” (Hollenstein 2004). Few studies concerning the adoption of environmental innovations (cf. Galliano and Nadel 2013) have examined this dimension. Yet, epidemic effects constitute a key role in influencing adoption and diffusion of eco-innovation, and therefore its appropriability conditions.

Finally, the “double externality” effect brings to the fore the question of regulatory policies and, more specifically, of strict and appropriate regulations capable of encouraging firms to engage in eco-innovation processes and compensate, through the benefits they generate, the costs of standard compliance. As the works of Porter and van der Linde (1995) and Rennings (“regulatory push/pull effect”, 2000) have shown, regulatory mechanisms, which are often contingent on sectoral contexts, are a central determinant of eco-innovations. Many empirical studies have emphasised this relationship in different sectors (Oltra and Saint Jean 2009, in the French automobile industry; Kammerer 2009, in the German electrical equipment industry; and Wagner and Llerena 2011, in three French industrial sectors) or different national industrial contexts (see the survey by Pereira and Vence 2012). Some recent papers also make a distinction between the impact of existing regulatory pressure and that of anticipated future regulation and confirm the significance of this anticipation effect (see Khanna, Deltas, and Harrington 2009; Horbach, Rammer, and Rennings 2012 or Veugelers 2012). These points will be tested in this study.

Nevertheless, beyond the regulatory pressure that is much emphasised by the literature, we assume that the other facets of sectoral conditions also play an important role in a firm’s eco-innovation intensity.

3. Data and Methods

This section aims to present the methodology used to study firms’ eco-innovation intensity. On the basis of nine different types of eco-innovation provided by French nationwide databases (Section 3.1), a score variable is constructed that allows us to analyse the intensity of eco-innovation (Section 3.2). We then use a two-step procedure (a ZINB model) that allows us to analyse, in a first step, the probability to adopt an eco-innovation, and in a second step, the intensity of eco-innovation (Section 3.3).

3.1 The Data

This study is based on data from two mandatory public surveys conducted by the French National Institute of Statistics (INSEE). The CIS 2008 is a declarative survey that aims to capture the innovations developed by firms during the period from 2006 to 2008. It provides information on the nature of firms and their innovation-related behaviour (Mairesse and Mohnen 2002). This information is supplemented by firm-level data (turnovers, activities, locations, etc.) derived from the Annual Survey of Firms (EAE 2007). This makes it possible to characterise the different innovation processes implemented within companies while accounting for the influence of the environment. The 2007 Annual Survey of Firms also provides general information on firm structure and innovation performance. Thus, we have a database of 4,686 companies with 20 employees or more and representative of French manufacturing industry, at the scale of its five sectors: agribusiness, consumer goods, equipment goods, transport and the intermediate goods sector (cf Table 1).

3.2 The Variables

3.2.1 The Dependant Variable: Eco-innovation Intensity . The empirical demonstration is based on a two-step model (ZINB model) that analyses, in a first step, the probability to adopt an eco-innovation, and in a second step, the intensity of eco-innovation. Environmental economics has mainly sought to test the effect of environmental regulation on the intensity of environmental innovation, particularly through R&D expenditures or number of patents (Jaffe and Palmer 1997; Popp 2006; Brunnermeier and Cohen 2003; Johnstone, Haščič, and Popp 2010; Lee, Veloso, and Hounshell 2011). Few studies on intensity have been made in economics of innovation, that have mostly focused on adoption process (Horbach 2008; Horbach, Rammer, and Rennings 2012; Horbach, Oltra, and Belin 2013; Triguero, Moreno-Mondéjar, and Davia 2013; Ziegler 2013; Cuerva, Triguero-Cano, and Córcoles 2014). Our proxy of eco-innovation intensity is a score from 1 to 9 types of eco-innovations. We assume here that the higher the score, the greater the intensity of eco-innovation.

The CIS 2008 defines environmental innovation using nine modalities on the basis of which a score indicating the degree of eco-innovation intensity is constructed. Six types of environmental innovations can be adopted during the production process: reduction of material use per unit of product, of the energy use per unit of output, reduction of the firm's CO₂ emissions, replacement of materials with less polluting or hazardous substitutes, reduction of soil, water, noise or air pollution, and recycling. Three eco-innovations occur during the consumption process, i.e. when the product is being used by the consumer: reduction of energy use, reduction of soil, water or air pollution generated by the consumer and finally, greater recycling of a product after use (see Table 2).

On the basis of those different types of eco-innovation, a score variable is constructed that allows us to analyse the microeconomic foundations of the intensity of eco-innovation. Thus, the endogenous score EI variable, which takes a value between 1 and 9, is as follows ():

Table 1 Descriptive statistics (in percent)

