Siep Società italiana di economia pubblica

XVII CONFERENZA

FINANZIAMENTO DEL SETTORE PUBBLICO

Pavia, Università, 15 - 16 settembre 2005

WHAT DRIVES ENVIRONMENTAL INNOVATION?

Empirical Evidence for a District-Based Manufacturing System

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pubblicazione internet realizzata con contributo della COMPAGNIA di San Paolo

società italiana di economia pubblica

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What Drives Environmental Innovation?

Empirical Evidence for a District-Based Manufacturing System♦

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Abstract

Technological innovation is a key factor for achieving a better environmental performance of firms and the economy as a whole, to the extent that helps increasing the material/energy efficiency of production processes and reducing emission/effluents associated to outputs. Environmental innovation may spur from exogenous driving forces, like policy intervention, and/or from endogenous factors associated to firm market and management strategies. Despite the crucial importance of research in this field, empirical evidence at firm microeconomic level, for various reasons, is still scarce. Microeconomic-based analysis is needed in order to assess what forces are lying behind environmental innovation at the level of the firm, where innovative practices emerge and are adopted. The paper exploits information deriving from two surveys conducted on a sample of manufacturing firms in the Emilia Romagna region -Northern Italy- in 2002 and 2004, located in a district-intense local production system. New evidence on the driving forces of environmental-related innovation is provided by testing a set of hypothesis, concerning the influence of: (i) firm structural variables; (ii) environmental R&D; (iii) environmental policy pressure and regulatory costs; (iv) past firm performances; (v) networking activities, (vi) other non-environmental techno-organizational innovations and (vii) quality/nature of industrial relations. We estimate various input and output-based environmental innovation reduced form specifications in order to test the set of hypothesis. The applied investigation shows that environmental innovation drivers, both at input and output level, are found within exogenous factors and endogenous elements concerning the firm and its activities/strategies within and outside its natural boundaries. In the present case study, usual structural characteristics of the firm and performances appear to matter less than R&D, induced costs, networking, organisational flatness and innovative oriented industrial relations. Environmental Policies and environmental voluntary auditing schemes exert some relevant direct and indirect effects on innovation, although evidence is mixed and further research is particularly needed. Although this new empirical evidence is focussing on a specific industrial territory, results concern a large set of hypothesis on potential driving forces of innovation. We thus provide food for discussion on firm environmental innovation strategies, and research suggestions for further empirical works.

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

Keywords: environmental innovation, environmental R&D, manufacturing sector, local system, environmental policy, networking

♦ The work is carried out within the research activities of the Department of Economics, University of Ferrara (Research team on *Organisational innovation, industrial relations and economic performances*) and of the CERIS-DSE Institute of the National Research Council in Milan. The research line on environmental innovation is one of the core elements of the 2005-2007 research programme on "Innovative dynamics in the knowledge-based economy" funded by the University budget for projects of local interests (ex 60%). Data derive from two surveys. One was funded by CERIS-CNR in 2004 and the other within the 2001-2003 research programme PRIN "Infrastructures, competitiveness and governance levels: knowledge and development of the New economy".

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1. Environmental Innovations and environmental policies in industrial settings

1.1 Conceptual framework

Growing evidence suggests that advanced economic systems operate with a decreasing intensity of energy and materials per unit of output. For energy and materials, these trends can be observed over the very long run. In general, the factors behind macro-level decoupling between economic growth and resources can be: (a) market factors, i.e. change in relative prices of basic commodities; (b) technological innovation at the macro and micro level, including structural changes of the sector composition of the economy and 'industry migration'; (c) public policies. The three are dynamically interrelated. Concerning the current European situation, we observe a mounting interest in environmental (less polluting) technologies, partly depending on the contribution they can make to complementarily reach the "Lisbon Objectives" on growth and innovation and the "Gothenburg priorities" on sustainable development (IPTS, 2004)[1].

