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Environmental Innovations, Local Networks and Internationalization

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Research Paper

Environmental Innovations, Local Networks and Internationalization

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ABSTRACT This paper investigates the forces correlated with environmental innovations (EIs) introduced by firms in local production systems (LPS). The role of inter-firm network relationships, agglomeration economies and internationalization strategies is jointly analysed for a sample of 555 firms in the Emilia–Romagna (ER) region (North-East Italy). Cooperating with a certain kind of local actors—i.e. suppliers and universities—is the most important EI driver for the investigated firms, along with their training coverage and their adoption of information and communication technologies. The role of agglomeration economies is instead less clear-cut. They spur EIs only in the presence of established LPS, with idiosyncratic sector specialization, while conversely they act as EI barriers. Networking effects and agglomeration economies are instead found to strongly promote the adoption of EIs by multinational firms, thus highlighting the importance of local–global interactions. Interesting specifications for these results are found for particular kinds of EIs, in such fields as CO_2 abatement and ISO labelling, generally extending the analysis of EI drivers by joining local and international factors. In addition, the role of regulatory sector factors confirms the induced innovation hypothesis and provides a robustness check to our results.

KEY WORDS: Environmental innovations, internationalization, foreign direct investments, local production systems, agglomeration economies

JEL CLASSIFICATION: C21, L60, O13, O30, Q20, Q58, F23

1. Introduction

The importance of environmental innovations (EIs) for achieving sustainable growth and win-win competitive pathways is by now widely recognized. On the one hand, in several countries policy makers consider EIs fundamental to reach sustainable patterns of growth and place EIs in their policy agendas: the Environmental Technologies Action Plan adopted by the European Commission in 2004 and the Europe 2020 strategy are main examples.

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On the other hand, EIs have been argued to be important drivers of the competitiveness of firms (Porter & Van der Linde, 1995; Ambec & Barla, 2002, 2006; Wagner, 2006; Ambec *et al.*, 2010; Porter, 2010).

EIs are also gaining importance in innovation studies.[1] Their manifold nature of technological, social and institutional innovations appears one of their most distinguishing feature, calling for an "EI theory", which extends the focus of the general one to the influence of environmental policy and institutional factors (Horbach, 2008). In a consistent way, with respect to EIs, effects and policy implications need to be addressed at a multiple level of analysis, by considering technologies, organizational processes and societal issues (Kemp, 2000).

On this basis, the need of investigating EIs with a plural theoretical framework and an eclectic methodology has come out (e.g. Elzen *et al.*, 2004). In particular, bridging innovation economics with ecological economics is emerging extremely fruitful to address the peculiarities of EIs (such as the "double-externality problem" and the "regulatory push/pull effect", on which see Horbach *et al.*, 2011) and to consider the regulatory instruments which influence their adoption (Rennings, 2000). On the other hand, EIs hesitate entering into other innovation-related fields of investigation, such as industrial dynamics (Andersen, 2008) and regional studies (Mirata & Emtairah, 2005), whose main topics—such as, for example, firm entry/exit and localization/agglomeration, respectively—have remained so far "neutral" to the consideration of non-standard technological innovations.

This is to us quite unfortunate and mainly due to an approach to EIs which misses their actual, complex nature, by focusing on "environmental technologies". On the contrary, as we will claim, EIs need to be consistently encapsulated in a "system" kind of approach (Kemp, 2010),[2] which brings to the front less-standard innovation drivers such as networking, spatial relationships and international strategies. This is even more so for firms located in regions and local production systems (LPS) characterized by "thick" markets and institutions (Amin & Thrift, 1995; McLaren, 2003).

Consistently with this system perspective, this paper intends to compare the relative weight that relational kind of drivers—such as networking, agglomeration economies and international relationships—have with respect to corporate kind of drivers—such as R&D, training and information and communication technologies (ICT).

The paper is organized as follows. Section 2 reviews the relevant literature and puts forward the main hypotheses. Section 3 illustrates the dataset and the methodology used to test them. Section 4 summarizes the main results of the econometric investigation. Section 5 concludes and suggests new items to be put on the research agenda.

2. Background Literature and Research Hypotheses

Although they have attracted a lot of attention since seminal works (Kemp, 1997, 2000; Rennings, 2000), EIs are still in a development phase in terms of definitions and analysis. The research project funded by the European Union (EU) called "Measuring Eco-Innovation"

[1] Among the others, the relevance of EI has been debated widely in Horbach (2008), Frondel *et al.* (2008), De Marchi (2012), Horbach *et al.* (2011) and Oltra and Saint Jean (2009).

[2] See Kemp (2000, 1997) and Kemp and Pontoglio (2011), and various papers in the recent special issue in *Industry and Innovation* edited by Renè Kemp and Vanessa Oltra.

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(MEI) consolidated the state of the art and provided (necessarily) broad, but careful definitions: an EI is defined as

> the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives.

Equating EIs to environmental technologies, as numerous project-based definitions do (e.g. CML *et al.*, 2008; Europe Innova, 2008; UNU-MERIT *et al.*, 2008), is however not entirely appropriate. EIs do not relate only to specific technologies. They also include new organizational methods, governance models and knowledge-oriented innovations. These innovations, in turn, are closely linked to education and training, and ultimately to human capital.

When taken outside their purely technical dimension of (improved) environmental impact, EIs can be seen to have a *systemic dimension* (e.g. Andersen, 2004; Horbach, 2008) and call for a system perspective (neo-Schumpeterian and evolutionary), which has emerged since long as the most convincing in dealing with innovation (e.g. Edquist, 1997; Edquist & McKelvey, 2000). This is a perspective which considers EIs as techno-organizational innovations, benefiting from network relationships—both internal and external to a certain geographically delimited system—and institutional embeddedness [see Boons and Wagner (2009) for a discussion of different "system levels" of EI].[3]

A system perspective to EI appears even more important when we refer to "LPS", generally meant as concentrations of co-localized small and medium enterprises (SMEs), marked by strong production specialization (e.g. Lombardi, 2003; Belussi & Sedita, 2011). In particular, it is important with respect to that specific typology of LPS (Markusen, 1996), which is represented by "industrial districts" (IDs). Their firms are in fact further characterized by production relationships along the value chain (typically in the form of subcontracting) and by the embeddedness in a network of social and economic relations of trust, co-operation and competition (e.g. Becattini, 1990; Dei Ottati, 1994; Sforzi, 2009).

LPS (and IDs) are increasingly more open to global competition and to the opportunities and threats that their firms face by becoming part of global value chains (e.g. Agostino *et al.*, 2011). Environmental pressures, especially those connected to international delocalization strategies (e.g. Mazzanti *et al.*, 2011), are for sure one of the most important of them (e.g. Cainelli & Zoboli, 2004; Dei Ottati, 2009). However, their analysis is still at an initial stage. Two sets of issues will be addressed here with respect to EIs: (i) networking and spatial relationships (agglomeration economics) and (ii) international strategies.

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[3] The works using this perspective have been recently cumulating. Among the others, see Cleff and Rennings (1999), Rennings (2000), Brunnermeier and Cohen (2003), Rennings *et al.* (2004, 2006), Wagner (2006, 2007a, 2007b, 2008), Horbach (2008), Johnstone and Labonne (2009), Ziegler and Nogareda (2009), Horbach and Oltra (2010) and Kesidou and Pemirel (2010).

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2.1 EI, Local Networks and Spatial Agglomeration

The importance of networking activities, both among firms and between firms and other kind of organizations (in particular, research organizations), has been largely recognized in urban and regional studies (Fritsch & Schwirten, 1999; Fritsch, 2001). In particular, several empirical works have shown that they can partially substitute for economies of scale in local environments, characterized by SME (e.g. Moreno & Casillas, 2007). This is also true for technological innovations (e.g. Hall *et al.*, 2009). Indeed, local SMEs usually lack the resources and incentives required to engage in formal innovative efforts such as R&D (Czarnitzki & Hottenrott, 2009). Although there are sectoral specificities, networking (along with proximity) is an essential strategy for SMEs' innovation in general (Freel, 2003; Capaldo, 2007). Firms in networks cooperate and compete, and this drives the evolution of knowledge and competences in sectoral systems of innovation and technological systems (Geels, 2004).

Following a system perspective, a similar argument can be extended to the introduction of EIs by firms, where the interaction with other agents (competitors, clients, suppliers, public institutions) can be argued to be an important driver (e.g. Geffen & Rothenberg, 2000). First of all, investments in EIs and EI-inspired organizational practices benefit from important inter-firm and inter-sectoral, network externalities: in the form of both environmental-knowledge spillovers and rent-kind of spillovers, affecting the allocation of EI-related incentives (e.g. Fritsch & Franke, 2004; Costantini *et al.*, 2010). Second, networking increases the efficiency of that particular kind of innovation–cooperation through which EIs are introduced. In particular, it enables collective learning and monitoring devices, which are important for the use of such negotiated instruments as voluntary agreements (e.g. Aggeri, 1999). Finally, inter-firm and other inter-organizational relationships favour the emergence of learning economies in the adoption and diffusion of EIs (e.g. Cantono & Silverberg, 2009).

All in all, network economies are important if we consider EIs as representing a transition towards a new sustainable, socio-technical regime, in which the economic actors do not have sufficient resources to influence unilaterally (Smith *et al.*, 2005). Given the necessary complementarities in skills and technology, networking—as a factor that is external to the firm, but internal and idiosyncratic to the local (innovation) system—becomes essential for achieving more radical and relatively new innovations such as EIs.[4]

On the basis of these arguments, we can put forward the following hypothesis:

HP1: Innovation–cooperation with both public and private local actors positively affects the introduction of EIs by local firms.