	Total of firms	Agribusiness	Consumer goods	Equipment goods	Transport	Intermediate goods
Firm's internal characteristics						
Permanent R&D	34.64	29.69	24.48	51.74	44.54	34.64
Product innovation: Radical	12.01	10.59	9.62	16.54	18.49	11.30
Incremental	12.61	12.31	11.51	14.18	11.34	12.97
Radical/ incremental	19.65	14.61	14.43	31.34	23.11	19.80
Process innovation	43.17	39.36	38.49	48.13	44.96	45.87
Changes in: Labour organisation	34.21	31.65	31.27	41.54	39.92	33.21
Production organisation	35.51	33.83	30.33	45.02	40.76	34.64
External relations	17.11	13.46	16.75	21.27	22.69	16.45
EMS: Before 2006	16.77	11.62	11.51	21.64	30.67	18.87
During the period 2006–2008	18.14	19.56	13.66	21.77	21.01	18.37
Size: 20–49 employees	40.08	44.53	44.76	32.34	21.43	40.91
50–249 employees	29.62	31.88	28.18	31.72	21.43	29.61
250–500 employees	17.39	14.61	17.27	18.66	25.21	17.19
More than 500 employees	12.91	8.98	9.79	17.29	31.93	12.29
Group	62.01	55.70	55.76	70.27	76.89	63.63
External resources						
Sources of information:						
Within the group	52.03	46.26	42.96	64.93	61.34	53.88
Supplier	33.53	34.06	28.69	39.30	35.71	33.52
Client	36.17	30.72	28.26	53.48	42.86	35.20
Competitor	23.50	21.52	20.88	34.58	27.31	20.36
University	10.58	7.25	8.76	14.93	15.13	10.86
Government or public research institute	7.68	5.75	7.13	10.57	11.34	7.14
Others conferences, trade fairs, journals	31.52	29.80	29.12	42.04	28.15	29.42
Sources of cooperation:						
Within the group	19.12	14.38	14.52	27.11	28.99	19.55
Supplier	19.59	17.38	15.55	24.88	28.57	19.74
Client	16.30	11.39	10.91	24.88	23.53	17.50
Competitor	8.43	7.13	7.13	10.82	15.97	7.76
University	13.87	10.13	11.17	19.65	21.01	13.90
Government or public research institute	9.67	9.44	7.39	13.31	15.13	8.81
Sectoral conditions						
Main market location: Regional market	24.90	33.37	29.12	10.32	13.03	26.32
National market	53.52	54.78	55.07	51.37	48.74	53.51
Foreign market	21.57	11.85	15.81	38.31	38.24	20.17

(Continued)

Table 1. (Continued)

	Total of firms	Agribusiness	Consumer goods	Equipment goods	Transport	Intermediate goods
Sector: Agribusiness	18.54	—	—	—	—	—
Consumer goods	24.84	—	—	—	—	—
Equipment goods	17.16	—	—	—	—	—
Transport	5.08	—	—	—	—	—
Intermediate goods	34.38	—	—	—	—	—
Head office location: Urban	57.68	39.93	61.43	66.29	71.43	58.22
Peri-urban	17.80	18.99	16.15	17.41	14.71	18.99
Rural	24.52	41.08	22.42	16.29	13.87	22.78
Existing environmental regulations	26.25	22.21	21.48	31.59	33.61	28.12
Anticipation of future regulation	17.61	13.00	12.80	21.77	24.79	20.42
Grants, subsidies	6.59	6.67	4.81	5.97	13.87	7.08
Voluntary codes or agreements for environmental good practice	20.74	16.34	19.16	26.00	25.63	20.92
Number of firms	4686	869	1164	804	238	1611
Number of eco-innovative firms	2354	387	484	487	128	868

Sources: CIS 2008 and EAE 2007.

$$\left\{ \begin{array}{l} Y_i = 1 \text{ if there is one environmental innovation,} \\ Y_i = 2 \text{ if there are 2 environmental innovations,} \\ \vdots \\ Y_i = 9 \text{ if all of the different types of innovations have been implemented.} \end{array} \right.$$

The descriptive statistics reveal that half of all companies in French industry (50.23 per cent) eco-innovate. Firms in the consumer goods and agribusiness sectors appear to be those that eco-innovate the least, with average respective rates of 1.78 and 1.79. The sectors with the highest eco-innovation score are the transport (2.69) and intermediate goods (2.86) sectors.

3.2.2 The Independent Variables . In the first step of the model, we used only variables related to a firm's internal characteristics not related to innovation activities. Therefore, we used the variables related to the firm's size, belonging to a group, but also export rate and capital intensity¹ in order to approximate the complexity of the firm's production process and to control for general incentives to introduce (or not) eco-innovations.

In the second step, the intensity of eco-innovation is analysed using three sets of independent variables. The first variables are those associated with a firm's internal characteristics, the second set comprises those related to external information sources and the third

¹ As noticed by Veugelers (2012), eco-innovation and particularly CO₂ reduction innovations are relatively capital intensive increasing the influence of adoption decisions of financial factors.

Table 2 Distribution of eco-innovation adoption by industry (in percent)

	Total firms	Agri-business	Consumer goods	Equipment goods	Transport	Intermediate goods
Number of firms	4,686	869	1,164	804	238	1,611
Per cent	100	18.5	24.9	17.1	5.1	34.4
<i>Environmental benefits from the production of goods within the firm</i>						
Reduced material use per unit of output	28.5	24.9	21.7	34.4	38.2	30.8
Reduced energy use per unit of output	26.4	25.1	19.5	30.3	32.3	29.3
Reduced CO "footprint" (total CO production) by the firm	17.9	14.7	14.5	19.8	24.8	20.1
Replaced materials with less polluting or hazardous substitutes	29.5	15.6	24.7	39.9	39.1	33.8
Reduced soil, water, noise or air pollution	26.8	25.8	20.5	28.7	33.2	29.9
Recycled waste, water or materials	35.8	33.9	32.3	38.1	40.3	37.6
<i>Environmental benefits from the after sales use of a good by the end user</i>						
Reduced energy use	20.6	12.5	14.6	32.7	31.5	21.7
Reduced air, water, soil or noise pollution	16.7	12.5	12.3	21.5	23.1	18.8
Improved recycling of product after use	18.1	14.3	16.5	22.3	24.8	18.4

Source: CIS 2008.

series consists of the variables related to the sectoral conditions. The first set of variables concerns the firm's internal characteristics. The variables related to the firms' size, their being part of a group of companies and their having a permanent R&D department are introduced to approximate their technological base. The data also contain information on the firms' innovation activities, that is to say, the development of other forms of innovation

Table 3 Distribution of eco-innovation intensity by industry (in percent)

