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Enviromental Innovations, Complementarity and Local/Global Cooperation

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Environmental Innovations, Complementarity and Local/Global Cooperation[1]

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Abstract

This paper exploits a rich, new innovation based dataset of 555 industrial firms, located in the Emilia Romagna region in 2006-2008, to analyse complementarity in factors related to eco-innovation (EI) and to test the role of firm cooperation and internationally oriented strategies. EI is providing additional competitive advantage and is relevant to all EU industries. Results show that the degree of complementarity between various correlated EI factors is quite high, with networking and corporate social responsibility (CSR) playing dominant roles. It would seem that EIs do not undermine economic performance, either in the short run or in the context of the global financial crisis. Econometric analyses highlight that international characteristics, especially foreign ownership, and networking with other firms and institutions are important for EI adoption, while general research and development is less so. Over and above the structural features of firms, strategic relationships within regions and at the international level are relevant and differentiate innovative performance. Spots of a green dawn seem appearing from the historical 'brown' and polluting industrial setting of the region. Its brilliant economic performances could decouple if this improvement continues. This study provides and in depth regional investigation which could complement the information gathered in the last wave of the Community Innovation Survey which included questions on EI.

Keywords: Eco-innovation; complementarity; local industrial systems, networking, international strategies

JEL classifications: C21, L60, O13, O30, Q20, Q58

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1. INTRODUCTION

Available definitions of eco-innovation (see CML et al., 2008; UNU-MERIT et al., 2008; Europe Innova, 2008; Kemp, 2010) tend to highlight the ‘eco’ attributes of individual new processes, products and methods evaluated from a technical and ecological perspective. For example, the MEI (Measuring Eco-Innovation) research project defines eco-innovation as *the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (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*.

Although this definition of eco-innovation (EI) is very close to the definition of environmental technologies, which are described as *all technologies whose use is less environmentally harmful than relevant alternatives*, it is about more than just specific technologies, and includes new organisational methods, products, services and knowledge oriented innovations. Organisational methods are closely linked to education and training, and in turn human capital. EI then is neither sector nor technology specific and can be part of any economic activity, not just those in the still loosely defined ‘eco-industry’ sectors. EI is not limited to environmentally motivated innovation, but includes the ’unintended’ eco-effects of any innovation. When considered outside the purely technical dimension of (improved) environmental impacts, EI can be seen to have a *systemic and behavioural dimension* that is consistent with both the conventional economic approach to innovation tout court and extensive evidence on the systemic dimension of EI (Horbach, 2008).

The challenge in research on EI is to establish robust techno-ecological measures of single EIs and of the eco-impact of innovations, based on the economic dimension of EI as a behavioural process.

These dimensions of EI compared to a purely techno-ecological perspective on individual (eco-) innovations, points to the possible importance of a complementarity based perspective when analysing the drivers of EI or correlated factors. Complementarity effects may be useful to explain observed jointness, and may characterise both the input and output sides of innovation. It is accepted that greater investment in inputs is needed to increase the likelihood of achievement and adoption of radical innovation. On the adoption side, the coincidence of several innovations may increase the linking between environmental and economic goals (Mazzanti and Zoboli, 2009, 2010). This may be achieved through joint investment in innovation inputs to achieve increasing returns to scale and sharing of inputs across firms, and by the clustering of EIs, of both eco and other innovations are adopted to achieve a common performance goal, e.g. economic, environmental-economic decoupling, at firm level. It may allow the integration of technical measurements of single EI within a broader socio- economic perspective that includes different ‘eco-innovating actors’. In this paper we focus primarily on complementarity, and two specific sources of firm competitive advantage based on eco innovation (correlated factors): networking with firms and institutions in the local system, and internationalization strategies. Both factors are ‘drivers’ that go beyond the narrow ‘firm specific’ internal innovation features, extending the competitive advantage picture. It considers firms that are located in dense local systems of relationships and districts, but are open to the international economy. This means that the sources of competitiveness (value creation, motivation for innovation to stimulate economic performance) are to be found at different levels, and that the 'relational' features of networking and internalisation are crucial for maintaining and improving firm competitiveness over the long run (Cainelli and Zoboli, 2004).

In previous work (Mazzanti and Zoboli, 2008, 2009), we proposed a conceptual framework that allowed us to analyse complementarity in EI, applying it to a sample of Italian industrial district firms, surveyed via questionnaire. The present work further develops this conceptual framework by including innovation complementarity in the measurement of EI. We develop an empirical analysis using data from a recent (2009) original survey of the eco-innovation behaviour of 555 manufacturing firms in the Emilia Romagna region of Italy, focusing on the role of networking (internal local competitive advantage) in the local system and international sources of competitive advantages (open factor competition). The empirical analysis is in two parts; one is mostly descriptive and the other is based on the econometrics of the adoption of innovation. First, we conduct a quantitative analysis of the 'complementarity hypotheses', taking into account various (eco)innovations and providing some insights on the links between economic performance and the adoption of EI, based on stated firm performance before and during the 2008-2009 crisis. Second we conduct an econometric analysis of the relevance for firms operating in a local system, of 'external to the firm but internal to the local system' (networking) and international, external to the system, sources of (new) completive advantage related to the development of EIs. The conceptual link between these analyses is the role of cooperation aimed at developing eco innovation in industry firms. In this paper, we deliberately frame our reasoning within this cross section environment around the concept of 'EI correlated factors'. We leave it to future efforts based on survey waves and merged data, to assess what are the 'driving forces' of EI. The analyses in this paper aim at assessing 'robust' (multivariate) statistical correlations.

Sections 2 and 3 debate the central issue of complementarity and discuss the role of international factors and local cooperation. Section 4 investigates the research hypotheses, the dataset and the empirical analyses. Section 5 concludes.

2. DIMENSIONS OF THE COMPLEMENTARITIES IN RELATION TO EI

2.1. TECHNICAL ALIGNMENT

Available definitions of EI include consideration of the 'unintended eco-effects of innovations', which could represent a class of complementarity effects in the form of 'technical jointness in impacts', which opens up the problem of EI measurement.

One form of technical jointness could be linked to the 'impure public good' nature of inputs or outputs in a specific process or product (Rubbelke and Markandya, 2008, Loschel and Rubbelke, 2009; Kotchen, 2005). EI in the form of greater energy efficiency may provide a dividend in the form of unintended emissions reduction (greenhouse gases - GHG and other air pollutants). Intended energy savings could be considered a priced private good, to which a public good component is attached through the social shadow price of the non-renewable resource, while unintended emissions reductions constitute a non-priced public good if the emitter is not subject to a carbon tax or emissions trading. The reverse may also apply: intended emissions abatement (GHG and air pollutants), a valued private good in the presence of regulation or carbon taxation or emissions trading, may produce energy saving as unintended impact if the relevant emission is proportional to the energy inputs.

This applies also to the technical jointness between GHG and air pollutants, whether jointly or individually regulated, as highlighted by the 'ancillary benefits' of climate change policy, and can be extended to other forms of technical jointness between different inputs, for example, energy saving that saves cooling water inputs and/or waste ash, both of which incorporate a mix of public good features.

The same jointness could apply also to product innovation without direct environmental aims, e.g. downsized products which save on packaging, where there is production of a priced private good and a mixed private good in the form of savings on packaging costs and packaging waste.

Technical jointness has a policy implication: it allows the possibility of leveraging the positive unintended effect by focusing on the main innovation or to focus on the joint effects as joint products of the policy. This possibility may be geared to the existence and influence of private good components of innovation outcomes that have the features of a mixed public good.[5]

The measurement of technical jointness introduces the possibility that the impact of specific innovations and related policies may be overstated. For example, observed emissions reductions may be the unintended effects of energy efficiency, and vice versa to some extent.

The technical features of processes and products may define the specific, possibly unique, features of relevant technical jointness, and the unintended effects may be negative depending on the specific case being examined. This could apply also to single processes within innovations aimed at savings related to a specific type of input, e.g. material, which require increased use of another type, e.g. energy, or biased innovations with input trade-offs. IPPC-type policies, based on joint regulation of different impacts at industry plant level, partly encompass the possibility of a trade-off. Measurement of environmental impacts could overstate the net environmental role of a specific innovation by disregarding the negative technical effects.

