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Environmental Innovations, Local Networks and Internationalization

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Summary

This paper investigates the drivers of the environmental innovations (EI) introduced by firms in local production systems (LPS). The role of firm network relationships, agglomeration economies and internationalization strategies is analysed for a sample of 555 firms in the Emilia-Romagna region, North-East of Italy. Cooperating with 'qualified' local actors – i.e. universities and suppliers – is the most important driver of EI for most firms, along with their training policies and IT innovations. The role of agglomeration economies is less clear and seems to depend on the EI propensity of more locally oriented firms playing in district areas, which might even turn agglomeration into dis-economies. Networking effects and agglomeration economies are instead found to strongly promote the adoption of EI by multinational firms, thus highlighting the importance of local-global interactions. We provide some interesting findings for particular kinds of challenging EI in fields as CO2 abatement and ISO labelling, generally extending the analysis EI driver by joining local and international factors.

Keywords: Eco-Innovation, Foreign Ownership, Networking, District, Agglomeration Economics, Local Production Systems

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

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Environmental innovations, local networks and internationalization

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Abstract

This paper investigates the drivers of the environmental innovations (EI) introduced by firms in local production systems (LPS). The role of firm network relationships, agglomeration economies and internationalization strategies is analysed for a sample of 555 firms in the Emilia-Romagna region, North-East of Italy. Cooperating with 'qualified' local actors – i.e. universities and suppliers – is the most important driver of EI for most firms, along with their training policies and IT innovations. The role of agglomeration economies is less clear and seems to depend on the EI propensity of more locally oriented firms playing in district areas, which might even turn agglomeration into dis-economies. Networking effects and agglomeration economies are instead found to strongly promote the adoption of EI by multinational firms, thus highlighting the importance of local-global interactions. We provide some interesting findings for particular kinds of challenging EI in fields as CO_2 abatement and ISO labelling, generally extending the analysis EI driver by joining local and international factors.

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1. Introduction

Although 'ecological innovation' (EI) has been debated widely in the context of environmental and innovation studies (e.g. Horbach, 2008; Frondel *et al.* 2008; Oltra and Saint Jean, 2009), a completely satisfactory economic account has yet to emerge. Available definitions of EI (CML *et al.*, 2008; UNU-MERIT *et al.*, 2008; Europe Innova, 2008) point to the 'eco' attributes of individual new processes, products and methods, which can be evaluated in technical and ecological term, and therefore relate strictly to 'environmental technologies'.[1] However, EI does not relate only to specific technologies; it also includes new organizational methods, governance models, and knowledge oriented innovations (Kemp, 2010). These innovations, in turn, are closely linked to education and training, and ultimately to human capital.

EI is neither sector nor technology specific, and can take place in any economic activity, not just the loosely defined 'eco-industry' sectors. Finally, EI is not limited to environmentally motivated innovations, but includes the 'unintended' eco-effects of all innovations. Thus, when taken outside its purely technical dimension of (improved) environmental impact, EI can be seen to have a *systemic and behavioral dimension* (e.g. Horbach 2008).

This latter dimension suggests the importance of *complementarity* for understanding EI dynamics. We adopt such an approach, in this paper, focusing on two specific drivers of EI: (i) *networking* and *spatial relationships*, and (ii) *international strategies*. Unlike other more standard determinants of EI – such as R&D (Horbach, 2008) – these two aspects have been relatively less explored.[2]

The general importance of network relationships for innovation activities has been acknowledged only recently in the specific case of EI and particularly in terms of network spillovers (e.g. Fritsch and Franke, 2004; Costantini *et al.*, 2010) and patterns of diffusion (e.g. Cantono and Silverberg, 2009). Relatively less attention has been paid to agglomeration economies, which emerge when networked firms are clustered within a territory and linked to local institutions (e.g. Mazzanti and Zoboli, 2008, 2009; Cainelli *et al.*, 2007; Mancinelli and Mazzanti, 2009).

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[1] E.g. in the EU funded MEI (Measuring Eco-Innovation) research project, eco-innovation 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". Apparently related are environmental technologies, defined as "all technologies whose use is less environmentally harmful than relevant alternatives" (definitions are cited by Kemp, 2010, in press).

[2] Del Rio-Gonzalez (2009) suggest an agenda for researching the drivers of EI.

The environmental impacts of globalization are still an open issue (e.g. Gallagher, 2009). On the one hand, empirical support for the alleged negative environmental impact of globalization – namely in the form of the so called "pollution-heaven-hypothesis" – is scant (e.g. Brunnermeier and Levinson, 2004). On the other hand, alternative views are emerging about the various channels through which the increasing international integration of economic actors – MNC in particular – might spur environmentally friendly, if not even environmentally innovative, behaviours (e.g. Christmann and Taylor, 2001).

Of course, both drivers are at work together, and possibly are intertwined, especially in a context of "thick" markets and institutions (McClaren, 2003; Amin and Thrift, 1995). That is, in local production system (LPS) such as industrial districts, with mainly small-medium and specialized firms which are becoming increasingly more open to foreign markets and are being faced with environmental and globalization pressures (e.g. Dei Ottati, 2009; Cainelli and Zoboli, 2004).

Addressing this rather unexplored issue is the main value added of this paper, which aims to assess the eventual and relative weight – compared to other internal firm drivers, such as R&D – of local networking and international factors in driving EI by firms in a LPS.

The paper is organised as follows. Section 2 reviews the literature and puts forward the main paper's hypotheses. Section 3 illustrates the dataset and the methodology used to test the hypotheses. Section 4 summarizes the main results of the econometric investigation and Section 5 concludes and suggests some items for the research agenda.