Score of eco-innovations	Entire industry	Agribusiness	Consumer goods	Equipment goods	Transport	Intermediate goods
0	49.77	55.47	58.40	39.43	46.22	46.22
1	6.42	6.56	5.50	7.59	2.94	6.95
2	7.34	6.10	6.79	9.70	7.56	7.20
3	7.75	7.71	6.70	9.08	6.30	8.07
4	6.59	8.06	5.07	7.09	5.04	6.89
5	6.08	4.83	5.67	6.59	6.30	6.77
6	4.76	3.34	3.18	6.34	6.30	5.65
7	3.93	4.26	3.09	4.73	3.36	4.03
8	3.05	1.61	1.61	3.98	6.30	3.66
9	4.31	2.07	3.61	5.47	9.66	4.66
Average score	2.41	1.79	1.78	2.69	2.86	2.41

Source: CIS 2008.

by the firm: the adoption of product innovations (radical, incremental or both²), process innovations, organisational innovations (changes in the organisation of labour, in the production organisation or in the firms' relations with external actors), as well as the implementation of an EMS (environmental audits, ISO 14001 certification, etc.) before 2006 or during the observation period (between 2006 and 2008). These variables, relative to firms' innovation profile, enable us to analyse the complementarities that can exist between the different types of innovation. The second series of variables are designed to measure external resources firms draw upon in their innovation processes. In line with several other authors, we hypothesise that the sources of information and cooperation a firm reports having used for innovation serve as an appropriate proxy for technological opportunities (Klevorick, Nelson, and Winter 1995; Becker and Peters 2000). A distinction is made between the variables indicative of the sources of industrial information (clients, suppliers and competitors) and those reflecting the non-industrial sources of information (a university or a public research organisation). The third set of variables concerns the appropriability conditions of eco-innovation. Concerning the competition regime and market conditions, the variables we have selected are the market structure (C4) and the location of the main market. Furthermore, to test the effect of the firm's location on the intensity of its eco-innovative activities, we consider the location of its head office. The rate of adopters in a given sector is used as a variable for approximating the epidemic nature of eco-innovation processes. Finally, four dummy variables serve to analyse the different dimensions of regulatory pressure. They are relative to whether a firm has eco-innovated in response to existing environmental regulations, in anticipation of future regulation, in response to a subsidy granted to promote environmental innovations, and finally, they are related to whether the firm eco-innovated following the implementation of a code of good practice within the sector (cf. Table A1 in Appendix).

3.3 The Model

To determine the intensity of the firm's eco-innovation, we adopt a zero negative binomial model (Greene 2011). Therefore, we use this two-step modelling process in order to avoid technical endogeneity. In a first step, the firm's decision to introduce an eco-innovation (yes/no) is evaluated. In a second step, we estimate the intensity of eco-innovation within the group of eco-innovators.

More precisely, the ZINB model is a two-step count model appropriate to explain the determinants of not adopting an eco-innovation (score = 0) and to highlight foundations of eco-innovation intensity, within the group of eco-innovators (score from 1 to 9). The first step of the model is a logit regression that predicts the probability of not adopting an eco-innovation. The second step evaluates the probability of raising the score by 1 (i.e. by 1 in the intensity of eco-innovation), for the group of observations for the group of eco innovative firms.

We make the hypothesis that some variables, which are determinant factors in the decision to eco innovate or not (See Cahuzac and Bontemps 2008), are introduced in

² Firms declare if they have introduced new or significantly improved products and, if yes, whether any of these products is new to the market (what we call "radical innovation") or only new for the firm (what we call "incremental innovation").

the first step of the model. In the second step, we introduce another set of variables that only concern the firms that have adopted at least one eco-innovation.

The ZINB model is as follows:

$$P(I_{ij} = 0) = \varphi_{ij} + (1 - \varphi_{ij}) \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_{ij}} \right), \quad (1)$$

$$P(I_{ij}) = (1 - \varphi_{ij}) \left(\frac{\omega(I_{ij} + \alpha^{-1})}{I_{ij}! \omega(\alpha^{-1})} \right) \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_{ij}} \right)^{\alpha^{-1}} \left(\frac{\mu_{ij}}{\alpha^{-1} + \mu_{ij}} \right)^{I_{ij}} \quad (2)$$

with $\mu_{ij} = \exp(\alpha_0 + \beta'X_{ij} + \sigma_i + \gamma_i)$ and φ_{ij} the proportion of observations with a score strictly more than 0 ($0 \leq \mu_{ij} \leq 1$), associated with the logit model.

This two-step model gives two types of information. Indeed, in a first step, it can highlight variables that explain the non-adoption of eco-innovation for the group of 2,354 firms that haven't adopted any environmental innovation. In a second step, it allows us to analyse the determinants of eco-innovation intensity of firms already engaged in eco-innovation process, i.e. the 2,352 firms that have developed from 1 to 9 eco-innovations.

Thus, the firm's eco-innovation intensity is as follows:

$$\text{Eco-innovation intensity} = \text{ECO-INNOV}_i = \alpha_0 + \alpha_1 \text{IC}_i + \alpha_2 \text{ER}_i + \alpha_3 \text{SC}_i + \varepsilon_i,$$

where the firm is denoted i ($i, \dots, n$) and a series of independent variables related to the three dimensions of eco-innovation intensity are considered: firm's internal characteristics (IC), external resources (ER) and the sectoral conditions, and ε_i is the error term.

4. The Results

The general model, concerning French industry as a whole, enables us to reveal general eco-innovation tendencies (Section 4.1), which will, in a second stage, let us place the sectoral models in perspective³ (Section 4.2).

