ICT investments, Eco-Innovations and Environmental Efficiency

Micro and sector studies from Italy

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Preliminary draft

9 November 2010

Abstract

This paper links two pieces of evidence in order to provide insights on how ICT affects environmental related performance. Sector and firm original data are used to compensate various lacks of data at different level of analyses (e.g. emissions typically lacking at firm level).

First, we study under the umbrella of the notion of Milgrom and Roberts (1995) complementarity how variously specification of ICT integrated innovations in firms are correlated to other innovations and specifically to green techno organizational innovation, including CSR environmental behavior and R&D green efforts. We exploit a rich CIS like dataset on 555 northern Italian firms covering 2006-2008 and issues such as technological innovation, training, eco innovations, ICT, international strategies. We thus analyze the (eventually joint) drivers of both eco innovations and ICT innovations along a wide array of specifications.

The second piece of the tale is the analysis of Italian NAMEA data (1990-2007, 29 branches, 14 manufacturing sectors) merged with trade, investments and R&D data. The theoretical framework is that of IPAT /EKC models where the aim is to analyze the drivers of delinking at sector level (with dependant variable emissions on output). Within investments, we newly added ICT sector based investments in order to shed light on the sector/dynamic effects of ICT investments on emission efficiency and decoupling performance.

Keywords: Eco-innovations, firm data, complementarity, NAMEA, emission efficiency, ICT investments

1. Introduction

Available definitions of eco-innovation (EI) (CML et al 2008; UNU-MERIT et al 2008; Europe Innova 2008) seems to mainly point to the 'eco' attributes of single new processes, products and methods to be evaluated on a technical and ecological side. For example, in the 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 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 the definition of eco-innovation is close to the one of environmental technologies, defined as "all technologies which use is less environmentally harmful than relevant alternatives", it is not only about specific technologies, and includes also new organizational methods, products, services and knowledge oriented innovations (Kemp, 2011). Organisational methods are also closely linked to human capital and the ability to integrate ICT in the production processes. Eco-innovation is then neither sector nor technology specific and it can take place in any economic activity, not only in the still loosely defined 'eco-industry' sectors. It is not limited to environmentally motivated innovations, but includes "unintended' eco-effects of all innovations. Thus, when taken outside its purely technical dimension of (improved) environmental impacts, eco-innovation display a systemic and behavioural dimension that is consistent with both the conventional economic approach to innovation tout court and the results from the extensive evidence on the systemic dimension of eco-innovation itself (e.g. Horbach 2008).

Thus, reconciling the need for sound techno-ecological measures of single eco-innovations, and eco-impact of all innovations, with the economic dimension of eco-innovation as a behavioural process is probably the most challenging issue of research on eco-innovation.

These latter dimensions of eco-innovation, as opposed to a purely techno-ecological perspective to single (eco-) innovations, suggests the possible importance of a complementarity perspective in understanding eco-innovation dynamics. Complementarity may be a useful element to explain observed jointness and clustering of eco-innovations at the firm level, and it can allow to integrate technical measurements of single eco-innovation within an economic perspective to 'eco-innovating actors', especially firms'. In the first part of this paper we focus on complementarity and on three specific sources of competitive advantage of the firm in terms of EI (drivers): networking with firms and institutions of the local system, international strategies and ICT intensity. The first two are 'drivers' that move out of the narrower 'firm specific' internal drivers by extending the picture of firm's competitive advantages. Firms that are intrinsically located in a dense local system full of relationships and districts, but that is open to the international economy. Thus the sources of competiveness (value creation, innovation stimulus as a pre condition to economic performance) are found at different levels, with the 'relational' feature of networking and internalisation are crucial to maintain a self sustained and improving firm competiveness in the long run (Cainelli and Zoboli, 2004). The third (ICT intensity) interacts with existing strategies and processes and enable more radical (environmental) technological changes for firms and sectors. The enabling and system impact of ICTs on environmental performance and innovation (OECD, 2010) has not been explored empirically. This paper tries to fill this gap both for firm- and sector- level empirical evidence.

In a previous work (Mazzanti and Zoboli 2008, 2009; Mazzanti and Montini, 2010) we depicted a conceptual framework allowing us to econometrically test for complementarity in eco-innovation and we applied it to a sample of firms surveyed by a questionnaire in an Italian industrial district.

Once the drivers of eco-innovation at the firm level are identified, a second step is needed in order to assess the effect of eco-innovations and other drivers on actual environmental outcomes. Due to the lack of firm-level data on the pressures exerted on the environment, we analyze the drivers of environmental performance at the sector level. We will focus on the role of general innovation effort, ICT intensity and openness to trade in affecting sector environmental efficiency of the Italian manufacturing sectors for the period 1990-2007. Their effect is likely to be partly determined by their effect on eco-innovations and partly by their direct effect on environmental efficiency. Using our sector data we are able to identify the net effect only.

The paper is structured as follows. Section 2 outlines the main ex-ante hypotheses about the drivers of environmental innovations and efficiency. Section 3 presents and discusses our data, methodology and results as concerns firm-level analyses. Section 4 presents and discusses our data, methodology and results as concerns sector-level analyses. Section 5 concludes.

2. Testable hypotheses

Based on existing theoretical and empirical literature, we outline a series of testable hypotheses on the drivers of eco-innovation and, more generally, environmental performance.

HP1: *The overall innovation intensity of the firm in fields as ICT, technological innovation (radical, incremental, product, process) and organisational innovations may be a complement to green options. However, the environmental performance depends on the overall net effect of innovation on the production process.*

Complementarities between different innovation fields can be of extreme relevance to stimulate EIs. Reconsidering processes and uncovering organizational inertia is definitely costly and must involve all ‘complementary’ assets. Environmental policy incentives are thus aimed at alleviating firm’s coordination problems, habits constraints in a comprehensive way. Not only market prices are the target, but in a Coasian way ‘inside the firm’ failures should be tackled (Gabel and Sinclair-Desgagnè, 1999, 1998).

Among others, the role of ICT development in correlation with EIs is partially untested but of mounting relevance. ICT innovation is a key element to spur green growth in the economic crisis and recovery and more applied research should be implemented (OECD, 2009 that recommended business surveys). In the survey we included a rich series of questions on technological specifications. In terms of ICT, we elicited various ICT innovation adoptions, from more trivial to highly complex and integrated with firm strategies, in order to highlight the ICT ‘innovation intensity’.

The correlation/complementarity[1] between various innovations can be a source of competitive advantage for firms linking various assets to improve effectiveness of performances and create non replicable innovative environments with an integration of tangible and intangible knowledge and technology that leads to ‘firm specific’ innovation portfolio. This non replicable set of links can assure higher competitive advantages and rent capture.

ICT intensity is generally found to be positively correlated to productivity and innovativeness at the firm level (Black and Lynch, 2001; Bresnahan, 2002; Greenan et al, 2001; Castiglione, 2009). We expect that this positive correlation holds for EIs too.

However, when looking at sector environmental performance, the role of ICTs is far more complex. As discussed in OECD (2010), MacLean and Arnaud (2008) and Erdmann et al (2004), the effect of ICT adoption on environmental performance may be categorized in three levels: direct impacts, enabling impacts and systemic impacts. Direct impacts are represented by the environmental pressures exerted by ICT products in their life cycle. This includes their production, their use and their disposal. The net environmental direct impact will depend on the volume of ICT products, on the environmental efficiency of ICT goods manufacturers and on the (energy/environmental) efficiency of ICT products. Enabling impacts consist in the result of the interaction of ICTs with other input of the economic process. At this level, ICTs influence the way existing economic activities exert pressures on the environment. A relevant example is the substitution of physical (paper) documents with digital documents, with beneficial effects on several environmental pressures (use of resources and air/water emissions) along the whole life cycle[2] of paper use (production of paper and toner, energy use of printing devices, disposal of paper as waste). Systemic impacts concern the effects on the environment determined by radical (technological and organizational) innovations, structural changes and behavioural changes induced by the adoption of ICTs (OECD, 2010, p. 10). The hypothesis we test at the sector level is whether ICT adoption has an overall net positive, negative or neutral effect on environmental efficiency.

HP2: *Provided that the international markets are characterised by high levels of environment sustainability, and international firms touch with hand and are exposed to the global environmental regulatory setting, the export propensity positively affects the introduction of environmental innovations by firms. Import penetration, on the other hand, may induce firms to reduce their effort in improving environmental efficiency in order to compete with ‘less green’ foreign competitors and/or it may ease the adoption of more environmental efficient technologies.*

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[1] As far as complementarity is concerned, we refer to Milgrom and Roberts (1995) framework, where innovation and organisational assets complementarity is defined and to the recent paper by Costinot (2009) who uses complementarity to explain international competitive advantages based on efficiency and endowments factors (we also refer the reader for some applications to Mancinelli and Mazzanti, 2009). Correlation in adoptions can be further tested by using bivariate probit analyses (Horbach, 2008) and specific tests (Lohskin et al., 2004; Mazzanti and Zoboli, 2008).

[2] Zoboli et al (2008) assess the total potential reduction of environmental pressures related to the implementation of the ‘digital document’ in Italy. However, this study does not take into account potential ‘rebound effects’.

While FDI and exports by firms are the main drivers of their globalisation strategies and are rarely studied[3] their impact on the environmental performance is also explained by other determinants.

On the one hand, a change in the patterns of trade in dirty goods following the introduction of environmental regulation is retained a first proof of PHH (Pollution Haven Hypothesis, see Wagner and Timmins, 2009). On the other hand, also in the case of a change in the location decision of MNC (that is, in front of FDI), the occurrence of international trade back from the host to the home country is essential in detecting a “proper” PHH (Sanna-Randaccio and Sestini, 2009).

Although this point has received less attention, international trade can be also seen as a vehicle of the positive relationship between globalisation and environment put forward by the heterodox view. The main argument is that international customers exert on firms higher environmental pressures than local ones do. Especially when they are in the downstream value-chain of international customers, domestic firms are required by them to keep its environmental supply standards and in so doing they are spurred to be environmentally innovative (Kraatz, 1998).

Export oriented firms are induced to adopt environmental innovations also to overcome the trade barriers export markets might pose against non sustainable suppliers. Meeting the highest environmental standards in the largest export market can be used as a strategy against this risk (Rugman et al, 1999).