Over the life cycle of a product, another dimension of technical complementarity or positive effect of sequentially linked combination of separated but reciprocally consistent processes, inputs, consumption activities and waste may arise. Any product innovation intended to reduce environmental impact may involve a single change or a combination of changes to the set of inputs (energy, materials, services) and their sources, the production process, consumption behaviour and type of waste generation. For example,

[5] A similar approach to innovation in green consumption is suggested by Benabou and Tirole (2010).

automobile innovations aimed at achieving greater fuel economy may involve not only changes to the car engines to accommodate different fuels, but also complementary changes in the materials used and in turn suppliers, changes to energy management devices involving new components, changes to the tyres, their technology and material, and changes in the form of the intended life of the cars, their waste disposal and scrap value. More radical intended innovations, such as plug-in hybrids, a recent and ongoing EI or LPG fuelled cars, an earlier innovation, may involve large scale infrastructural and networking innovation. The definition and success of radical innovations involve more than just R&D and production: they require a recombination of existing technologies, investment in infrastructure and marketing and diffusion efforts (Kemp, 2010; Van den Bergh, 2007, Zeppini and van den Bergh, 2010).

A system-wide, life cycle analysis (LCA) approach is required to analyse the non-intended environmental effects innovations to complex socio-technical systems and networks. An example of one such innovation is Information and Communication Technologies (ICT). The specific and direct and the general and indirect environmental implications of ICT use and diffusion are very extensive and differentiated, and depend on scale and network effects. They include increased demand for electricity vs reduced need for mobility and physical interaction (rebound effect):,[6] a complete assessment picture of the net environmental (unintended) effects has still to be completed.

All innovations have environmental implications that may be greater - positively or negatively – outweigh than the impacts of innovations categorised as EI based on their sector of application or declared eco-attributes. Surveying firms about their eco innovations would thus be useful.

[6] The literature on 'rebound effects' maintains that efficiency improvements paradoxically can lead to higher energy consumption (OECD, 2008). Higher labour productivity, driven by technological and human capital investments, generates positive welfare effects in terms of higher wages and more leisure time: after a certain wage level workers react by reducing their work effort. Eventual 'overall economic-environmental productivity' at the macro level occurs if both components are integrated. Despite the need to improve technology and productivity to achieve environmental and social sustainability, there may be negative compensation in the form of rebound effects based on higher efficiency and increased available time (Hammer and Hubacek, 2003). The final effects will depend on the environmental oriented nature of the preferences: are the incremental wages and time achieved allocated to the consumption of green or brown goods or a mix of the two (buying a new car vs buying more organic food, paying for education vs travelling, driving as a leisure activity vs visiting a museum/cinema). The large literature on rebound effects is not conclusive. Holm and Englund (2009) analyse long run trends in the EU and US of increased eco efficiency and increased use of natural resources. The OECD surveyed the households in 7 OECD countries to analyse SCWHAT IS SC behaviour in various areas, including energy saving. It found negligible rebound effects. See also the OECD conference on household behavior and environmental policy organised by the Environment Directorate, held on 3-4 June 2009 (http://www.oecd.org/document/62/0,3343,en_2649_34331_42638270_1_1_1_37465,00.html).

2.2. ENVIRONMENTAL MANAGEMENT SYSTEMS (EMS) AND CORPORATE SOCIAL RESPONSIBILITY (CSR) AS EI CLUSTERING

Eco-management systems (EMS) and formalised, accountable approaches to environmental corporate social responsibility (CSR) involve an interesting set of complementarity dimensions. These types of innovations, intended to improve the environmental performance of the firm as a whole, might encompass a set of measurable eco-improvements in process/product/organisation (Frondel et al., 2008, 2007). Their perceived benefits for the firm must be manifest in a consistent set of improvements (Johnstone and Labonne, 2009; Rennings et al., 2006) including improved competitiveness (Wagner, 2009). In this case, complementarity between intended/unintended EIs, in the form of technical jointness or synergies, are intrinsic. Regulation/standardisation, evolving reference parameters, and the increased number of environmental attributes encompassed by the innovation acts to cluster EIs around holistic complementarity settings conditional on their adoption.

In the context of EI measurement, we can differentiate between EMS and CSR, as in the economics-management literature[7]. A good proxy for a single innovation measure of an EMS based on its technical requirements, etc. might be diffusion, for example, by weighting adoption according to regulation on different attributes (emissions, waste, water, etc.). This does not eliminate the internal and external unintended effects throughout the life cycle. In the case of CSR, which usually encompasses an EMS, the dimension of holist complementarity may be even stronger, but the small chances of standardisation prevent this being used to measure EI.

2.3. COMPLEMENTARITY AT FIRM LEVEL

A different form of complementarity, which we can call ‘strategic’, emerges from the empirical observation that firms tend to pursue *together* intended EI that are *disjointed* technically and are not necessarily part of a holistic EMS/CSR system. This perspective highlights the firm and the firm strategy as the reference point for understanding and measuring EI, and the perspective of eco-innovator and eco-innovative business models.

Complementarity at firm level can include different configurations, for example, consistent combinations of single EIs, tight links between EIs and early-mover eco-strategies. Such a level of complementarity may be

[7] Note that CSR behaviour (Lyon and Maxwell, 2008; Reihnardt et al., 2008) an be present in economic/institutional frameworks characterised by regulated markets, where more innovative firms take a long run, ‘beyond compliance’ perspective to profit making. Socially responsible firms are oriented towards achieving long run profits and mitigating trade off in line with Porter’s hypothesis, at least at the micro level (Margolis et al., 2007). Sustainability strategies (such as adoption of EMAS or CSR criteria) are followed by very innovative firms –in innovation intense sectors – positioned at the innovation frontier, which are able to anticipate social needs and new technology adoption. These firms are ‘sustainable’ in profit, economic, social and environmental terms. They define sustainable profit as the medium to long run maximisation of corporate asset values (Portney, 2008).

driven by the characteristics of the sector, but also may be firm specific in terms of capabilities and unique firm attributes.

Complementarity is a potential driver of innovation in highly embedded local systems that are rich in idiosyncratic factors, for example, industrial districts which achieve agglomeration economies, knowledge spillovers, close relations, etc. In this framework, complementarity is based on interdependence and coordination in resources, such as knowledge, factor endowments and policy, whose effects may be felt in the short and the long term according to Porter (Rexhäuser and Rennings, 2010). Embeddedness emerges through networking, a factor external to the firm but internal to its socio-technical system, and impacts on firm behaviour. The role of firm size in innovation is important according to Nooteboom (1999), who emphasises Schumpeter's (DATE) hypotheses and the ambiguous results provided by some more recent empirical research: "the relevant variable is not firm size, but degree of integration and the strength of links" (Nooteboom, 1999, p. 143). Depending on network linkages and the organisational structure of the firm, both small and large organisations can become the engines of innovation in the form of 'creative destruction'. Complementarity can also be studied systemically, for example, Teece (1996) sees complementarity as associated with asset specificity in the form of firm inputs and/or innovation, which may generate an idiosyncratic (non-replicable) organisational framework that enables increased performance based on co-specialisation among productive factors. Complementarity then is a non-transferable and non-modular intangible asset (Langlois, 2002).

Complementarity between two firm activities implies that were one of these activities to be increased, it would be beneficial also to increase the other activity. This produces system effects where the whole is more than the sum of its parts. When two or more activities in a firm are in a complementary relationship, firm and policy efforts should be targeted to all these activities, since improvements to only one area might result in reduced overall firm performance.[8]

The importance of complementarity is underlined in the literature on innovation strategy and firm performance. Since the mid 1990s, scholars have pointed to the limited short run effects of strategies directed to organisational (cost) efficiency and the higher potential for increasing long run performance in innovation-based management of firms (Huselid, 1995; Black and Lynch, 1996, 2004; Ichniowski et al., 1997).

A multi-driver and complementarity oriented perspective is coherent with the evolution of socio-technical regimes in Geels and Schot (2007), Geels (2004) and Smith et al. (2005), where the joint effects of market features, policy, firm strategy and external influences (network) matter and stem from different theoretical approaches (Krozer and Nentjes, 2006) and the joint analysis of R&D, idiosyncratic factors and policy stimuli in neoclassic, behavioural and evolutionary theories of the firm.

[8] On this refer to the examples described in Milgrom and Roberts (1995, p. 194).

Evidence of complementarity in terms of innovation and performance factors is provided in the applied EI literature. However, there is less explicit recognition of a theoretical complementarity framework, which is referred to mainly at the level of joint adoption of EI, based on multivariate probit analysis (Horbach, 2008; Ziegler and Nogareda, 2009; Wagner, 2007). The present study aims to provide new empirical evidence and suggest directions for future research.