In addition to networking, the analysis of EIs in LPS brings to the front another related, but different issue: the role of spatial proximity. Indeed, firms in LPS are also and above all

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[4] Particularly relevant in this last respect is an important hypothesis that emerged from the social capital literature (Glaeser *et al.*, 2002), that is, the positive relationship between R&D and social capital. In an impure public goods framework (Cornes & Sandler, 1986), social capital arises as an intangible asset, defined as firm investments in cooperative/networking agreements (Capello & Faggian, 2005; Mancinelli & Mazzanti, 2009). The role of social capital investments for firms' innovation at the local level emerges also from different perspectives (e.g. Cooke & Wills, 1999). We also note a bulk of studies that assessed the role of cooperative behaviour for driving the adoption of technological innovation (Fritsch & Lukas, 2001; Cassiman & Veugelers, 2002, 2005; Fritsch & Franke, 2004).

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co-located in the territory and benefit from a number of economic advantages due to their geographical proximity, which in urban and regional studies go under the general heading of "agglomeration economies". Among these, particularly relevant are those externalities that accrue to local firms from their production specialization in specific economic activities (e.g. sectors). In brief, these are increases of internal efficiency due to learning-by-doing, reduced search costs from pooled labour markets and lower transaction costs from the availability of specialized institutions (e.g. banks, chambers of commerce and so on).

These effects have been shown to be particularly important in IDs, where they combine with virtuous social relationships and the availability of a pervasive social capital (Brusco, 1982). In IDs, these effects have been shown to increase firms' technological innovation in general, by setting at work different kinds of knowledge spillovers and learning-by-interacting effects (e.g. Cainelli, 2008). Only recently and in circumscribed empirical applications (e.g. with respect to one province, Reggio Emilia, of the ER region), similar results have been obtained also with respect to EIs (e.g. Mazzanti & Zoboli, 2008, 2009). Belonging to the same ID has been found to increase EIs by firms through the emergence of complementarity effects among the firms' innovation activities and through their embeddedness in environmentally friendly institutional set-ups. These results support previous case study evidence on the importance of spatial proximity for those processes of collective learning which lead to the adoption of EIs in a regional context (e.g. Mirata & Emtairah, 2005).

We expect that the following hypothesis is to hold in our wider empirical application:

HP2: Agglomeration economies from being member of an ID positively affect the introduction of EIs by local firms.

2.2 EI, International Strategies and Local Relationships

Investigation of the environmental effects on firms' internationalization—and globalization in general—is currently dominated by the so-called pollution heaven hypothesis (PHH). Accordingly, international trade and foreign direct investments (FDIs) are assumed to be channels through which firms exploit asymmetries in international environmental regulations (Wagner, 2001). In brief, they do so by re-locating production/trade of pollution-intensive goods from the "home" country to relatively less regulated host countries (e.g. Jeppesen *et al.*, 2002; Grether & de Melo, 2004).[5]

The focus on PHH tends to obscure the positive impact that globalization could have on EIs by firms, both through foreign competition (e.g. Gorodnichenko *et al.*, 2010) and international R&D spillovers (e.g. Franco *et al.*, 2011). Not only have asymmetries in environmental regulations been recognized of secondary importance for the firms' environmental performances (e.g. Dasgupta *et al.*, 2000). But it has also been shown that internationalization provides higher incentives for firms to adopt more environmentally sustainable behaviours. This fact tends to turn the PHH argument on its head (Christmann & Taylor, 2001).

[5] The PHH has not found consistent empirical support yet (e.g. Brunnermeier & Levinson, 2004; Smarzynska Javorcik & Wei, 2004, Levinson & Taylor, 2008, Wagner & Timmins, 2009). In this paper we do not intend to directly assess the role of regulatory instruments in driving EI, an aspect that is central to PHH.

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Although these arguments have been mainly developed for the firms' attitudes towards environmental self-regulation—i.e. to exceed locally enforced government regulations (e.g. Rondinelli & Berry, 2000)—their extension to EIs is straightforward: especially, in terms of the relationship between FDI and EIs. First, FDI are an important mechanism for (local) firms to enter global networks, within which knowledge about environmental best practices and innovation can be shared and circulated (Gulati *et al.*, 2000). Second, FDI provide local firms with transnational linkages for increasing environmental efficiency: for example, through the generation of environmentally beneficial technological spillovers, stimulation of competitive dynamics and the effect of "green" procurement requirements on domestic suppliers (Neumayer & Perkins, 2003). Third, FDI expose firms to higher institutional pressures for environmental sustainability and innovativeness, providing a higher reputation for environmental responsibility (Kostova & Zaheer, 1999). Finally, given the larger scale of their operations, multinational corporations (MNCs) usually obtain financial benefits from the adoption of standard environmental strategies across the world. They also have higher capabilities to exploit the so-called "Porter hypothesis" (Porter & van der Linde, 1995; Ambec & Barla, 2002, 2006; Wagner, 2006; Ambec *et al.*, 2010; Porter, 2010) "offset", in the medium long run (Requate, 2005; Rexhauser & Rennings, 2010) the initial cost of environmental regulations (Costantini & Mazzanti, 2012).[6]

On the basis of these arguments, and using the multinational ownership of the local firms as a proxy of their involvement in FDI, we propose the following hypothesis.

HP3: Multinational ownership of local firms positively affects the introduction of EIs.

A similar positive effect on the adoption of EIs can be hypothesized with respect to the involvement of (local) firms in international trade (Wakelin, 1998). First, in general, international customers can be expected to exert higher environmental pressures than local customers on innovating firms. Indeed, if they are located downstream along the value chain of international customers, domestic firms will be required to adhere to environmental supply standards, which is likely to spur them to EIs (Kraatz, 1998). Second, export-oriented firms are induced to adopt EIs to overcome the trade barriers imposed to non-sustainable producers in exporting to certain markets. Meeting the highest environmental standards in the largest export markets will reduce these barriers (Rugman *et al.*, 1999). Third, as well as FDI, exports can generate knowledge spillovers for domestic firms—interacting with foreign competitors on the adoption and/or improvement of green technologies—expose them to keener competition and finally, motivate them to invest in technologies with better environmental performance (Perkins & Neumayer, 2008). Also, both FDI and trade accelerate the cross-border diffusion of environmental best practices and increase the pressure on firms to be environmentally sustainable through closer scrutiny of environmental performance (Vogel, 2000).[7]

[6] Germany is a leading exponent of this strategy (Frondel *et al.*, 2010; Rehfeld *et al.*, 2007; Kammerer, 2009).

[7] Some studies focus on the specific propensity of export-oriented SMEs to adopt EIs (Martin-Tapia *et al.*, 2008), given that SME account for 60% of the world's greenhouse gas emissions.

The previous arguments might suggest a simple export-based version of what HP3 states for FDI. However, as has been shown with respect to self-enforcing environmental regulations, the positive effect is less "automatic" than in the case of FDI (Christmann & Taylor, 2001). The identity of the trade partner (and of the traded goods) is a crucial condition for it to hold. In brief, trade relationships with countries with low environmental efficiency would be expected to reduce the positive externalities identified above, or even countervail them into negative ones. With this important caveat, we propose the following hypothesis:

HP4: Providing that international markets are characterized by high levels of environment sustainability, the export propensity of local firms positively affects their introduction of EIs.

In concluding this section about the international strategies of the firms, it should be noted that in LPS they eventually intertwine with their local relationships. As many empirical works in regional economies have shown, under the pressure of globalization, local networks are becoming sort of sub-networks of larger international ones: an idea to which the global value chain approach explicitly refers (e.g. Coe *et al.*, 2008; Agostino *et al.*, 2011).

This overlapping of local and global relationships is extremely important in terms of innovation. This is clearly shown in the literature on international R&D spillovers, where the impact of FDI on innovation depends on the relationships between foreign-owned and local firms: both in the case they are competitors (horizontal spillovers) and suppliers/customers (vertical spillovers) (e.g. Motohashi & Yuan, 2010). In the same respect, the embeddedness of foreign-owned firms in the local institutional set-up is also very relevant (e.g. van Beers *et al.*, 2008; Coe *et al.*, 2009). Our expectation is that this interlinking is relevant also in the context of EIs, as it is suggested by the following hypothesis:

HP5: HP3 and HP4 are reinforced by local firms' being part of an innovation–cooperation network and/or belonging to an ID.

2.3 Other EI Drivers and Complementarities

Although the focus of this study is on local networking and international strategies, in testing our hypotheses we also consider (technically, "control for") other aspects that emerge from the literature to have a role in spurring EIs (e.g. Horbach, 2008; Mazzanti & Zoboli, 2009). This is so both for econometric reasons (mitigating the omission of relevant variables and therefore reducing the effects of unobserved heterogeneity) and for enriching our understanding of the phenomenon under investigation.

A first important aspect is represented by the overall innovation intensity of firms in the fields of technology (radical, incremental, product, process) and organization (quality circles, job-rotation practices, labour flexibility and so on). Indeed, because of complementarity effects between the respective inputs and outputs, correlations among different innovation fields have been found to stimulate EI (e.g. Mazzanti & Zoboli, 2008).

Training in firms deserves attention too in the adoption of EIs. In particular, the level of training administrated to the employees has been found to "filter" the impact that the stakeholder pressure exerts on the adoption of EI (e.g. Sarkis *et al.*, 2010). For example, a

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weak company's business culture and a low-skilled human capital have been found to hamper corporate environmental actions (e.g. Daily & Huang, 2001).

The development of ICT is also important in the context of EI.[8] Berkhout and Hertin (2004), for example, distinguish three environmental effects of ICT: *direct* (pollutant) effects, driven by the larger scale of production and use of activities that ICT allow for; *indirect* effects, due to the dematerialization of introducing ICT in production processes (on the actual extent of these effects, see Montresor & Vittucci Marzetti, 2011) and generating lower environmental impacts; *structural change* effects, linked to behavioural comprehensive effects and value-based changes for firms and households. When data availability permits it, the research hypothesis to target would be whether the more diffuse and intense—not just present—is the ICT adoption in a firm, the more likely is that EI and ICT will be correlated and integrated in the firm's innovative strategy. Direct compensating effects may emerge if innovation adoption increases the firm's turnover and production.[9] We are able to exploit intensity in ICT adoption proxies, given the several questions on the firm strategy. Given its importance, further research on the relationship between ICT and EI will be the scope for future analyses.