4.1 The General Model

Several major findings emerge from this general analysis. The first result confirms that a firm's technological structures and absorptive capacity strongly interact with the intensity of eco-innovation. The innovation profile and the co-evolution of environmental innovations with other forms of innovation within a firm play a highly significant role in the model. We draw attention to the influence of product innovation and its radicality (a radical product innovation has stronger correlation than incremental innovation with environmental innovation), the highly significant marginal effect of process innovations and, finally, the strong relationship between eco-innovation and changes in the organisation of work. The results also confirm that the presence of an R&D department in the firm has a significant correlation, and, according to some authors, reflects the firm's absorptive capacity (Becker and Peters 2000; Veugelers 1997). Organisational practices such as EMS also have a positive

³ One could notice that the result of the two-step model is, first of all, that the correlation between the two equations is significant. This suggests that both stages of the eco-innovation process are interdependent and that this model allows to control for selection bias (cf Table 2 in appendix for the results of the first step model).

and significant marginal effect on eco-innovation intensity, especially if the EMS was implemented before the analysis period, indicating that the process whereby the firm has acquired environmental practices began in the past, which has a positive influence on its present eco-innovation intensity. As for the more general organisational resources—related to the firm's size or its being part of a group—they have little or negative influence. French industrial eco-innovative firms tend to be independent SMEs that are not part of any group. The innovation profile of a firm and the complementarity between the different types of innovation therefore remain the central components of the firm's internal characteristics, which interact with its eco-innovation intensity.

The second result pertains specifically to the association with the firm's environment and the influence of knowledge spillovers on its eco-innovative behaviour. The firm's internal sources of information—drawn from within its own organisational network—and the information supplied by external sources such as suppliers seem to have a decisive effect and this finding applies to the entire French industry. We also note the importance of informal knowledge sources such as trade fairs, exhibitions, trade associations or tools such as scientific and professional journals. Regarding the cooperation processes, whereas the literature highlights a positive relationship between cooperation and technical innovation (Tether 2002, Cohen 2010) and between cooperation and environmental innovation adoption (De Marchi 2012; Horbach, Oltra, and Belin 2013 and Cuerva, Triguero-Cano, and Córcoles 2014), we find no such significant correlation between cooperation and eco-innovation intensity.

Concerning the influence of sectoral conditions, the result related to the market structure is non-significant. A final striking point concerns regulation. In keeping with the literature on environmental innovations (Porter and van der Linde 1995a, 1995b; Rennings 2000) and the specificity of this type of innovation, the results highlight the important role of environmental regulatory constraints in interacting with eco-innovation firms' behaviour. The need to comply with existing regulation is the primary factor that interacts with eco-innovation. It must also be noted that the anticipation of future regulations as well as aids and subsidies towards environmental innovation play a significant role though with a lesser marginal effect. This latter result is in line with the literature, which reports that environmental grants are generally not a key driver behind environmental innovation (Veugelers 2012, in the Flemish case; Horbach, Oltra, and Belin 2013, in the case of France and Germany). We note further that a firm's desire to comply with and engage in good environmental practices implemented in the sub-sector to which it belongs has a particularly strong effect. Interpreting this result is complex. It may be explained either by the need to comply with certain practices necessary for inter-firm exchanges, or, more generally, by a firm's need to maintain or improve its reputation vis-à-vis the industry and the market. The important role of sector-specific spillovers is also confirmed by the limited influence of the other environment-related variables, and more specifically that of spatial spillovers (the non-significant effect of firms' locations and the negative effect of the local and regional markets) (Table 4).

4.2 Firms' Eco-innovation Intensity of the Five Manufacturing Sectors

In this second stage, we test the three sets of variables for comparison purposes, in the five sectors of French industry, to identify the tendencies common to all sectors and the

Table 4 Determinants of eco-innovation intensity in the French industry: a general model (second step^a)

	French Industry	
	Marginal effect	Standard error
Firm's internal characteristics		
Permanent R&D	0.16***	0.02
Product innovation: Radical	0.37***	0.03
Incremental	0.20***	0.03
Radical/incremental	0.25***	0.03
Process innovation	0.49***	0.02
Changes in: Labour organisation	0.41***	0.02
Production organisation	0.23***	0.02
External relations	0.07**	0.02
EMS: Before 2006	0.37***	0.02
During the period 2006–2008	0.32***	0.02
Size: 20–49 employees	Ref.	
50–249 employees	0.12***	0.02
250–500 employees	0.06	0.04
More than 500 employees	– 0.01	0.04
Group	– 0.10***	0.02
External resources		
Sources of information: Within the group	0.35***	0.03
Supplier	0.16***	0.02
Client	0.01	0.02
Competitor	– 0.03	0.02
University	– 0.09*	0.03
Government or public research institute	– 0.04	0.04
Others conferences, trade fairs, journals, etc.	0.13***	0.02
Sources of cooperation: Within the group	– 0.020	0.02
Supplier	– 0.01	0.02
Client	– 0.03	0.03
Competitor	0.05	0.03
University	0.02	0.03
Government or public research institute	– 0.01	0.04
Sectoral conditions		
Market concentration	– 0.03	0.01
Sector: Agribusiness	Ref.	
Consumer goods	– 0.04	0.03
Equipment goods	0.06	0.03
Transport	0.04	0.05
Intermediate goods	0.15***	0.03
Main market location: Regional market	Ref.	
National market	0.11***	0.02
Foreign market	0.14***	0.03
Head office location: Urban	Ref.	
Peri-urban	0.04	0.02
Rural	0.01	0.02

(Continued)

Table 4. (Continued)

	French Industry	
	Marginal effect	Standard error
Eco-innovation in response to:		
Existing environmental regulations or taxes	0.60***	0.02
Anticipation of future regulation	0.16***	0.02
Grants, subsidies or other financial incentives	0.19***	0.03
Voluntary codes or agreements for environmental good practice within the sector	0.56***	0.02
Constant	-1.14***	0.07
Observations	4,686	
Non-zero observation	2,354	
Zero observation	2,332	
Alpha	0.5199754	
Prob> = chiibar ²	0.000	

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Source: CIS 2008.

^aThe first-step model results are shown in Table A2 in Appendix.

specificities of the sectoral systems of eco-innovation. The results reveal the diversity of sector-specific eco-innovation models that cannot be observed in the general model. The sectoral specificities primarily pertain to the different ways in which firms capture the different kind of external resources, on the one hand, and how they interact with their sectoral conditions, in these different dimensions (market, spatial, regulatory), on the other hand.