3. INNOVATION, THE PORTER HYPOTHESIS AND INTERNATIONAL COMPETITIVENESS

As referred to in the introduction, we extend the reasoning on the correlated factors of eco innovation to include previously less well examined issues related to internationalisation, relevant to the long run performance of firms and the economic and environmental sustainable development of open local industrial systems. Trade has been thoroughly debated in the context of environmental economics: we do not enter this debate here apart from commenting that trade obviously presents both pros and cons in terms of the environmental and economic benefits, both national and international. If the focus is on the specific effects generated by environmental regulation on comparative trade advantages, the dominant perspectives are the pollution haven (Levinson, 2010; Muradian *et al.*, 2002) and Porter hypotheses. According to Copeland and Taylor (2004), environmental policy enters a Heckscher-Ohlin theoretical framework as a constraint on factor endowment. Thus, the introduction of more stringent environmental regulation would be potentially harmful to the productivity and competitiveness of domestic firms facing higher production costs. This could lead to the delocalization of production towards countries with relatively less strict environmental regulation.

The Porter hypothesis revolves around the potential complementarities and private beneficial effects of properly designed environmental regulation. which are likely to emerge in a dynamic context where innovation and environmental strategies co-evolve (Wagner, 2007). Given that ideas emerge and evolve over time, within the Porter hypothesis, a set of hypotheses related to micro and macro frameworks has emerged. Since 1990, we have seen a hybridisation of approaches from pure managerial business relying on case study analyses (Esty and Porter, 1998), to environmental economics essays dealing with micro and macro issues related to trade, innovation and economic performance (Ambec and Lanoie, 2008).

Nevertheless, the taxonomy proposed by Jaffe and Palmer (1997) remains valid since most contributions fall into one or other category of the Porter hypothesis. The stronger version (or strong Porter hypothesis) claims that environmental regulation enhances net economic performance for the economy as a whole, at least in the medium run. The innovation it promotes can produce a net effect on economic performance which is positive with regard to innovation offsets (process efficiencies and product value enhancements deriving from the early adoption of technological and organizational innovation as in Porter and van der Linde, 1995).

The weak Porter hypothesis predicts that a very stringent regulatory framework impacts positively only on the green innovation aspects of the economy, with no complete offset of regulatory costs overall. In this case, compliant firms need to choose between investing in innovative, green activities or simply adopting green technologies. In the first case, environmental regulation affects the supply side, in the second case there is a demand-side effect. If the environmental regulatory framework is appropriate to the economic system, supply and demand effects will be coherent, producing long run equilibrium.

If we assume that the two streams of research can be interlinked, the combination of environmental policies and (induced) innovation may lead to increasing environmental efficiency combined with productivity gains, as in Porter and van der Linde, 1995) framework.

Achieving overall sustainable economic development requires dynamic innovation activity combined with strict environmental regulation. If the objective is to reduce the pollution embodied in imports, then similar reductions need to be achieved in the production of exports. The greening of exports will require joint economic-technological-environmental dividends. In the literature, more stringent environmental regulation traditionally is seen as potentially harmful to the productivity and competitiveness of national industry since it can lead to higher costs for firms (Antweiler *et al*., 2001; 2004; Levinson and Taylor, 2004). However, the contributions that build on Schumpeter's *creative response* of economies in adapting to changes in conditions, and on the extensive literature on the induced-innovation hypothesis proposed by Hicks (DATE), argue that the introduction of strict environmental regulation may stimulate green innovation and increase competitiveness in exports of environmental technologies (Costantini and Mazzanti, 2010).

Specialization by the advanced economies in energy intensive sectors and relative man made capital abundance, the advantages of Italian industry may explain why support for the pollution haven hypothesis is scarce and depends on specific industry conditions (Cole et al., 2010; Wagner and Timmins, 2009). Some studies show that EU trade openness in some cases is linked to negative environmental performance (Marin and Mazzanti, 2010): core intra EU trade can be environmentally beneficial through innovative intense trade relationships. To summarise, it is necessary to analyse all the conditions (environmental stringency, trade openness by area, capital abundance) in order to provide robust evidence of. Innovation is central and trade related effects may explain why the pollution haven hypothesis cannot be taken for granted since trade effects ultimately are complex and innovation dependent.

We next discuss some issues relevant to Italy. First, increasing trade openness may be associated with stricter integration of environmental policy. Italy is a 'follower' and a convergent country in terms of environmental policy implementation in the EU context, thus this hypothesis has robust roots (Johnstone et al., 2010). Italy is able to benefit from trade links with Germany and other countries with strict environmental regulation. Second, through increased openness, intra-branch specialisation may favour more efficient technologies and production processes over time (Femia and Marra Campanale, 2010). This would support increasing Italian specialisation in more environmentally benign sectors and production processes (Marin and Mazzanti, 2011; Mazzanti and Zoboli, 2010). Thus, we have evidence of trade related innovation/R&D and embodied international knowledge supporting national economic-environmental competitiveness. This confirms the importance for economic growth and environmental performance of a common trade area. The evidence indirectly links to the literature analysing direct and indirect trade related innovation effects (Keller, 2004; van Pottelsberghe de la Potterie, 1997; Lumenga Neso et al., 2005, Eaton and Kortum, 1999), which builds on R&D rent spillovers and embodied and disembodied technological diffusion (Jaffe, 1986). Trade enables the flow of innovation between direct and indirect partners, with decreasing effects as trade rounds multiply. Although distance promotes decay, external R&D transmitted through trade may matter for sector economic and environmental productivity even more than internal innovation efforts (Griliches, 1992, Franco et al., 2009; Costantini et al., 2010). Direct trade effects are especially important: the largest share of Italian export (13%) and import (17%) trade is with Germany, a leader in green technology adoption and diffusion. Import and export trade involves machinery and transport equipment, foodstuffs, ferrous and nonferrous metals, wool, cotton and energy products.

Thus, institutional, economic, trade and policy issues contribute to the creation and diffusion of major innovations (Rennings and Smidt, 2008, Johnstone *et al*., 2010). There is increasing consensus on the potential win-win effects deriving from a good combination of environmental and innovation strategies, both private and public (Kemp, 1997, 2000). The introduction of new environmental regulation will stimulate research only if innovation systems are equipped with the required scientific and technological knowledge to allow their responses to be coherent with environmental goals (Costantini and Crespi, 2008; Rennings, 2000).

In terms of 'trade and external links', export and FDI can improve green content, although the role of regulation and policy to stimulate innovation and greener economic performances remains crucial. The real challenge is increasing (environmental) efficiency in exports and imports (Levinson, 2009, 2010): creating the conditions for a race to the top rather than the bottom through the processes of development and globalisation. It is important to assess whether international firm features are correlated to more robust EIs.

4. EMPIRICAL ANALYSES

4.1 RESEARCH HYPOTHESES ON *COMPLEMENTARITIES AND CORRELATED FACTORS OF EI IN AN OPEN LOCAL ECONOMIC SYSTEM*

We test complementarity at the level of the jointness between pairs of 'EI correlated factors' (e.g. innovation inputs), relying on Milgrom and Roberts' (1995) framework of managerial, innovation and organisational asset complementarity.[9] We refer also to a paper by Costinot (2009) who uses complementarity to explain

[9] More formally, complementarity holds according to the test in this way: (11) + (00) ≥ (01) + (10). If an agent implements just one of these factors, there will be no benefit. In a multivariate setting all 4 coefficients need to be estimated (Mancinelli and Mazzanti, 2009) in order to conduct the test.

international competitive advantage based on efficiency and endowment factors (we refer the reader also to Mancinelli and Mazzanti, 2009). We first assess which innovation correlated factors can be seen as having substantial complementarity and for which eco innovations produce positive or at least negligible effects on economic performances in the short run (and Porter type reasoning in the medium run). We conduct our complementarity analysis by means of descriptive investigation of the data as described below.

Second, since the correlated factors of eco innovations have been shown to be multiple and diverse (Mazzanti and Zoboli, 2009; Horbach, 2008), we conduct econometric analysis of the relevance of internationalization and cooperation oriented to innovation in addition to structural firm variables and R&D. See Table 1 for the research hypotheses and expected signs/correlations.

In terms of networking, intended as innovation oriented cooperation with regional agents (competitors, clients, outsourcers, public institutions), we note that networking activities may partially substitute for economies of scale in the small and medium sized firm (SME) environment. We gathered data on the sources of EI, including networking with firms and public institutions, to test an important recent hypothesis in the social capital (SC) literature (Glaeser –et al., 2002) that there is a positive relationship between R&D and SC in an impure public goods framework (Cornes and Sandler, 1986), where SC arises as an intangible asset, defined as firm investment in co-operative/networking agreements (Capello, 1999; Capello and Faggian, 2005). Others (Smith et al., 2005) suggest that in the sustainable transition of socio-technical regimes, actors do not have sufficient resources unilaterally to influence a regime. Regime members are bound together by resource interdependencies necessary for functioning and reproduction. Networking, as a factor external to the firm but internal and idiosyncratic to the local (innovation) system, is vital for radical innovation. Cooperation and competition drive the evolution of the sectoral system of innovation and technological system, which consist mainly of dynamic knowledge and competence networks (Geels, 2004). In order to capture the effect of networking, we exploit firms' responses about their innovative oriented relationship with other firms, suppliers, clients, and research centres/universities. We use membership of an industrial district to proxy for agglomeration.