The issue of environmental innovation in district-oriented local productive system is particularly important given the high density of firms in industrial areas. This is extremely relevant for some industrialised Italian Regions, like Emilia-Romagna, since cluster or districts of firms may generate critical harmful local "hot spots" in emission and waste production (Montini and Zoboli, 2004). The local relevancy is particularly serious for externalities like river pollution and (urban) landfills. This negative environmental feature could be counterbalanced by the high innovative propensity of district firms that, exploiting networking relationships, knowledge spillovers due to proximity and internal sources, may dynamically increase the environmental efficiency of the productive area[2]. The relative rate of growth of externalities and innovation is crucial for determining whether a *Delinking* between growth and environmental externalities is occurring or not. Environmental Innovative capacity, endogenously driven and/or spurred by policies and networking spillovers and agreements, is currently the key issue. Environmental innovations are particularly crucial in industrial local frameworks since they often give rise to a "double externality", providing on the one hand the typical R&D spillover and on the other hand reducing environmental externalities.

Specifically concerning manufacturing, pollutant emissions from the manufacturing industries are main determinants for the general pollution affecting the environment, in Italy and in the European industrial environment. Manufacturing industries apart from the energy production industry, account for a relevant part of total emissions for respective species[3]. They are the principal offenders in the case of methane (CH_4); the transport sector is the most polluting in the case of carbon monoxide (CO), the nitrogen oxides (NO_x) and the non-methane volatile organic compound (NM-VOC). Six air pollutants are considered in the Italian official environmental data. Data refer to air pollution emissions from household consumption (transport, heating and others) and production activities (agriculture, industry and services). Upon examination of the macro sources of

[1] The IPTS report stems from the 2004 Commission communication "Stimulating technologies for sustainable development: an environmental technology action for the EU", which derived from a 2001 European Council that requested the preparation of a report "assessing how environmental technology can promote growth and employment".

[2] Aggeri (1999) calls those informal agreements "innovation-oriented voluntary agreements", where pollution is diffuse, uncertainty is high and innovation becomes the central feature.

[3] Jaffe et al. (1996) present a ranking of "environmental efficiency" concerning manufacturing and non manufacturing sectors, relatively to the US environment.

emission in Italy it appears that the manufacturing industry is primarily responsible for carbon dioxide pollution and accounts for about 40% in the sulphur oxides emissions too.

Strictly relevant for our case, the last decoupling indicator for waste suggested by OECD (2002) focuses on manufacturing processes, and it is strictly related to the concept of resource efficiency, the amount of waste generated by manufacturing industry versus manufacturing value added can in fact be interpreted as a partial measure of their resource efficiency or productivity. The available data shows that no decoupling has occurred during the period 1990-97.

The specific evidence for Emilia Romagna, which is the Regional area under consideration here, suggests the importance of local industrial concentration for the local environmental pressure (Montini and Zoboli, 2004). The high potential impact depends on either specific features of the sector production technologies or spatial concentration of industrial activities. It also appears that industrial districts are quite frequently in the top ranking positions of the most polluted Local production systems. Examination of rank by per capita emissions shows that two Emilia Romagna industrial districts, in Sassuolo and Castellarano Municipal areas, with high specialisation in other non metallic mineral products are the most polluted with regard to sulphur oxides (SO_X), nitrogen oxides (NO_X), carbon dioxide (CO_2) and nitrous oxide (NO_2) and they have absolute per capita values which are double, or even more, of the third ranking areas. In addition to this, the worldwide known export-oriented ceramic district of Sassuolo is top ranking in terms of the per area emissions of all pollutants.

Not surprisingly, then, the historical development of environmental policy in Italy have significantly involved manufacturing industries in industrial districts, as sector-based policies on a specific issue (water quality, waste), agglomeration of specific environmental policy and more recently local integrated policies addressing the state of the environment in the local system.

Regarding innovation adoptions, we may briefly say that most initiative for introducing low impact technologies have been taken in sectors/districts like machineries, leather, and ceramic. Nevertheless, most innovations tend to be end of pipe rather than structural: investments in clean technologies are rather rare and can be observed only in few districts and firms. Environmental management systems are not widespread on average and in industrial districts as well (Iraldo, 2002) for a recent assessment on the EMAS dynamics in Italian districts)[4]. The situation is clearly in transition. Industrial districts firms are slowly moving to more advances approaches based on clean technologies and environmental management schemes.