Our set of "controls" obviously includes also standard innovation regressors, such as general—i.e. not specifically environmental—R&D expenditures. Their expected role is to improve the "knowledge capital" of the firms and their "absorptive capacity" of external knowledge, also and above all in terms of EI (Horbach, 2008; Horbach & Oltra, 2010). On the other hand, the so-called "green R&D", specifically addressed to environmental outcomes (Arimura *et al.*, 2007), will not be retained as a covariate given the very high correlation with EI. Industry, geographical and size variables conclude the list of the standard innovation controls.

As we said in Section 2, in addition to the previous techno-economic drivers, the system approach to EIs that we are following would require us to consider regulatory and policy stringency aspects that frame the firm and the sector to which it belongs. We note here that some contexts, such as the Italian one we investigate, have been historically quite free of environmental policy measures (e.g. environmental taxation only amounts at 0.02% of gross domestic product (GDP) even today, and it is landfill taxation for the great part; the EU emissions trading system (ETS) which has been in place since 2005 is the only real policy in action). In order to deal with regulations in any case, a possible option is to introduce, as often is the case in the innovation literature, some sector-specific indicators that capture policy and regulation contents. Accordingly, at least our baseline investigation model will be augmented by inserting a number of proxies which, more and less indirectly, are retained to account for these aspects and to positively correlate with the introduction of EIs by the firms in LPS.

[8] More in general, innovation in ICT has been claimed to stimulate "green" economic growth and spur a recovery from the current global crisis (OECD, 2009).

[9] Apart from this and other few recent contributions (Berkhout & Hertin, 2004; Collard *et al.*, 2005; Hilty *et al.*, 2006), how ICT is integrated with EI has been rather ignored.

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3. Empirical Analyses

3.1 Dataset and Descriptive Statistics

The dataset used in this paper is based on information drawn from a very rich and detailed survey conducted in ER on a sample of 555 manufacturing firms with more than 20 employees.

ER is a North-East Italy region (at the NUTS2 level in the relevant EU classification), with a population of nearly 5 million people, which accounts for about 20% of Italian industrial production (ISTAT, 2010). For a number of reasons, ER represents an ideal test for the hypotheses we put forward in the paper. On the one hand, it is well known for being an ID-based, open local system, rich in networking and spatial agglomeration of firms and institutions: also called the “Emilian model” (Brusco, 1982). On the other hand, the industrial system of the region is export-oriented and outperforms the innovativeness of the whole country (along with the Lombardy region) along a series of innovative indicators (Hollanders *et al.*, 2009). From an environmental point of view, ER compares to the other Italian regions in a non-unambiguous way (ISPRA, 2009). On the one hand, it is (in 2009) among the best regions in terms of environmental management system’s (EMS) registered organizations, ECOLABEL licenses, efforts to improve air quality and other specific EIs. On the other hand, it is also relatively polluting compared with other industrial areas of Italy (Costantini *et al.*, 2010; Mazzanti & Montini, 2010). For example, ER is (in 2009) the fourth region (after Lombardy, Piedmont and Veneto) in terms of concentration of “major-accident hazard” (MAH) establishments and it includes one of the most MAH concentrated provinces within its boundaries.[10]

As far as our empirical application is concerned, a structured questionnaire on EI (and innovation in general) was administered to the ER firms in 2009, and referred to the period 2006–2008: the same as the most recent EU community innovation survey (CIS), which for the first time included questions on EI.[11]

Tables 1–3 show information on sector and size distribution of EIs in the sample. The survey response rate was around 30%, and the data are strongly representative of industry, size and province. Table A2 in Appendix A provides details about the percentage distribution of the population and of the sample.

The overall share of firms adopting EIs is 20% of the total. The analysis of the motivations behind the adoption of EIs (for the 111 EIs active firms) by size and sector (Table A3 in Appendix A) is worth being commented on. In general terms, the most striking share difference is between “current” regulations, which are relevant for 79% of innovative firms, and future regulations (only 48%). Current regulations are the main motivation that overwhelms market conditions. While

[10] MAH is defined as “an establishment containing dangerous substances (used in the production cycle or simply stored) in quantities that exceed the thresholds established under the Seveso regulations (Directive 82/501/ EEC, plus subsequent modifications)” (ISPRA, 2009, p. 47).

[11] Some of the most relevant questions of the survey are reported in Appendix B. About the pros and cons of using CIS data, see Mairesse and Mohnen (2010).

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Figure 1. Intensity (number of firms) of CO_2 reduction EIs by province in ER (2006–2008). *Source*: Our own elaborations on survey data.

Table 1. Population and sample distribution (%) by sector and size.

	Size					
Industry	20–49	50–99	100–249	250 +	*Total*	Total
Food	5.65	1.94	1.16	0.64	9.39	382
Textile	6.17	1.47	0.71	0.37	8.73	355
Wood, paper and other industries	7.79	1.67	0.79	0.42	10.67	434
Chemical and rubber	5.01	1.87	1.11	0.42	8.41	342
Non-metallic mineral products	3.81	1.23	1.18	0.79	7.01	285
Metallurgy	16.99	3.29	1.18	0.25	21.71	883
Machinery	21.44	6.37	4.06	2.24	34.10	1.387
Total	66.86	17.85	10.18	5.11	100.00	
Total	2720	726	414	208		4.068

size cannot be taken as a relevant factor here, sectorally speaking we observe that ceramics leads the way mainly in response to market demand.

The industrial specialization of the region should be carefully considered too. In particular, given the role of the sector in the historical development of the region, the gloomy performance of machinery and equipment might be somewhat surprising. However, the share of EI adoption for the sector appears in descriptive statistics more in line with a key regional sector, such as food, than with industrial sectors, such as ceramics and metallurgy.

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Table 2. Sample distribution by size.

Industry	Size 20–49	50–99	100–249	250 +	*Total*	Total
Food	2.88	3.78	1.62	0.54	8.8	49
Textile	2.70	1.44	1.62	0.54	6.3	35
Wood, paper and other industries	3.60	2.88	1.08	0.90	8.5	47
Chemical and rubber	3.78	3.42	1.80	1.08	10.1	56
Non-metallic mineral products	1.62	2.16	1.62	2.16	7.6	42
Metallurgy	8.83	5.77	2.16	0.18	16.9	94
Machinery	14.05	15.32	7.39	5.05	41.8	232
Total	37.48	34.77	17.30	10.45	100.0	
Total (a.v.)	208	193	96	58		555

This outcome is apparently coherent with the effects of regulations we will comment on later, given that ceramics and metallurgy are under the EU ETS regulation.[12]

3.2 Modelling Strategy

Our econometric model is based on the following probit specification:

$$\Pr\left(Y_i = \frac{1}{X}\right) = \Phi(X'\beta), \tag{1}$$

where X is the vector of identified regressors, Φ is the cumulative distribution function of the standard normal distribution of X and Y_i is a dummy variable taking the value 1 if firm i introduces an EI, and 0 otherwise.

We consider five different types of EIs for Y, related to, respectively: (i) materials, (ii) CO_2, (iii) emissions, (iv) ISO_{14001} and (v) EMS. However, given the very small number of cases, the adoption of environmental management system (EMS) will be not analysed, remaining with four typologies. At first, model (1) is estimated with respect to the occurrence of any of these four groups of EIs, irrespectively from their nature. Then, in order to investigate whether our five hypotheses present some specificities in different realms, we re-estimated model (1) for each of the different kinds of EIs separately, paying attention to more radical EIs as CO_2 abatement. Finally, an augmented version of this baseline model is estimated to capture the role of policy and regulatory issues in a robustness check exercise.

The vector X denotes the regressors. In order to test for our first hypothesis (HP1), we construct a set of specific dummies indicating whether, in developing and realizing EIs, a firm has collaborated with customers, suppliers, competitors and universities, respectively. Although it has just a dichotomic outcome, this set of variables is a standard one in the

[12] For brevity, we do not comment on other descriptive statistics and refer to the extensive presented tables which offer detailed insights by sector and size.

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Table 3. Adoption of EIs by industry and size: percentage of firms.

Industry	Size 20–49	50–99	100–249	250 +	*Total*
Adoption of at least one eco-innovation					
Food	0.24	0.07	0.30	0.14	0.18
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.05	0.17	0.40	0.50	0.19
Chemical, rubber, plastics	0.24	0.24	0.54	0.40	0.32
Non-metallic minerals	0.13	0.17	0.40	0.36	0.24
Metallurgy	0.22	0.35	0.40	0.67	0.30
Machinery	0.10	0.13	0.20	0.29	0.16
Total	0.14	0.17	0.29	0.30	0.20
Process/product innovation: emissions					
Food	0.06	0.00	0.30	0.14	0.10
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.05	0.00	0.30	0.00	0.09
Chemical, rubber, plastics	0.24	0.06	0.38	0.40	0.23
Non-metallic minerals	0.13	0.06	0.40	0.27	0.17
Metallurgy	0.14	0.31	0.27	0.67	0.22
Machinery	0.07	0.08	0.17	0.23	0.12
Total	0.10	0.10	0.23	0.23	0.14
Process/product innovation: energy/materials					
Food	0.06	0.07	0.10	0.14	0.08
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.05	0.17	0.20	0.50	0.15
Chemical, rubber, plastics	0.19	0.12	0.38	0.40	0.23
Non-metallic minerals	0.13	0.17	0.40	0.36	0.24
Metallurgy	0.10	0.31	0.33	0.67	0.21
Machinery	0.09	0.10	0.15	0.20	0.12
Total	0.09	0.14	0.21	0.26	0.15
Process/product innovation: CO_2 abatement					
Food	0.06	0.00	0.10	0.14	0.06
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.05	0.00	0.20	0.00	0.06
Chemical, rubber, plastics	0.10	0.06	0.23	0.20	0.13
Non-metallic minerals	0.13	0.06	0.40	0.27	0.17
Metallurgy	0.12	0.31	0.20	0.67	0.20
Machinery	0.06	0.10	0.15	0.17	0.11
Total	0.07	0.10	0.17	0.19	0.11
EMS					
Food	0.12	0.00	0.00	0.14	0.06
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.00	0.00	0.10	0.25	0.04
Chemical, rubber, plastics	0.00	0.00	0.15	0.20	0.05
Non-metallic minerals	0.00	0.00	0.20	0.18	0.07
Metallurgy	0.04	0.04	0.00	0.00	0.03

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Table 3 – *continued*

Industry	Size 20–49	50–99	100–249	250 +	*Total*
Machinery	0.01	0.00	0.02	0.00	0.01
Total	0.02	0.01	0.05	0.07	0.03
ISO_{14001}					
Food	0.06	0.07	0.20	0.14	0.10
Textile and clothing	0.00	0.00	0.00	0.00	0.00
Wood, paper, publishing	0.05	0.08	0.40	0.00	0.13
Chemical, rubber, plastics	0.10	0.12	0.54	0.20	0.21
Non-metallic minerals (ceramics)	0.00	0.17	0.00	0.18	0.12
Metallurgy	0.08	0.23	0.13	0.67	0.15
Machinery	0.03	0.06	0.20	0.26	0.11
Total	0.05	0.10	0.22	0.21	0.12

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literature on innovation–cooperation and takes stock of the several works based on CIS data (Mairesse & Mohnen, 2010).