As much as FDI, also exports might entail knowledge spillovers for domestic firms – by interacting with foreign competitors about adopting and/or improving green technologies – and expose them to greater competition – by stimulating them to invest in technologies with higher environmental performance (Perkins and Neumayer , 2008).

Still as much as FDI, exports accelerate the cross-border diffusion of environmental best-practices and expose firms to higher pressures for environmental sustainability and deeper scrutiny on environmental performance (Vogel, 2000).

On the basis of the previous arguments, overall the export propensity of the firms can be expected to have a “potential” positive impact on their environment innovations. However, the potential nature of this effect should be emphasised, as it is less “automatic” than that identified with respect to FDI. The extent to which exports drive environmental innovations actually depends on the identity of the trade partner and on that of the traded goods. As for the former, it is apparent that trade relationships with countries with low environment-efficiency are expected to dampen the positive externalities identified above[4]. As for the latter, trade in intermediate and final goods should be expected to have a different impact from that of capital goods, while their use in more or less pollution-intensive goods should be controlled for (Perkins and Neumayer , 2008).

When considering sector level evidence, the extent to which different sectors open to international trade (in terms of either import penetration and export propensity) is likely to influence their environmental behaviour in different ways. First, competition of foreign firms is likely to affect domestic environmental performance in two opposite ways. It may induce a

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[3] For example, recent works by Horbach, 2008 and Horbach and Oltra, 2010, slightly touch international issues. The latter paper analyse whether it matters the local/national/European/global scale of the market where firms sell products, finding insignificant impacts.

[4] For this reason, in their application to the Chinese firms, Christmann and Taylor (2001) specify their hypotheses by differentiating them with respect to Europe and Japan as main export markets with different environmental implications.

‘race to the bottom’ in environmental efficiency when resources are moved from environmental investments to activities directed to increase productivity. This is particularly relevant in cases in which the environmental performance is not valued either by consumers or policy makers. On the contrary, it may induce a ‘race to the top’ in environmental efficiency if foreign competitors are ‘greener’ than the domestic ones. In this case, in order to meet domestic environmental policy target and to meet ‘green’ demand, domestic producers will be forced to improve their environmental performance. Furthermore, a ‘race to the top’ effect may emerge when considering the diffusion (import) of more environmental efficient technologies through trade. As regards the export propensity, we expect that global markets and global environmental regulatory settings are likely to spur environmental innovations and environmental efficiency.

In the contingent case of Italy, the main trade relationship with Germany, a leader in (environmental) technology and standards in the EU, is a relevant anecdotal fact.

HP3: *Cooperation aimed at innovating with public and private agents can stimulate adoptions of EIs, given the necessary complementarities in skills and technology to achieve more radical and relatively new innovations*

We note that networking activities, intended as innovation-oriented cooperation with other agents (various firms: competitors, clients, outsourcers, public institutions), may partially substitute economies of scale in an environment characterised by SMEs. We elicited data on the source of eco-innovation, including networking with other firms and public institutions, to test an important hypothesis which recently emerged from the “social capital (SC) literature” (Glaeser et al, 2002): the positive relationship between R&D and social capital in an impure public goods framework (Cornes and Sandler, 1986), where social capital arises as intangible asset, defined as firm investments in co-operative/networking agreements (Mancinelli and Mazzanti, 2009; Capello and Faggian, 2005). Other authors (Smith et al, 2005) have suggested that in the sustainable transition of socio-technical regimes, actors do not have sufficient resources to unilaterally influence a regime. Regime members are bound together by resource interdependencies necessary for functioning and reproduction. Networking, as a factor which is external to the firm but internal and idiosyncratic to the local (innovation) system, is especially needed for achieving radical innovations. Cooperation and competition both drive the evolution of sectoral systems of innovation and technological systems that mainly consist of dynamic knowledge and competence networks (Geels, 2004). The empirical relevance of networking as main driver is found in many works, including recent analyses on provinces of the Region Emilia Romagna (Mazzanti and Zoboli, 2008, 2009; Cainelli et al, 2007; Mancinelli and Mazzanti, 2009, Antonioli et al, 2009, to which we refer for a amore extended analysis of the relevant literature). We employ various cooperation oriented actions (innovative cooperation with suppliers, competitors, clients, and with public agents such research centres and universities) and we also test the relevance of the ‘district’ effect. Whether firms belonging to a district area associated to more EIs depending on the stimulating effect of clustering, innovation spillovers and knowledge sharing. There are examples in the Region for instance of district based green innovation adoptions (EMS in the ceramic sector). Cooperation and clustering is a major way for SME to overcome size constraints.

HP1 and HP2 will be tested both in the firm- and sector-level analyses while HP3, which is based on firm heterogeneity regarding the relationships with third parties, will be tested for firms only. Finally, in addition to these testable hypotheses, which are related to specific variables in our data, we introduce additional controls in our econometric estimates, mainly linked to firm size for firm-level estimates and scale of production for sector-level estimates.

3. The adoption of eco-innovations by firms

In this part we investigate the extent to which drivers internal and external to the firm affect the likelihood of adopting environmental innovations.

3.1 Data

The dataset used in this part is based on information drawn from a very rich and detailed survey conducted in Emilia Romagna on a sample of 555 manufacturing firms with more than 20 employees. A structured questionnaire on the (eco)innovative behaviour of these firms was administered in 2009, focused on the period 2006-2008 in coherence with the last CIS wave. The response rate of the survey was about 30% and data are strongly representative by industry, size and province (Table 2). Questions on eco-innovation included the adoption (yes/no) of eco-innovations in 2006-2008, the aims or pursued benefits of eco-innovation adoption (CO2 abatement, pollution abatement, energy/material saving), the adoption of EMS systems (EMAS, ISO, others), investments of own economic resources in eco-innovation (R&D, specific equipments, clean technologies), the motivation of eco-innovation (legislation compliance, market demand, expected policy developments, expected change in demand), the adoption of eco-innovations during the crisis. Table 3 shows a preliminary sketch on the sector and size based distribution of EIs.

The overall share of firms adopting eco-innovations is 20% of the total number, which suggest that a large part of firms do not pursue the combination between economic and environmental efficiency as a strategy, or simply do not intentionally eco-innovate. This low share may be also influenced by the large share of firms in machinery/equipments/transport in the sample.

Firm size seems to be a good predictor for the rate of adoption (percent of total firm) of eco-innovations. Firms over 100 employees have adoption rates double than firms between 20 and 99 employees, and the same rate is three/four times in certain sectors. Evidence on the relationship between adoption rate and firm size is similar to the results found in Mazzanti e Zoboli (2009) on a sample of firms in the Reggio Emilia province (data for 2001-2003) as well as international literature. The breakpoint at 100 employees also emerges as relevant for the adoption rates for EMS and ISO14001, and even more for environmental R&D investments.

At the level of sectors, the adoption of at least one eco-innovation is higher than the average, around 28%-32%, for sectors DD-DE-DN, DF-DG-DH, DI, DJ, and lower for the food sector and the machinery & equipment sector. No eco-innovations are adopted by the firms of the textile sector.

The adoption of EMS is led by sector DI, as expected given the existence of a 'district-level environmental certification' in the ceramic tiles industry, and it is significant in sectors DF-DG-DH for environmental ISO. Environmental R&D investments are led by sectors DF-

DG-DH, DI e DJ, but sector level variability is lower in this latter case, with a distribution similar to the general innovation activity.

Looking at innovation by aims, i.e. abatement of CO2, of pollutants (PM, NMVOC e SOx, NOx), and efficiency for materials and energy, a firm-size effect again emerges, with the exception of air pollutants, which present a similar adoption rates below and above 100 employees. As expected, the adoption of CO2-aimed innovations is lower compared to other aims, given the lack of regulation before the implementation of EU ETS in specific sectors. Only firms in these sectors, in particular DI e DJ, achieve adoption rates above 20%. Greater adoption rates emerge however for the efficiency in material and energy use, the latter being technically jointed with CO2 emissions (as a sketch Figures 1 and 2 present the Italian framework in terms of emission trends). On average, energy/material saving aims is relevant in 15% of total firms, with a peak of 26% in larger firms. In terms of motivations behind innovations adoption, most firms do innovate as a response to environmental legislation/regulation or to fit with market demand characteristics. However, for half of innovating firms (and 13% of total firms) a relevant motivation is that of being pro-active, or ‘CSR oriented’, mainly to anticipate future legislations, to respond to the expectation triggered by the EU ‘20-20-20 strategy’ for climate-energy, and to fit with expected developments in demand. The ‘CSR oriented’ strategy is clearly correlated with firm size, and some sectors are particularly active, like DD-DE-DN. For these firms, the market and policy motivation seems to be complementary.

We refer to Tables 4 and 5 for a summary of descriptive statistics regarding the covariates we exploit in the analysis that we present in the next paragraph.

3.2 Empirical strategy

For our econometric investigation on firm eco-innovation, we identify the factors affecting the probability that a firm introduces an environmental innovation. In particular, we consider five different types of environmental innovations: (i) materials; (ii) CO2; (iii) emissions; (iv) EMS and (v) ISO14001. The analysis is based on a Probit specification as follows:

$$\Pr(Y_i=1|\mathrm{X})=\Phi(\mathrm{X}'\beta) \quad (1)$$

where Φ is the cumulative distribution function of the standard normal distribution and Y_i is a dummy variable taking the value 1 firm *i* introduces an environmental innovation and 0 otherwise. X denotes the regressors. The latter includes the constant term and several other variables at firm levels such as (i) R&D a dummy that takes value 1 if the firm has realized Research and Development expenditure; (ii) ICT intensity, an indicator ranging from 0 to 1, denoting for each firm the propensity to adopt Information and Communication Technologies (Internet, Intranet, web site, etc.); (iii) Central Emilia dummy, a dummy indicating if a firm is located in the Provincia of Bologna, Reggio Emilia or Modena. This variable should capture – as suggested by Brusco (1982) – some specificities of this geographic area in terms of long-term local development path, historical conditions and so on; (iv) university cooperation and suppliers cooperation are two dummies indicating whether or not a firm collaborates with universities or suppliers in developing and realizing EI; (v) export propensity is a continuous variable ranging from 0 to 100 which indicates for each firm of our sample the share of total export on sales; (vi) foreign ownership is a dummy equals to 1 if a firm is owned and controlled by a foreign firm; (vii) information on firms' membership (or not) in an industrial district. We can distinguish by using the dummy district between district and non-district firms. This is enabled by the Sforzi-ISTAT methodology (ISTAT 1997), which allows us to identify empirically 11 Emilian industrial districts, based on information on commuting obtained from the 2001 Population Census. The statistical procedure involves two steps. First, the regional territory is divided into 38 Local Labour Systems (LLS), which are groupings of municipalities that are characterized by a degree of commuting by the workforce. Second, it defines as industrial districts those LLS that satisfy the following criteria: 1) percentage of employees engaged in manufacturing compared to total non-agricultural employees is higher than the national average, 2) specialisation in one particular manufacturing industry, and 3) percentage of employees working in firms with less than 20 employees higher than the national average (Cannari and Signorini 2000). This methodology identifies in Emilia Romagna 11 industrial districts. In our data set, this information is represented by a dummy variable – district – that takes the value 1 if the firm belongs to a district and 0 otherwise. This dummy variable constitutes our proxy for what we can define as district-specific agglomeration effects. We also distinguish the industry specialization of the district. In particular, this enables us to construct another dummy – mechanical district – which identifies firms belonging to mechanics, one of the major manufacturing of the region.