1.2 Empirical evidence: the state of the art

We may subdivide the relevant empirical literature in three streams: (i) investigations using environmental Innovation output and/or input indexes as dependant variable, which are the primary interest for our applied analysis, and contributions focusing on (ii) drivers of firm/sector pollution indexes, and (iii) firm performances and firm and industry location decisions used as dependant variables, with an analysis of "environmental drivers". Since innovation, performances, policy and pollution are intrinsically co-evolving and co-determinant

[4] 148 Italian organisations were registered to EMAS in 2003, of which 87% were northern Italian companies. ISO 14001, the most known and used voluntary eco-label certificate, witnessed an increase of 1000 units in 2002/2003, leading to a total of 2700 certificates, also mostly present in Northern Italy. Recently, even some districts got EMAS certification.

variables at firm level, each contribution may focus on a specific piece of the conceptual "model", depending on both data availability and research aims.

The paper focuses on research stream (i)[5]. Within this literature, a first worthwhile contribution is by Jaffe and Palmer (1997) who study environmental innovation by defining R&D and patents as dependant variables, at industry level, then analysing the two output and input innovation proxies separately. The study aims at empirically investigating the relationship between innovation and policy, rooting on the (ambiguous) set of "porter" hypothesis. The weaker hypothesis says only that regulations will stimulate certain kinds of innovation, but they may worsen firm outcomes. They find, in a panel framework (1976-1991), where two reduced form equations for R&D and patents are modeled, that higher lagged abatement costs lead to higher R&D expenditures. Overall, they conclude "data at the industry level are mixed with respect to the hypothesis that increased stringency of environmental regulations spurs increased innovative activity by firms". No statistically significant relationships between regulations and innovative output are found. It is worth noting that they include all R&D and patents, whether environmentally related or not.

One of the most recent contributions is that by Brunnermeier and Cohen (2003) who employ panel data on manufacturing industries to provide new evidence on the determinants of environmental innovation. They measure innovation by the number of patents (waste destruction and containment, recycling and reusing, acid rain prevention, waste disposal, alternative energy sources, air pollution, water pollution) and found, exploiting a simple reduced form, that it responded to increases in abatement expenditures, while monitoring and enforcement activities associated to regulations do not impact innovative strategies. Internationally competitive industries are also more likely to innovate. It is worth noting that although data are based on firm specific information deriving from surveys, only aggregated are available to the public. It is therefore not firm level evidence, but a panel on 146 US manufacturing industries.

In the European setting, evidence on environmental innovation is recently provided by Frondel et al. (2004), who exploit OECD survey data for Germany at firm level (manufacturing industry), in order to investigate whether environmental auditing schemes (voluntary management-oriented organizational innovation) and pollution abatement innovation are correlated. The driving forces of voluntary schemes and pollution abatement technologies are jointly assessed; covariates are grouped in three sets: motivations (corporate image, compliance, policy stringency, cost savings), policy tools (voluntary, subsidies, market, regulatory, EMS, information), pressure groups (unions, green organizations, authorities). Main conclusions are that the enhancement of corporate image is a potential force behind the adoption of EMS, while policy inputs do not seem to affect this organizational innovation. In addition, the influence of public authorities and the strictness of environmental policy seem to trigger abatement while EMS and other policy instruments do not.

Rennings et al (2003) also provide evidence on Germany, deeply focusing on auditing schemes like EMAS and correlated environmental organisational innovations. The main hypothesis they test is the influence of the "maturity" of EMAS (depending on age of EMAS, revalidation of EMAS and other elements) on environmental process, product and organisational innovation indexes. They find that EMAS has a positive effect on all three

[5] Regarding stream (ii), we refer to Cole et al. (2005), Greenstone (2004), Magat and Viscusi (1990), while Gray and Shabdegian (1995), Greenstone (2001), Cohen et al (1997), Konar and Cohen (2001), Brunnermeier and Levinson (2004) and Gray (1997) are key papers within (iii).

forms of environmental innovation at firm level, with a key role played by the R&D department. Firms achieving significant learning success with EMAS also show better economic performances.