In terms of international firm strategies, these are captured by the share of exported value, where we expect a positive correlation with innovation. We also test for a correlation between foreign ownership and EI. We examine whether the sub class of firms with foreign ownership is associated with more intense EI. Preliminary descriptive statistics would seem to indicate that this is the case. Being aware the that the nexus of causality could be reciprocal (though our innovation data are over 2006-2008, and we can robustly assume that most foreign ownership /FDI related links date back 2006 and characterise themselves as medium run structural factors for a firm in the local industrial system). This indicates that contrary to defensive strategies and consistent with a value creation approach à la Porter, along the whole value chain, foreign ownership promotes EI strategies. Foreign firms invest in the regional system (the local system of production) not (only) to exploit relatively cheaper labour costs (such as in Italy) and a relatively laxer environmental regulation framework, but also to invest in more innovative firms. This may promote the 'greening' of foreign organisations, and a reshaping of innovation based competitive advantage since international firms focus on international policy and demand frameworks.

We also consider firm structural variables. Economies of scale may spur innovative strategies and we use the number of firm employees to proxy for size. We also include R&D and the share of final market production.

Table 1 - The set of research hypotheses (main tests)

Complementarity assessment (descriptive analyses)	
Innovation correlated factors (input level)	Complementarity is likely to characterise some firms' innovative behaviour, but should be tested case by case
Correlated factors of Innovation adoptions (econometric analyses)	
International firm features /strategies • Share of exports on turnover • Foreign ownership	A firm embedded in international markets and which is trade dependent may be induced to adopt more green innovations as a source of competitive advantage, indirectly driven by the more stringent policies of foreign clients and partners
District membership	EI, ,more than organisational innovations such as EMS/auditing, may be positively correlated to district areas
R&D	R&D should drive stronger innovation adoption, although it may be that general R&D is merely a proxy for absorptive capacity not an intentional firm innovation oriented strategy, which is key to radical innovation or extension of the frontier of green options
Networking /cooperation	Networking may be positively correlated to innovation, jointly with or separately from R&D effects

4.2 THE SURVEY BASED DATASET: ADOPTION OF ECO INNOVATIONS AND BEYOND

4.2.1 Descriptive and preliminary investigations

We exploit data from an original CIS-type survey administered in 2009,which allows generalisation and comparison of results. We administered our questionnaire to the population of firms with over 20 employees; we administered 555 questionnaires to manufacturing firms in nine provinces in the Emilia Romagna region in the North East of Italy, covering all sectors. The questionnaire response rate was around 30%; the data are representative of sector, firm size and province (Table 2) and cover the period 2006-2008. The questionnaire enquired about firms' innovation activities encompassed by their technological, organisational, ICT, training and internalisation strategies. Our multivariate setting provides rich information. Reflecting the specialisation of the regional manufacturing system, 223 firms in the sample are in sector DK-DL-DM (machinery and equipments and transport). The EI dataset was constructed from the responses to a more extensive questionnaire administered in 2009 to the firms that responded to the first survey, which asked about structural economic features, performance, productivity, employment, investments, general innovation, internationalisation, responses to crises, etc.. It allowed us to correlate EI dimensions with other dimensions of firm structure and behavior. The questions related specifically to EI included questions about adoption (yes/no) of EIs in 2006-2008, the aims or objectives of EI adoption (CO_2 reductions, other pollutant reductions, energy/materials savings), the adoption of EMS systems (EMAS, ISO, others), investment of own economic resources in EI (R&D, specific equipments, clean technologies), motivation for EI (legislation compliance, market demand, expected policy developments, expected change in demand). The actual survey questions are presented in the appendix.

The share of firms adopting EIs is 20% of the total, showing that the majority of firms do not adopt a strategy of economic and environmental efficiency or engage in EI. This may be because of the large share of firms in the sample in machinery/equipment/transport sector. This sector tends to produce fewer emissions than say, firms in the ceramic and metallurgy sectors.

Firm size seems to be a good predictor of the rate of adoption of EI. Firms with more than 100 employees show rates of adoption that are double those among firms with between 20 and 99 employees: the rates is three or four times in some sectors (Table 3). This relationship between adoption rate and firm size echoes the results in the literature (e.g. Johnstone, 2007). The breakpoint of 100 employees applies also to adoption of EMS and ISO_{14001}, and especially environmental R&D investment.

At the level of sectors, the adoption of at least one EI is higher than the average (around 28%-32%) for sectors DD-DE-DN, DF-DG-DH, DI, DJ (see the appendix for a sector code taxonomy), and lower for the food and machinery & equipment sectors. Textiles firms do not engage in any form of EI.

The adoption of EMS, as expected, is most dominant in sector DI, due to the 'district-level environmental certification' in the ceramic tiles industry; it also figures significantly in sectors DF-DG-DH for environmental ISO. Environmental R&D investment is highest in sectors DF-DG-DH, DI and DJ; in DJ the pattern follows the pattern of general innovation activity. The geographical distribution of EI (see figures 1-3) highlights central Emilia (Brusco, 1982) as more innovative based on historically very good export performance. EI activity may be a response to global demand or to environmental weaknesses in the industry specialization or the need for greater production efficiency. Mazzanti and Montini (2010a,b) and Costantini et al. (2010) show that regional environmental performance in terms of emissions reduction and value added, are not a priority in the region. This regional case study presents some idiosyncrasies, but is generally characterized by a series of factors including internationalization of production and networking, local firm clustering, environmental hot spots generated by agglomeration and specialization, which may apply also to other EU industrial areas. EI could emerge from these correlated factors, in order to compensate global/local environmental externalities and to further extend the competitiveness frontier.

In terms of technological objectives,[10] for example, reduction of CO_2 and greater materials and energy efficiency, we see that there is a firm-size effect; in the case of air pollutants (PM, NMVOC, SOx, NOx) adoption rates are similar for firms with less than 100 employees and firms with over 100 employees. As expected, there is less emphasis on the adoption of innovations to reduce CO_2 which is likely because Italy does not have a carbon policy and implementation of the EU emission trading scheme did not occur until in 2006. Only firms in highly polluting sectors, such as DI and DJ, show EI adoption rates higher than 20%. For materials and energy efficiency, EI rates are higher. On average, energy/material savings efforts are made by 15% of the firms in our sample, with a peak of 26% among larger firms. The motivations for innovation adoption are response to environmental legislation/regulation and market demand. However, for half of innovating firms (and 13% of total firms) being pro-active, or 'CSR oriented' is the main driver in anticipation of future legislation and demand, and as a response to the EU '20-20-20 strategy' for climate-energy. The importance of CSR is clearly correlated with firm size, and it is especially significant in some sectors such as DD-DE-DN. For the firms in these sectors, market and policy motivations seem to be complementary.

[10] For reasons of space, Table 3 includes only the first three ranked sectors. Full information is available upon request. Metallurgy, chemicals and ceramic are the three most polluting sectors.

Table 2 - Sample distribution (%) by sector and size

Sample distribution (%)	Size					
Sector	20-49	50-99	100-249	250+	*Total*	*Total (a.v.)*
FOOD	2,88	3,78	1,62	0,54	8,83	*49*
TEXTILE	2,70	1,44	1,62	0,54	6,31	*35*
WOOD, PAPER AND OTHER INDUSTRIES	3,60	2,88	1,08	0,90	8,47	*47*
CHEMICAL AND RUBBER	3,78	3,42	1,80	1,08	10,09	*56*
NON METALLIC MINERAL PRODUCTS	1,62	2,16	1,62	2,16	7,57	*42*
METALLURGY	8,83	5,77	2,16	0,18	16,94	*94*
MACHINERY	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*

Table 3 - Adoption of EIs: percentage of firms (total N. 555)

Adoption of at least one eco-innovation[11]	Size				
Sector	*20-49*	*50-99*	*100-249*	*250+*	*Total*
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 (ceramics)	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***

[11] At least one adoption in the period 2006-2008 of CO_2 or other emissions or materials/energy efficiency or organizational innovations (EMS, ISO).