3.3 Results

In Table 6 we report the results of our econometric application on firm-level data. We report marginal effects in order to ease the interpretation of our estimates.

Before assessing the empirical validity of our three ex-ante hypotheses, we briefly discuss the role of our main controls: training coverage, firm size and geographical aspects (central Emilia dummy and District dummy). First note that training is driving EIs across all specifications of innovation. Correlations between training and innovation activities in some LPS of the region were investigated in Guidetti and Mazzanti (2007) and Antonioli et al (2010), who assess training as driver of firm competitiveness. Its complementarity with innovations is relevant (Mancinelli and Mazzanti, 2009), a fact that is recently explicitly recognized in the 'Porter hypothesis' literature (Ambec et al, 2010)[5]. Further research should devote efforts to specific green contents of training and its synergies with adoptions of green innovations. Training coverage, expressed in term of share of trained employees, has a positive and robust positive effect for all the different declinations of eco-innovation except for the adoption of an EMS, for which the effect is statistically weak. This robust result highlights the importance of a trained labour force as a pre-requisite for a firm to be involved in innovation and, in our specific case, in eco-innovation activities.

Size does not seem to affect the likelihood that eco-innovation are adopted, except for the case of the adoption of EMS for which the probability of adopting an EMS system is lower for firms with less than 100 employees relative than for firms with more than 250 employees[6]. Differently from 'usual' innovations (Antonioli et al, 2010), size emerges not so relevant for EIs. Cooperation and agglomeration matter more. As we will show when discussing HP3, networking appears to dominate, in the effects operating through economies

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[5] Rochon-Fabien and Lanoie (2010) investigate the benefits of an original Canadian training program, the Enviroclub initiative. This initiative was developed to assist SMEs in improving their profitability and competitiveness through enhanced environmental performance'. The role of training as a HPWP that enhances green innovation adoptions and complement EI implementation is highly under studies.

[6] More specifically, the probability is 1.9% lower for firms with 50-99 employees and 0.9% lower for firms with 20-49 employees.

of scale, the mere firm size effect. Foreign ownership does not affect the propensity to adopt eco-innovations.

The geographical covariates (central Emilia dummy and District dummy) are mainly linked to local specialization in specific sectors which, besides sector fixed effects, are likely to affect the propensity to eco-innovate. The fact of being located in central Emilia increases the likelihood of eco-innovate, with the only exception being innovations on materials and the adoption of the ISO14001 standard. The fact of belonging to an industrial district, on the contrary, reduces the likelihood of adopting eco-innovations, again with the exceptions being innovations on materials and the adoption of the ISO14001 standard.

We now move to the test of our ex-ante hypotheses. The first hypothesis regards the complementarity between overall innovation intensity, broadly defined, and eco-innovation. As far as R&D involvement is concerned, we find a lack of significance for the dummy R&D (which takes the value of 1 if the firm reported some R&D expenditure). This result is not completely unexpected, since overall R&D is on the hand far too general as an element (we possess data on green R&D: it is highly significant), on the other hand R&D may just represent absorptive capacity rather than (radical) innovative activity. Having said this, we conclude that EI adoption is related to Green R&D (maybe trivial, though green R&D is less widespread than adoptions, only a sub part of eco innovative firms internally implement green R&D programs) but not to general R&D. This is food for thought for management and policy making. On the contrary, the propensity to integrate ICT into the production process (measured by an index from 0 to 1 which summarizes different aspects of the ICT involvement of a firm) seems to increase the likelihood of adopting specific types of environmental innovations. This effect is statistically relevant as regards environmental innovations in general and innovations in materials and CO2 technology while it is weak for emissions-reducing technologies and EMS and absent for ISO14001. As discussed in the previous section, ICTs are likely to play an important role in enabling (eco-)innovations. In particular, its effect is particularly relevant for de-materialization strategies of the administrative bodies of the firm (e.g. reducing the use of paper for internal and external communications). The substitution of physical documents with digital documents is likely to reduce substantially the use of materials such as paper and toner[7].

The second hypothesis regards the possibility that foreign commercial partners (in our case customers) induce domestic exporting firms to improve their environmental performance. For none of our declinations of eco-innovation the propensity to export has any effect on the likelihood of adopting eco-innovations. The irrelevance is coherent as already noted with the results regarding Germany and France presented by Horbach and Oltra (2010) that study the local/global flavour of markets. Local factors, either external and internal to the firm, seem to outweigh pressures from foreign actors.

Finally, our third hypothesis states that cooperation in innovative activities with private and/or public agents is likely to stimulate the adoption of environmental innovations. Except than for EMS, cooperation with universities and suppliers increases the likelihood of adopting eco-innovations, the cooperation with universities being more important than the cooperation with suppliers. Innovation adoptions in local production systems (LPS) pass

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[7] Zoboli et al (2008) estimate that the potential reduction of paper use due to the implementation of the ‘digital document’ in Italy ranges between 168,347 and 259,017 tons (respectively 13.8% and 21.6% of the use of paper by service activities). Using a LCA approach, they estimate that this reduction of paper use as additional positive effects on the environment in terms of reduction of air emissions (between 581,000 and 893,000 tons of CO2, between 2,323 and 3,574 tons of NO3 and between 1,788 and 2,752 tons of SO2) and water use (between 11,4 and 17,5 million of tons.

through synergies stimulated and offered by networking with other agents. The four universities of the region, including the main Bologna University, appear to contribute to stimulating EIs in an important way. Relationships with suppliers are as expected relevant. It is known that the spreading and adoption of more radical changes occur with an involvement of the whole supply chain (Mazzanti and Zoboli, 2006). Economies of scale and complementarities explain such evidence which is not new. Networking appeared as a major driver of economic performance and innovations in analyses on specific provinces/LPS of the region (Mancinelli and Mazzanti, 2009; Antonioli et al, 2010). We here confirm this core role for the region as a whole in the specific case of EIs. It is expected but not trivial in terms of consequences that EIs need to be stimulated by technological and competence synergies between firms (suppliers in this case, along the supply chain that adapts to new demands and innovates on an integrated manner) and between firms and public agents. We underline the significance of the cooperation with universities and research centres: the size of the coefficients is generally larger with respect to cooperation with suppliers.

4. The drivers of sector environmental performance

In this part we investigate the extent to which various sets of sector-level drivers affect the environmental performance of Italian manufacturing sectors.

4.1 Data

In order to investigate the aggregate environmental performance of eco-innovations and other economic drivers, we move in this section to sector analyses. While firm-level environmental performance measures are not available for Italian firms, we exploit the richness of sector environmental performance of the NAMEA (National Accounting Matrix including Environmental Accounts) database which contains direct air emissions by economic sectors. The main value added of environmental indicators which use NAMEA is that they can be directly compared to the full set of national sector accounts (supplied by national statistical offices) and statistics (supplied by specialized institutions such as OECD).

Data on air emissions (NAMEA, ISTAT)

We use NAMEA tables for Italy for the period 1990-2007, with a 2-digit Nace (Rev. 1.1) disaggregation level. In the NAMEA tables, environmental pressures (for Italian NAMEA 18 different air) and economic data are assigned to the economic branches of resident units or to the household consumption categories directly responsible for environmental and economic phenomena. We use only data on manufacturing economic branches, with a disaggregation of 14 sectors and we focus on CO2, SOx and NOx air emissions[8]. The added value of using environmental accounting data comes from the definitional internal coherence and consistency between economic and environmental

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[8] The various drivers of environmental efficiency are likely to affect each type of emissions in a different way. CO2 is a global externality, with no local effects: for this reason no stringent specific policy has been introduced until recent years. Furthermore, due to the fact that CO2 cannot be abated through end-of-pipe devices, the only channels through which it may be reduced are (i) the improvement of energy efficiency, (ii) the shift to more CO2-efficient fuels, (iii) the substitution of fossil fuels with renewables. On the other hand, SOx, NOx and PM area pollutants characterized by local negative externalities. Especially SOx and NOx have been strictly regulated through command-and-control policies since mid-80s in all European countries. The important difference of pollutants relative to CO2 is that the formers may be abated by the introduction of end-of-pipe devices to existing plants, even without any energy-saving technological change.

modules and the possibility of extending the scope of analysis, while still maintaining this coherence and consistency.

Data on national accounts (ISTAT)

As usual measures of economic scale and performance we use data on output (at current and constant prices), value added (at current and constant prices), full-time equivalent employment and hours worked with the same time and sector coverage as NAMEA.

Data on sector capital stock by commodity (ISTAT)

ISTAT supplies each year national sector accounts on capital stock and investment trends (both at current and constant prices) for 9 categories of capital goods[9]., with the same Nace disaggregation as NAMEA. ISTAT provides a disaggregation in 9 categories of investments: machinery, equipment for office, equipment for communication, furniture, road vehicles, other vehicles, buildings, software and other goods not elsewhere specified.

To reduce the problems related to the instability and the truncation of some series for various sectors, we group together ICT (equipment for office, equipment for communication and software) and non-ICT investments and capital stocks.