2. Background literature and research hypotheses

The literature on EI determinants is rapidly increasing (Cleff and Rennings, 1999; Rennings, 2000; Rennings *et al.* 2004, 2006; Horbach, 2008; Brunnermeier and Cohen, 2003). In this paper we adopt a system perspective (Andersen, 2004), which considers EI as techno-organizational innovations benefiting from network relationships – both internal and external to a certain geographically delimited system – and institutional embeddedness (Boons and Wagner (2009), for a discussion of different 'system levels' of eco innovation).[3]

In applying a system perspective to a LPS – e.g. a sub-national region or an even smaller territorial unit of analysis – two sets of issues become particularly relevant: (i) networking and spatial relationships, and (ii) international strategies.

[3] Relevant examples of this perspective are Horbach and Oltra (2010), Johnstone and Labonne (2009), Ziegler and Nogareda (2009), Wagner (2008, 2007a,b, 2006), and Kesidou and Pemirel (2010).

2.1. EI, local networks and spatial agglomeration

Several empirical studies have shown that networking activities can partially substitute for economies of scale in local environments characterized by small and medium sized enterprises (SME) (e.g. Moreno and Casillas, 2007). This is also true for technological innovations (e.g. Hall et al., 2009). Indeed, local SME usually lack the resources and incentives required to engage in formal innovative efforts such as R&D (Czarnitzki and Hottenrott, 2009). Although there are sectoral specificities, networking (along with proximity) is an essential strategy for small and medium firms' innovation in general (Freel, 2003; Capaldo, 2007). Firms in networks cooperate and compete, which drives the evolution of knowledge and competences in sectoral systems of innovation and technological systems (Geels, 2004).

Within a systemic and behavioral perspective (Horbach 2008), a similar argument can be extended to the introduction of EI by firms, where innovation oriented cooperation with other agents (competitors, clients, suppliers, public institutions) can be expected to be an important driver (e.g. Geffen and Rothenberg, 2000). This is even more likely if we consider "green technologies" as representing a transition towards a new sustainable, socio-technical regime, which the economic actors do not have sufficient resources to influence unilaterally (Smith *et al.*, 2005). Regime members are bound together by resource interdependencies necessary for functioning and reproduction. 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 EI.[4]

We can put forward the following hypothesis:

HP1: *Innovation-cooperation with both public and private local actors positively affects the introduction of EI by local firms.*

The reference to LPS in dealing with innovation highlights another related issue: the role of spatial proximity and agglomeration economies, in turn differentiated into those accruing from specialization (MAR (Marshall-Arrow-Romer) externalities) and those accruing from variety (Jacobs externalities) (Frenken *et al.*, 2007). It is argued that their

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

impact on innovation for clustered firms works through different kinds of knowledge spillovers and learning-by-doing effects, especially in Industrial Districts (ID), where social relationships intertwine with economic ones (e.g. Cainelli, 2008). Our expectation is that the same mechanisms are at work with respect to EI, which leads to the following hypothesis:

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

The empirical relevance of networking as an important driver of innovation has been highlighted in several studies – including recent analyses of provinces in Emilia Romagna (ER) (Mazzanti and Zoboli, 2008, 2009; Cainelli *et al.*, 2007; Mancinelli and Mazzanti, 2009, Antonioli *et al.*, 2009) – and suggest that both our hypotheses will be confirmed. However, there is an important *caveat* related to the international strategies of local firms.

2.2. EI, international strategies and local relationships

Investigation of the environmental effects of firms' international strategies – and globalization in general – is currently dominated by the so called "pollution heaven hypothesis" (PHH). In brief, international trade and foreign direct investments (FDI) are assumed to be channels through which firms exploit asymmetries in international environmental regulations (Wagner, 2001) in order to re-locate the production of pollution intensive goods in another country (e.g. Grether and de Melo, 2004, Jeppens *et al.*, 2002)[5].

This tends to obscure the positive impact of globalization generally on firm innovativeness, based on foreign competition (e.g. Gorodnichenko *et al.*, 2010) and international R&D spillovers (e.g. Franco *et al.*, 2010). We think that this is unfortunate. Not only have asymmetries in environmental regulation been recognized as being of secondary importance in determining firms' environmental performances (e.g. Dasgupta et al, 2000), but also it has been shown that internationalization provides higher incentives for firms to adopt more environmentally sustainable behaviors, which tends to turn the PHH argument on its head (Christmann and Taylor, 2001).

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5 Although this idea is very intuitive (e.g. Sanna-Randaccio and Sestini, 2009), PHH has not found consistent empirical support (e.g. Brummermeier and Levinson, 2004; Smarzynska Javorcik and Wei, 2004), and has become a current research topic. In particular, the econometric complexity of the testing procedure (e.g. Levinson and Taylor, 2008) is addressed along with the problem of the latent variables which are assumed in testing (Wagner and Timmins, 2009), and of idiosyncratic sector features (Cole *et al.*, 2010). In this paper we do not directly assess the role of regulatory instruments in driving EI, an aspect that is central to PHH. However, the firms we analyze belong to industries embedded in a (European, global) market that is increasingly characterized by environmental policy, both in terms of existing (EU ETS) or expected regulations.

Although these arguments have been developed mainly in terms of firms' attitudes to environmental self-regulation – i.e. to exceed locally enforced government regulations (e.g. Rondinelli and Berry, 2000) – their extension to EI would seem straightforward and particularly in terms of the relationship between FDI and EI. First, FDI is an important mechanism for (local) firms to enter global networks, within which knowledge about environmental best practice and innovation can circulate, which is advantageous for "domestic" firms (Gulati *et al.*, 2000). Second, FDI provides trans-national 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 and Perkins, 2003). Third, FDI exposes firms to higher institutional pressures for environmental sustainability and innovativeness, providing a higher reputation for environmental responsibility, and higher environmental standards to aim for (Kostova and Zaheer, 1999). Finally, given the larger scale of their operations, multinational corporations (MNC) 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 (Ambec *et al.*, 2010; Wagner, 2006; Ambec and Barla, 2002, 2006, Porter and van der Linde, 1995, Porter, 2010) and "offset", in the medium long-run (Requate, 2005; Rexhauser and Rennings, 2010), the initial cost of environmental regulations with a 'sustainable competitive advantage'.[6]

On the basis of the above arguments, and using the multinational ownership of the firms as an indicator, we can propose the following hypothesis.