Adoption of Process/product innovation in Emissions reduction[12]					
Chemical, rubber, plastics	0.24	0.06	0.38	0.40	*0.23*
Non-metallic minerals (ceramics)	0.13	0.06	0.40	0.27	*0.17*
Metallurgy	0.14	0.31	0.27	0.67	*0.22*
Total	*0.10*	*0.10*	*0.23*	*0.23*	*0.14*
Adoption of Process/product innovation in Energy/materials[13]					
Chemical, rubber, plastics	0.19	0.12	0.38	0.40	*0.23*
Non-metallic minerals (ceramics)	0.13	0.17	0.40	0.36	*0.24*
Metallurgy	0.10	0.31	0.33	0.67	*0.21*
Total	*0.09*	*0.14*	*0.21*	*0.26*	*0.15*
Adoption of Process/product innovation in CO_2 abatement[14]					
Chemical, rubber, plastics	0.10	0.06	0.23	0.20	*0.13*
Non-metallic minerals (ceramics)	0.13	0.06	0.40	0.27	*0.17*
Metallurgy	0.12	0.31	0.20	0.67	*0.20*
Total	*0.07*	*0.10*	*0.17*	*0.19*	*0.11*
EMS adoption[15]					
Food	0.12	0.00	0.00	0.14	*0.06*
Chemical, rubber, plastics	0.00	0.00	0.15	0.20	*0.05*
Non-metallic minerals (ceramics)	0.00	0.00	0.20	0.18	*0.07*
Total	*0.02*	*0.01*	*0.05*	*0.07*	*0.03*

[12] At least one adoption in the period 2006-2008 of a process or product technological innovation aimed at emissions reduction.

[13] At least one adoption in the period 2006-2008 of a process or product technological innovation aimed at materials/energy reduction.

[14] At least one adoption over 2006-2008 for process or product technological innovation aimed at carbon dioxide reduction.

[15] Adoption of EMS over 2006-2008.

ISO14000 adoption[16]					
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*
Metallurgy	0.08	0.23	0.13	0.67	*0.15*
Total	*0.05*	*0.10*	*0.22*	*0.21*	*0.12*
Environmental R&D presence[17]					
Chemical, rubber, plastics	0.24	0.12	0.54	0.20	***0.27***
Non-metallic minerals (ceramics)	0.13	0.17	0.40	0.36	***0.24***
Metallurgy	0.16	0.31	0.33	0.67	***0.25***
Total	***0.11***	***0.15***	***0.23***	***0.27***	***0.17***
Environmental CSR oriented firms					
Chemical, rubber, plastics	0.14	0.06	0.38	0.20	*0.18*
Non-metallic minerals (ceramics)	0.00	0.17	0.40	0.36	*0.21*
Metallurgy	0.10	0.23	0.27	0.00	*0.16*
Total	*0.07*	*0.11*	*0.21*	*0.23*	*0.13*
CSR behaviour as a Response to policy[18]					
Wood, paper, publishing	0.00	0.00	0.40	0.50	*0.13*
Chemical, rubber, plastics	0.14	0.06	0.15	0.20	*0.13*
Non-metallic minerals (ceramics)	0.00	0.17	0.40	0.18	*0.17*
Total	*0.06*	*0.08*	*0.16*	*0.19*	*0.10*

[16] Adoption of ISO_{14001} over 2006-2008.
[17] Investments in environmental R&D over 2006-2008.
[18] Process or product technological innovations aimed at reducing environmental impact motivated by expectations about future policy.

CSR behaviour as a Response to market demand[19]					
Chemical, rubber, plastics	0.10	0.06	0.31	0.20	*0.14*
Non-metallic minerals (ceramics)	0.00	0.11	0.40	0.27	*0.17*
Metallurgy	0.08	0.15	0.20	0.00	*0.12*
Total	*0.05*	*0.07*	*0.16*	*0.17*	*0.10*

The data suggest there is a strong correlation at firm level among the different dimensions of EI, that is, energy efficiency, materials, CO_2, other air pollutants, EMS/ISO, R&D (Table 4). Also, process/product innovations and organizational innovations are correlated, as previously suggested (Ziegler and Nogareda, 2009) and even in terms of co-causation (Mazzanti and Zoboli, 2008).

Correlation of simple factors is generally above 0.70, with a peak of 0.80 for CO_2 and other air pollutants, possibly due to the 'technical jointness' discussed above (only the total indexes show higher values). However, despite this seeming high level of integration, there are sectoral differences in the patterns of innovation: firms in sectors DI, DJ adopt correlated process/product innovations even as early movers, while the correlation is lower (0.23) for organisational innovations such as EMS and ISO_{14001}. In this case, few firms adopt EMS, which is more complex and expensive than ISO, but the correlation between EMS and process innovation is higher at around 0.35 (0.34 for CO_2).

Finally, environmental R&D is strongly correlated with output innovations, and the link is increasingly strong between CO_2, an almost entirely public good, and materials and energy, which have strong private good components. Economic appropriability seems to be the criterion for R&D investment.

[19] Process or product technological innovations aimed at reducing environmental impact motivated by expected demand.

Table 4: Correlations between EIs adoption (firm level)

	Material/energy	*CO_2*	*Air pollutants*	Total index EI	*EMS*	*ISO14001*	Total Index organisational innovation (EMS; ISO)	Environmental R&D
Material/energy	1							
CO_2	0.787	1						
Air pollutants	0.737	0.795	1					
Total index EI	0.916	0.930	0.917	1				
EMS	0.322	0.342	0.302	0.349	1			
ISO14001	0.687	0.628	0.709	0.734	0.233	1		
Total Index organisational innovation (EMS; ISO)	0.715	0.657	0.704	0.753	0.584	0.860	1	
Environmental R&D	0.792	0.684	0.734	0.802	0.240	0.663	0.681	1

4.2.2 COMPLEMENTARITY and EI ADOPTION

We assess degree of complementarity by examining the extent to which, when considering two correlated factors of eco innovations, the case of the world defined as “1,1” (i.e. two potentially correlated factors assume values above the average) is superior in performance terms to other states of the world, where both factors are either below the sample average or only one is present with intensity. The framework t is consistent with the complementarity conceptual frameworks developed by Milgrom and Roberts (1995) and Mohnen and Roller (2005).

We highlight some particular situations. In terms of complementarity between resources invested in innovation (general R&D) and technological cooperation, that is, the two main correlated factors of innovation, (tab. 5), we see that although the innovation index (ranging between 0 and 100 representing the share of firms adopting a defined innovation) is higher when both factors are above the average compared to when both are below the average, cooperation with other firms and institutions in the region for innovation is weighted higher than internal R&D. If both are ‘intensively present’ the EI index is 0.22 (average is 0.13), but where the level of cooperation but not R&D is higher than average the index is 0.27. Results are similar for energy/materials, CO_2, and other air pollutants.

It seems that EI is driven by cooperation. Economies of scale may explain the need for cooperation among firms in the production chain and in the same sector.

Table 5- Technological cooperation, economic resource for innovation, and EI[20]

process/product EI index	Economic resources for innovation		
Technological cooperation	0	1	Total
0	0.064	0.088	0.073
1	0.273	0.224	0.241
Total	0.114	0.159	0.134

We examined the role of a CSR oriented strategy as a motivation for EI adoption (Table 6). We compared correlated and other factors to test the hypothesis of their relevance for joint innovation. We take the adoption of process/product EI as the dependent variable and find strong complementarity between the resources invested in (general) R&D and all other potential inputs. Table 6 presents the cases where cooperation for innovation is related to specific factors. It seems that there is significant complementarity among all other inputs. Although complementarity cannot be taken for granted (as Table 5 shows), it seems to characterize most of the links among the possible inputs to EI.

[20] All indexes are shares of firms in relation to one of the defined items (e.g. share of firms investing in R&D, share of firms engaging in technological cooperation, etc.).

Table 6- Complementarity assessment (input of eco innovations)

Index of environmental process/product EI adoption					
	Demand / policy driven CSR strategy	Demand driven innovation	Policy driven innovation	Organisational innovation (EMS, ISO14001)	Environmental R&D
Economic resources for innovation (general R&D)	Yes	Yes	NO	Yes	Yes
Technological cooperation	Yes	Yes	Yes	Yes	Yes

The complementarity effects between the adoption of CSR strategies for environmental objectives and the resources invested in R&D and cooperation for innovation are presented in Table 7.

Only for radical innovations (as opposed to incremental innovations), and particularly radical product innovation (see Kemp, 2010) does a CSR strategy combined with high R&D intensity and networking/cooperation lead to higher innovation adoption. The hypothesis is that CSR and investment in innovation produce structural breaks at the innovation frontier which are associated with the radicalness of the EIs.