Data on sector openness (OECD Stan)

We employ two indicator of sector openness: import penetration (that is the fraction of products of a particular branch which are imported as fraction of total domestic output of the same branch) and sector export share of output. These indicators do not need to be deflated. They are available with the same sector and time coverage as NAMEA.

Data on sector R&D (OECD ANBERD)

Finally, as an indicator of sector general innovative effort, we employ R&D expenditure as fraction of value added, provided by the OECD ANBERD database[10].

Table 11 contains some descriptive statistics for the economic indicators and Table 10 for the emissions. Table 9 reports the correlation among dependent variables and covariates (conditional on sector fixed effects). In Table 7 we report the categories of goods (CPA) included in the different variables of gross capital stock.

4.2 Empirical strategy

We exploit the panel nature of our data (cross-section of 14 manufacturing sectors for 18 years) to identify which are the main drivers of the strong delinking we observe for SOx and NOx and the weak relative delinking we observe for CO2 (see Marin and Mazzanti, 2009, 2011 for evidence on delinking patterns for Italian manufacturing and service sectors). The deliking trends are reported in Figures 1, 2 and 3.

We estimate the following equation:

$$\begin{aligned}\ln(E_{st}/Y_{st}) = \beta_1 \ln(K_{st}^{ICT}) + \beta_2 \ln(K_{st}^{non-ICT}) + \beta_3 \ln(VA_{st}/Fte_{st}) + \\ + \beta_4 (R\&D_{st}/VA_{st}) + \beta_5 (M_{st}/Y_{st}) + \beta_6 (X_{st}/Y_{st}) + \gamma_s + \tau_t + \varepsilon_{st}\end{aligned} \qquad (2)$$

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[9] The list of the products included in each category is reported in Table 7. Data on investments come from the database `Investimenti fissi lordi per branca proprietaria, stock di capitale e ammortamenti' by ISTAT.

[10] The series of R&D expenditure for Italy in OECD ANBERD starts in 1991.

where

- *E/Y*: respectively CO2, SOx and NOx emissions efficiencies in terms of emissions per output[11];
- *VA/Fte*: labour productivity in terms of value added per full-time equivalent employment;
- K^{ICT}: gross capital stock of ICT goods;
- $K^{non\text{-}ICT}$: gross capital stock of non-ICT goods;
- *R&D/VA*: innovative effort in terms of performed R&D expenditure per unit of value added;
- *M/Y*: import penetration expressed as import of good s as share of total output of sector s;
- *X/M*: export share of total output
- sector (γ) and time (τ) fixed effects.

This model, under the constraint of data availability for the entire period 1990-2007, allow us to account for the same groups of drivers as for the firm-level estimates. In particular, we consider three common sets of drivers: the role of ICT capital (K^{ICT}), the role of the general innovative effort (*R&D/VA*) and the role of international pressures/opportunities (*M/Y* and *X/Y*). Our empirical model does not allow to directly identify the extent to which the adoption of eco-innovations affects the environmental performance. However, the effect we estimate associated to our drivers regards both their direct effect on environmental performance and their indirect effect through their role as drivers of eco-innovations.

We estimate equation 2 for 14 manufacturing sectors and for the period 1990-2007 (1991-2007 when *R&D/VA* is included) using a fixed effect static model. Furthermore, we allow the parameter β_1 to vary for each sector (β_{s1}) to check whether sector-specific opportunities for ICT to enable improvements of environmental efficiency are relevant. Finally, we try to cluster sectors in terms of ex-ante potential of environmental improved linked to ICT investment as opposed to sector with ex-ante low potential or even possible worsening environmental performance linked to ICT investment. The clustering is made by classifying the 14 manufacturing sectors into low-tech sectors and high-med-tech sectors[12]. We expect high-med tech sectors to exploit to a greater extent the enabling and systemic impacts (OECD, 2010) of ICTs on the environment relative to low-tech sectors.

4.3 Results

Before commenting on the results of our econometric estimates, we begin with a descriptive analysis of the main sector-specific trends of environmental efficiency and economic indicators along the 1990-2007 period. First note that most of the manufacturing sectors were able to achieve a relative decoupling of SOx and NOx emissions with respect to output while the ratio between CO2 and output did not experience a similar performance and

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[11] By normalizing emissions with sector output, we implicitly assume that the elasticity of emissions with respect to output is unitary. This assumption is rejected only for CO2 (where the elasticity is positive but significantly lower than 1) while it cannot be rejected for NOx and SOx.

[12] The classification in low- and high-med-tech sectors is taken from Hall and Vopel (1997). See Table 8 for the assignment of each manufacturing sector to its class.

in some cases it increased (for example in sector DA ‘Food, beverage and tobacco’ and sector DF ‘Coke, refined petroleum and nuclear fuels’). Manufacturing sectors differed substantially in their emissions coefficients (emissions per unit of output), the most intensive being sector DI (Other non-metallic mineral products) for CO2 and NOx and sector DF (Coke, refined petroleum and nuclear fuels) for SOx and the most efficient being DL (Electrical and optical equipment) for CO2 and NOx and DM (Transport equipment) for SOx.

As regards the trend of the stock of ICT capital goods, their share in total gross capital stock peaked in 2001 (with a share, for manufacturing sectors, of 2.99%) after almost two decades of uninterrupted growth. The peak occurred in 2001 and 2002 for most of the sectors[13]. However, the volume of gross capital stock in ICT goods grew for most of the sectors until 2004. The most ICT-intensive (in terms of share of ICT capital goods in total capital stock) sectors were DL (‘Electrical and optical equipment’ with an average of 8.02%) and DE (‘Pulp, paper, paper products, publishing, printing’ with an average of 4.07%) while the less ICT-intensive sectors were sector DF (‘Coke, refined petroleum and nuclear fuels’ with an average of 0.96%) and DJ (‘Basic metals and fabricated metal products’ with an average of 1.31%). Finally, considering the ranking of total ICT gross capital stock, the first three sectors were respectively DL (Electrical and optical equipment), DK (Machinery and equipment n.e.c.) and DG (Chemicals, chemical products and man-made fibres) while the last three sectors were DF (Coke, refined petroleum and nuclear fuels), DD (Wood and wood products) and DC (Leather and leather products).

Only few sectors have an average intensity of R&D expenditure higher than 1% (DM, DL, DG, DK and DH) while the less R&D intensive sector is DD (‘Wood and wood products, with an average R&D/VA ratio below 0.1%). Import penetration, an indicator of the competitive pressures exerted by foreign competitors, is on average particularly high for sectors DM (Transport equipment) DL (Electrical and optical equipment) and DG (Chemical, chemical products and man-made fibres), all high-tech sectors, highlighting the reliance of Italian firms and consumers on imported high-tech goods. The evidence concerning export propensity (export share of total production) is more mixed with high export propensity for both high-tech sectors (DK, DM and DL) and low-tech sectors (DC and DB). Finally, it is worth discussing the dynamics of labour productivity in the considered period (Figure 7). On average, it increases slowly until 2001 and it experienced a stagnation/reduction after 2-a001. The post-2001 stagnation is common to all manufacturing sectors, with the only exception of sector DF ‘Coke, refined petroleum and nuclear fuels’ for which the decline of labour productivity started in the mid-90s.

Results of our base econometric estimates for CO2, SOx and NOx are reported in Tables 12, 13 and 14 respectively. In all cases, our preferred specification (column 4) contains the full set of covariates and time dummies. In fact, the various controls other than the gross capital stocks (labour productivity, R&D intensity and trade openness indexes) are likely to be correlated with the capital stock variables.

Table 15 reports the results when sector heterogeneity of β_1 is allowed while Table 16 contains the estimates when we allow for β_1 to change between high-med-tech sectors and low-tech sectors.

Before assessing the extent to which our ex-ante hypotheses (for sector analyses, HP1 and HP2) are confirmed by the sector-level empirical evidence, we discuss briefly the results for our main controls (labour productivity and gross non-ICT capital stock). Labour

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[13] DA in 2002, DB in 2001, DC in 2001, DD in 2002, DE in 2001, DF in 2002, DG in 1995, DH in 2002, DI in 2001, DJ in 2002, DK in 2001, DL in 2001 and DM in 2003.

productivity affect positively (negatively) sector environmental performance (emission coefficients), the effect being significant when controlling for year fixed effect only in the case of CO2 emissions. The absence of complementarity between labour productivity and emissions efficiency for NOx and SOx may depend on the fact that these types of emissions are generally abated through the installation of ‘end-of-pipe’ devices, which are a pure cost for the firms. On the contrary, CO2 abatement are generally achieved by improving the energy efficiency of the production processes (thus improving economic productivity too) and by modifying the fuel mix. The stock of gross non-ICT capital affects positively sector emission coefficients in our preferred specification for all emissions. Moreover, the estimated elasticity is rather high, equal (SOx) or greater (CO2 and NOx) than unity. Note that the estimated elasticity is rather unstable in the different specifications and changes dramatically when (correctly) including year fixed effects.

We use a rather rough test of our first hypothesis regarding the extent to which complementarities between ICT intensity, innovation and environmental performance are relevant. Once controlling for the main drivers of sector environmental efficiency, we estimate the effect of R&D intensity and ICT gross capital stock on environmental efficiency. General R&D intensity affects negatively CO2 and NOx efficiency while it does not influence SOx efficiency. This weak and positive effect of R&D is found in other studies on delinking for Italian manufacturing sectors such as Marin and Mazzanti (2011). This outcome is the result of a generally low fraction of environmental R&D on total R&D expenditure in Italy (see Antonioli and Mazzanti, 2009, for some evidence for the Emilia Romagna region). Moreover, this result indicates that the direction of innovation of Italian manufacturing sectors is towards emission intensive products/processes.

The stock of gross ICT capital affects positively CO2 efficiency, affects negatively SOx efficiency and does not affect NOx efficiency when we assume a unique average effect for all manufacturing sectors. Despite different geographical and temporal scope, this result is in line with the estimated role of ICT at the firm level for the Emilia Romagna region examined in the previous section. As expected, the positive net effect of ICT adoption (direct, enabling and system effects) on emissions efficiency is found for CO2 (for which enabling and system effects linked to improved energy efficiency play an important role) and it is absent for NOx and SOx.