With regard to *firms' internal characteristics*, the results show that in most sectors, the firms' size and their being part of a group have limited correlation with their eco-innovation intensity. With the exception of the transport sector, being a large firm is not correlated with the probability of eco-innovating (see Table A2 in Appendix) and eco-innovation intensity has a correlation with the medium size of firm in all sectors. With respect to the firms' innovative activity, the results show that in all sectors, with the exception of the agribusiness sector, radical innovation has a stronger positive marginal effect than incremental innovation on firms' eco-innovation intensity. Process innovations and changes in the organisation of labour are highly significantly associated with the eco-innovation intensity of firms in all sectors. There is also a strong correlation between the implementation of an EMS (before or after 2006) and eco-innovation in most sectors. The only difference being that in the case of the equipment goods industry, the most eco-innovative firms are those that adopted those systems before 2006; and in the case of the transport sector, the firms that eco-innovate the most are those that implemented an EMS recently. This tends to reveal that there are important differences between sectors in the ways in which firms acquire and accumulate innovations.

The other differences between sectors pertain to the relationship with organisational changes in the firms' relations with external actors and the existence of an internal R&D department. Changes in external relations are significantly related to the eco-innovation intensity of firms in the consumer goods and equipment goods industries. However, they have a positive relation with eco-innovation in the case of firms in the agribusiness and

intermediate goods sectors, which are characterised by vertical relations and sector-specific patterns. It must be noted, however, that on the whole, changes in external relations have a much lower marginal effect than changes in labour organisation. Moreover, the role of internal R&D differentiates the consumer goods and transport industries from the other three sectors. For both those sectors, we find that the existence of a permanent R&D department in a firm has no association with eco-innovation intensity and that there is no significant correlation between the latter and incremental innovation, but that engaging in radical innovation is strongly correlated with eco-innovation intensity. This would tend to reveal that a permanent R&D department plays a particularly important role in incremental innovation. It is confirmed by the case of the other three sectors, particularly in agribusiness.

Concerning external resources, the sources of information and cooperation are utilised and articulated differently depending on the sector. We note a difference between the sectors that draw information from clients (agribusiness) and those that, in this regard, rely on their suppliers to a greater extent (consumer goods, equipment goods and intermediate goods). Those three sectors share the characteristic of using the information they draw from their suppliers, on the one hand, and internally from the group or networks they belong to, on the other hand. Moreover, information derived from research organisations has a non-significant or even negative marginal effect in the case of universities on the eco-innovation intensity of firms in the agribusiness and intermediate goods sectors. Finally, the results reveal that informal, industry-specific sources of information, such as professional associations, journals or trade fairs are particularly strongly related to eco-innovation behaviour in the sectors close to end users, such as agribusiness and the consumer goods sector. Regarding cooperation for innovation, it has a much weaker correlation with the intensity of eco-innovation. For each type of partner, we note that cooperation has often the opposite effect of the source of information. The positive relation with cooperation with client becomes negative or non-significant even for the sectors that draw their information from downstream (agribusiness). Similarly, in most sectors, the positive influence of information sources from suppliers becomes a negative or non-significant interaction between cooperation for innovation and eco-innovation. On the other hand, we find a strong correlation between the intensity of eco-innovation and cooperation with universities (in agribusiness and the consumer goods sector) or with research organisations (for the equipment goods sector). Ultimately, it is quite clear that eco-innovative firms rely more on their various sources of information than on cooperation. Cooperation for innovation tends to serve the purpose of developing technical innovations and innovations that are sensitive to sectoral conditions, than of developing environmental innovations per se.

Regarding the *sectoral conditions*, the results show, first, that there is strong interaction (high marginal effects) between the share of eco-innovative firms in the sub-sector and the firm's eco-innovation intensity. It can be assumed that when a large number of firms in a sector have adopted an innovation, the probability of this innovation being adopted by other firms in the sector—including through imitation—increases (Galliano and Nadel 2013; Nadel 2013). This is true for all sectors with the exception of the equipment goods industry, characterised by the highest rate of adopters (see Table 2).

The second strong result concerns regulatory pressure, which, according to the literature, presents a major interaction with eco-innovation—which, however, varies accord-

ing to sector. Thus, among the equipment and intermediate goods industries, the firms' eco-innovation intensity is positively related to their need to comply with existing regulations, associated with the search for subsidies or aids for eco-innovation. The profile of firms in the transport sector is essentially the same but more correlated with the anticipation of future regulation. In contrast, agribusiness and the consumer goods sectors have a different profile. They eco-innovate essentially in order to comply with existing regulations and with the voluntary codes and agreements between firms in the same industry. There is no correlation between subsidies and aids and eco-innovation intensity. These results are in line with the conclusions of some authors who distinguish between sectors that produce final goods or services from those that produce intermediate goods and services. In the first case, environmental pressure usually comes from end users (green image strategy, etc.). In the second case, the pressure more often comes from regulation and with the associated need of minimising the cost of norm compliance (Pereira and Vence 2012; Del Rio Gonzalez 2009). This distinction might also explain why market location has no effect in the case of the end-user industries (agribusiness and consumer goods) for which there is no significant difference—in terms of interaction—between being present on local markets and being present on international markets. For the other sectors, on the contrary, there is a positive and strong correlation between firms' openness to national and international markets and eco-innovation intensity. Also, the influence of firms' spatial environment on eco-innovation intensity varies according to the sector. For firms in the consumer goods and equipment goods, there is strong interaction between being located in an urban area and eco-innovation intensity, whereas in the case of intermediate goods sector and agribusiness, being located in a peri-urban or rural area has a positive interaction with eco-innovation intensity.