Table 7 - Radical innovations and complementarity between CSR, cooperation for innovation, and economic resources for innovation

Radical product innovation (share of firms adopting)	Economic resources for innovation		
CSR (innovative behavior driven by future demand and policy)[21]	0	1	Total
0	0.056	0.145	*0.095*
0.5	0.035	0.167	*0.097*
1	0.063	0.270	*0.180*
Total	*0.055*	*0.157*	*0.101*
Radical product innovation (share of firms adopting)	Innovation cooperation		
CSR (innovative behavior driven by future demand and policy)	0	1	
0	0.068	0.154	*0.095*
0.5	0.069	0.111	*0.097*
1	0.045	0.237	*0.180*
Total	*0.068*	*0.159*	*0.101*
Radical process innovation (share of firms adopting)	Innovation cooperation		
CSR (innovative behavior driven by future demand and policy)	0	1	
0	0.048	0.106	*0.066*
0.5	0.069	0.125	*0.106*
1	0.106	0.173	*0.153*
Total	*0.051*	*0.117*	*0.075*
Radical process innovation (share of firms adopting	Economic resources for innovation		
CSR (innovative behavior driven by future demand and policy)	0	1	
0	0.049	0.089	*0.066*
0.5	0.070	0.147	*0.106*
1	0.104	0.190	*0.153*
Total	*0.053*	*0.101*	*0.075*

[21] The index takes the value 1 if firms state that both future demand and policy are the motivation for EI adoption and 0.5 if only one of these is a driver.

4.2.3 COMPLEMENTARITY, INNOVATION AND STATED ECONOMIC PERFORMANCE[22]

Data on the structural/behavioral features of firms allows us to check whether EI affects economic performance, and whether complementarity in EI is relevant in this respect.

We check first whether firms that adopt EIs (20% of the sample) show different performance from other firms in 1st Q of 2009 and in the whole period 2006-2008.[23] In 1st Q 2009, eco-innovating firms do not differ substantially from other enterprises, which means also that firms investing in EI in 2006-2008 did not suffer as a result of the crisis more than other firms (Table 8).

Table 8- Stated Economic performance indexes (from 0 to 1) of firms adopting and not adopting EIs in 2006-2008

Variable: Economic performance indexes	Overall performance 2009 first quarter	Performance during crisis	Overall performance 2006-2008	Productivity 2006-2008	Employment 2006-2008	Profits 2006-2008
Firms adopting at least one EI (process/product, EMS, ISO)	0.400	0.609	0.659	0.614	0.586	0.550
Firms not adopting EIs	0.406	0.568	0.614	0.575	0.567	0.526

The performance of eco-innovating firms in 2006-2008 during the crisis is better than that of non innovating firms. Investment in EI seems not to have weakened firms but rather made them more economically resilient to shocks, which is in line with Porter's conceptual framework.

These firms performed better in terms of productivity, employment and profits although the causation is not clear (see fn 23) The possibility of reduced employment as a result of EI based on re-skilling effects and reductions in unskilled workers seems not be confirmed. Furthermore, note that since EI is related to firm

[22] We gathered information on economic performance (profits, turnover, employment) by asking managers to rate their firms' performance (on a -5 to 5 scale) for a given period, with respect to the historical average performance. We are interested in cross section variation. We plan to merge innovation data with past real accounting data as they become available.

[23] In 1st Quarter of 2009 we can infer causation between environmental innovation and firm performance (or at least the non-existence of reverse causation). Instead, the links with performance in 2006-2008 suffers from simultaneity problems: eco-innovation might be causal to economic performance or the opposite might be true. Even inside a Porter Hypothesis there could be even negative effects in the short run, see Cainelli *et al.* (2010a,b).

size and sector (see above) there might be a spurious correlation between these indexes. The data show however that environmental innovators did not suffer economic losses as a result of this strategy.

We also investigated the possible complementarity relationships between technological, organisational, and CSR oriented EI on the one hand, and general innovative propensity, ICT adoption, and human capital investments in terms of economic performance on the other hand. Tables 9-11 present the results. We repeated the method described above. We examined pairs of 'drivers' to assess whether the economic performance index (a 0-1 continuous index) is higher in the (1,1) state of the world with respect to other states. If it is, then this means that combinations of inputs lead to a premium over disjointed investment.

The areas of firm intervention showing complementarity with EI in terms of economic performance, are ICT adoption and outsourcing. These findings are new. These factors might be complementary in terms of cost savings and/or creating higher value added for the firm. It might also be the case that EI requires networking and technological cooperation (as already noted).

There are also strong synergies between general propensity for innovation and EI, for economic performance, which is in line with the findings in Mazzanti and Zoboli (2008). In short, innovation in processes/products, including EI, is good for the firm. This is not to eliminate the possibility of specific trade-offs among innovation strategies as suggested by neoclassical hypotheses.

Another area of complementarity for economic performance is between investment in employee education and training and environmental organisational innovation, in particular EMS/ISO. These results confirm previous evidence (Johnstone and Labonne, 2009).

Table 9 - Complementarity between EI (process and product) and general innovative behaviours, and period of reference[24]

	Overall economic performance	Productivity	Employment
Organisational innovation/human resource management			* 2006-2008
Technological innovation	* 2006-2008	* 2006-2008	* 2006-2008
Outsourcing activities	* 2006-2008	* 2006-2008	* 2006-2008
ICT innovations	* 2006-2008, * 2009 (1^Q), * 2009 (1+2^Q)	* 2006-2008	* 2006-2008
Training coverage	* 2006-2008	* 2006-2008	* 2006-2008
Good relations with employees (quality of management-employee index)			* 2006-2008
Good relations with union (industrial relations index)			

[24] The EI adoption index is interacted with the indexes presented in the rows (all range between 0-1: at the level of the single firm, they may either be an index, such as intensity of innovation in a defined realm, or a dummy: adoption of a defined innovation. This means that on aggregate they represent 'intensities' of innovation or adoption of high performance practices, such as training and good industrial relations). Tables 10 and 11 follow the same pattern.

Table 10 - Complementarity between environmental organizational innovation EMS/ISO and general innovative behaviours, and period of reference

	Overall economic performance	Productivity	Employment
Organisational innovation/human resource management		* 2006-2008	* 2006-2008
Technological innovation	* 2006-2008	* 2006-2008	* 2006-2008
Outsourcing activities	* 2006-2008	* 2006-2008	* 2006-2008
ICT innovations	* 2006-2008 * 2009 (1^Q) * 2009 (1+2^Q)	* 2006-2008	* 2006-2008
Training coverage	* 2006-2008	* 2006-2008	* 2006-2008
Good relations with employees (quality of management-employee index)	* 2006-2008 * 2009 (1+2^Q)	* 2006-2008	* 2006-2008
Good relations with union (industrial relations index)	* 2006-2008	* 2006-2008	

Table 11- Complementarity between environmental CSR oriented strategy and general innovative behaviours, and period of reference

	Overall economic performance	Productivity	Employment
Organisational innovation/human resource management	* 2006-2008	* 2006-2008	* 2006-2008
Technological innovation	* 2006-2008	* 2006-2008	* 2006-2008
Outsourcing activities	* 2006-2008 * 2009 (1^Q) * 2009 (1+2^Q)	* 2006-2008	* 2006-2008
ICT innovations	* 2006-2008 * 2009 (1^Q) * 2009 (1+2^Q)	* 2006-2008	* 2006-2008
Training coverage	* 2006-2008	* 2006-2008	* 2006-2008
Good relations with employees (quality of management-employee index)	* 2006-2008 * 2009 (1^Q) * 2009 (1+2^Q)		* 2006-2008
Good relations with union (industrial relations index)		* 2006-2008	

4.2.5 EI AND INTERNATIONALISATION

The index for EI adoption by all firms suggests that firms that are more internationalised[25] show more intense adoption of innovations related to energy, CO_2 and emissions. However, the data in Table 12 suggests that this is not true of larger firms. The results are similar for environmental R&D and organisational innovation. In the latter case, larger but less internationalised firms shower higher levels of adoption of ISO/EMS. In terms of sectors (tab. 13), internationalised firms in sectors DJ e DF-DG-DH are more environmentally innovative, with rates of around 40%, and the highest rates applying to firms in these sectors with between 100-249 employees. Firms with foreign ownership[26] show very high innovation adoption rates for all size classes, (tab. 14a,b) but with the highest rates for the biggest companies, which show adoption rates of around 45%. For ceramic firms with foreign participation the rate is 50%. These same groups of large internationalised firms show high rates of adoption of R&D and EMS/ISO, respectively 39%

[25] The index takes account of all the firm's international related activities (FDI, foreign ownership, international outsourcing, etc.). It is subdivided into weak and strong according to the fact that the firm value is below or above the average.

[26] This is a dichotomous variable.

and 17% and are the leaders for CSR strategy (tab. 15): all firms with foreign participation (including small companies) score well for CSR, with a peak at 33% for the biggest firms.