H3: Multinational ownership of local firms positively affects the introduction of EI.

A similar positive effect on EI can be hypothesized with respect to (local) firms involvement in international trade. First, international customers can be expected to exert higher environmental pressures than local customers on firms. Especially if they are in the downstream value-chain of international customers, domestic firms will be required to adhere environmental supply standards which is likely to spur them to EI (Kraatz, 1998). Second, export-oriented firms are induced to adopt EI to overcome the trade barriers to non-sustainable producers exporting to certain markets. Meeting the highest environmental standards in the largest export markets will reduce these barriers (Rugman *et al.*, 1999). Third, both FDI and exports can generate knowledge spillovers for domestic firms –

[6] Germany is a leading exponent of this strategy in terms of its economic system and approach to regulation (Kammerer, 2009; Rehfeld et al., 2007; Frondel et al., 2006).

interacting with foreign competitors on the adoption of and/or improvement to green technologies –exposures to keener competition and motivate them to invest in technologies with better environmental performance (Perkins and Neumayer , 2008). Also, both FDI and trade accelerate the cross-border diffusion of environmental best-practice and increase the pressure on firms to be environmentally sustainable through closer scrutiny of environmental performance (Vogel, 2000).[7]

The previous arguments might suggest a simple export-propensity based version of HP3. However, as shown with respect to self-enforcing environmental regulations, the positive effect is less "automatic" than in the case of FDI (Christmann and Taylor, 2001). Indeed, the identity of the trade partner (and of the traded goods) is a crucial condition.[8] With this important caveat, we propose the following hypothesis:

H4: Providing that international markets are characterized by high levels of environment sustainability, the export propensity of local firms positively affects their introduction of EI.

As already noted, the networking and international drivers of EI work together in the LPS. What is more, as much as with respect to the case of "standard" technological innovations, the two are expected to intertwine. This is assumed in the literature on international R&D spillovers. The impact of FDI on innovation depends crucially on the relationships between foreign-owned and local firms: competitors (horizontal spillovers) or suppliers/customers (vertical spillovers) (e.g. Motohashi and Yuan, 2010). The embeddedness of foreign owned firms in the local institutional set-up is also relevant (e.g. Coe *et al.*, 2008; van Beers *et al.*, 2008). Our expectation is that this interlinking is strong also in the context of EI, which suggests the following hypothesis:

H5: HP3 and HP4 would be expected to be 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 local networking and international strategies, in testing our hypotheses, we introduce some "controls" emerging from the literature on EI (e.g. Mazzanti and Zoboli, 2009; Horbach, 2008). This is for econometric reasons

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

[8] In terms of the trade partner, it is clear that trade relationships with countries with low environment-efficiency would be expected to reduce the positive externalities identified above. In terms of traded good, the impact of trade in intermediate and final goods should be different from the impact of capital goods, while their use in more or less pollution-intensive goods should be controlled for (Perkins and Neumayer , 2008).

(mitigating the omission of relevant variables and therefore reducing the effects of unobserved heterogeneity) and to enrich our understanding of the phenomenon under investigation.

A first important control is represented by the overall innovation intensity of firms in the fields of technology (radical, incremental, product, process) and organization. Complementarities and correlations among different innovation fields have been found to stimulate EI (e.g. Mazzanti and Zoboli, 2008). Reconsidering processes and uncovering organizational inertia are costly and involve 'complementary' assets.

Training in firms deserves attention too in the adoption of EI. In particular, the level of training in companies appears to 'filter' the impact that the stakeholder pressure exerts on the adoption of EI (e.g. Sarkis et al., 2010). For example, a weak company's business culture and low skilled human capital, have been found to hamper corporate environmental action (e.g. Daily and Huang, 2001).

The role of ICT developments is also important in the context of EI.9 The literature emphasizes that the diffusion of ICT generates both negative and positive environmental effects (e.g. Yi and Thomas, 2007; EEA, 2006). Although interesting studies have been recently carried out (Hilty et al., 2006; Collard et al., 2005, Berkhout and Hertin, 2004), how ICT are integrated with EI has been rather ignored. A valuable exception is represented by the conceptual framework proposed by Berkhout and Hertin (2004). They distinguish three environmental effects of ICT: direct (pollutant) effects, driven by its larger scale of production and use; indirect effects, due to the dematerialization of introducing ICT in production processes, and generating lower environmental impacts; *structural change effects*, linked to behavioural comprehensive effects, and value based changes for firms and households. Their research hypothesis is that ICT adoptions is likely to be associated with indirect and structural change effects. The more diffuse is its adoption in a firm, the more likely 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 (Bohringer *et al.*, 2008)[10].

Finally, our set of 'controls' include standard innovation regressors, such as general 'non specifically environmental' R&D expenditures. Their expected role is to improve the "knowledge capital" of the firms and their "absorptive capacity" of external knowledge,

[9] More in general, innovation in ICT can stimulate "green" economic growth and spur a recovery from the current global crisis; it is therefore worthy more applied research in this field (OECD, 2009)

[10] As we will see, unfortunately, our empirical analysis captures only adoption intensity. We note the recent November 2010 ZEW (Centre for European Economic Research) workshop on 'IT and the green economy' that collected some of the new works o the theme and provided an update of the research agenda. Presentation are available at the ZEW website.

also and above all in terms of EI (Horbach, 2008; Horbach and Oltra, 2010).11 Industry, geographical and size variables conclude the list of controls.