In order to test HP2, we first constructed a dummy to capture the most virtuous agglomeration effects of the region, whose economic history (Brusco, 1982) suggests us to expect for firms located in the so-called Central Emilia, covering the provinces (administrative jurisdictions between Region and Municipality, at the NUTS3 level) of Bologna, Reggio Emilia or Modena. In brief, the dummy Central Emilia takes value 1, if the firm is based in one of these three provinces, and 0 otherwise.

Second, we include a generic ID dummy, which indicates if the firm is based in one of the 11 IDs that the Italian National Statistical Office (ISTAT) has identified in the ER region.[13] Finally, in order to consider one of the strongest manufacturing specialization of the region, we construct another dummy—mechanical district—which identifies firms belonging to the IDs of ER which have a specialization in the mechanical sector.

To test HP3, HP4 and HP5, the degree of internationalization of ER firms is captured by two variables: one binary and the other continuous. On the one hand, FDI are proxied by looking at the ownership of the firm, building up a foreign ownership dummy, which is equal to 1 if the firm belongs to a group with a foreign parent company, and 0 otherwise. On the other hand, the firm's involvement in international trade is captured by calculating its export propensity, defined as the share of each firm's total exports on its total sales.

As far as the controls at the company level are concerned, unfortunately the available data allow us to deal with them mainly with dummy variables. More precisely, R&D is a dummy, which identifies those firms which have made, over the reference period, occasional or continuous investments in R&D. ICT is continuous 0–1 variable that summarizes the intensity of adoption on ICT activities (i.e. build up a company website, make some kind of Internet-based business

[13] ID are identified following the Sforzi-ISTAT methodology (ISTAT, 1997). Although the methodology suffers from some limitations (see Brusco *et al*., 1996, p. 19), which can be overcome by applying more complex and sophisticated statistical algorithms (Iuzzolino, 2005), we here use the official definition of ID by ISTAT.

Table 4. Descriptive statistics: dependent variables.

	Observed	Mean	Standard deviation	Minimum	Maximum
Environmental innovations	555	0.200	0.400	0	1
Innovation in material efficiency	555	0.147	0.355	0	1
Innovation in CO_2 abatement	555	0.115	0.319	0	1
Innovation in emission abatement	555	0.140	0.347	0	1
ISO_{14001} adoption	555	0.120	0.326	0	1

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(B2B or B2C) and resort to some kind of company intranet). Finally, the training coverage of the firm is defined as the share of trained employees over total employment.

Finally, as far as the role of regulation and policy stringency is concerned, in order to disentangle general sector effects from sector policy ones, we first exploit the sectoral data made available by the Italian National Statistical Office (ISTAT) on "investments aimed at reducing firm environmental impacts". More precisely, we focus on the impact of the total of these investments, of investments in air pollution abatement and in waste reduction (see Table A4 in Appendix A).

In addition, assuming that, in line with other works in the field, the higher the overall regulation stringency to which a firm is associated (depending upon economic instruments and command–control bills to which the sector is subject), the higher its environmental efficiency, as an indirect proxy of the former we use national accounting sector data (National Accounting Matrix with Environmental Account, NAMEA) for constructing efficiency indicators like the ratios between greenhouse gases (GHGs) and value added (VA), and acidificants (ACID) and VA (see Table A5 in Appendix A).

All in all, we do expect that these indicators we have selected will be correlated, respectively, positively and negatively, to EI as a whole. On the other hand, given the quite indirect nature of these proxies (see Section 3.2), rather than inserting them in the baseline specifications of model (1), we build up an augmented version, which we use as robustness check. Furthermore, in order to be parsimonious, we limit this check to the impact on the general EI.

Tables 4 and 5 report the main statistics of the dependent variables and the significant covariates, respectively (Tables A6 and A7 in Appendix A show their correlation coefficients). All descriptive statistics are available upon request.

Rather than reporting coefficients, our estimates report the marginal effect, that is, the change in the probability of an infinitesimal change in each independent, continuous variable and, by default, reports the discrete change in the probability for the dummy variables.

The (potential) endogeneity of "foreign ownership" is an issue that needs to be dealt with, since our specification assumes it to be exogenous. The economics and management literature suggests that EI can affect inward FDI, thus generating a classical reverse causality problem (Ziegler & Nogareda, 2009). We adopt an instrumental variable strategy, using as instrument the firm's membership to a business group. By definition, firms owned by multinationals belong to a business group, while this cannot be the case for firms owned by domestic owners. Anyway, using this instrument and adopting a test of (weak) exogeneity

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Table 5. Descriptive statistics: relevant independent variables.

	Observed	Mean	Standard deviation	Minimum	Maximum
R&D programmes	555	0.800	0.400	0	1
University cooperation	555	0.114	0.167	0	1
Suppliers cooperation	555	0.174	0.262	0	1
ICT adoption	555	0.591	0.171	0	1
Training coverage (share of trained employees)	555	37.801	36.909	0	100
ID	555	0.603	0.489	0	1
Export propensity	555	33.384	31.082	0	100
Foreign ownership	555	0.117	0.321	0	1
Environmental investments (total)[a]	555	115.63	127.75	14.99	416.49
Waste reduction investments[a]	555	10.40	11.15	0.60	429.95
Air emissions investments[a]	555	44.02	61.24	4.18	213.44
GHG on VA[a] (million tonnes/million euro)	555	0.843	1.56	0.059	3.472

Notes: Statistics for not significant covariates pertaining to other cooperation actions and innovation realms are available. Investments are in millions of €. [a]Sector variable.

for probit models, proposed by Smith and Blundell (1986), we do not reject the null hypothesis that the model is appropriately specified with all explanatory variables exogenous. The *p* value of the test is in fact equal to 0.000. Potential endogeneity could also concern our export propensity variable. However, this is not a problem in our analysis since, as we will see, this variable is never statistically significant.

4. Results

We start by presenting the results of those techno-economic aspects which we have recognized as EI drivers (Section 2.3). We then move to the test of our hypotheses, by considering different kinds of EIs (Tables 6–10).[14] Finally, we will comment on the outcomes of the robustness check with the policy/regulatory indicators (Table 11).

4.1 The "Standard" EI Drivers

First of all, the major driver of "standard" innovations, i.e. *R&D*, in our case is not significant. Although at first sight this might appear an unexpected result, to a deeper scrutiny it is not completely so. On the contrary, it is consistent with what other works on the determinants of EI find. The recent paper by Horbach *et al.* (2011), for example, which analyses the technology

[14] EMS was in the end excluded given the very low number of adopting firms. Still, we note that though the correlation between technological innovation adoption and ISO/EMS can be analysed (see Ziegler & Nogareda, 2009), we here aim at investigating the broad picture of EI adoptions, following the broad EI framework we have presented in Sections 1 and 2. Finally, bivariate probit analyses that test correlation between EIs were not implemented since past works had already focused on that issue.

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Table 6. Overall EI, cooperation, agglomeration and internationalization.

	Dependent variable: *EIs*				
Estimation method: dprobit	[1] d*F*/d*x*	[2] d*F*/d*x*	[3] d*F*/d*x*	[4] d*F*/d*x*	[5] d*F*/d*x*
R&D	−0.011 [−0.25]	−0.006 [−0.15]	−0.007 [−0.17]	−0.018 [−0.40]	−0.013 [−0.29]
ICT adoption	0.229** [2.23]	0.233** [2.27]	0.221** [2.17]	0.244** [2.40]	0.248** [2.43]
Training coverage	0.001*** [4.26]	0.001*** [4.22]	0.001*** [4.21]	0.001*** [4.33]	0.001*** [4.27]
Central Emilia dummy	0.059* [1.71]	0.059* [1.71]	0.060* [1.76]	0.056 [1.62]	0.055 [1.60]
20–49 empl.	−0.028 [−0.51]	−0.025 [−0.46]	−0.025 [−0.46]	−0.019 [−0.33]	−0.015 [−0.26]
50–99 empl.	−0.053 [−1.08]	−0.048 [−0.99]	−0.045 [−0.91]	−0.036 [−0.70]	−0.031 [−0.60]
100–249 empl.	0.062 [1.07]	0.070 [1.20]	0.075 [1.26]	0.076 [1.25]	0.085 [1.38]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0002 [0.48]	0.0003 [0.56]	0.0003 [0.63]	0.0003 [0.52]	0.0003 [0.60]
ID	−0.106*** [−2.73]	−0.123*** [−2.99]	–	−0.101** [−2.54]	−0.117*** [−2.86]
Mechanical district	–	–	−0.120*** [−2.73]	–	–
University cooperation	0.268*** [2.71]	0.256** [2.55]	0.258** [2.55]	0.309*** [2.76]	0.305*** [2.73]
Suppliers cooperation	0.205*** [3.54]	0.207*** [3.61]	0.207*** [3.57]	0.124* [1.88]	0.127* [1.92]
Foreign ownership	0.084 [1.63]	0.050 [0.96]	0.049 [0.95]	−0.147 [−0.61]	−0.038 [−0.52]
Foreign own. × ID	–	0.244 [1.51]	–	–	0.276 [1.45]
Foreign own. × Mech. District	–	–	0.293* [1.68]	–	–
University coop. × foreign own.	–	–	–	−0.147 [−0.61]	−0.225 [−0.88]
Suppliers coop. × foreign own.	–	–	–	0.441*** [2.91]	0.436*** [2.97]
Pseudo-R^2	0.186	0.190	0.188	0.202	0.206
N. Obs.	555	555	555	555	555

Note: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Robust standard errors; *t* statistics in parentheses.