Finally, though the econometric analysis does not enable us to provide a monographic treatment of the sectoral models, it highlights the importance of the key elements of the sectoral systems of eco-innovation, such as knowledge base, but also embeddedness in market and non-market relations. The results show that each sector has its own idiosyncratic structure. Thus, in the case of the agribusiness and consumer goods for example, we find empirically that they are sectors dominated by SMEs, which tend to be oriented towards local markets located in proximity to end users (see descriptive statistics Table 1). For these sectors, the results of the econometric model highlight the determining influence of their external relationships with other firms in the same supply chains (customers and/or suppliers) but also with institutional stakeholders such as universities or research organisations. The role of sectoral informal arrangements and the similar regulatory profiles of firms in those sectors—profiles characterised among other things by the importance of voluntary codes and agreements—highlight the importance of this embeddedness in the sectoral dynamics. The process of institutional isomorphism (DiMaggio and Powell 1983) and the extensive use of external resources play a particularly important role for these sectors, which comprise a large part of SMEs often dominated by large retail firms and *filieres* rationales (Galliano and Orozco 2013). However, these sectors each have their own technological base, which promotes, in a specific manner, their eco-innovative behaviour. Thus, the eco-innovation intensity of firms in agribusiness is strongly correlated with the presence of a permanent R&D department associated with incremental innovation. It interacts with processes of change in the organisation of work, and above all in relations with external partners. As for eco-innova-

Table 5 Firms' eco-innovation intensity of the five manufacturing sectors

	Agribusiness		Consumer goods		Equipment goods		Transport		Intermediate goods	
	ME [*]	SE ^{**}	ME	SE	ME	SE	ME	SE	ME	SE
Firm's internal characteristics										
Permanent R&D	0.53 ^{***}	0.07	-0.03	0.05	0.24 ^{***}	0.05	-0.27 ^{**}	0.10	0.16 ^{***}	0.03
Product innovation:										
Radical	0.27 ^{**}	0.09	0.32 ^{***}	0.07	0.29 ^{***}	0.06	0.82 ^{***}	0.19	0.33 ^{***}	0.05
Incremental	0.34 ^{***}	0.08	0.09	0.07	0.16 [*]	0.07	0.18	0.15	0.15 ^{**}	0.04
Radical/incremental	0.17	0.09	0.2 [*]	0.07	0.21 ^{***}	0.06	0.71 ^{***}	0.18	0.23 ^{***}	0.04
Process innovation	0.3 ^{***}	0.06	0.89 ^{***}	0.05	0.34 ^{***}	0.04	0.28 [*]	0.14	0.37 ^{***}	0.03
Changes in:										
Labour organisation	0.46 ^{***}	0.06	0.63 ^{***}	0.05	0.28 ^{***}	0.04	0.23 [*]	0.1	0.38 ^{***}	0.03
Production organisation	0.28 ^{***}	0.05	0.12 [*]	0.05	0.2 ^{***}	0.04	0.36 ^{**}	0.13	0.27 ^{***}	0.03
External relations	0.25 ^{***}	0.07	0.02	0.05	0.03	0.04	-0.35 ^{***}	0.10	0.16 ^{***}	0.03
EMS: Before 2006	0.25 ^{**}	0.08	0.49 ^{***}	0.07	0.2 ^{***}	0.05	0.13	0.10	0.41 ^{***}	0.04
2006-2008	0.28 ^{***}	0.06	0.44 ^{***}	0.05	0.05	0.04	0.3 ^{**}	0.11	0.33 ^{***}	0.03
Size: 20-49 employees	Ref.		Ref.		Ref.		Ref.		Ref.	
50-249 employees	0.21 ^{**}	0.06	0.16 ^{**}	0.05	0.17 ^{**}	0.06	0.6 [*]	0.21	0.09 [*]	0.03
250-500 employees	0.17	0.10	0.18 [*]	0.09	0.025	0.08	0.1	0.16	0.05	0.06
More than 500 employees	0.09	0.15	0.04	0.11	0.07	0.08	0.26	0.17	-0.04	0.07
Group	0.11	0.06	0.14 [*]	0.04	0.23 ^{***}	0.05	0.26 [*]	0.12	-0.07 [*]	0.03
External resources										
External information sources within the group:										
Supplier	0.04	0.08	0.39 ^{***}	0.06	0.43 ^{***}	0.06	0.4 [*]	0.17	0.35 ^{***}	0.04
Client	0.07	0.07	0.23 ^{***}	0.05	0.15 ^{***}	0.04	0.04	0.09	0.13 ^{***}	0.03
Competitor	0.24 ^{**}	0.07	0.29 ^{***}	0.05	0.06	0.05	0.08	0.10	0.12 ^{**}	0.03
University	0.17 [*]	0.07	0.08	0.05	0.01	0.03	0.13	0.08	0.01	0.03
Government or public research institute	0.26 [*]	0.12	0.03	0.08	0.06	0.05	0.01	0.13	0.14 [*]	0.05
Others Conferences, trade fairs, journals, etc.	0.25	0.14	0.14	0.08	0.05	0.06	0.04	0.11	0.05	0.07
	0.27 ^{***}	0.07	0.22 ^{***}	0.05	0.07	0.03	0.04	0.10	0.05	0.03