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 Emilia-Romagna (ER) on a sample of 555 manufacturing firms with more than 20 employees.

ER is a North-East Italy region (NUTS2 level), with a population of nearly 5 million and accounts for about 20% of Italian industrial production (ISTAT, 2010). ER represents and ideal test for the hypotheses we put forward in the paper. On the one hand, it is well-known for being a district-based, open local system, rich in networking and spatial agglomeration of firms and institutions: also called the "Emilian model" (Brusco, 1982; Brusco et al., 2006). On the other hand, the industrial system of the region is export oriented, and outperforms the innovativeness of the whole country (along with Lombardia) 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 EMAS registered organisations, ECOLABEL licenses, efforts to improve air quality, and other specific EI. On the other hand, however, it is also relatively polluting compared to other industrial areas of Italy (Mazzanti and Montini, 2010; Costantini et al., 2010). For example, ER is (in 2009) the 4th region (after Lombardy, Piedmont and Veneto) in terms of concentration of "Major-Accident Hazard Establishment" (MAH), including one of the most concentrated MAH provinces (i.e. Ravenna).12

As far as our empirical application is concerned, a structured questionnaire on (eco) innovative behavior was administered to the ER firms in 2009, and referred to the period 2006-2008, the period covered by the most recent EU Community Innovation Survey (CIS data for Italy should be available in early-mid 2011), which for the first time included questions on EI. This survey was thus preceding – and extending in scope – the national

[11] As we will see, in the survey we also elicited the presence of environmental R&D, which is also addressed by the literature (Arimura et al., 2007). However, we will not exploit this as a covariate given the expected and very high correlation with R&D *tout court*.

[12] 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).

survey on a regional scale that witnesses specific interests. Tables 1-3 show information on sector and size distribution of EIs in the sample.[13]

Insert Table 1, 2 and 3 around here

The overall share of firms adopting EI is 20% of the total. Thus, most firms appear not interested in economic and environmental efficiency or do not eco-innovate. This result is somehow consistent with the "blurred" environmental profile of the region (ISPRA, 2009). At the level of sectors, the adoption rate is higher than the average, around 28%-32%, for sectors such as ceramic, metallurgy, chemicals, wood/paper and cardboard (Appendix, Tab.1), and lower for the food and machinery & equipment sectors. None of the firms in the textile sector have adopted EI. We could observe that eco innovation adoptions are somewhat correlated to the 'emission responsibility' of sectors, which is quite concentrated, as sector based studies that exploit data availability on emissions highlight (Marin and Mazzanti, 2011; Costantini et al., 2010). As exception we note instead food, a sector which presents strong direct and mainly indirect emission impacts, and here seems to be a weak link in the regional eco-innovation capability, even if it is a structural source of value added creation. We see that industrial composition matters for competitiveness, environmental performance and innovation adoption. The relatively low – compared to adoption rates in German industry (Horbach and Oltra, 2010, other comparisons are difficult due to scarcity of micro data over 2006-2008) – adoption of eco innovation can be here driven by the most prominent role of machinery in the regional economy. This is a sector that pollutes much less and presents a comparatively low emission/value ratio, which leads to a – other things being equal – lower necessity to eco innovate.

Coming to specific EI, the adoption of Environmental Management Systems (EMS) is led by non-metallic mineral products, which was expected ex ante, given the existence of 'district-level environmental certification' in the ceramic tiles industry. Sector eco labeling is aimed at both diluting fixed organizational costs and at signaling the idiosyncratic environmental value of the group of firms to the market more strongly.

[13] The survey response rate was around 30%; and the data are strongly representative of industry, size and province. The questions on eco innovations (reported in the Appendix) are consistent with the most recent CIS wave eco-innovation section, and with the conceptual framework described by Kemp (2010) and Kemp and Pearson (2007) among others. Questions on eco-innovation included the adoption (yes/no) of eco-innovations in 2006-2008, the aims or pursued benefits of eco-innovation adoption (CO_2 abatement, pollution abatement, energy/material saving), the adoption of EMS systems (EMAS, ISO, others), investments of own resources in eco-innovation (R&D, equipments, clean technologies), motivation for eco-innovation (legislation compliance, market demand, expected policy developments, expected change in demand), adoption of eco-innovation during the crisis. The questionnaire is available upon request.

In terms of the aims of innovation adoption, we observe a firm-size effect, except in the case of air pollutants, which adoption rates are similar for firms of different sizes. Adoption of CO_2-reducing innovations is lower than EI aimed at other externalities, probably due to the lack of regulation in Italy before the implementation of EU ETS for most heavy industrial sectors that occurred in 2005-2006. Only firms in these sectors, in particular ceramic and metallurgy, achieve adoption rates above 20%. More than an effect of ETS, which must be screened in the future and does not appear to be a strong innovation driver due to 'wait and see' strategies and average low prices (Pontoglio, 2010; Rogge et al., 2010), such adoption rates are probably driven more by the energy intensive structure of the sectors, which generate incentives to eco innovate for cost reduction aims even in absence of (strict) environmental policies (Kemp, 2010; Mazzanti and Zoboli, 2009).

3.2. Modeling strategy

Our econometric model is based on the following probit specification:

$$\Pr\left(Y_i = 1 / X\right) = \Phi\left(X'\beta\right)$$

where Φ is the cumulative distribution function of the standard normal distribution, and Y_i is a dummy variable taking the value 1 if firm *i* introduces an environmental innovation (EI) and 0 otherwise. We consider five different types of environmental innovations for Y, related to, respectively: (i) materials; (ii) CO_2; (iii) emissions; (iv) EMS; and (v) ISO_{14001}.