Finally, Khanna and Anton (2002) provide US evidence on EMS adoption drivers using a merged dataset deriving from survey-based and official sources for 154 corporates. Explanatory variables include environmental and financial factors. Main findings are that EMS adoption appears to be driven more by a desire to cut regulation costs than as a reaction to improve compliance with existent regulations. Although significant, the effect linked to liability concerns is weaker with respect to market pressures created by consumers and other firms.

The added value of the present paper is to provide new evidence on the factors associated to environmental innovations, by exploiting a specific dataset rich in information on firm strategies and structure. The dataset is very detailed since it stems from two surveys on the same firms (2002 and 2004, eliciting data respectively on 1998-2001 and 2001-2004 trends). Thus, it only partially suffers from "cross sectional bias", insofar it is built on two consequential surveys: some of the correlations between innovation and its explanatory factors are not affected by eventual ambiguity regarding the causal direction of the link. We aim at providing additional new evidence with detailed firm data covering a full comprehensive set of explanatory factors for innovation. It is worth noting that evidence grounding on firm level data possessing richness in details and representativeness is rare relatively to industry-based data since survey based approaches are the only option for data collection (Khanna and Anton, 2002; Lee and Alm, 2004). This also emerges from the above literature review. Jaffe and Palmer point out the need of further applied micro-oriented research (1997, p.618): *given the inconsistency between our findings for R&D and for patents, the highly aggregate nature of the data in this study, and the shortcomings of using compliance expenditures as a measure of regulatory stringency, further research is necessary before these results can be considered conclusive. It is to these topics for future research we now turn. […] Perhaps the best way to overcome the aggregated nature of the data used in this study and to develop a better understanding of the nature of the relationship between regulation and innovation would be to conduct some focused industry study.*

Although specific to the industrial system here studied, our results may allow a generalisation concerning the northern Italian and European industrial situation with respect to the recent trends in environmental innovation. The analysis also opens some new research directions, widening the vector of potential driving forces of environmental innovation in complex and evolving industrial systems.

2. Innovation dynamics in an industrial system

2.1 Data and Context

We ground our applied analysis on a district-based manufacturing local system in Emilia Romagna, Northern Italy. Emilia Romagna is an area of Northern Italy characterised by a high density of industrial districts, it shows a very high level of per capita GDP (around 27.000€ in 2003); and with four millions residents represents the 7% of the Italian population. The industrial system of Reggio Emilia is a complex one, primarily characterised by a high degree of dynamism of the system, with important variations and exceptions to this general feature.

Firms preliminarily included in the universe are those belonging to the manufacturing sector (257 firms, see tab.1a) with at least 50 employees and located in the province of Reggio Emilia in year 2001. The first survey carried out in 2002 was made up of a questionnaire addressed to the Management. The firms responding to the survey were 199. The investigation focused mainly on high-performance practices, industrial relations and technological/organisational innovations (Antonioli et al., 2004).

The survey on environmental issues was carried out by administering a short focused questionnaire to the 199 firms who had joined the first survey. Telephone interviews were made in November 2004. We ended up with 140 out of 197 firms joining the second survey, showing no significant distortion by sector and by size, as shown by tab.1b.

The questionnaire elicited information on (i) process and product technological innovation introduced over 2001-2003, aimed at increasing environmental efficiency in (a) emission production, (b) waste production and management (c) material inputs, (d) energy sources. Then, we asked whether those innovations were (a) produced from within the firm (b) stemming from co-operative agreements with other firms, (c) stemming from co-operative agreements with research institutions, (d) acquired from other firms. Whether innovation was associated to patenting activity was also asked. Further, the adoption of environmental corporate management schemes was elicited. As far as environmental policy is concerned, a question was devoted to whether the firm was subject to policies on (i) emissions and (ii) waste/energy. We asked for how many years the policy had been implemented. Three more questions elicited the expenses on environmental R&D, capital investments and direct costs (current costs plus tax payments, etc..) over 2001-2003. Finally, we asked whether the firm had exploited governmental environmental grants/subsidies over the past 3 years.