However, when allowing for sector heterogeneity (sector or macro-sector specific effects), we observe that average elasticities hide different sector-specific patterns. The null hypothesis of sector or macro-sector homogeneity of β_1 is rejected for all emissions. The more disaggregated estimates (reported in Table 15), where we compute sector-specific elasticities, are rather volatile, especially when looking at the effect of the stock of gross non-ICT capital. This is likely to depend on the huge reduction in the degrees of freedom when estimating sector-specific elasticities (relative to homogeneous results, we estimate 13 additional parameters). However, it is interesting to note that ‘negative’ elasticities (either significant or not) are found in the sub-set of high-med tech sectors only[14]. This fact justifies the choice of further estimating different elasticities for low-tech and high-med tech sectors. Another interesting result regards the evidence for sector DG (Chemicals, chemical products and man-made fibres), which is among the most emissions- and capital-intensive manufacturing sectors: it is the only sector in which ICT gross capital stock affects negatively all emissions coefficients, with the largest (negative) elasticities as regards SOx and NOx.

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[14] The only exceptions being the negative (and significant) elasticity for sector DE in SOx emissions and the negative (and not significant) elasticity for sector DN in SOx emissions.

During the period we analyze, this sector experienced a dramatic structural change where ICT played a relevant role, with evident results in terms of environmental efficiency.

Table 16 contains our estimates when we allow β_1 to differ for low-tech and high-med tech sectors. In this case, we do not observe significant changes in the estimates for our controls. The stock of gross ICT capital has a negative and significant effect only in the case of CO2 emissions and high-med tech sectors, it is positive and significant at 1% confidence level for SOx emissions and high-med tech sectors and it is positive and significant at 10% confidence level for SOx and NOx in low-tech sectors. Med-high tech sectors performed better due to their higher (internal to the firm) capability to absorb and integrate into the production process new (ICT) capital goods relative to low tech sectors. Thus, med-high tech sectors exploited to a greater extent the potential energy efficiency gains linked to enabling and system effects of ICT adoption relative to low tech sectors.

Moving to our second hypothesis, export propensity is found to affect positively CO2 efficiency and negatively NOx efficiency while import penetration is found to affect negatively CO2 efficiency and positively SOx efficiency. However, results for import penetration are significant at 5% level only and disappear when we allow for heterogeneity in β_1. Our ex-ante hypothesis of a positive effect of export propensity on environmental innovation and performance is confirmed also in our sector level analysis. Domestic exporter manufacturing firms seems to adapt to stringent environmental regulations and standards and to ‘green’ demand in the partner countries. On the contrary, the two opposite forces at work when considering import penetration (technological environmental spillovers plus race to the top effects and race-to-the-bottom effect) seem to compensate each other leading to a weak net effect of import penetration.

Most of the results of our sector analyses are robust to the use of one or two years lag of our explanatory variables instead of contemporary variables[15].

5. Conclusions

This paper shed light on the role of a series of driving forces of environmental innovation and efficiency with a two step approach. At the firm level, we found that network linkages, ICT adoption and human capital are the main drivers of eco innovation while, rather surprisingly, general propensity to innovate, export propensity and firm size were not playing a significant role.

At the sector level we exploited the richness of the Italian NAMEA, further merged with other sector accounts and statistics, to assess the effect of a series of drivers on actual environmental (emission) efficiency of the Italian manufacturing sectors for the period 1990-2007. Although not very robust due to small sample size, results highlight highly heterogeneous net effect of ICT adoption on sector environmental performance. However, consistent with our ex-ante hypothesis, high-tech sectors experienced a sort of (weak) ‘green’ structural change induced by ICTs.

Further research is needed both for firm- and sector-level analyses. As regards firm-level analyses, in addition to similar tests on samples with a greater geographical coverage, additional effort should be devoted to investigate possible interactions among the determinants of eco-innovation. As regards sector-level analyses, the most promising direction of research are related to the assessment of interaction among sectors in different countries through the exploitation of the European NAMEA and to the explicit inclusion of

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[15] Results are available upon request.

measures of environmental innovation creation/use by using data on eco-patents. The measurement of sectoral eco-innovation allows to disentangle direct and indirect (through innovation) effects of our set of drivers of environmental performance.

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Appendix

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	**2,720**	**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**
ISO14001					
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
Cooperation with. universities	555	0.114	0.167	0	1
Cooperation with suppliers	555	0.174	0.262	0	1
ICT adoption intensity	555	0.591	0.171	0	1
Training coverage (share of trained employees)	555	37.801	36.909	0	100
District effect	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

Table 6 – Environmental innovations and ICT at the firm level

Estimation method: Probit	Env. Innov.	Materials	CO2	Emissions	EMS	Iso14001
	dF/dx	*dF/dx*	*dF/dx*	*dF/dx*	*dF/dx*	*dF/dx*
R&D	-0.011	0.049	0.019	0.001	-0.004	-0.042
	[-0.25]	[1.41]	[0.70]	[0.03]	[-0.68]	[-1.22]
Training coverage	0.001***	0.001***	0.0009***	0.001***	0.0001*	0.001***
	[4.26]	[3.78]	[3.30]	[3.72]	[1.90]	[3.79]
Central Emilia dummy	0.059*	0.023	0.052**	0.057**	0.011***	0.022
	[1.71]	[0.85]	[2.46]	[2.21]	[2.77]	[0.97]
20-49 empl.	-0.028	-0.022	-0.003	-0.017	-0.009*	-0.053
	[-0.51]	[-0.51]	[-0.09]	[-0.39]	[-1.72]	[-1.44]
50-99 empl.	-0.053	-0.026	-0.011	-0.057	-0.019***	-0.028
	[-1.08]	[-0.71]	[-0.38]	[-1.56]	[-3.92]	[-0.90]
100-249 empl.	0.062	0.020	0.033	0.062	-0.004	0.062
	[1.07]	[0.46]	[0.89]	[1.37]	[-1.00]	[1.56]
250 empl.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Export propensity	0.0002	0.0004	-0.00002	0.0001	-0.00001	0.0001
	[0.48]	[0.94]	[-0.08]	[0.38]	[-0.24]	[0.28]
District	-0.106***	-0.051	-0.067***	-0.079***	-0.007*	-0.031
	[-2.73]	[-1.63]	[-3.08]	[-2.77]	[-1.68]	[-1.15]
University cooperation	0.268***	0.165**	0.138***	0.214***	0.012	0.200***
	[2.71]	[2.23]	[2.57]	[3.18]	[1.55]	[3.28]
Suppliers cooperation	0.205***	0.127**	0.107***	0.152***	-0.003	0.142***
	[3.54]	[2.89]	[3.28]	[3.55]	[-0.48]	[3.98]
Foreign ownership	0.084	0.033	0.052	0.032	-0.003	0.066*
	[1.63]	[0.92]	[1.60]	[0.81]	[-0.74]	[1.87]
ICT intensity	0.229**	0.257***	0.224***	0.141*	0.021*	0.075
	[2.23]	[3.21]	[3.41]	[1.70]	[1.74]	[1.03]
Pseudo-R^2	0.186	0.201	0.221	0.205	0.256	0.227
N. Obs.	555	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 – Capital goods (CPA 2002)

non-ICT	Machinery	01.1, 01.2, 05.0, 17.4, 17.5, 19.1, 19.2, 20.1, 22.0, 25.2, 26.1, 26.2, 26.6, 27.2, 28.1, 28.2, 28.3, 28.6, 28.7, 29.1, 29.2, 29.4, 29.5, 29.6, 29.3, 29.7, 31.1, 31.2, 31.5, 31.6, 33.1, 33.2, 33.3, 33.4, 33.5, 36.4, 36.5, 36.6
	Furniture	36.1, 36.3
	Road vehicles	34.1, 34.2, 34.3, 34.4, 35.5
	Other vehicles	35.1, 35.2, 35.3
	Buildings	45.0
	Other goods	50.2, 70.3, 74.1, 74.2, 92.0
ICT	Equipment for office	30.0
	Equipment for communication	32.1, 32.2, 32.3
	Software	72.0

Table 8– Nace classification (manufacturing

Sub-section	Nace 2-digit	Low- (L) vs high-med- (HM) tech	Description
DA	15-16	L	Manufacture of food products, beverages and tobacco
DB	17-18	L	Manufacture of textiles and textile products
DC	19	L	Manufacture of leather and leather products
DD	20	L	Manufacture of wood and wood products
DE	21-22	L	Manufacture of pulp, paper and paper products; publishing and printing
DF	23	HM	Manufacture of coke, refined petroleum products and nuclear fuel
DG	24	HM	Manufacture of chemicals, chemical products and man-made fibres
DH	25	HM	Manufacture of rubber and plastic products
DI	26	HM	Manufacture of other non-metallic mineral products
DJ	27-28	HM	Manufacture of basic metals and fabricated metal products
DK	29	HM	Manufacture of machinery and equipment n.e.c.
DL	30-33	HM	Manufacture of electrical and optical equipment
DM	34-35	HM	Manufacture of transport equipment
DN	36-37	L	Manufacturing n.e.c.