This evidence suggests that firms with foreign participation benefit from being closer to international standards in terms of demands of foreign shareholders and customers, early perception of policy and market demand changes, and the need to be in line with the prevailing standards in international firms. Based on this evidence on the relationship between 'innovation favouring' factors such as technological local cooperation and foreign participation we conducted some multivariate tests. We check for robustness and significance in economic and statistical terms.

Table 12 - EI and internationalization, by size

Total index of EI adoption (all EI innovations)	Size				
Index of internationalisation	20-49	50-99	100-249	250+	*Total*
weak	0.110	0.157	0.280	0.318	*0.166*
strong	0.228	0.182	0.298	0.292	*0.240*
Total	*0.143*	*0.169*	*0.290*	*0.300*	0.199
Environmental R&D presence	Size				
Index of internationalisation	20-49	50-99	100-249	250+	*Total*
weak	0.089	0.135	0.200	0.318	*0.137*
strong	0.175	0.159	0.263	0.250	*0.204*
Total	*0.113*	*0.147*	*0.234*	*0.271*	0.167
Organisational EI (EMS/ISO) adoption	Size				
Index of internationalisation	20-49	50-99	100-249	250+	*Total*
weak	0.016	0.045	0.113	0.152	*0.050*
strong	0.047	0.038	0.099	0.097	*0.065*
Total	*0.025*	*0.041*	*0.106*	*0.114*	0.057
Materials/energy EI adoption	Size				
Index of internationalisation	20-49	50-99	100-249	250+	*Total*
weak	0.062	0.146	0.160	0.273	*0.117*

strong	0.158	0.125	0.246	0.250	*0.184*
Total	*0.089*	*0.136*	*0.206*	*0.257*	*0.147*
CO_2 EI adoption	Size				
Index of internationalisation	20-49	50-99	100-249	250+	*Total*
weak	0.062	0.101	0.120	0.227	*0.094*
strong	0.105	0.102	0.211	0.167	*0.140*
Total	*0.074*	*0.102*	*0.168*	*0.186*	*0.115*
Air emission EI adoption	Size				
Index of internationalization	20-49	50-99	100-249	250+	*Total*
weak	0.068	0.056	0.220	0.318	*0.107*
strong	0.175	0.136	0.246	0.188	*0.180*
Total	*0.099*	*0.096*	*0.234*	*0.229*	*0.140*

Table 13 - EI and internationalisation, by sectors

Total index of EI adoption (all EI innovations)	Sector						
Index of internationalisation	DA	DB-DC	DD-DE-DN	DF-DG-DH	DI	DJ	DK-DL-DM	*Total*
weak	0.212	0.000	0.179	0.278	0.188	0.259	0.086	*0.166*
strong	0.125	0.000	0.211	0.400	0.400	0.350	0.217	*0.240*
Total	*0.184*	*0.000*	*0.191*	*0.321*	*0.238*	*0.298*	*0.158*	*0.199*

Table 14a - EI and foreign participation, by size

Total index of EI adoption (all EI innovations)	Size				
Foreign participation	20-49	50-99	100-249	250+	*Total*
weak	0.138	0.153	0.284	0.250	*0.181*
strong	0.286	0.300	0.316	0.444	*0.344*
Total	*0.143*	*0.169*	*0.290*	*0.300*	0.199

Table 14b: EI and foreign participation, by sector

Total index of EI adoption (all EI innovations)	Sector							
Foreign participation	DA	DB-DC	DD-DE-DN	DF-DG-DH	DI	DJ	DK-DL-DM	*Total*
weak	0.182	0.000	0.163	0.311	0.225	0.292	0.125	*0.181*
strong	0.200	0.000	0.500	0.364	0.500	0.400	0.353	*0.344*
Total	*0.184*	*0.000*	*0.191*	*0.321*	*0.238*	*0.298*	*0.158*	0.199

Table 15: EI, internationalisation and foreign participation, by size

CSR behaviour	Foreign participation		
Size	Weak	Strong	*Total*
20-49	0.071	0.143	*0.074*
50-99	0.102	0.200	*0.113*
100-249	0.193	0.263	*0.206*
250+	0.192	0.333	*0.229*
Total	*0.116*	*0.250*	*0.131*
CSR behaviour	Index of internationalization		
Size	Weak	Strong	*Total*
20-49	0.062	0.105	*0.074*
50-99	0.101	0.125	*0.113*
100-249	0.180	0.228	*0.206*
250+	0.227	0.229	*0.229*
Total	*0.104*	*0.164*	*0.131*

4.3 ECONOMETRIC RESULTS

4.3.1 MODEL AND ESTIMATION METHOD

To extend the findings in §4.2.3 and §4.2.1, we analyse EI correlated factors in relation to the hypothesis of the effects of networking/cooperation and international relationship factors. This multivariate analysis shows that EI is embedded in a 'glocal' or open local system of production. We use dprobit as our estimator tool to study the probability of adoption, given that our EI variables are specified as dichotomous indexes. Dprobit fits with maximum-likelihood probit models and is an alternative to probit. Rather than reporting the coefficients, dprobit reports the marginal effects, that is, the changes in the probability of an infinitesimal change in each independent, continuous variable and, by default, reports the discrete changes in the probability for the dummy variables. Table 16 provides summary statistics for the main factors tested. The descriptive statistics for non-significant variables (cooperation actions and innovations, which are not significant) are available upon request.

Recall that in order to test our hypotheses on local networking effects, we constructed a set of dummies for whether or not a firm collaborates with *customers*, *suppliers*, *competitors* and *universities* in developing and implementing EI. We test all forms of networking. We include a dummy for industrial district (ID), which takes the value 1 if the firm belongs to an ID and 0 otherwise – to account for district-specific agglomeration effects.[27] To test internationalisation effects, the degree of internationalisation of Emilia Romagna firms is captured by three variables: *foreign ownership*, which is equal to 1 if the firm is owned and controlled by a foreign firm, Foreign Direct Investments (*FDI) propensity of the firm in EU countries* 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 which is equal to 1 if the firm invests in R&D; a dummy for *ICT intensity* (ranging from 0 to 1), defined as the propensity to adopt ICT (Internet, intranet, web site, etc.); and a dummy for *training coverage*, as the share of trained employees.

4.3.2 ECONOMETRIC EVIDENCE: EI ADOPTION IN A GLOCAL CONTEXT

The probit estimations (table 17) provide some interesting results. First R&D is never significant. This may be related to the general content of R&D as a correlated factor of EI. Environmental R&D (not shown here) logically is positively associated to EI adoption: some 50%-60% of firms adopting EI stated they also invest in specific green R&D. Thus, the reason for the lack of significance of R&D may be that it is often a proxy for absorptive capacity; these results are in line with Horbach and Oltra's (2010) findings for Germany and France. Enhancement of environmental efficiency requires heavy and specific investment and is not 'occasional monitoring of the external technological environment'. On the other hand, the discrete nature of R&D variable used here perhaps leads to non significance. What matters is the intensity of R&D (R&D as a share of turnover), not whether the firm engages in some R&D activity. This was also shown by Mazzanti and Zoboli (2009) for the province of Reggio Emilia.

Our results confirm earlier evidence (Mazzanti and Zoboli, 2009) that (technologically oriented) cooperation with other institutions arises as a necessary correlated factor. Cooperation with public institutions, such as universities and public research centres, and cooperation with other firms (in this case suppliers) is especially important. This has important implications for regional policy making and firms' management of green strategies. It is in line with case study and anecdotal evidence on Italian local systems of innovation showing that firm relationships are especially important (Brioschi et al., 2002; Cainelli et al., 2006, 2007). Suppliers often provide technological options, a signal of the importance of analysing EI in a multi agent and filiere based perspective. Networking adds to the promotion of EI. Knowledge based spillovers in local systems depend also on the role of public research centres and polytechnics. There are several universities in the area: Bologna, with subsidiaries in the Romagna area, Ferrara, Parma, Modena and Reggio Emilia. Most are

[27] ID are identified following the Sforzi-ISTAT methodology: there are 11 in ER. Although the methodology has some limitations these can be overcome by applying more complex and sophisticated statistical algorithms.

located in the core industrial part (see fig.1). This geographical concentration of business and research could explain the higher EI performance of firms located here. This good economic performance might decouple if the trends identified continue

Cooperation is highly and statistically significant for all aspects except EMS. For EMS, the 'district' dummy (for the firm's being located in the historically district dense areas of Bologna, Modena and Reggio Emilia) is significant. In our view this could mean that district relationships and networking are playing different roles for different aspects of EI. In our case cooperation and district membership appear substitute factors. The EMS related evidence confirms anecdotal evidence: one of the first 'green label' adopted at the level of district, not firm, occurred for the ceramic sector, that is the primary manufacturing branch in those aforementioned provinces. We show that cooperation at various levels matters and the technological skills and competencies required by firms to adopt EI require synergies.