The vector X denotes the regressors. In order to test our first hypothesis (HP1), we construct and test a whole set of dummies indicating whether (value 1) or not (value 0) a firm collaborates with *customers*, *suppliers*, *competitors* and *universities* in developing and realizing EI.

To test HP2, we first construct a *Central Emilia dummy* – to indicate whether (value 1) or not (value 0) a firm is located in the provinces (administrative jurisdictions between Region and Municipality, at the NUTS3 level) of Bologna, Reggio Emilia or Modena in order to include geographic specificities of this area in terms of long-term local development (Brusco, 1982). We also include a dummy for industrial districts (ID), which takes the value 1 if the firm belongs to an ID and 0 otherwise – to account for district-specific agglomeration effects. Finally, to distinguish the industry specialization of the district, we construct another dummy – *mechanical district* – which identifies firms belonging to mechanics (value 1 vs. 0), one of the region's major manufacturing sectors.[14]

To test HP3, HP4 and HP5, the degree of internationalization of ER firms is captured by two variables: *foreign ownership*, which is equal to 1 if the firm is owned and controlled by a foreign firm (and 0 otherwise), and a continuous *export propensity* variable, given by the share of each firm's total exports on its total sales.

We also include an *R&D* dummy, equal to 1 if the firm does R&D investments (0 otherwise); a dummy for *ICT adoption*, defined by the firm's adoption of Internet, Intranet, web site, and the like (value 1 vs. 0); and a continuous variable for the *training coverage* of the firm, as the share of trained employees over total employment.

Tables 4 and 5 report the main statistics of the dependent variables, and the significant covariates. The descriptive statistics for non-significant variables are available upon request.

Insert Table 4 and 5 around here

Form an econometric point of view, model (1) is estimated by using *dprobit*, which fits maximum-likelihood probit models and is an alternative to a standard probit. Rather than reporting coefficients, dprobit reports 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 and Nogareda, 2009). We adopt an Instrumental Variable (IV) strategy, using as instrument the firm's membership to a business group. Using this instrument and adopting a test of (weak) exogeneity for probit models, proposed by Smith and Blundell (1986), we accept the null hypothesis that the model is appropriately specified with all explanatory variables exogenous. The p-value of the χ^2 test is in fact equal to 0.000.

[14] ID are identified following the Sforzi-ISTAT methodology (ISTAT 1997), according to which there are 11 in ER. Although the methodology suffers from some limitations (see Brusco *et al.*, 1996:19) that can be overcome by applying more complex and sophisticated statistical algorithms (Iuzzolino 2005), we here use the official definition of ID by ISTAT, based on the previously described statistical procedure.

4. The probability of being eco innovation adopters

Before we test our hypotheses, we need to look at the roles of what are usually assumed to be the structural drivers of EI adoption, both overall (Table 6) and in the specific cases of CO_2, emissions, materials and ISO14001 (Tables 7 – 10).[15]

Insert Tables 6 – 10 around here

First, the major driver of innovation, i.e. *R&D*, in our case is not significant. This result is not completely unexpected since overall R&D is regarded as a too general activity. It is presumably more relevant as an investment to improve absorptive capacity of external knowledge, rather than as an investment to introduce a radically new EI.[16]

We find that *ICT adoption* is highly significant driver of EI[17], although mainly with respect to innovations in materials and CO_2 emissions. This might suggest that the role of ICT investments is complementary to energy and materials saving strategies, as well as in helping to dematerialize production processes. This hypothesis needs further investigation.

Training coverage in firms is generally significant across all the specifications of EI. Consistent with the correlations between training and innovation activities found in some provinces of the ER region (e.g. Antonioli *et al.*, 2010), their complementarity has been studied at the local level (e.g. Mancinelli and Mazzanti, 2009) and in the 'Porter hypothesis' literature (Ambec *et al.*, 2010)[18]. This suggests that, green content of training is worthy of more attention.

The absence of correlation between EI and other techno organisational innovations can be explained by the dominant role of ICT and training. However, it deserves critical attention as a potential weakness in terms of lack of integration between green (defined) and standard innovations.

Finally, despite what was noted (Section 3.1), *firm size* is never significant. It may be that, in a multivariate econometric setting, size is overwhelmed by other factors: i.e., local networking aimed at generating innovation. This interpretation seems supported in what follows.

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15 EMS is not analyzed given the very small number of cases.

16 So called "green R&D" is highly significant in explaining EI; however, it is not included since the two are perfectly correlated.

17 The questionnaire asks about the adoption of ICT innovations from the simplest to integrated ones such as intranet, CRM, etc. Information on ICT adoptions is available upon request.

18 Rochon-Fabien and Lanoie (2010) investigate the benefits of an original Canadian training program, the Enviroclub initiative. This initiative was developed to help SMEs improve profitability and competitiveness through enhanced environmental performance. The role of training as a HPWP that enhances green innovation adoptions and complements EI implementation requires further study.

In terms of our main hypotheses, HP1 is confirmed, but only with respect to "qualified" public and private actors. First, innovation-related cooperation with universities significantly spurs the adoption of EI by firms, suggesting the importance that basic research and codified knowledge have for this kind of innovations. The presence of top-ranked universities in the region – especially, the University of Bologna – with diffuse spin-offs and linked research centers, and relatively higher involvement in R&D expenditure with respect to the national average, both contribute to this result.

HP1 is also confirmed for innovation relationships with *suppliers*, but not with customers or competing firms.[19] This is an interesting result since it suggests that the spread and adoption of radical changes such as EI require a qualified involvement of the entire *filiere* (Mazzanti and Zoboli, 2006). Thus backward vertical relations play a role in the adoption of EI. On the contrary, forward vertical ones do not, and neither horizontal ones, suggesting that, with respect to EI, customers and competitors are not significant sources of learning, pointing to a possible problem of rivalry in disclosing EI knowledge.