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Table 7. Materials/resources reducing EI, cooperation, agglomeration and internationalization.

	Dependent variable: *material/resource reduction technology*				
	[1]	[2]	[3]	[4]	[5]
Estimation method: dprobit	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*
R&D	0.049 [1.41]	0.050 [1.44]	0.050 [1.43]	0.047 [1.34]	0.048 [1.38]
ICT adoption	0.257*** [3.21]	0.260*** [3.25]	0.255*** [3.20]	0.263*** [3.29]	0.267*** [3.34]
Training coverage	0.001*** [3.78]	0.001*** [3.76]	0.001*** [3.76]	0.001*** [3.77]	0.001*** [3.76]
Central Emilia dummy	0.023 [0.85]	0.023 [0.87]	0.024 [0.91]	0.021 [0.78]	0.020 [0.76]
20–49 empl.	−0.022 [−0.51]	−0.020 [−0.47]	−0.021 [−0.48]	−0.021 [−0.47]	−0.018 [−0.41]
50–99 empl.	−0.026 [−0.71]	−0.024 [−0.65]	−0.023 [−0.61]	−0.021 [−0.57]	−0.019 [−0.50]
100–249 empl.	0.020 [0.46]	0.024 [0.55]	0.026 [0.59]	0.021 [0.48]	0.026 [0.59]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0004 [0.94]	0.0004 [0.99]	0.0004 [1.03]	0.0004 [0.91]	0.0004 [0.96]
ID	−0.051 [−1.63]	−0.060* [−1.81]	–	−0.049 [−1.54]	−0.057* [−1.83]
Mechanical district	–	–	−0.061* [−1.74]	–	–
University cooperation	0.165** [2.23]	0.157** [2.07]	0.157** [2.06]	0.187** [2.21]	0.185** [2.19]
Suppliers cooperation	0.127** [2.89]	0.128*** [2.92]	0.128*** [2.90]	0.087* [1.73]	0.088* [1.76]
Foreign ownership	0.033 [0.92]	0.017 [0.45]	0.016 [0.43]	−0.016 [−0.32]	−0.019 [−0.38]
Foreign own. × ID	–	0.135 [1.15]	–	–	0.161 [1.31]
Foreign own. × Mech. District	–	–	0.168 [1.30]	–	–
University coop. × foreign own.	–	–	–	−0.077 [−0.50]	−0.142 [−0.93]
Suppliers coop. × foreign own.	–	–	–	0.187* [1.76]	0.183* [1.77]
Pseudo-R^2	0.201	0.203	0.203	0.208	0.210
N. Obs.	555	555	555	555	555

Note: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Robust standard errors; *t* statistics in parentheses.

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Table 8. Carbon reduction EI, cooperation, agglomeration and internationalization.

	Dependent variable: CO_2 *abatement technology*				
	[1]	[2]	[3]	[4]	[5]
Estimation method: dprobit	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*
R&D	0.019 [0.70]	0.021 [0.78]	0.021 [0.75]	0.019 [0.68]	0.020 [0.73]
ICT adoption	0.224*** [3.41]	0.224*** [3.44]	0.214*** [3.36]	0.225*** [3.46]	0.227*** [3.48]
Training coverage	0.0009*** [3.30]	0.0008*** [3.30]	0.0008*** [3.29]	0.0008*** [3.28]	0.0008*** [3.30]
Central Emilia dummy	0.052** [2.46]	0.051** [2.51]	0.055*** [2.69]	0.053** [2.54]	0.052** [2.54]
20–49 empl.	−0.003 [−0.09]	0.001 [0.03]	−0.004 [−0.01]	−0.004 [−0.12]	0.001 [0.03]
50–99 empl.	−0.011 [−0.38]	−0.006 [−0.21]	−0.004 [−0.16]	−0.008 [−0.25]	−0.002 [−0.06]
100–249 empl.	0.033 [0.89]	0.041 [1.12]	0.044 [1.18]	0.035 [0.91]	0.044 [1.13]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	−0.00002 [−0.08]	0.00002 [0.03]	0.00003 [0.12]	−0.00004 [−0.13]	−0.00001 [−0.04]
ID	−0.067*** [−3.08]	−0.075*** [−3.42]	–	−0.068*** [−3.17]	−0.074*** [−3.39]
Mechanical district	–	–	−0.078*** [−3.68]	–	–
University cooperation	0.138*** [2.57]	0.127** [2.32]	0.126** [2.29]	0.127** [2.09]	0.126** [2.10]
Suppliers cooperation	0.107*** [3.28]	0.107*** [3.39]	0.108*** [3.42]	0.071* [1.93]	0.073** [2.01]
Foreign ownership	0.052 [1.60]	0.028 [0.89]	0.026 [0.86]	−0.036 [−0.99]	−0.036 [−1.03]
Foreign own. × ID	–	0.220* [1.78]	–	–	0.194 [1.42]
Foreign own. × mech. District	–	–	0.277** [2.00]	–	–
University coop. × foreign own.	–	–	–	0.140 [1.03]	0.089 [0.68]
Suppliers coop. × foreign own.	–	–	–	0.170** [2.07]	0.160** [2.05]
Pseudo-R^2	0.221	0.227	0.231	0.234	0.238
N. Obs.	555	555	555	555	555

Note: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Robust standard errors; *t* statistics in parentheses.

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Table 9. Emission reduction EI, cooperation, agglomeration and internationalization.

	Dependent variable: *emissions abatement technology*				
	[1]	[2]	[3]	[4]	[5]
Estimation method: dprobit	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*	d*F*/d*x*
R&D	0.001 [0.03]	0.008 [0.24]	0.007 [0.22]	−0.001 [−0.03]	0.006 [0.20]
ICT adoption	0.141* [1.70]	0.144* [1.76]	0.131 [1.63]	0.145* [1.76]	0.149* [1.82]
Training coverage	0.001*** [3.72]	0.001*** [3.70]	0.001*** [3.67]	0.001*** [3.73]	0.001*** [3.71]
Central Emilia dummy	0.057** [2.21]	0.055** [2.25]	0.058** [2.39]	0.055** [2.14]	0.051** [2.11]
20−49 empl.	−0.017 [−0.39]	−0.011 [−0.26]	−0.012 [−0.29]	−0.014 [−0.32]	−0.006 [−0.16]
50−99 empl.	−0.057 [−1.56]	−0.048 [−1.34]	−0.045 [−1.26]	−0.053 [−1.41]	−0.042 [−1.16]
100−249 empl.	0.062 [1.37]	0.077* [1.71]	0.082* [1.78]	0.067 [1.46]	0.084* [1.82]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0001 [0.38]	0.0002 [0.59]	0.0002 [0.69]	0.0001 [0.33]	0.0002 [0.54]
ID	−0.079*** [−2.77]	−0.098*** [−3.53]	–	−0.076*** [−2.63]	−0.096*** [−3.45]
Mechanical district	–	–	−0.101*** [−3.68]	–	–
University cooperation	0.214*** [3.18]	0.192*** [2.85]	0.192*** [2.84]	0.244*** [3.19]	0.230*** [3.11]
Suppliers cooperation	0.152*** [3.55]	0.154*** [3.76]	0.154*** [3.75]	0.126*** [2.60]	0.126*** [2.71]
Foreign ownership	0.032 [0.81]	−0.009 [−0.26]	−0.009 [−0.28]	−0.142 [−0.87]	−0.016 [−0.35]
Foreign own. × ID	–	0.443*** [2.65]	–	–	0.499*** [2.85]
Foreign own. × Mech. District	–	–	0.508*** [2.82]	–	–
University coop. × foreign own.	–	–	–	−0.142 [−0.87]	−0.231 [−1.26]
Suppliers coop. × foreign own.	–	–		0.120 [1.14]	0.130 [1.36]
Pseudo-R^2	0.205	0.219	0.222	0.209	0.226
N. Obs.	555	555	555	555	555

Note: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Robust standard errors; *t* statistics in parentheses.

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Table 10. ISO_{14001} adoption EI, cooperation, agglomeration and internationalization.