A proof of the good degree of representativeness for the two surveys also comes from the following test (Cochran, 1977) which allows determining, given the universe and the final sample, in addition to a given level of probability, the maximum error we are experimenting.

The formula is:

$n = N/[(N-1)theta^2+1]$;

where n is the sample, N the universe, and theta the error we face (i.e.. 0,05, 0,04).

As far as the first is concerned, n=199 and the universe is 257; the sampling error is equal to 0,046. For the second survey, n=140, so taking N=199 gives barely 0,04, while taking the full universe 0,055. Values of 0,05 or not much distant from that threshold level are generally considered as good.

2.2 Input/output based Environmental Innovation: a preliminary descriptive analysis

Concerning the specific data on environmental issues, we note and comment the following descriptive elements. The 79% of firms reported to have adopted environmental related innovation (process/product innovations increasing environmental efficiency in various directions) over the period considered (2001-2003) at least in one of the environmental areas. Concerning the four specific environmental areas, the adoption of innovation is respectively of 49%, 42%, 28% and 46%[6]. Finally, firms adopting all four forms of innovations are less than 10% of the sample.

Innovation intended as the adoption of (voluntary) auditing schemes (EMAS, ISO[7]) concerns 26% of firms[8]. We can partially compare this outcome with that of Frondel et al. (2003) who find half firms of their sample adopting EMS[9]. Among those auditing-oriented firms, we note that various ISO management schemes are more common (20 firms having ISO9000 and 17 firms ISO14000) than EMAS (6 firms). EMAS is only present in firms of the ceramic sector, which has experienced the achievement of a district-based EMS certification. The lower number of firms involved in EMS is compatible with the more stringent rules and the European level of EMAS scheme. Only 3 firms have introduced both EMAS and ISO environmental certification schemes. Those schemes lie within the broad and still vague realm of "environmental organisational innovation" (Bradford et al., 2000).

The share of firms reporting an environmental-related patent activity is very low (2%). This figure was expected, given the low number of patents registered by Italian firms and the specific realm here analysed. Though the outcome is compatible with the historically low number of patents produced by Italian firms (with the exception of machineries sector), it is worth observing that there may exist an incentive, in district-oriented local system characterized by a majority of small and medium firms, to under-patenting innovation given uncertainties concerning the defence of intellectual property rights. Thus, differently from other studies on the determinants of innovation (Brunnermeier and Cohen, 2003), patenting does not appear to represent the best proxy for innovative capacity and adoption in the present case. The imperfect measuring of innovation by patents is commented by Gu and Tang (2004), who stress that some firms protect property rights by trade secrets and copyrights instead of patenting.

It is worth examining the sources of innovation. This is new information concerning environmental innovation. We asked whether adopted innovations were developed (i) entirely within the firm; (ii) by cooperating with other firms, (iii) by cooperating with research institutes, or whether they were (iv) acquired from other firms in the market. Summing up, innovation developed by firms themselves is highest for material input related innovation (62% of innovating firms) and lowest for emission reduction (34%). Cooperation in terms of networking with other firms is quite high and mirroring the previous case, with percentage ranging from 28% (material input) to 41% (emission reduction). The share of firms developing innovation by cooperating

[6] Frondel et al. (2004) consider a sample of 899 German manufacturing firms, finding that half of firms have undertaken significant technical measures to reduce their environmental impact. Among those, largely predominant (90%) is the occurrence of process rather than product innovations. Concerning process innovations, the shares of structural changes and end of pipe technology are respectively 56% and 42%.

[7] EMAS is the European management auditing schemes adopted by the EU in 1993. A formal policy and programme of site measures and a management system were included in this standard. The International Organization for Standardisation (ISO) then developed a series of environmental auditing/labelling standards over 1996-1998, known as ISO14000 series (ISO14001 is the most known).