Overall, local network relationships can be said to be a major driver of economic performance and innovation in specific provinces/LPS of the region (Mancinelli and Mazzanti, 2009). However, in contrast to the case for more 'standard' innovations (Antonioli *et al.*, 2010), size is not so relevant for EI: cooperation and agglomeration apparently matter more.[20]

HP2 seems only partially confirmed. The *Central Emilia dummy* (capturing firms in the Modena, Bologna and Reggio Emilia LPS) is the only agglomeration-related variable with the expected positive and significant effect (Table 6), mainly with respect to CO_2 (Table 8) and emissions technological adoptions (Table 9). The ID dummy is unexpectedly negative and significant (Table 6), especially and symmetrically for CO_2 and emissions (Tables 8 and 9). In these cases the *machinery district*, which historically has been prominent in the regional industrial development, is also negative, showing doom performance for EIs.

Closer examinations of these results make them more supportive of HP2. It should be noted that, 8 out of 11 ID of the region are outside the 'central Emilia' area. In this area we find 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. Most of the ID outside the Central Emilia area present instead very weak EI signs: 4 are specialized in

19 The coefficients of cooperation with university are generally larger than the coefficients of cooperation with suppliers.

20 This is not a new result in ER, given that we found similar outcomes in studying the EI adoption in a single province (e.g. Reggio Emilia). Mazzanti and Zoboli (2009) also find a similar not significant effect of size in a study of networking activity to promote green R&D.

textile related products, the sector with no EI adoptions.[21] The bottom line of the argument is quite interesting. Agglomeration economies and district effects seem to spur the adoption of EI after their have reached a minimal threshold of diffusion in the territory, such as for the central Emilia area. Conversely, agglomeration factors, in a non mature stage and/or in an idiosyncratic sector, can produce negative environmental externalities: e.g., congestion effects because the local infrastructures to support EI – 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.

With the exception of the situation in the Central-Emilia area, the results for HP2 have two implications for ER policy. Unlike other technological innovations, for EI it seems that the typical social capital of the ID has not evolved into a social responsibility in the region. Also ER firms seem to follow a myopic strategy in entering the current economic crisis along the period investigated. ER firms were involved in innovation exploitation, rather than exploration, which has been proved to be the cause of low resilience to it in Italian local systems in general (Bugamelli *et al.*, 2009).

Our expectations about the role of local firms' internationalization strategies on EI adoption – i.e. HP3 and HP4 – do not find support in the case of ER. Neither export propensity nor foreign ownership of firms are significant drivers for EI. With respect to HP3, which refers to firms' export propensity *conditional on* their destination markets, the non-significance might be interpreted in an alternative way. It might suggest that the environmental profiles of international customers are not sufficient to spur ER suppliers to eco-innovate: a suggestion which should be controlled further using bilateral trade data.[22]

The case of FDI, here proxied by foreign ownership of local firms, is different. Although foreign (owned) firms generally do not have an advantage over domestic firms in eco-innovation (as HP4 states), those of them that are embedded in the local systems of ER in some cases do: there is some support for HP5.

First, interacting with local suppliers is an essential condition for foreign firms to eco-innovate, while interacting with local universities is less relevant (Table 6). In line with most

[21] Relative performance in EI 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, SOx, NOx, PM_{10} per unit of value. Machinery performance is relatively better. This might be driving the lower observed EI effort. If the EU ETS price stabilizes at a medium high level, this might promote further innovation oriented abatement efforts by high emitters.

[22] This result is consistent with those in Horbach and Oltra (2010) for Germany and France. Given the strong international links between ER and Germany, this result would need to be controlled for by referring to intra vs. extra EU international trade. Unfortunately, we do not have the necessary data for this control: in particular, information on capital imports, which may be a primary way for innovation diffusion.

of the literature on R&D spillovers from FDI, it seems that user-supplier relationships are the most inducing of (eco-) innovative behaviours, as they are vehicles for tacit knowledge transmission, whose importance in LPS has been extensively documented. Conversely, cooperating with public research institutions, although important for enabling local firms to access the codified knowledge required to adopt EI (see HP1), is not effective for foreign subsidiaries. These firms may prefer knowledge produced in their internal R&D labs (possibly located abroad) available to them at lower access costs and with lower risks of leakage.

Second, being located in any ID does not give foreign firms any general eco-innovative advantage. However, being located in an established one, such as the mechanical ID in ER (e.g. Antonietti *et al.*, 2009), does (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 the costs of reputation damage from non eco-innovative behaviours by MNC. It is interesting, for example, that, in the interaction, the positive sign of foreign ownership (although not significant) dominates the negative sign of the mechanical IDs (significant). It seems that when reached by FDI, mechanical ID firms switch their strategies from reluctance to favouring EI.

The general results for HP5 change if we consider different kinds of eco-innovations (Tables 7-10).

A first set of results emerges from interacting foreign ownership with supplier's cooperation. This form of cooperation is significantly explaining CO2-related innovation in interaction with foreign ownership, but it loses statistical significance when foreign firms' influences are considered (Table 9). This is not completely unexpected: in front of the hottest environmental issue at global level, a close interaction with the suppliers helps in getting more locally sustainable. Local competencies and incentives are not sufficient, and probably foreign ownerships transmit signals of international policies and international greening markets at the local level. The negligible impact o emission innovation is instead as signal of the weakness of local efforts to cope with regional externalities. It implicitly also says that national and regional policies are not focused on cutting emissions (such as SOx, PM), for which we recall the region presents critical hot spots at sector/geographical level.