	Dependent variable: *ISO_{14001} adoption*				
Estimation method: dprobit	[1] d*F*/d*x*	[2] d*F*/d*x*	[3] d*F*/d*x*	[4] d*F*/d*x*	[5] d*F*/d*x*
R&D	−0.042 [−1.22]	−0.037 [−1.12]	−0.037 [−1.12]	−0.052 [−1.50]	−0.046 [−1.38]
ICT adoption	0.075 [1.03]	0.080 [1.09]	0.073 [1.02]	0.018 [1.60]	0.088 [1.22]
Training coverage	0.001*** [3.79]	0.001*** [3.75]	0.001*** [3.75]	0.001*** [3.91]	0.001*** [3.84]
Central Emilia dummy	0.022 [0.97]	0.022 [0.99]	0.024 [1.06]	0.020 [0.85]	0.018 [0.80]
20−49 empl.	−0.053 [−1.44]	−0.049 [−1.36]	−0.049 [−1.38]	−0.046 [−1.20]	−0.042 [−1.09]
50−99 empl.	−0.028 [−0.90]	−0.024 [−0.76]	−0.021 [−0.68]	−0.016 [−0.48]	−0.010 [−0.30]
100−249 empl.	0.062 [1.56]	0.070* [1.73]	0.074* [1.78]	0.075* [1.78]	0.086** [1.98]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0001 [0.28]	0.0001 [0.45]	0.0001 [0.51]	0.0001 [0.26]	0.0001 [0.44]
ID	−0.031 [−1.15]	−0.047* [−1.68]	–	−0.026 [−0.90]	−0.042 [−1.50]
Mechanical district	–	–	−0.052* [−1.79]	–	–
University cooperation	0.200*** [3.28]	0.187*** [3.07]	0.186*** [3.06]	0.231*** [3.36]	0.223*** [3.31]
Suppliers cooperation	0.142*** [3.98]	0.143*** [4.11]	0.143*** [4.11]	0.083* [1.96]	0.084** [2.03]
Foreign ownership	0.066* [1.87]	0.033 [1.02]	0.031 [0.97]	−0.027 [−0.52]	−0.042 [−1.00]
Foreign own. × ID	–	0.231* [1.75]	–	–	0.301* [1.67]
Foreign own. × Mech. District			0.296** [1.97]		
University coop. × foreign own.	–	–	–	0.231*** [3.36]	−0.111 [−0.61]
Suppliers coop. × foreign own.	–	–	–	0.083* [1.96]	0.300*** [3.32]
Pseudo-R^2	0.227	0.234	0.236	0.252	0.261
N. Obs.	555	555	555	555	555

Note: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Robust standard errors; *t* statistics in parentheses.

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Table 11. EI adoption and regulatory/policy drivers.

	Dependent variable: EI*s*			
Estimation method: probit	[1] d*F*/d*x*	[2] d*F*/d*x*	[3] d*F*/d*x*	[4] d*F*/d*x*
R&D	−0.013 [−0.68]	−0.012 [−0.68]	−0.013 [−0.68]	−0.012 [−0.68]
ICT adoption	0.167*** [3.88]	0.162*** [3.88]	0.167*** [3.88]	0.162*** [3.88]
Training coverage	0.001*** [5.64]	0.001*** [5.64]	0.001*** [5.64]	0.001*** [5.64]
Central Emilia dummy	0.037*** [2.96]	0.035*** [2.96]	0.037*** [2.96]	0.035*** [2.96]
20−49 empl.	−0.018 [−0.41]	−0.018 [−0.41]	−0.018 [−0.41]	−0.018 [−0.41]
50−99 empl.	−0.032 [−1.03]	−0.031 [−1.03]	−0.032 [−1.03]	−0.031 [−1.03]
100−249 empl.	0.056*** [3.33]	0.055*** [3.33]	0.056*** [3.33]	0.055*** [3.33]
250 empl.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes
Export propensity	0.0002 [0.56]	0.0002 [0.56]	0.0002 [0.56]	0.0002 [0.56]
ID	−0.083*** [−8.20]	−0.080*** [−8.20]	−0.083*** [−8.20]	−0.080*** [8.20]
University cooperation	0.196*** [3.67]	0.190*** [3.67]	0.196*** [3.67]	0.190*** [3.67]
Suppliers cooperation	0.095*** [2.74]	0.092*** [2.74]	0.095*** [2.74]	0.092*** [2.74]
Foreign ownership	−0.020 [−0.38]	−0.019 [−0.38]	−0.020 [−0.38]	−0.019 [−0.38]
Foreign own. × ID	0.202*** [4.13]	0.198*** [4.13]	0.202*** [4.13]	0.198*** [4.13]
University coop. × foreign own.	−0.168*** [−2.75]	−0.163*** [−2.75]	−0.168*** [−2.75]	−0.163*** [−2.75]
Suppliers coop. × foreign own.	0.292*** [2.80]	0.283*** [2.80]	0.292*** [2.80]	0.283*** [2.80]
Ln(air investments)	0.965*** [49.36]	–	–	–
Ln(waste investments)	–	0.464*** [18.81]	–	–
Ln(total investments)	–	–	0.732*** [50.50]	–
Ln(GHG/VA)	–	–	–	−0.822*** [606.42]
Pseudo-R^2	0.219	0.219	0.219	0.219
N. Obs.	555	555	555	555

Notes: ***Significant at the 1%, **significant at the 5%, *significant at the 10%. Standard errors are clustered at the industry level; *t* statistics in parentheses. The column ln(ACID/VA) is not included due to excess of collinearity.

pull and push effects of EI (using CIS German data) shows that both internal and external R&D is not a significant driver for high medium level EIs. Internal R&D is also only significant in just one case out of 10 (with respect to air), when specific EIs are disentangled. Other recent analyses based on Italian CIS data confirm this evidence (Borghesi *et al.*, 2012).

According to a system perspective to EI, R&D is too far a generic and weak innovation commitment to enhance the adoption of EIs. While it might be found significant in increasing the firm knowledge base and its absorptive capacity, other techno-organizational internal features are possibly required to complement better the adoption of EI.

In this respect, we first find that *ICT adoption* is a highly significant factor correlated to EI[15] in general. At a more specific level, this correlation is significant mainly with respect to EI in materials and CO_2 emissions. This result is supportive of the manifold effects that ICT has been found to have on EI in the literature: in particular, looking at specific EIs, those which pass through a dematerialization of the production processes ICT could induce. The analysis of this issue, however, is beyond the paper's scope.

Training coverage in firms is generally significant across all the specifications of EI. This result is consistent with both the literature background we have reviewed (in particular, the "Porter hypothesis" literature[16]) and other empirical evidences on the correlations between training and innovation activities found in some provinces of the ER region (e.g. Antonioli *et al.*, 2010). It also suggests that the green content of training is worthy of more attention.

Quite interestingly, in all the specifications of our model, there is no correlation between EI and the other techno organizational innovations for which we tested for. The dominant role of ICT and training, which also accounts for the techno-economic profile of the firms, partially accounts for this result. However, it deserves critical attention as a potential weakness in terms of lack of integration between green (defined) and standard innovations.

4.2 Testing the Main Hypotheses

The first hypothesis we have put forward to account for the role of inter-firm cooperation (HP1) is not rejected. Out of all the alternative partners we have considered (Tables 6–10), EIs are stimulated by the firms' interaction with such "qualified partners" as universities and business suppliers. This result suggests interesting theoretical and applied explanations. On the one hand, the significance of innovation–cooperation with universities confirms the importance that basic research has for this kind of EI, for which an important part of the underlying knowledge is actually codified (as an immediate example, one just need to think about the role of environmental standards). From an empirical point of view, the presence of top-ranked universities in the region—especially, the eldest University of Bologna—with diffuse spin-offs and linked research centres and relatively higher involvement in R&D expenditure with respect to the national average—contributes to explain this result too.

HP1 is also supported with respect to the relationships with *business suppliers*, but not with customers or competing firms. This is also an interesting result. At first, it suggests that,

[15] The questionnaire asks about the adoption of ICT innovations from the simplest to integrated ones such as intranet, customer relations management (CRM), and so on. Information on ICT adoptions is available upon request.

[16] Rochon-Fabien and Lanoie (2010), for example, investigate the benefits of an original Canadian training programme, the Enviroclub initiative.

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consistently with what emerges from the majority of the studies on innovation–cooperation, relationships with competitors are usually hampered by problems of rivalry and knowledge leakages (e.g. Cassiman & Veugelers, 2002). Second, it confirms that the spread and adoption of the substantial changes that EIs imply require a qualified involvement of the production *filiere* (Mazzanti & Zoboli, 2006). More precisely, backward vertical relations, through which final producers get intermediate commodities that could have an important environmental impact on their final goods, play a role in the adoption of EI. On the contrary, forward vertical relationships, which are generally retained to stimulate innovation by providing firms with market and preference-related feedbacks, do not have a significant role.

Overall, as it has been found with respect to more "standard" innovations in specific provinces/LPS of the ER, local network relationships appear an important driver of EI too (Antonioli *et al.*, 2010).

Moving to HP2, the *Central Emilia* dummy is the only agglomeration-related variable with the expected positive and significant effect (Table 6), mainly with respect to EI for CO_2 (Table 8) and emissions (Table 9).[17] On the contrary, the more general ID dummy is negative and significant (Table 6), especially for CO_2 and emissions (Tables 8 and 9). In these cases, in particular, the *machinery district*, which historically has been prominent in the regional industrial development, is also negative, showing doom performance for EI.

In interpreting these results, we should bear in mind that the IDs of the Central Emilia area (3 out of the 11 of the region) and the IDs outside of it have a substantially different industrial structure and EI profile. Within the Central Emilia area, we have the strongest signs of EI, based on the notable case of the ceramic district of Sassuolo (Modena), which produces high emissions, but it is also EI intensive. Outside the Central Emilia area, instead, we have very weak EI signs by firms which are particularly specialized (four out of eight) in textile-related products, the only sector with no EI adoptions.[18]

The bottom line of the argument is quite interesting: HP2 does find support, but only with respect to specific sectors and locations. Agglomeration economies and district effects spur the adoption of EI only in areas that have historically rooted specialization patterns in "EI-friendly" sectors, such as for the Central Emilia area and its ceramics sector. Conversely, in areas whose specialization patterns are in non-EI friendly sectors, and do not have an established industrial tradition—such as for the textile IDs outside Central Emilia—agglomeration phenomena can even act as diseconomies. A possible explanation of this fact can be that, in the latter contexts, the local infrastructures to support EIs—both "immaterial" (public research and knowledge about green technologies) and "material" (institutions supporting the adoption of environmental standards and green business strategies)—may become overstretched under the concentration of agglomerated EI efforts and actually make them more costly to obtain.

With the exception of the situation in the Central Emilia area, the results for HP2 have two implications for ER innovation policy. Unlike other technological innovations, with

[17] With respect to CO_2, for example, Figure 1 shows a high concentration in the three provinces of Central Emilia (i.e. Bologna, Modena and Reggio Emilia).