[8] Regarding a US study, Florida et al (2001) estimate that 24% of manufacturing firms with more that 50 employees adopt EMS schemes.

[9] "A collection of internal efforts at formally articulating environmental goals, making choices that integrate the environment into production decisions, identifying opportunities for pollution reduction and implementing plans to make continuous improvements in production methods and environmental performances. They establish new organizational structures to gather information and track progress towards meeting environmental targets" (Khanna and Anton, 2002, p.541).

with research institutes/universities is very low (2-3% in the different cases). Finally, innovations introduced but developed by other firms (thus acquired) range from 8% (material inputs) to 16% (emission reduction). The very low level of research institutes involvement should suggest a reflection for future policy actions at regional level, since marginal added value may stem from increased firm-research institutes cooperation. We see that the role played by networking dynamics, which is crucial in industrial district areas, is relevant, as expected, also for environmental issues. It is worth noting the paper by Karl et al. (2005), who present a case study based analysis of forms of cooperation regarding innovation in general and environmental innovations, using data for Germany concerning 1999 and 1995. They show cooperation intensity indexes (percentage of firms involved at last in one exchange) for all industrial sectors: machinery and chemical are associated to the highest score. Our data confirms that chemical is the most cooperation intense sector for environmental issues (the only one with a significant correlation). Disaggregating by environmental objectives, results do not change: the chemical sector overwhelms the other two main sectors (machinery and ceramic) in terms of correlations with networking activities, with other firms and research institutes. The correlation is highest for energy-related objectives. They also show that the link between firm size and cooperation is positive, but weaker when focussing only on environmental objectives; looking at correlation indexes, our data show that the relationship is significant and positive for waste-related objectives and when considering a total networking index. Such correlations never overcome a 0,15 threshold; size and networking tend to be quite independent to each other as explanatory factors. Table 2c shows a moderate but not monotonous size effects.

As far as innovation inputs are concerned (environmental R&D and environmental capital investment), data shows that 61 firms report positive R&D related to environmental issues, and 72 positive capital investments. The mean values are, in percentage of annual turnover, 0,64% for R&D and 0,95% for investments. It is worth noting that a 15%-20% of firms did not report values for R&D, investment and costs. Considering then all 140 firms (inserting zero values for non responding firms[10]) the mean value is instead barely 0,6% and 0,8% of turnover (with maximum values of 10%) or 2000€ per employee. Those lower values may represent a cautious estimate, in absence of official datasets. As a rough term of comparison, the Italian industrial R&D value elicited by the *Third EU Community Innovation Survey* is about 3000€ considering only formalised R&D, and more than 8000€ including also expenditures on innovative man-made capitals, skilled labour training and know-how acquisitions (data for year 2000, per employee).

Concerning environmental direct costs and expenses (regulatory driven, current expenses, etc..) the reported mean value is 0,86% of turnover for reporting firms and 0,7% considering all firms as above. 16% is the maximum value observed.

To conclude the paragraph we descriptively examine the extent to which innovation is influenced by size and sector. Concerning output innovations, it does not emerge a clear size effect. Although smaller firms are associated to the lowest (mean) index for all environmental indexes, the percentage of firms involved in environmental innovations is only slightly, if not, increasing by size. The effect is dependant on the environmental realm. Concerning emission-related innovations, firms between 250 and 499 show the highest

[10] We argue that most firms not reporting values are likely to have very low or even zero values for environmental R&D, investments and expenditures. This hypothesis helps providing a precautious estimate of such figures.

percentage. Waste innovations are definitely immune from size effects. Energy related innovation instead present an inverted U shape by size: the “innovation peak” is for firms between 500 and 999 employees, the decreasing for the largest ones. When analysing firms that present all four forms of innovations, we note instead a monotonous size effects, from 2%, for smallest firms, to 30%, for largest firms. Looking at the index INNO-TOT (tab.2c), the peak is in association with firms between 500-999 employees.