In terms of international features, our estimates are quite clear. The most significant factors we test according to the set of hypotheses are the share of turnover associated with international markets (a structural factor), FDI in EU countries and 'foreign ownership'. The first factor is not significant at all. It is dominated by the other two; its general flavour and the fact that most firms heavily export could well explain this outcome.

On the 'outward side' of internationalisation, firms that are active regarding FDI investments in the EU innovate more. Nevertheless, the effect is weak from both an economic and statistical point of view. Only in the case of EMS is statistically significant. This is a specific and actually 'minor' innovations in our case study (3% of firms adopting EMS), that seem correlated to idiosyncratic factors such as FDI at international level and district membership at local level.

On the 'inward side' of internationalisation, we find that firms with foreign ownership are more eco innovative (mostly ISO14001 and general EI, for CO_2 significance is 5%, plausibly representing the 'market value' of such innovations – Carbon-oriented and ISO - for relatively more globalised foreign firms). The causation effects are diverse and cannot be disentangled in cross section environments. It might be that greener firms are more attractive to foreign investors. The significance of ISO is perhaps evidence of this: ISO is a first signal to the market of product and process quality. Then other more radical innovations (CO_2, integrated process reshaping involving materials and energy) may be stimulated by the partnership following FDI. Greener firms are more proactive and more competitive in the long run and take account of expected new demands and more stringent policies. It could be that the greening of firms is another effect of FDI investment by (German firms) with stricter standards which 'import' their EI strategies. The first reason has implications for regional policy making for enhancing the attractiveness of firms. Both explanations highlight the importance of international relationships and trade for promoting and spreading EI. Future research should identify FDI originating country to understand how international relationships affect EI. Finally, the role of size is confirmed, although it does not dominate other factors. Medium large firms are the most innovative and the quickest to react to new challenges and belonging to an industrial district is especially important for EMS adoption. Future research should analyse correlation and complementarity between various EI and other innovations by implementing a series of bivariate probit regressions.

We also recognise that on a comparative basis the economic significance of the foreign ownership factor is much higher that of FDI, and compete in strength with the economic relevance of cooperation driving forces.

Table 16 – Summary of main covariates

	mean	Description
EI	0.20	Any kind of techno organisational EI adoptions
CO_2	0.12	Technological process product innovations aimed at abating carbon dioxide
Emissions	0.14	Technological process product innovations aimed at abating emissions
EMS	0.03	Organizational EMS adoption
ISO_{14001}	0.12	ISO 14001 adoptions
R&D	0.80	Dummy variable capturing the action of internal general R&D investment
Share of export sales	33.5	Share of sales on the foreign market
FDI in EU countries	0.082	FDI in EU countries
Foreign ownership	0.12	Presence of a foreign ownership in the firm
Cooperation with universities	0.11	Networking innovation oriented activities joint with universities
Cooperation with suppliers	0.17	Networking innovation oriented activities joint with suppliers

We present the covariates used in the final specifications. Complete information on all the variables in the dataset is available upon request.

Table 17 – Econometric outputs

	ENVIR. INNOV.		CO_2		EMISSIONS		EMS		ISO14001	
	Coeff.	*t-values*	*Coeff.*	*t-values*	*Coeff.*	*t-values*	*Coeff.*	*t-values*	*Coeff.*	*t-values*
R&D	0.022	0.49	0.040	1.24	0.021	0.57	-0.003	-0.41	-0.026	-0.75
Share of export sales	0.00009	0.16	0.00004	0.10	0.0001	0.21	-0.00008	-0.86	0.00004	0.10
FDI in EU countries	0.094*	1.73	-0.004	-0.11	0.061	1.25	0.049**	2.73	-0.017	-0.47
Foreign ownership	0.239**	2.28	0.062*	1.65	0.042	0.98	-0.006	-1.05	0.074**	1.95
Cooperation with universities	0.239**	2.28	0.165**	2.40	0.208**	2.70	0.018	1.54	0.204**	3.02
Cooperation with suppliers	0.239**	3.87	0.147**	3.59	0.178**	3.70	-0.005	-0.55	0.170**	4.26
District effect	0.030	0.90	0.034	1.41	0.035	1.29	0.017**	2.56	0.007	0.31
20-49 empl.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
50-99 empl.	0.001	0.05	0.005	0.18	-0.029	-0.86	-0.010	-1.18	0.050	1.39
100-249 empl.	0.106**	1.97	0.064	1.55	0.096**	2.08	0.012	1.19	0.175**	3.66
250 empl.	0.076	1.21	0.043	0.91	0.053	1.01	0.040**	2.04	0.119**	2.10
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo-R^2	0.123		0.129		0.146		0.212		0.182	
N. Obs.	555		555		555		555		555	

** significant at 5%; * significant at 10%

5. CONCLUSIONS AND IMPLICATIONS FOR MEASURING EI

Our results suggest that EI adoption is embedded in firms' characteristics and business vision and may be influenced by the embeddedness of the firm in its (local) production environment and the international context. Local-global links characterise the adoption of new strategies such as green innovations. Even small firms (around 20%) that adopting EIs use a deliberate strategy of complementary consistent combinations of EI. EI is generally a part of the innovation process and cannot be easily separated from the firm's general innovation efforts. The case of smaller firms highlights the relational dimension of EI and cooperation with other actors in the local production system or the production chain. All these dimensions of complementarity, based on the firm as a unitary actor and a unit in a local production system, present different degrees of coherence, conditional on the different features of firms.

Size and sector emerge as relevant for explaining EI adoption. In our sample, firms with less than and over 100 employees show different rates of adoption of all kinds of EI, with higher rates corresponding to increasing firm size. Sector is a good predictor of firms' aims (energy/materials, CO_2, etc.) and motivations (policy/market) for EI adoption, especially in the energy/emission/pollution intensive sectors, where adoption rates are high even for small firms. Degree of internationalisation and foreign ownership also explain a greater focus on EI among all firms. This can be seen as a dimension of embeddedness, in this case in international production chains and standards, favouring EI.

In our complementarity analysis, pairs of specific EIs and firm features were tested for their capacity to augment augmenting or reduce the performance of an indicator. In general, our complementarity hypotheses hold: innovation inputs are more effective if jointly implemented. There is high correlation at firm level between adoptions of different kinds of EIs. Some of this correlation can be explained by technical jointness (e.g. between CO_2 and air pollutants), but high levels of correlation generally exist between all EIs (output). At a more intuitive level, the data suggest that for EI performance one input is generally better than none, but two joint inputs are generally better than one, with exceptions of cases where no inputs are better than one (but never better than two).

The rich information in our dataset allow us to explore how EI adoption influences the economic performance of firms with respect to non EI and to test whether the combination of EI and other innovative/organisational features of the firm also influences economic performance. In general, eco-innovating firms perform better than non eco-innovating firms, both in 2006-2008 and during the global financial crisis (early 2009). The results of our various analyses show that the degree of complementarity between various EI correlated factors is quite high, with a dominant role of networking and CSR strategies. , Based on the responses from firms, EI also seem not to undermine, even in the short run, the achievement of economic performance even during a financial crisis.

Econometric analysis highlights that international characteristics, especially foreign ownership, and networking with firms and institutions, play a major role, while general R&D does not explain EI adoptions. Over and above the structural features of firms, strategic relationships within the region and at the international level matter and differentiate firms' innovative performance. The possible implications for the measurement of EI are that EI *firms rather than specific EIs,* should be the unit of analysis for examining the economic and behavioural dimension of EI. SME in local systems of production, as opposed to large multinational conglomerates leading their value chains, indicate the trigger points for EI behaviour by firms, and the line between no EI (or no innovation of any kind) and the different stages of an EI strategy. Firms either do not adopt EIs or adopt them in combinations that are increasingly dense and strategic in proportion to firm size, internationalisation, or networking with the local system, or general innovation attitude, or some/all of these attributes. EI in firms seems to range from zero to passive settings marked by limited EI for policy compliance, to active strategic settings in which EI is an integral part of the firm's strategy and performance. This suggests a set of intended, reciprocally consistent, holistic and radical changes. For all firm sizes, EI adoption cannot be perceived as disjoint from other firm adaptation processes that progressively involve increasingly articulated sets of EIs. Different levels of complementarity and embeddedness seems to guide these processes.

Figure 1. Provincial Intensity of the Eco innovation adoption (GHG reductions)

Figure 2. Provincial Intensity of the Eco innovation adoption (air emissions)

Figure 3. Provincial Intensity of the Eco innovation adoption (EMS and ISO)

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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

Table A.2 - Relevant EI 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.