Also expected is the result that, only in the case of the ISO140001 adoption, is collaboration with universities significant for foreign firms' EI as cooperation with local suppliers. For learning about standards regulation and how to introduce them, interacting with public research institutes is very beneficial.

Another set of results for HP5 concern agglomeration economies. In particular, the need for strong agglomeration to induce the involvement of foreign firms' in EI (see HP4) is in general attenuated, with the only exception of energy-material savings. For CO_2 and other emissions abatement and the adoption of ISO140001, interaction with "any kind" of ID is enough to stimulate their adoption by foreign firms. Iin the case of energy-materials savings, instead, even location in the mechanical ID does not spur innovations by foreign MNC subsidiaries. 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 prioritise global over local environmental problems. They 'export' their internationally minded firm strategy, which probably insists in the relatively weak environmental innovation basis of the region. That is why we witness stronger impact of agglomeration-foreign factors interactions in favour of carbon dioxide options and ISO14001. Even if the latter poses relatively milder challenges and costs to firms with respect to energy-CO2 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), where global and EU environmental policies play a major role (especially, EU ETS and the CAFE frameworks). Given that Italy has a non very strict environmental policy (Johnstone *et al.*, 2010), it could be argued that 'foreign policy stringency' could be 'imported' via FDI in local clusters. However, this aspect needs further research. It is true 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 the case of ISO140001 adoption, multinational ownership increases the probability to eco-innovate.[23] ISO14001 is the only variable where the positive and negative effects of agglomeration disappear: the ID variable is weakly significant and the Central Emilia dummy is not significant at all. Given the institutional, rather than the economic nature of this type of EI, this result is not unexpected.

[23] This result is consistent with anecdotal evidence for 'German' based ownership of chemical firms (e.g. BASF), which in all cases and situations stimulated an upgrade and new adoption of green techno- organizational innovations.

5. Conclusions

We have investigated the drivers of EI by firms across various techno-organizational categories. We examined potential associations to local oriented factors (firms' networking and agglomeration), international oriented factors (firms' export propensity and foreign ownership) and their interaction. Our findings help to explain how LPS with many SMEs, that are territorially embedded, but open to international relationships, can reshape the techno-organizational content of their products and processes in the face of the challenges posed by the "green economy".

The econometric results are interesting, extend previous micro based evidence and open windows of future research. 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 such 'proactive actions', related to investments in innovation based advantage, outweigh the importance of the more usual structural factors, such as firm size and R&D.

Spatial agglomeration economies role is less clear cut. While the core of the Emilian model – including the environmental harmful ceramic district – is making strong EI efforts, other main geographically agglomerated industries, such as textiles and also machinery, are lagging behind in, and sometimes even hampering the adoption of EI. The specialization patterns of ID, along with their history and urbanization features, are 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 less weight than local factors in explaining EI adoption. The most striking evidence is that firms' foreign ownership matters for EI adoption only when interacted with their production networking – i.e. with their suppliers – and with their location in established IDs as mechanical ones. Globalisation does not hamper EI in ER, which contrasts with the pollution heaven argument. However, and mostly relevant, 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).

Specific EI effects are also worth noting: CO_2 abatement is associated more with supplier related cooperation (but the effect vanishes for foreign ownership) and eco labelling related to collaboration with universities. For ISO_{14001} only the main hypotheses of the paper hold unconditionally. In brief, the specificity of single EI typologies should be included in any analysis of its drivers, which should be based on a system perspective.

These findings have a relevance for both management and policy making. First, it is evident that EI needs 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 effects and EI strategies can be 'imported' from abroad. However, this would not seem to be sufficient and requires appropriate contextualization efforts at the local level. Such joint 'glocal' effects could substitute for the lack of (stringent) environmental policy as main eco innovation driving force.

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Appendix - Tables

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

INDUSTRY	Size					
	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**

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**

Table 3 - Adoption of environmental innovations by industry and size: % 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: CO2 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**
Machinery	0.01	0.00	0.02	0.00	**0.01**
Total	**0.02**	**0.01**	**0.05**	**0.07**	**0.03**

ISO14000					
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**

Table 4 – Some descriptive statistics : dependent variables

	Obs.	Mean	Std. Dev.	Min.	Max.
Env. Innovations	555	0.200	0.400	0	1
Innovation in Material efficiency	555	0.147	0.355	0	1
Innovation in CO2 abatement	555	0.115	0.319	0	1
Innovation in Emission abatement	555	0.140	0.347	0	1
Ems adoption	555	0.028	0.167	0	1
Iso14001 adoption	555	0.120	0.326	0	1

Table 5 – Some descriptive statistics : independent variables

	Obs.	Mean	Std. Dev.	Min.	Max.
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
Industrial district	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

Stats for non significant covariates pertaining to other cooperation actions and innovation realms are available

Table 6 – Overall EI, foreign ownership, cooperation and agglomeration

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

*** significant at the 1%; ** significant at the 5%; * significant at the 10%; robust standard errors; t statistics in parentheses

Table 7 – Materials/resources reducing innovations, foreign ownership, cooperation and agglomeration

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

*** significant at the 1%; ** significant at the 5%; * significant at the 10%; robust standard errors; t statistics in parentheses

Table 8 – Carbon reduction innovations, foreign ownership, cooperation and agglomeration