Sources of cooperation within the group:											
Supplier	0.04	0.08	0.15 [*]	0.06	0.01	0.05					0.07
Client	0.25 ^{**}	0.09	0.10	0.06	0.1 [*]	0.04	0.59 ^{***}		0.13	0.07	0.04
Competitor	0.29 ^{**}	0.11	0.05	0.07	0.01	0.05	0.25	0.25	0.13	0.08	0.04
University	0.04	0.11	0.15	0.08	0.1	0.06	0.21	0.18	0.10	0.07	0.06
Government or public research institute	0.41 ^{***}	0.11	0.22 ^{**}	0.08	0.14 [*]	0.05	0.18	0.16	0.16	0.07	0.05
	0.40 ^{**}	0.12	0.05	0.09	0.13 [*]	0.06	0.16	0.14	0.14	0.05	0.07
Sectoral conditions											
Sectoral adoption rate	2.18 ^{***}	0.47	1.12 ^{***}	0.27	0.1	0.32	0.95 [*]	0.41	1.33 ^{***}	0.18	
Market concentration	0.03	0.07	0.07	0.03	0.03	0.05	0.03	0.05	0.07 [*]	0.03	
Main market location:											
Regional market	Ref.		Ref.		Ref.		Ref.		Ref.	Ref.	
National market	0.11	0.06	0.04	0.05	0.22 ^{**}	0.06	1.24 ^{***}	0.25	0.12 ^{**}	0.03	
Foreign market	0.12	0.09	0.07	0.07	0.23 ^{**}	0.07	1.00 ^{***}	0.25	0.19 ^{***}	0.04	
Head office location:											
Urban	Ref.		Ref.		Ref.		Ref.		Ref.	Ref.	
Peri-urban	0.22 ^{**}	0.06	0.36 ^{***}	0.05	0.07	0.04	0.08	0.11	0.18 ^{***}	0.03	
Rural	0.05	0.06	0.2 ^{***}	0.05	0.22 ^{***}	0.05	0.11	0.12	0.14 ^{***}	0.03	
<hr/>											
Eco-innovation in response to:	0.67 ^{***}	0.06	0.88 ^{***}	0.05	0.34 ^{***}	0.04	0.05	0.09	0.62 ^{***}	0.03	
–existing environmental regulations or taxes											
–anticipation of future regulation	0.33 ^{***}	0.07	0.3 ^{***}	0.06	0.14 ^{**}	0.04	0.34 ^{**}	0.13	0.02	0.04	
–grants, subsidies or other financial incentives	0.1	0.09	0.14	0.08	0.32 ^{***}	0.06	0.23 [*]	0.10	0.23 ^{***}	0.05	
–voluntary codes or agreements within the sector	0.55 ^{***}	0.06	0.6 ^{***}	0.05	0.48 ^{***}	0.04	0.31 [*]	0.13	0.51 ^{***}	0.03	
Observations	869		1,164		804		238		1,611		
Constant	2.03 ^{***}	0.27	1.78 ^{***}	0.15	0.528	0.28	1.537 [*]	0.61	1.37 ^{***}	0.11	
Non-zero observation	387		484		487		128		868		
Zero observation	482		680		317		110		743		
Alpha	0.50916		0.73887		0.12264		0.006819		0.45169		
Prob> = chibar ²	0.000		0.000		0.000		0.000		0.000		

Notes: See Table A2 in Appendix for the results related to the first step model (logit regression).

ME: marginal effect; SE: standard error, $p < 0.05$; $p < 0.01$; $p < 0.001$.

Source: CIS 2008.

tion in consumer goods firms, it is more correlated with radical product innovation, process innovation and change in work organisation. We will not develop this further, but, as highlighted above, the other sectors analysed here have different and specific profiles and interactions (Table 5).

5. Conclusion

The purpose of this paper has been to analyse how the internal structures of firms and the ways in which they mobilise external resources influence their eco-innovation intensity. Beyond a general model that reveals common firm-level determinants in the entire French industry, the objective has been to highlight the influence of sectoral systems of innovation on a firm's eco-innovation intensity. The respective effects of firms' internal characteristics, external resources and sectoral conditions of innovation on their eco-innovation intensity have been tested, at the firm level, for the five sectors of the French industry.

Thus, although some tendencies revealed in the general French industry model are also observed in the sectoral models, the latter reveal a diversity in the ways in which firms mobilise their internal resources and those provided by their environments for their eco-innovation intensity. The sectoral system of innovation framework enables us to highlight the importance of some key elements, namely the knowledge base as well as embeddedness in market and non-market interactions. This highlights the main dimensions of each sector's idiosyncratic structure. Therefore, we have shown that beyond the incentive effects of regulation, which also vary according to the sector, environmental innovation is highly dependent on how information and knowledge are captured and utilised, and on the sectoral conditions of innovation.

Thus, the results show first that, beyond the effect of regulatory pressure confirmed by the models, firms' technological base and the sectoral conditions have a structuring effect on firms' eco-innovation intensity. With respect to the *firm's internal characteristics*, the innovation activity and the process of co-evolution of eco-innovations with other forms of innovation also play a very active role in eco-innovation intensity. It must also be emphasised that the specificities of sectoral systems are associated with the different ways in which the relevant factors interact, particularly through the types of innovation and of organisational changes that "accompany" eco-innovation. The first type of combination, where the firm has a permanent R&D team, engages in incremental innovation and changes in external relations, is observed in the case of agribusiness firms and forms the basis for their eco-innovation intensity. A second combination can be emphasised in explaining eco-innovative intensity, one based on radical innovation, process innovation and changes in the organisation of labour, in the case of firms in the consumer goods industry. *Sectoral conditions* are strongly associated with mimetic effects and the more or less formal sectoral regulations firms face. The strong overall impact of the share of adopters in the sector to which the firms belong, codes of good practices and the specific regulatory processes point out a firm's embeddedness in sectoral dynamics. Each sector has its specificities, including those related to regulation (innovating in response to existing regulations in the case of consumer goods companies, rather than in anticipation of future regulations in the case of firms in the transport industry).

The diversity of the conditions for the diffusion of knowledge spillovers is also revealed through the geographical environment variables; the results show that firms have very different ways of relating to agglomeration processes and the locations of their markets (regional vs. international). Finally, concerning *external resources* employed in the innovation process, the analysis reveals a variety of sectoral systems, from the sectors that tend to use information collected primarily from clients for their eco-innovation activities (agribusiness) to sectors that are more oriented towards suppliers and tend to be driven by pressure from upstream actors (consumer goods, equipment and intermediate goods). The cooperation structures have a less significant effect, though cooperation with universities or research institutions has a significant role, which confirms the specific role of this variable in knowledge development and protection.