Table 9 – Correlation matrix (conditional on sector fixed effects)

	ln(CO2/Y)	ln(SOx/Y)	ln(NOx/Y)	ln(K^{ICT})	ln($K^{non-ICT}$)	ln(VA/Fte)	X/Y	M/Y	R&D/VA
ln(CO2/Y)	1.00								
ln(SOx/Y)	0.60	1.00							
ln(NOx/Y)	0.74	0.84	1.00						
ln(K^{ICT})	-0.31	-0.72	-0.62	1.00					
ln($K^{non-ICT}$)	-0.27	-0.74	-0.59	0.84	1.00				
ln(VA/Fte)	-0.42	-0.45	-0.45	0.31	0.14	1.00			
X/Y	-0.45	-0.65	-0.69	0.48	0.58	0.32	1.00		
M/Y	-0.58	-0.78	-0.72	0.49	0.49	0.53	0.77	1.00	
R&D/VA	0.30	0.23	0.33	-0.16	-0.23	-0.11	-0.30	-0.23	1.00

Table 10 – Some descriptive statistics: dependent variables

NACE	Statistic	CO2/Y	SOx/Y	NOx/Y	NACE	Statistic	CO2/Y	SOx/Y	NOx/Y
DA	Mean	85.6	0.131	0.194	DI	Mean	1,288	1.61	3.46
	Median	82.4	0.0939	0.175		Median	1,294	1.47	3.38
	Max	101	0.337	0.326		Max	1,400	2.22	4.42
	Min	72.3	0.0233	0.15		Min	1,172	1.27	2.81
	SD/Mean	0.103	0.685	0.278		SD/Mean	0.0451	0.192	0.149
DB	Mean	158	0.386	0.297	DJ	Mean	253	0.36	0.356
	Median	152	0.211	0.231		Median	227	0.302	0.303
	Max	193	0.989	0.605		Max	366	0.666	0.572
	Min	115	0.0417	0.173		Min	175	0.176	0.214
	SD/Mean	0.147	0.832	0.51		SD/Mean	0.279	0.489	0.379
DC	Mean	42.7	0.12	0.123	DK	Mean	39.9	0.0415	0.115
	Median	42.3	0.0655	0.112		Median	39.6	0.0274	0.117
	Max	51.5	0.305	0.222		Max	49.6	0.0914	0.149
	Min	33.8	0.0139	0.0625		Min	32.4	0.00509	0.076
	SD/Mean	0.106	0.843	0.451		SD/Mean	0.0988	0.752	0.208
DD	Mean	74.9	0.186	0.276	DL	Mean	28.3	0.0279	0.0871
	Median	71.4	0.0801	0.266		Median	28.5	0.0188	0.0933
	Max	89.9	0.529	0.41		Max	31.2	0.0601	0.116
	Min	58.6	0.0148	0.153		Min	24.5	0.00408	0.0592
	SD/Mean	0.128	0.95	0.322		SD/Mean	0.0653	0.712	0.224
DE	Mean	147	0.0446	0.122	DM	Mean	64.5	0.0265	0.109
	Median	147	0.0235	0.123		Median	58.4	0.0108	0.0933
	Max	158	0.124	0.15		Max	91.4	0.0696	0.187
	Min	119	0.00853	0.0925		Min	46.8	0.0027	0.0699
	SD/Mean	0.061	0.832	0.111		SD/Mean	0.192	0.952	0.364
DF	Mean	716	5.55	1.23	DN	Mean	32.7	0.0625	0.133
	Median	728	5.38	1.24		Median	32.1	0.028	0.134
	Max	776	9.5	1.64		Max	36.3	0.163	0.187
	Min	641	2.62	0.847		Min	29.7	0.0066	0.0874
	SD/Mean	0.0547	0.417	0.218		SD/Mean	0.0527	0.914	0.268
DG	Mean	304	1.18	0.616	Total	Mean	237	0.706	0.522
	Median	278	0.507	0.315		Median	88.4	0.0967	0.18
	Max	461	3.13	1.72		Max	1,400	9.5	4.42
	Min	207	0.182	0.197		Min	24.5	0.0027	0.0592
	SD/Mean	0.297	0.976	0.852		SD/Mean	1.44	2.24	1.71
DH	Mean	85	0.158	0.191					
	Median	85.1	0.0622	0.156					
	Max	101	0.462	0.348					
	Min	66.5	0.0142	0.107					
	SD/Mean	0.12	0.976	0.424					

Table 11 – Some descriptive: independent variables

NACE	Statistic	$K^{non\text{-}ICT}$	K^{ICT}	R&D/VA	X/Y	M/Y	VA/FTE	H	FTE	Y
DA	Mean	91,291	1,502	0.376	13	17.3	43.5	915,568	473	87,753
	Median	89,311	1,463	0.358	13.1	17.1	43.6	920,238	472	89,376
	Max	120,894	2,214	0.536	16.9	20	47.9	965,852	499	99,832
	Min	69,721	825	0.278	8.39	15.3	38	856,206	446	70,429
	SD/Mean	0.166	0.333	0.178	0.199	0.075	0.0638	0.0337	0.0328	0.104
DB	Mean	86,258	1,975	0.183	35.3	20.8	69.3	1,169,824	648	65,253
	Median	85,893	1,964	0.082	36.8	19.7	31.7	1,100,000	636	65,124
	Max	96,810	2,431	0.544	40.9	30.3	725	1,600,000	894	72,490
	Min	77,810	1,553	0.0241	26.2	13	23.3	812,375	31.1	59,860
	SD/Mean	0.0634	0.174	0.869	0.129	0.255	2.36	0.191	0.293	0.0625
DC	Mean	15,919	482	0.158	45	23.8	70.4	369,246	205	25,085
	Median	15,273	506	0.121	45.8	21.8	30.2	373,392	213	25,450
	Max	18,562	624	0.425	49	33.9	764	464,568	266	28,483
	Min	14,937	322	0.0257	38.8	13.5	25.1	266,267	9.67	21,011
	SD/Mean	0.0753	0.261	0.748	0.0719	0.272	2.46	0.161	0.281	0.0965
DD	Mean	33,199	462	0.0955	7.26	16.3	62.2	355,075	177	15,614
	Median	32,460	444	0.109	7.77	16.2	30	358,857	186	16,165
	Max	36,940	537	0.171	8.49	19.6	629	414,281	214	18,442
	Min	31,501	412	0.0213	4.93	14.1	22.9	265,519	8.17	12,875
	SD/Mean	0.0463	0.0909	0.469	0.157	0.0891	2.28	0.0982	0.248	0.13
DE	Mean	47,614	2,079	0.152	12.5	14.8	110	494,122	257	40,232
	Median	45,439	2,162	0.128	13	15.5	49	488,745	268	41,193
	Max	67,566	2,955	0.702	14.4	17.3	1154	550,170	296	45,095
	Min	33,406	1,086	0.00864	8.32	11.5	40.9	437,747	11.3	33,664
	SD/Mean	0.229	0.349	1.05	0.156	0.128	2.38	0.051	0.241	0.104
DF	Mean	19,015	188	0.725	16.2	16.9	517	46,024	24.3	32,227
	Median	18,473	179	0.563	15.1	17.1	190	45,854	25.5	32,133
	Max	29,069	264	1.99	24.9	20.2	6395	52,815	28	34,350
	Min	12,230	101	0.0449	11.7	13.9	89.1	40,396	1.04	30,377
	SD/Mean	0.243	0.286	0.94	0.252	0.112	2.84	0.0633	0.243	0.0313
DG	Mean	94,990	2,253	5.33	30.2	40.4	168	372,100	204	60,954
	Median	94,490	2,313	5.02	28.7	38.6	80.1	363,204	209	64,150
	Max	107,047	2,439	7.71	42.8	52.4	1753	460,541	257	70,365
	Min	86,907	1,912	4.2	16.5	29.1	57	337,934	8.79	49,228
	SD/Mean	0.068	0.0726	0.193	0.264	0.166	2.35	0.0897	0.25	0.13
DH	Mean	47,443	800	1.47	26.6	17	105	350,699	189	30,502
	Median	46,107	843	1.33	26.7	16.6	46.3	345,325	197	33,108
	Max	59,380	1,083	2.15	32.1	21.4	1107	384,734	217	36,582
	Min	39,062	482	0.956	20.2	13.6	40.1	291,750	7.84	21,757
	SD/Mean	0.134	0.281	0.25	0.118	0.124	2.38	0.0714	0.25	0.18

(continue)

(continue)

NACE	Statistic	$K^{non\text{-}ICT}$	K^{ICT}	R&D/VA	X/Y	M/Y	VA/FTE	H	FTE	Y
DI	Mean	52,506	788	0.283	23.2	8.9	102	469,249	249	33,993
	Median	50,125	810	0.24	23.1	9.19	47.4	460,800	256	32,917
	Max	71,115	1,109	0.479	27.3	9.99	1061	571,293	314	38,956
	Min	41,600	432	0.12	17.7	7.32	37.1	402,559	10.7	29,051
	SD/Mean	0.169	0.32	0.406	0.135	0.0833	2.35	0.0793	0.25	0.108
DJ	Mean	159,538	2,175	0.38	19.1	20.6	94.6	1,475,000	768	100,968
	Median	152,372	2,138	0.289	18.8	19.7	42.1	1,500,000	810	103,469
	Max	199,476	3,082	0.789	25.2	26.9	1015	1,600,000	918	130,476
	Min	140,382	1,286	0.181	14.3	17.7	32.7	1,300,000	31.3	75,131
	SD/Mean	0.11	0.338	0.485	0.152	0.127	2.43	0.0533	0.249	0.175
DK	Mean	108,740	3,097	1.99	52.6	28.7	110	1,042,214	541	85,743
	Median	107,631	2,964	1.71	54.2	29.2	48.3	1,000,000	563	87,238
	Max	132,393	3,717	2.81	59.5	34.9	1178	1,200,000	641	112,261
	Min	91,719	2,498	1.25	39.9	21.8	42.2	941,568	22	62,019
	SD/Mean	0.111	0.158	0.286	0.102	0.123	2.42	0.0662	0.251	0.181
DL	Mean	56,978	4,991	7.75	35.8	42.5	101	816,463	426	59,808
	Median	54,670	5,058	7.61	36.9	43.3	46.2	802,951	446	60,979
	Max	76,533	6,352	9.91	40.5	49.5	1064	902,026	481	73,754
	Min	43,311	3,419	5.65	26.4	34.1	37.4	760,078	18.1	45,874
	SD/Mean	0.175	0.23	0.181	0.119	0.104	2.37	0.0446	0.243	0.156
DM	Mean	76,840	2,277	13.2	47.6	51.3	44.1	494,581	286	52,058
	Median	77,222	2,322	13.1	49.1	51.5	44.9	489,403	283	54,089
	Max	92,160	2,924	18	54.6	59.3	47.1	615,136	359	64,047
	Min	59,504	1,393	10.1	35.2	39.4	38	398,180	243	37,927
	SD/Mean	0.117	0.213	0.187	0.115	0.117	0.0588	0.106	0.0961	0.141
DN	Mean	41,455	1,419	0.271	38.5	13.8	76.3	597,409	303	35,718
	Median	40,740	1,473	0.217	39.7	13.6	33.7	597,375	318	37,285
	Max	48,813	1,770	0.491	43.7	18.4	815	648,444	338	40,993
	Min	36,876	1,058	0.0638	29.6	8.68	28.9	498,714	13.8	28,842
	SD/Mean	0.0843	0.19	0.546	0.108	0.178	2.42	0.0525	0.24	0.114
Total	Mean	66,556	1,749	2.31	28.8	23.8	120	640,541	339	51,850
	Median	57,622	1,563	0.396	26.9	18.4	44.6	496,249	270	44,054
	Max	199,476	6,352	18	59.5	59.3	6395	1,600,000	918	130,476
	Min	12,230	101	0.00864	4.93	7.32	22.9	40,396	1.04	12,875
	SD/Mean	0.584	0.753	1.66	0.499	0.53	3.76	0.599	0.644	0.507