[18] Results may depend on the sector environmental performance. If we compare DI and DK (ceramics and machinery), for example, we see that the former is responsible for very high levels of emissions for CO_2, SO_x, NO_x, PM_{10} per unit of value in the region. Machinery performance is relatively better.

respect to EI it seems that the typical social capital of the ID has not evolved into a social responsibility in the region. ER firms have been perhaps involved in innovation exploitation, rather than exploration, which has been proved to be the cause of the low resilience of the Italian LPS in front of the latest economic downturn (Bugamelli *et al.*, 2009).

Coming to the last two hypotheses, HP3 and HP4 are here basically rejected. With respect to HP4, which refers to firms' export propensity *conditional on* their destination markets, its non-significance suggests that the environmental profile of the international customers of the ER firms is not (yet) such to spur them to eco-innovate. Indeed, this result is explained by the peculiar bilateral trade patterns of the ER region (as they emerge, for example, from Unione Regionale delle Camere di Commercio dell'Emilia-Romagna, 2007).[19]

The case of FDI is different. Although foreign-(owned) firms generally do not have an advantage over domestic firms in EI, as HP3 would claim, those of them that are embedded in the local systems of ER in some cases do have it. In other words, HP5 cannot be rejected.

First of all, interacting with local suppliers is an essential condition for foreign-(owned) firms to eco-innovate (Table 6). In line with most of the literature on R&D spillovers from FDI, it seems that user–supplier relationships are the most inducing of EI behaviours, as they are vehicles of tacit knowledge transmission, whose importance in LPS has been extensively documented. Conversely, cooperating with public research organizations—although important for local firms to access the codified knowledge required to adopt EIs (see HP1)—is not effective for foreign subsidiaries. These firms may prefer knowledge produced in their internal R&D labs (possibly located abroad), which is available to them at lower access costs and with lower risks of leakage.

A second point with respect to HP5 is that foreign-(owned) firms gain an EI advantage when they are located in specific IDs only, such as the mechanical one (Table 6). On the one hand, this suggests that a sustained and qualified degree of agglomeration economies is necessary to motivate foreign subsidiaries to introduce EI. On the other hand, belonging to a well-established ID might increase EI by augmenting the costs of reputation damage from non-EI behaviours by MNC. In this last respect, it is interesting that, in the interaction, the positive sign of foreign ownership (although not significant) dominates the negative sign of the mechanical ID (significant). It seems that when reached by FDI, mechanical ID firms switch their strategies from reluctance (or indifferent) to favouring EI.

A third point to note is that, while our previous hypotheses (HP1–HP4) get in general confirmed, or at most specified (in the way we have illustrated above) when we consider the four different kinds of EI, the results for HP5 change quite substantially with respect to some of them (Tables 7–10).

A first set of specific results emerges from the interaction of foreign ownership with the suppliers' cooperation. This form of cooperation explains significantly CO_2-related innovation in the interaction with foreign ownership (Table 8). The same cooperation instead looses statistical significance when foreign firms' influences are considered with respect to emission reductions (Table 9). This is not completely unexpected. In front of the hottest environmental issue at the global level, a close interaction with the suppliers helps MNC in getting more locally sustainable. Local competencies and incentives are not sufficient, and probably

[19] The result about exports is consistent with those in Horbach and Oltra (2010).

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foreign ownerships transmit signals of international policies and international greening markets at the local level. The negligible impact on emission innovation is instead a signal of the weakness of local efforts to cope with regional externalities.

Also expected is the result that, only in the case of the ISO_{14001} adoption, collaborating with universities is significant for foreign firms' EI (Table 10). Interacting with public research institutes seems very beneficial in order to allow firms to learn about standard regulation and about how to introduce them.

Another set of specific results for HP5 concerns agglomeration economies. In particular, the need for strong agglomeration to induce the involvement of foreign firms' in EI (see HP4) is in general attenuated. For CO_2 and other emissions abatement, and for the adoption of ISO_{14001} (Tables 8–10), interaction with "any kind" of ID is enough to stimulate their adoption by foreign firms.

Again, this is a case where local public good features prevail, and also the share of appropriable savings out of externality reductions is high. It seems that the impact of foreign ownership prioritizes global over local environmental problems. This result is consistent with the evidence about the adoption of corporate social responsibility (CSR) strategies by MNC in emerging markets. In these contexts, the CSR international agenda overrides local needs (on this point see, e.g. Campbell, 2006). In brief, foreign subsidiaries "export" their internationally minded firm strategy, which probably insists in the relatively weak EI basis of the region. That is why we witness stronger impact of the interaction between agglomeration and foreign factors in favour of carbon dioxide options and ISO_{14001}. Even if the latter poses relatively milder challenges and costs to firms with respect to energy–CO_2 abatement, it is a corner stone for upgrading the firm to international market levels.

In general, it seems that "foreign effects" on EI overshadow agglomeration effects. Note that the evidence is more robust for firms involved with global public goods (CO_2 abatement), for which global and EU environmental policies play a major role (especially EU ETS and the corporate average fuel economy (CAFE) frameworks in the US). Given that Italy has not a very strict environmental policy (Johnstone *et al.*, 2010), it could be argued that "foreign policy stringency" could be "imported" via FDI in local clusters. In this last respect, it should also be noted that the largest share of intra-EU trade and relationships for Italian and ER firms is with Germany and France, and Germany has some of the strictest environmental policy terms and is the most eco-innovative European country.

In concluding, it should be noted that only in the case of ISO_{14001} adoption (Table 10), multinational ownership *per se* is found to increase the probability to eco-innovate.[20]

4.3 The Role of Regulatory and Policy Issues: A Robustness Check Analysis

Estimating the augmented model, which integrates some meso-economic policy elements, leads to pretty unchanged results (Table 11[21]). The two different kinds of proxies we use also deliver similar estimations. Those are two good robustness signs.

[20] This result is consistent with anecdotal evidence for the German subsidiaries of chemical firms (e.g. BASF), which in all cases and situations stimulated an upgrade and new adoption of green techno-organizational innovations in the region.
[21] Regressions using as dependent variable CO_2, emissions and material/waste EI provide significant effects in relation to the coherent policy proxies. Results are available on request.

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At first, all investments aimed at reducing environmental impacts are significantly and positively correlated to the adoption of EI. The considered emissions on VA indicators are also all significantly correlated with EI, but negatively, in coherence with the indicator. This suggests that the regulations that contribute to an increase in the environmental efficiency of the relevant sectors (along with spontaneous Porter-like behaviours) have a positive impact on the adoption of EI.

More specific assessments will be possibly pursued in further research (special attention deserves the EU ETS). On the other hand, it is worth noting that when we match the EI type and the policy proxy type (e.g. EI in carbon abatement—air emissions abatement and GHG/VA indicators), results are confirmed at this level as well. Furthermore, although these results refer to a specific region/country, and should thus be replicated for a general validation, we nevertheless note their coherence with other studies at the country level (e.g. Costantini & Crespi, 2008).

In concluding, we note that the results we have obtained by estimating the baseline model are in general confirmed by the augmented version. Nevertheless, firm's size gains some role in the augmented model, with respect to previous analyses, as medium enterprises (in between 100 and 249 employees) are associated with significant EI adoption. The strength of medium large firms, the backbone of the regional system, is underlined. It is worthwhile noting that the medium large firms (100–249 employees) descriptively present EI adoptions equal or very close to that of largest firms, and overcome the latter for the motivation "EI introduced due to current policies" (Table A3).

Universities and suppliers are again the partners with respect to which our HP1 gets supported. Central Emilia is again the only area in which agglomeration economies have a positive impact on EI, while HP2 does not get supported with respect to the firm's location in IDs in general. The EI role of the openness to trade of the considered local firms still appears counterbalanced by the profile of their international customers, and HP3 remains not supported. The same occurs for HP4, as the foreign ownership of the local firms, alone, does not make them more innovative in environmental terms.

The interaction with suppliers still provides foreign-owned firms with a significant correlation with EI, while this time the interaction with universities becomes significant. Reinforcing our previous argument, it now seems that not only might foreign firms prefer relying on the knowledge produced by the labs internal to their groups, but that the interaction with local universities could create such cognitive and rivalry problems to reduce their eco-innovativeness. Finally, belonging to any ID becomes now sufficient to stimulate EI.

We stick to this evidence and note that sector regulatory factors might further reduce the noise produced by omission of residual relevant variables.

5. Conclusions

From a theoretical point of view, our analysis suggests that a system approach to EIs is also urged by the complex set of relationships in which firms get embedded when they are part of LPS, such as for example IDs. In other words, urban and regional studies appear an important complement to innovation studies also and above all with respect to environmental issues.

From an empirical point of view, our findings help to explain how LPS with many SMEs, which are territorially embedded, but open to international relationships, can reshape the

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techno-organizational content of their products and processes in the face of the challenges posed by the "green economy". The most relevant "internal" drivers of EI are firm cooperation with suppliers and universities, and firm exploitation of ICT and training. It should be noted that, overall, such "pro-active actions", related to investments in innovation-based advantage, outweigh the importance of the more usual structural factors, such as firm size and R&D.

The role of spatial agglomeration economies is less clear-cut. Although the core of the Emilian model—including the environmental harmful ceramic district—is having a strong impact on EI efforts, in other geographical areas with different specializations, such as textiles and also machinery, agglomeration economies are lagging behind and sometimes even hampering the adoption of EI. The specialization patterns of IDs, along with their history and urbanization features, are thus crucial elements for enhancing the EI impact of agglomeration. Our results suggest that it will be important to prevent agglomeration from becoming a source of congestion diseconomies by stretching "thin", green institutional set-up.

International driving forces seem to carry relatively less weight than local factors in explaining EI adoption. The most striking evidence is that ID and foreign ownership if taken alone matter less than networking and can even act as a brake. Nevertheless, firms' foreign ownership matters for EI adoption when interacted with their production networking—i.e. with their suppliers—and, in general, with their location in (established) IDs. The crystal clear message is that MNC need to be locally embedded and geographically agglomerated in order to have an EI advantage with respect to national firms. The famous *glocal* story in innovation seems to hold with respect to EI (e.g. Perkmann, 2006; Onsager *et al.*, 2007). As a corollary of this message, merely being in a district or having foreign links is not sufficient to challenge the green economy pathways.