Finally, as Malerba (2005) noted, a sectoral system approach constitutes a prerequisite to any sectoral policy and permits the identification of system failures and related variables that constitute potential policy targets. This theoretical framework allows us to reveal the heterogeneity of actors, networks and dynamics of change that are foundational to co-evolution processes between eco-innovation and other forms of innovation. The results tend to show that incentives to undertake both technical and organisational innovations serve as a lever for eco-innovation. The results prompt us to take into account not only the financial and regulatory incentives but also the informal diffusion of knowledge and practices. Furthermore, they highlight the importance of both the mechanisms at work internally, and, at the same time, the sensitivity of firms' eco-innovation behaviours to external regulation, which would tend to show not an opposition between the two mechanisms but, as noted by Wagner and Llerena (2011), an interaction between regulation and the development of relevant capabilities.

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Appendix

Table A1. Variables description

Variable	Description
Firm's internal characteristics	
Permanent R&D	= 1 if the firm has permanent R&D staff in-house, 0 otherwise
Product innovation:	
Radical	= 1 if the the firm developed only innovation(s) new for the market, 0 otherwise
Incremental	= 1 if the the firm developed only innovation(s) new only for the firm, 0 otherwise
Radical/incremental	= 1 if the firm develop both innovations new for the firm and innovations new for the market, 0 otherwise
Process innovations	= 1 if the firm introduces a process innovation, 0 otherwise
Changes in:	
Labour organisation	= 1 if introduction of new methods of organising work responsibilities and decision making, i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems, etc, 0 otherwise
Production organisation	= 1 if introduction of new business practices for organising procedures, i.e supply chain management, business re-engineering, knowledge management, lean production, quality management, etc., 0 otherwise
External relations	= 1 if introduction of new methods of organising external relations with other firms or public institutions, i.e. first use of alliances, partnerships, outsourcing or sub-contracting, etc, 0 otherwise
EMS: Before 2006	= 1 if implementation of a EMS before 2006, 0 otherwise
During 2006–2008	= 1 if implementation of a EMS during the period 2006–2008, 0 otherwise
Size no. of employees	Qualitative variable with four modalities: 20–49 employees reference; 50–249; 250–499; and more than 500
Group	= 1 if the firm is the subsidiary of a group, 0 if independent
Capital intensity	Logarithm of the ratio total assets on sales
Export rate	Logarithm of export/total revenues of the firm
External resources	
Information sources	= 1 if the firm has identify information sources that provided information for new innovation projects or contributed to the completion of existing innovation projects:
Within the group	From other enterprises within the group, 0 otherwise
Supplier	From suppliers of equipment, materials, components, or software, 0 otherwise
Client	From clients or customers, 0 otherwise
Competitor	From competitors or other enterprises in the sector, 0 otherwise
University	From universities or other higher education institutions, 0 otherwise
Public research institute	From government or public research institutes, 0 otherwise
Other	From conferences, trade fairs, exhibitions, scientific journals and trade/technical publications, professional and industry associations, 0 otherwise

(Continued)

Table A1.. (Continued)

Variable	Description
Cooperation sources	= 1 if the firm has cooperated for innovation activities with:
Within the group	Other enterprises within the enterprise group, 0 otherwise
Supplier	Suppliers of equipment, materials, components, or software, 0 otherwise
Client	Clients or customers, 0 otherwise
Competitor	Competitors or other enterprises in the sector, 0 otherwise
University	Universities or other higher education institutions, 0 otherwise
Public research institute	Activities with with government or public research institutes
Sectoral conditions	
Sectoral adoption rate	Logarithm of the average rate of eco-innovation adoption by the firms of the same sector level 3 of Naf 2008 rev. 2
Market concentration	Logarithm of the C4 concentration ratio: cumulated market shares of the first four firms in the sector
Main market location	Qualitative variable with 3 modalities: Regional market reference; National market; Foreign market
Head office location	Qualitative variable with 3 modalities for the location of the firm's head office: urban area reference; peri-urban area; rural area
Eco-innovation in response to:	= 1 if the firm introduced an environmental innovation in response to existing
Existing environmental regulations or taxes	environmental regulations or taxes on pollution
Anticipation of future regulation	= 1 if the firm introduced an environmental innovation in response to environmental regulations or taxes that you expected to be introduced in the future
Grants, subsidies or other financial incentives	= 1 if the firm introduced an environmental innovation in response to availability of government grants, subsidies or other financial incentives for environmental innovation
Voluntary codes or agreements for environmental good practice within the sector	= 1 if the firm introduced an environmental innovation in response to voluntary codes or agreements for environmental good practices within the sector

Sources: CIS 2008 and EAE 2007.

Table A2 The first-step model results

		Entire industry			Agribusiness			Consumer goods			Equipment goods			Transport			Intermediate goods		
		ME	SE		ME	SE		ME	SE		ME	SE		ME	SE		ME	SE	
Firm's Internal Characteristics																			
Capital intensity		0.8***	0.07		0.09	0.1		2.1***	0.45		0.53***	0.13		0.9***	0.18		0.9***		
Size																			
20–49 employees		Ref.			Ref.			Ref.			Ref.			Ref.			Ref.		
50–249		0.88***	0.2		1.585	1.4		0.12	0.75		0.19	0.40		0.15	0.38		0.15	2.34**	0.74
250–500		15.4	0.80		13.44	1.54		15.4	8.33		0.69	1.01		1.99	1.31		1.59	1.48	
More than 500		3.71	4.7		11.22	2.32		13.4	2.34		1.65	1.27		1.52*	0.64		3.59	7.6	
Group		1.18***	0.2		14.44	504		0.16	0.73		1.61**	0.53		0.69*	0.31		1.69**	0.52	
Export rate		1.53*	0.7		18.24*	9.2		8.33**	3.18		1.45*	0.58		0.68	0.77		2.62**	0.97	
Constant		1.67***	0.2		0.428	0.61		3.20***	0.86		1.42	0.39		4.07***	0.68		1.76***	0.48	