Figure 1 – Sector trends of CO2 emissions efficiency

Figure 2 – Sector trends of SOx emissions efficiency

Figure 3 – Sector trends of NOx emissions efficiency

Figure 4 – Sector trends of the share of ICT gross capital stock on total gross capital stock

Figure 5 – ICT gross capital stock as share of total gross capital stock

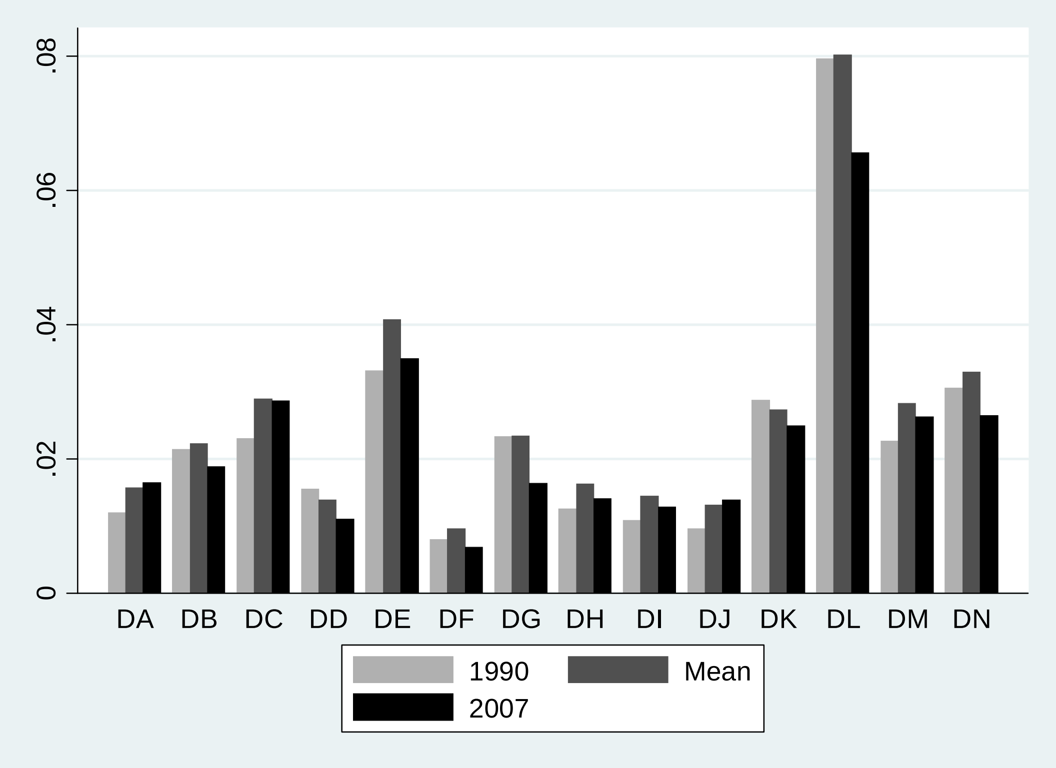

Figure 6 – Sector trends of import penetration and export share of production

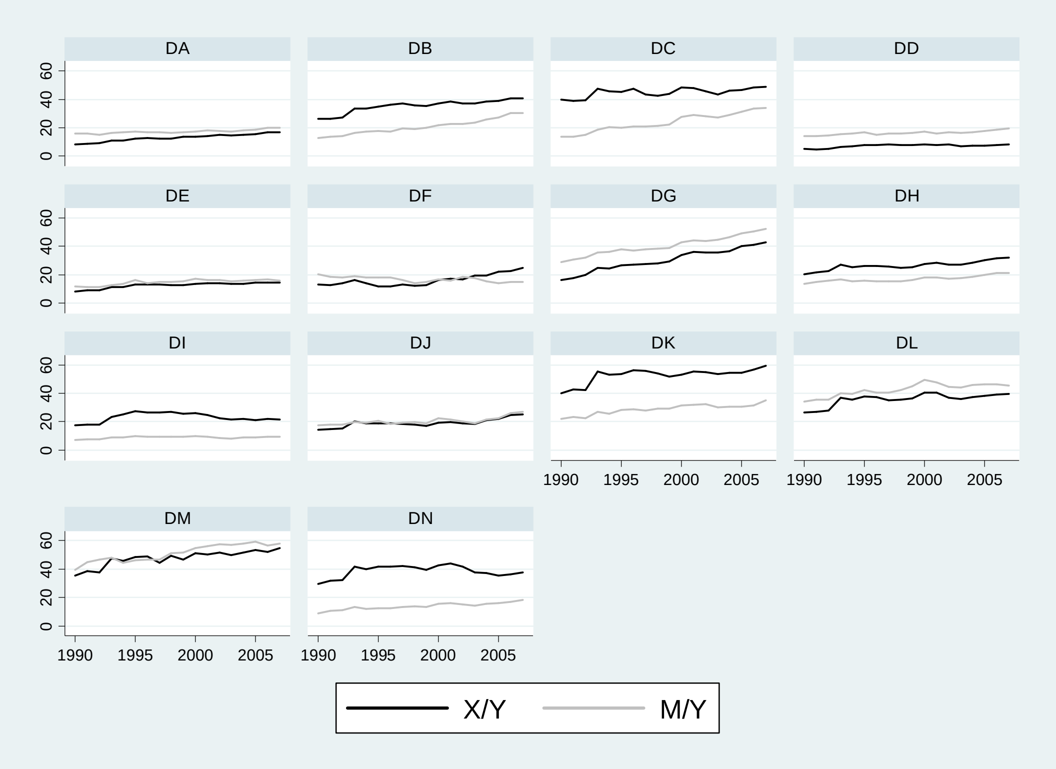

Figure 7 – Sector trends of labour productivity

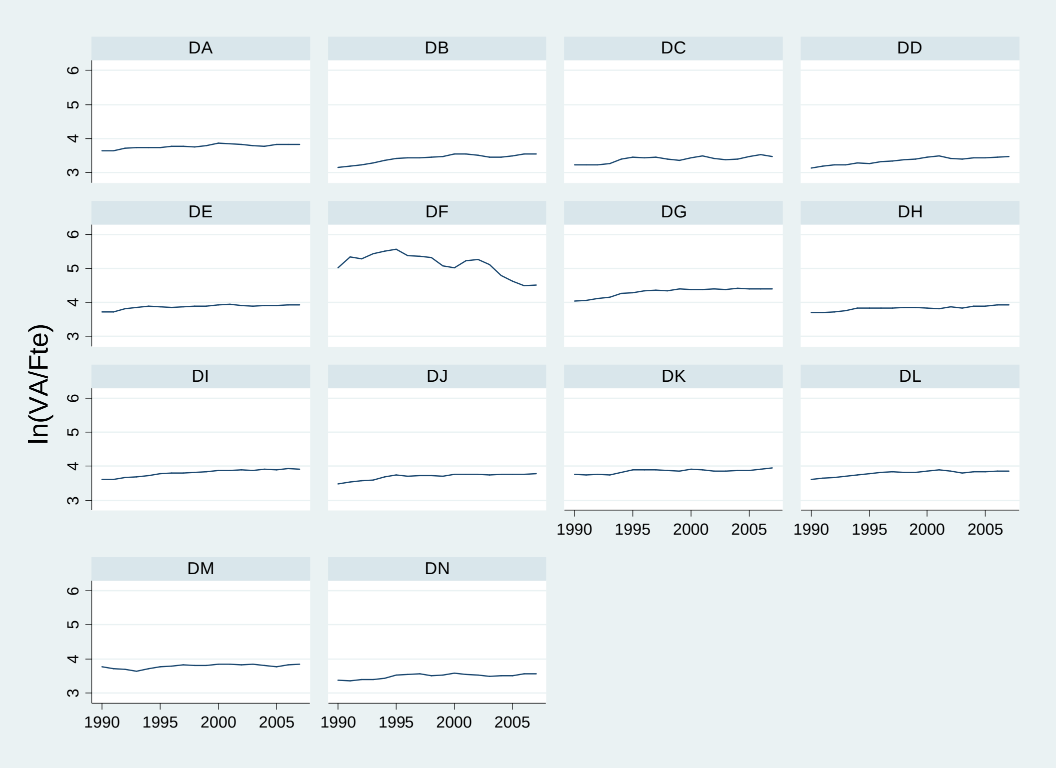

Figure 4 – Unconditional correlations between emission efficiency and (ICT and non-ICT) gross capital stock

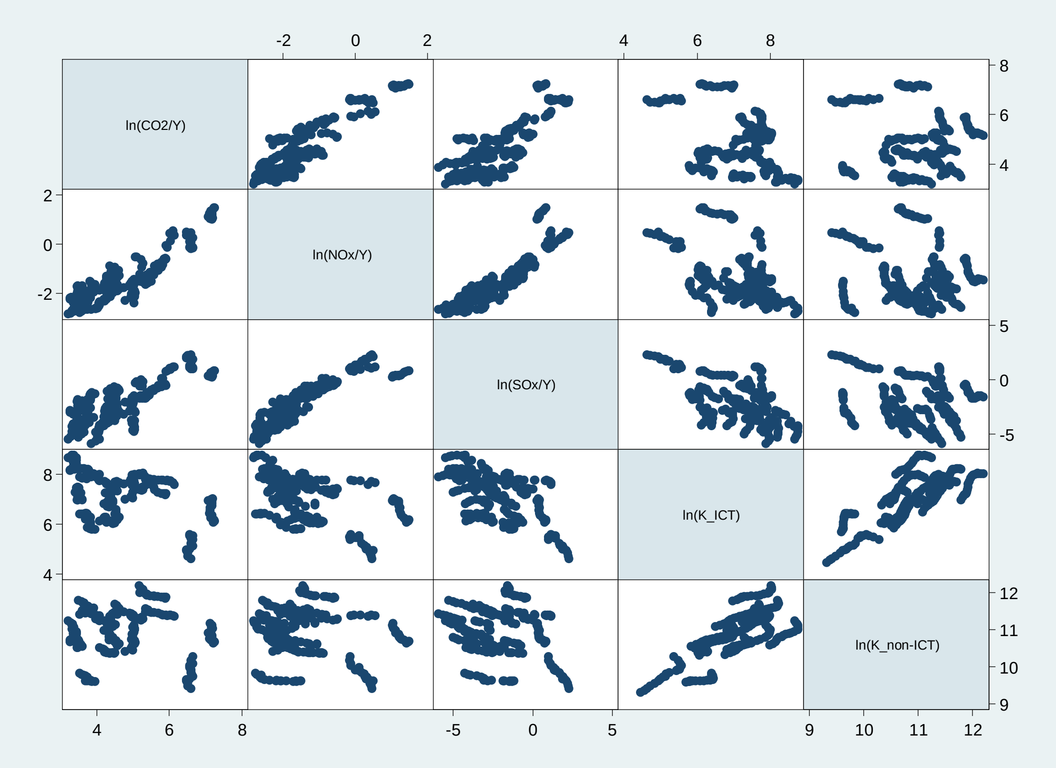

Figure 5 – Unconditional correlations between emission efficiency and trade openness indexes