Environmental auditing is finally presenting a moderate increase by size, though firms with more than 250 employees show a constant percentage index for all classes. Empirical evidence for Germany (Frondel et al., 2004) confirms that ISO typologies dominate EMAS (25% of firms in the German case study, mainly concentrated in the chemical industry), and the latter is more likely to be present above a certain facility size.

By sector, we first note that Textile, as expected (it is historically a low innovation sector), shows the lowest involvement in environmental issues within manufacturing. Concerning the most relevant sectors for numbers of firms, the investigation shows that emission related and material inputs innovations are more likely to characterise the chemical sectors (60% and 50% of firms), while waste management related innovations the ceramic sector (57%). Ceramics has also the highest score (60%) for energy efficiency innovations. All in all, chemical and ceramic sectors confirm to be highly involved in local environmental issues in the Region, and responding with higher innovative efforts.

Turning attention to R&D, investments and environmental costs, elicited as percentage of turnover, once again size effects are not dominating figures. R&D is not associated to any clear size effect. Table 2c shows that both in terms of investments and in terms of firm shares, size cannot be identified as a crucial factor. For capital investments, an inverted U shape arises, with largest firms showing the lowest value. Medium-large sized firms show the highest values. As far as costs are concerned, no size effect emerges, although the highest value is for the largest firms. By sector, we report the highest and lowest observed values: chemical and textile for R&D (1,3% and 0,0%), paper-publishing and textile for capital investments and also for environmental costs (respectively 2,6%/0,0% and 1,7%/0,0%).

To summarize dimensional and sector effects, tab. 2c presents the mean values of output innovations, R&S, Investments and environmental costs for each defined dimensional class and for main sectors. A general conclusion stemming from the descriptive analysis is that sector effects on innovation, as expected, prevail over size effects, on both input and output sides of the innovative process. Environmentally critical sectors like chemical, ceramic and also paper seem to be more involved in innovative dynamics. Medium and medium-large firms emerge overall as the more involved, but the picture is quite heterogeneous by type of innovation and index considered. Although size effects on innovation only weakly emerge from the case study, we should point out that a stringer structural break could have been observed if firms under 50 employees had been included. Firms under that threshold represent the 50% of the productive structure of the area. Size and sector effects will be further investigated in the multivariate analysis that follows, in order to find more robust evidence.

3. Empirical analysis

3.1 The set of hypothesis

The applied analysis provides new evidence on the driving forces of environmental innovation in industrialised settings by testing the following set of hypotheses[11]. Although the set of hypotheses is discussed with reference to environmental innovations in a general meaning, hypotheses [1, 2] concern explanatory factors for both output and input innovations. In other cases we underline the hypothesized link between input/output innovation and the set of covariates (hypotheses 3,4,6,7 may refer to R&D, while 4,5,7,8 to innovation outputs).

(1) *Firm structural variables.* Economies of scale may spur innovative strategies and reduce the cost burden: either/both largest firms may bear the fixed costs of investing in innovation. We test the hypothesis using the number of firm employees (including linear and squared terms). The set of covariates also include additional control variables which may act as explanatory factors of innovation[12]. Following the literature on firm innovation, we include the share of revenue in international markets (INT_REV), the share of final market production, complement to subcontracting production (FIN-MKT), the firm sector, using a set of dummies for Machineries (MACH), ceramics (CER) and chemicals (CHEM). Other less innovative and more importantly less environmentally strategic/critical (in terms of polluting outflows) sectors identify the base case. Those dummies also capture a first "district agglomeration effect", as associated to the machineries and ceramic local district agglomerates. Finally, a dummy capturing the membership to national or international industrial groups is also used as control, and may capture dimensional effects (GROUP).

(2) *Firm performances positively affect innovation.* Exploiting lagged data about investments per employee, value added per employee (index of productivity) and gross profit/turnover we check which performances element is eventually acting as a determinant for innovation (Cohen et al., 1997). The sign of the relationship is difficultly assessable ex ante. This is a very general statement which also concerns non environmental technological and organizational innovation (Antonioli et al., 2004). On the one hand, environmental performance, and the associated regulatory pressure, is costly, on the other hand a firm that is efficient in controlling pollution is likely to be efficient also at production. Moreover, a firm that does well financially can afford to spend more on cleaner technologies. We use as performance indicators the average level (in logs) of two "performance periods", 1995-2000 and 1998-2000, in order to test diverse lagged effects (dropping year 2001). Acronyms are PROF, PROD, INV_N, indicating the time span of reference (i.e. $PROF_{95\text{-}00}$). Given the observed high correlation between productivity and both profits and investments, the PROD index is introduced *alternatively* to other indexes.