Some specific EI effects are also worth noting. CO_2 abatement is associated more with supplier-related cooperation (but the effect vanishes for foreign ownership), while eco-labelling with collaboration with universities. Overall, the techno-economic and institutional specificities of different EIs intertwine in making our hypotheses supported/rejected to a different extent.

Our findings have relevance for both management and policy-making. First, it is evident that EIs need to be stimulated by adopting "integrated" innovation strategies—which put innovation complementarity at the centre—and by developing technological and competence synergies between firms (especially suppliers) and between firms and public agents. Second, EI adoption seems to be fostered by multinational links, even in a country without strict carbon emission policies.

Policy/regulatory effects appear important anyhow. These sector-related effects can be also "imported" from abroad. Joint "glocal" effects could (partially?) compensate for the lack of (stringent) environmental policy as main EI driving force. Stringent environmental policy might create pressure through trade and international relationships. However, this is area for further research.

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Appendix A

Appendix B: Relevant survey questions

Table A1. Classification of manufacturing activities.

Codes	Description
DA	Food products, beverages and tobacco
DB	Textile and clothing
DC	Leather and leather products
DD	Wood and wood products
DE	Pulp, paper and paper products, publishing and printing
DF	Coke, refined petroleum products and nuclear fuel
DG	Chemicals, chemical products and man-made fibres
DH	Rubber and plastic products
DI	Non-metallic mineral products
DJ	Basic metals and fabricated metal products
DK	Machinery and equipment
DL	Electrical and optical equipment
DM	Transport equipment
DN	Other manufacturing

[22] Environmental innovations are a product/service, a process, a marketing/organizational strategy improved in a substantial way in order to generate significantly larger environmental benefits compared to existing alternatives. Such benefits may either constitute the main aim of the innovative development, or being second order indirect effects. Benefit can be generated during the production of the good/service and/or during the post selling consumption phase.
[23]This elicitation as in CIS2008 is filtered by the EI binary statement and cannot thus be used as a "driver" of EI due to endogeneity. Descriptive statistics are available upon request.

Table A2. Population and sample distribution (%) by sector and size.

Sector	Size 20–49	50–99	100–249	250 +	*Total*	Total (a.v.)
Population distribution (%; NACERev1)						
Food (DA)	5.65	1.94	1.16	0.64	9.39	382
Textile (DB-DC)	6.17	1.47	0.71	0.37	8.73	355
Wood, paper and other industries (DD-DD-DN)	7.79	1.67	0.79	0.42	10.67	434
Chemical and rubber (DF-DG-DH)	5.01	1.87	1.11	0.42	8.41	342
Non-metallic mineral products (DI)	3.81	1.23	1.18	0.79	7.01	285
Metallurgy (DJ)	16.99	3.29	1.18	0.25	21.71	883
Machinery (DK-DL-DM)	21.44	6.37	4.06	2.24	34.10	1387
Total	66.86	17.85	10.18	5.11	100.00	
Total (a.v.)	2720	726	414	208		4068
Sample distribution (%)						
Food (DA)	2.88	3.78	1.62	0.54	8.83	49
Textile (DB-DC)	2.70	1.44	1.62	0.54	6.31	35
Wood, paper and other industries (DD-DD-DN)	3.60	2.88	1.08	0.90	8.47	47
Chemical and rubber (DF-DG-DH)	3.78	3.42	1.80	1.08	10.09	56
Non-metallic mineral products (DI)	1.62	2.16	1.62	2.16	7.57	42
Metallurgy (DJ)	8.83	5.77	2.16	0.18	16.94	94
Machinery (DK-DL-DM)	14.05	15.32	7.39	5.05	41.80	232
Total	37.48	34.77	17.30	10.45	100.00	
Total (a.v.)	208	193	96	58		555

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Table A3. EI motivation: (a) coping with current regulations, (b) coping with current market demand, (c) coping with future regulations and (d) coping with future market demand.

Size/sector branch	DA (%)	DD-DE-DN (%)	DF-DG-DH (%)	DI (%)	DJ (%)	DK-DL-DM (%)	Total (%)
(a) Coping with current regulations							
20–49	50	100	100	100	100	90	92
50–99	100	67	100	50	88	80	83
100–249	100	100	67	0	67	89	78
250 +		33	0	60	0	63	50
	78	67	83	60	86	81	79
(b) Coping with current market demand							
20–49	75	100	50	50	31	60	50
50–99	0	67	40	100	38	70	53
100–249	67	0	50	0	83	33	48
250 +		33	100	80	0	75	67
	56	44	50	70	43	59	53
(c) Coping with future regulations							
20–49	50	0	67	50	38	70	53
50–99	50	33	0	100	38	40	37
100–249	33	100	33	100	50	56	52
250 +		100	100	60	0	75	72
	44	67	39	70	39	59	51
(d) Coping with future market demand							
20–49	25	0	50	0	38	50	39
50–99	0	67	40	100	38	50	47
100–249	33	50	33	100	50	56	48
250 +		67	100	80	0	63	67
	22	56	44	70	39	54	48

Source: Own survey. Shares on total of 111 EI firms.

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Table A4. Environmental investments by sector (share and monetary values).

	Environmental investments (air; %)	Environmental investments (water; %)	Environmental investments (waste; %)	Other investments (%)	Total (%)	Environmental investments (air)[a]	Environmental investments (water)[a]	Environmental investments (waste)[a]	Other investments[a]	Total[a]
DA	1.51	4.75	0.70	0.61	7.57	24.52	77.00	11.28	9.93	122.73
DB	0.81	0.71	0.17	0.10	1.78	13.09	11.45	2.73	1.57	28.84
DC	0.35	0.52	0.02	0.04	0.93	5.67	8.35	0.37	0.60	14.99
DD	0.57	0.78	0.20	0.68	2.23	9.28	12.59	3.22	11.00	36.08
DE	1.16	3.19	0.16	0.59	5.09	18.80	51.63	2.54	9.52	82.48
DF	0.26	0.71	0.08	3.26	4.30	4.18	11.43	1.26	52.81	69.68
DG	8.60	6.38	2.21	8.50	25.70	139.43	103.44	35.88	137.73	416.49
DH	1.06	0.51	0.65	0.84	3.06	17.11	8.22	10.59	13.65	49.56
DI	5.24	1.09	0.87	1.99	9.19	84.94	17.68	14.05	32.21	148.88
DJ	13.17	5.18	1.66	4.08	24.09	213.44	84.01	26.87	66.13	390.45
DK	1.53	1.11	1.51	1.52	5.67	24.77	17.93	24.52	24.63	91.84
DL	0.73	0.46	0.17	0.80	2.16	11.88	7.42	2.82	12.94	35.05
DM	2.04	0.88	0.38	2.39	5.69	33.09	14.29	6.22	38.67	92.27
DN	0.99	0.10	0.20	1.15	2.44	16.03	1.68	3.24	18.56	39.51
TOTAL	38.03	26.36	8.98	26.53	100.00	616.22	427.11	145.58	429.95	1620.57

[a]Millions of €.

Source: ISTAT, Rome.

Table A5. Emissions per VA by sector.

sector branches	GHG/VA index (GHG/VA)	Acidificants/VA index (ACID/VA)
DA	0.731	0.032
DB	0.283	0.009
DC	0.237	0.010
DD-DH-DN	0.240	0.010
DE	0.388	0.008
DF-DG	3.472	0.158
DI	2.037	0.227
DJ	0.059	0.004
DK-DL-DM	0.141	0.006

Source: NAMEA dataset; ISTAT, Rome.

Table A6. Spearman's rank correlation coefficients: dependent variables.

	[1]	[2]	[3]	[4]	[5]
[1]	1.000				
[2]	0.832	1.000			
[3]	0.722	0.787	1.000		
[4]	0.808	0.737	0.795	1.000	
[5]	0.741	0.687	0.628	0.709	1.000

Notes: [1], EIs; [2], material/resources reduction technologies; [3], CO_2 abatement technology; [4], emission abatement technology and [5], ISO 14001 adoption.

Table A7. Spearman's rank correlation coefficients: some covariates.

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
[1]	1.000							
[2]	0.190	1.000						
[3]	0.046	−0.105	1.000					
[4]	0.041	0.036	0.266	1.000				
[5]	0.045	0.046	0.319	0.926	1.000			
[6]	0.233	0.100	−0.052	0.016	0.016	1.000		
[7]	0.184	0.159	−0.006	0.035	0.038	0.142	1.000	
[8]	0.070	0.096	−0.004	−0.04	−0.040	0.112	0.109	1.000

Notes: [1], R&D; [2], Training coverage; [3], Central Emilia dummy; [4], IDs; [5], Mechanical districts; [6], University cooperation; [7], Suppliers cooperation and [8], Foreign ownership.

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- **Did the firm adopted technological and organizational innovations of environmental nature over 2006–2008?**[22] (if not, goto next section)
- **Did the firm adopted process / product environmental technological innovations over 2006–2008, that produced the following benefits?**

Benefits	Yes	No
1. Reduction in the use of materials/Energy sources per unit of output (including recovery, recycling, closed loops)		
2. CO_2 Abatement		
3. Emission reductions gene rating effects on soil, water, air		

- **Is the firm structurally characterized by environmental performance oriented procedures?**

Procedure	Yes	No
1. EMS		
2. ISO 14001		
3. Other, as LCA, ISO14040, …………………………		

- **Did you invest own economic resources (es. R&D, investments in manmade capital) over 2006–2008 with the aim of reducing firm's environmental impact?**

Yes	No

- **State the motivations behind the adoption of environmental innovations?**[23]

Motivations	Yes	No
1. Coping with existing regulations and environmental laws of regional, National, european/global level)		
2. Satisfying current market demand		
3. Anticipating environmental regulations and laws that are expected to be key in the future or generally more stringent environmental policy in the future (es. EU 20/20/20 targets)		
4. Anticipating future 'sustainable consumption' based market demands		
5. Other (specify)		

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