ESTIMATION METHOD: DPROBIT	Dependent variable: *CO2 abatement technology*				
	[1]	[2]	[3]	[4]	[5]
	dF/dx	*dF/dx*	*dF/dx*	*dF/dx*	*dF/dx*
R&D	0.019	0.021	0.021	0.019	0.020
	[0.70]	[0.78]	[0.75]	[0.68]	[0.73]
ICT adoption	0.224***	0.224***	0.214***	0.225***	0.227***
	[3.41]	[3.44]	[3.36]	[3.46]	[3.48]
Training coverage	0.0009***	0.0008***	0.0008***	0.0008***	0.0008***
	[3.30]	[3.30]	[3.29]	[3.28]	[3.30]
Central Emilia dummy	0.052**	0.051**	0.055***	0.053**	0.052**
	[2.46]	[2.51]	[2.69]	[2.54]	[2.54]
20-49 empl.	-0.003	0.001	-0.004	-0.004	0.001
	[-0.09]	[0.03]	[-0.01]	[-0.12]	[0.03]
50-99 empl.	-0.011	-0.006	-0.004	-0.008	-0.002
	[-0.38]	[-0.21]	[-0.16]	[-0.25]	[-0.06]
100-249 empl.	0.033	0.041	0.044	0.035	0.044
	[0.89]	[1.12]	[1.18]	[0.91]	[1.13]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	-0.00002	0.00002	0.00003	-0.00004	-0.00001
	[-0.08]	[0.03]	[0.12]	[-0.13]	[-0.04]
Industrial district	-0.067***	-0.075***	…	-0.068***	-0.074***
	[-3.08]	[-3.42]		[-3.17]	[-3.39]
Mechanical district	…	…	-0.078***	…	…
			[-3.68]		
University cooperation	0.138***	0.127**	0.126**	0.127**	0.126**
	[2.57]	[2.32]	[2.29]	[2.09]	[2.10]
Suppliers cooperation	0.107***	0.107***	0.108***	0.071*	0.073**
	[3.28]	[3.39]	[3.42]	[1.93]	[2.01]
Foreign ownership	0.052	0.028	0.026	-0.036	-0.036
	[1.60]	[0.89]	[0.86]	[-0.99]	[-1.03]
Foreign own. Industrial district	…	0.220*	…	…	0.194
		[1.78]			[1.42]
Foreign own. Mech. district	…	…	0.277**	…	…
			[2.00]		
University coop. Foreign own.	…	…	…	0.140	0.089
				[1.03]	[0.68]
Suppliers coop. Foreign own.	…	…	…	0.170**	0.160**
				[2.07]	[2.05]
Pseudo-R^2	0.221	0.227	0.231	0.234	0.238
N. Obs.	555	555	555	555	555

*** significant at the 1%; ** significant at the 5%; * significant at the 10%; robust standard errors; t statistics in parentheses

Table 9 – Emission reduction innovations, foreign ownership, cooperation and agglomeration

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

*** significant at the 1%; ** significant at the 5%; * significant at the 10%; robust standard errors; t statistics in parentheses

Table 10 – Organizational eco innovations, foreign ownership, cooperation and agglomeration

ESTIMATION METHOD: DPROBIT	Dependent variable: *ISO14001 adoption*				
	[1]	[2]	[3]	[4]	[5]
	dF/dx	*dF/dx*	*dF/dx*	*dF/dx*	*dF/dx*
R&D	-0.042	-0.037	-0.037	-0.052	-0.046
	[-1.22]	[-1.12]	[-1.12]	[-1.50]	[-1.38]
ICT adoption	0.075	0.080	0.073	0.018	0.088
	[1.03]	[1.09]	[1.02]	[1.60]	[1.22]
Training coverage	0.001***	0.001***	0.001***	0.001***	0.001***
	[3.79]	[3.75]	[3.75]	[3.91]	[3.84]
Central Emilia dummy	0.022	0.022	0.024	0.020	0.018
	[0.97]	[0.99]	[1.06]	[0.85]	[0.80]
20-49 empl.	-0.053	-0.049	-0.049	-0.046	-0.042
	[-1.44]	[-1.36]	[-1.38]	[-1.20]	[-1.09]
50-99 empl.	-0.028	-0.024	-0.021	-0.016	-0.010
	[-0.90]	[-0.76]	[-0.68]	[-0.48]	[-0.30]
100-249 empl.	0.062	0.070*	0.074*	0.075*	0.086**
	[1.56]	[1.73]	[1.78]	[1.78]	[1.98]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0001	0.0001	0.0001	0.0001	0.0001
	[0.28]	[0.45]	[0.51]	[0.26]	[0.44]
Industrial district	-0.031	-0.047*	…	-0.026	-0.042
	[-1.15]	[-1.68]		[-0.90]	[-1.50]
Mechanical district	…	…	-0.052*	…	…
			[-1.79]		
University cooperation	0.200***	0.187***	0.186***	0.231***	0.223***
	[3.28]	[3.07]	[3.06]	[3.36]	[3.31]
Suppliers cooperation	0.142***	0.143***	0.143***	0.083*	0.084**
	[3.98]	[4.11]	[4.11]	[1.96]	[2.03]
Foreign ownership	0.066*	0.033	0.031	-0.027	-0.042
	[1.87]	[1.02]	[0.97]	[-0.52]	[-1.00]
Foreign own. Industrial district	…	0.231*	…	…	0.301*
		[1.75]			[1.67]
Foreign own. Mech. District	…	…	0.296**	…	…
			[1.97]		
University coop. Foreign own.	…	…	…	0.231***	-0.111
				[3.36]	[-0.61]
Suppliers coop. Foreign own.	…	…	…	0.083*	0.300***
				[1.96]	[3.32]
Pseudo-R^2	0.227	0.234	0.236	0.252	0.261
N. Obs.	555	555	555	555	555

*** significant at the 1%; ** significant at the 5%; * significant at the 10%; robust standard errors; t statistics in parentheses

Appendix

Table A.1 – 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

A2 - Relevant survey questions

- **Did the firm adopted technological and organizational innovations of environmental nature over 2006-2008?**[i] (if not, go to 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. EMAS		
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?**

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)		

[i] 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.

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