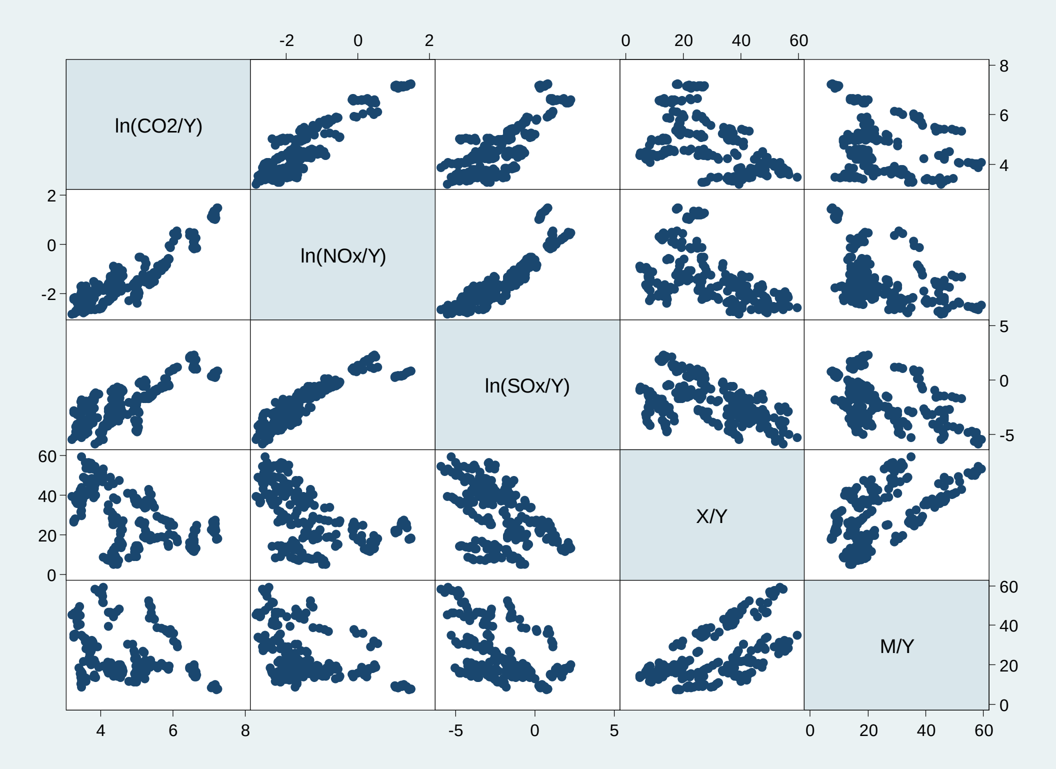

Table 12 – Drivers of CO2 emissions sector efficiency

Dep: ln(CO2/Y)	(1)	(2)	(3)	(4)
$\ln(K^{ICT})$	-0.16***	-0.02	-0.05	-0.17**
	[0.06]	[0.06]	[0.05]	[0.07]
$\ln(K^{non\text{-}ICT})$	-0.01	-0.18	0.08	1.38***
	[0.12]	[0.12]	[0.11]	[0.17]
ln(VA/Fte)		-0.45***	-0.16**	-0.18**
		[0.07]	[0.08]	[0.07]
R&D/VA			0.03***	0.05***
			[0.01]	[0.01]
X/Y			0.00	-0.02***
			[0.00]	[0.00]
M/Y			-0.02**	0.01**
			[0.00]	[0.00]
Obs	252	252	238	238
R^2 (within)	0.1	0.22	0.42	0.65
F	12.58***	22.43***	26.51***	16.97***
F (time dummies)	No	No	No	8.17***

Table 13 – Drivers of SOx emissions sector efficiency

Dep: ln(SOx/Y)	(1)	(2)	(3)	(4)
$\ln(K^{ICT})$	-1.10***	-0.32	-0.42*	0.86***
	[0.28]	[0.26]	[0.22]	[0.23]
$\ln(K^{non\text{-}ICT})$	-3.29***	-4.22***	-2.98***	1.00*
	[0.53]	[0.49]	[0.44]	[0.55]
ln(VA/Fte)		-2.51***	-0.78**	-0.30
		[0.31]	[0.31]	[0.24]
R&D/VA			0.01	0.03
			[0.04]	[0.03]
X/Y			0.01	0.01
			[0.01]	[0.01]
M/Y			-0.13***	-0.03**
			[0.01]	[0.01]
Obs	252	252	238	238
R^2 (within)	0.58	0.67	0.79	0.91
F	164.22***	161.36***	134.82***	98.78***
F (time dummies)	No	No	No	18.89***

Table 14 – Drivers of NOx emissions sector efficiency

ln(NOx/Y)	(1)	(2)	(3)	(4)
ln(K^{ICT})	-0.57***	-0.26**	-0.39***	0.20
	[0.13]	[0.13]	[0.10]	[0.13]
ln($K^{non\text{-}ICT}$)	-0.62**	-1.00***	-0.17	1.70***
	[0.25]	[0.23]	[0.21]	[0.30]
ln(VA/Fte)		-1.00***	-0.35**	0.03
		[0.15]	[0.15]	[0.13]
R&D/VA			0.05***	0.06***
			[0.02]	[0.01]
X/Y			-0.02***	-0.02***
			[0.01]	[0.01]
M/Y			-0.03***	0.01
			[0.01]	[0.01]
Obs	252	252	238	238
R^2 (within)	0.40	0.49	0.67	0.83
F	77.19***	76.08***	72.86***	44.81***
F (time dummies)	No	No	No	12.08***

Table 15 – Heterogeneous effect of ICT capital on sector emissions efficiency

	ln(CO2/Y)	ln(SOx/Y)	ln(NOx/Y)
ln(K^{ICT})			
DA	0.49***	0.43**	0.99***
	[0.08]	[0.20]	[0.15]
DB	0.17	0.38	0.64***
	[0.11]	[0.28]	[0.21]
DC	0.13	0.01	0.05
	[0.08]	[0.21]	[0.16]
DD	0.37	0.46	1.57***
	[0.22]	[0.57]	[0.43]
DE	0.10	-0.73***	1.25***
	[0.10]	[0.25]	[0.18]
DF	0.08	0.35	1.04***
	[0.12]	[0.30]	[0.22]
DG	-0.45*	-2.94***	-2.49***
	[0.25]	[0.62]	[0.47]
DH	-0.06	-0.83***	0.39**
	[0.08]	[0.21]	[0.16]
DI	0.17**	2.08***	1.07***
	[0.08]	[0.21]	[0.16]
DJ	-0.38***	1.50***	0.44***
	[0.06]	[0.15]	[0.12]
DK	0.47***	0.12	1.54***
	[0.13]	[0.34]	[0.25]
DL	0.50***	-0.03	1.54***
	[0.12]	[0.30]	[0.22]
DM	-0.04	-0.59**	1.27***
	[0.11]	[0.28]	[0.21]
DN	0.39***	-0.28	1.09***
	[0.11]	[0.27]	[0.20]
ln($K^{non-ICT}$)	0.69***	3.20***	-0.04
	[0.21]	[0.52]	[0.39]
ln(VA/Fte)	-0.29***	-0.58***	-0.27**
	[0.07]	[0.18]	[0.14]
R&D/VA	0.04***	0.05***	0.06***
	[0.01]	[0.02]	[0.01]
X/Y	-0.01***	-0.01	-0.02***
	[0.00]	[0.01]	[0.00]
M/Y	0.00	0.03**	0.01
	[0.00]	[0.01]	[0.01]
Obs	238	238	238
R^2 (within)	0.84	0.98	0.91
F	29.08***	218.80***	54.90***
F (time dummies)	7.92***	40.82***	13.09***
F (H_0: $\beta_{s1}=\beta_1 \ \forall \ s$)	17.61***	37.44***	12.47***

Table 16 – Heterogeneous (HM vs L) effect of ICT capital on sector emissions efficiency

	ln(CO2/Y)	ln(SOx/Y)	ln(NOx/Y)
ln(K^{ICT})			
High-med-tech	-0.27***	1.16***	0.18
	[0.07]	[0.23]	[0.13]
Low-tech	-0.02	0.41*	0.25*
	[0.07]	[0.24]	[0.14]
ln($K^{non\text{-}ICT}$)	1.27***	1.31**	1.67***
	[0.16]	[0.52]	[0.30]
ln(VA/Fte)	-0.21***	-0.21	0.03
	[0.07]	[0.22]	[0.13]
R&D/VA	0.04***	0.06**	0.05***
	[0.01]	[0.03]	[0.01]
X/Y	-0.01***	0.01	-0.02***
	[0.00]	[0.01]	[0.01]
M/Y	0.00	-0.01	0.01
	[0.00]	[0.01]	[0.01]
Obs	238	238	238
R sq (within)	0.69	0.92	0.83
F	19.62***	106.55***	42.80***
F (time dummies)	8.19***	22.05***	11.76***
F (H_0: $\beta_1^{HM}=\beta_1^{L}$)	17.19***	19.98***	1.60