(3) Policy actions affect output innovation. The role of policies in stimulating innovation is a long debated issue at both theoretical and empirical level (Grubb and Ulph, 2002). Given official policy-related data do not exist at micro-firm level, survey data is consequently the only available option. Given the limited experience with market based instruments which are not widespread in the Italian environment, we cannot verify the different

[11] We specify in brackets acronyms used when presenting regression results in the econometric section.

[12] Schmultzer (2001) notes that the policy stimulus is not sufficient in many cases, and highlights the potential stronger role of drivers associated to firm structural variables, and (we add) external structural factors such as networking. Regulatory intensity and typology, technological factors, market dynamics and firm structure are all potential determinant of environmental innovations. The point is crucial for environmental policy actions.

effectiveness of market and non market instruments in stimulating innovation (Requate and Unhold, 2003; Kemp, 1997). We exploit two different proxies for policy impact. First, having elicited whether emission and waste policies are being imposed to firms (policy "stringency" proxy), and for how many years firms have been subject to policies, we may analyse the eventual impact of policy-related indicators. We here use dummy variables for policy-regulatory pressures for emissions and waste (POL-EM, POL-WA) and the (log) number of years since the policy was introduced (POL-YRS), to test an eventual lagged/dynamic response of firms to environmental regulations introduced in a given year in the past.

Though model based analysis of policy effects is complicated given the intrinsic systemic framework and lagged effects which are hardly predictable ex ante[13], one would expect a positive sign on the proxy of policy stringency/presence, while no clear hypothesis is associable to the number of years: on the one hand firms experiencing policies for a longer time may show higher innovative effort as result of a long-run dynamic effect, on the other hand a shorter policy experience may also present innovative effort since (i) some firms react promptly to new policy targets to comply with them and (ii) newer firms, intrinsically experiencing policies by less years, could present higher innovative efforts with respect to new areas like environmental issues.

Secondly, another candidate variable for representing policy action is the amount of induced cost for policy implementation. Expenses seem to be a proxy for "costs", and most authors use environmental expenditures as a proxy for "policy stringency" (Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997). However, expenses and costs show different perspectives: expenses are closer to private and public investments, thus representing a close and instrumental consequence of policy action. Instead, costs are referring to all figures of direct, indirect and shadow costs (opportunity costs) associated to policy implementation and compliance with the policy, by both private agents and eventually by society as large (if social market and non-market costs are also accounted for). Therefore, costs can also be accounted for as a part for the "achievements" of the policy (although with a possible negative sign) that parallel other achievements on the environmental side. Expenses may also be used with some caution in cost-effectiveness analysis of regulation/policy, provided the different units show the same level of performance indicator. Otherwise, the assessment is just possible on the basis of an examination of the effort specifically devoted to the environmental program under scrutiny. No efficiency consideration is instead plausible. What costs to include may represent a final controversial point, which is to be investigated case by case. Financial costs, current and capital expenses, indirect costs, external costs, opportunity costs are all possible candidates to enter ex post evaluations. We elicited information on direct environmental costs linked to current expenses and all financial burdens deriving from policies, excluding expenses for safety and security obligations, in order to take into account the aforementioned cost-related effect (ENV_COST).

(4) *Public grants for investing in more environmentally efficient technologies influence innovation dynamics*. We also test whether firms that exploited environmental grants (GRANT) for innovation related investments from governmental bodies were more likely to adopt innovation. Subsidies may be justified given the two market failures, environmental externalities and the public good nature of new knowledge (Popp, 2004). As a result, government subsidies and grants for less polluting technologies oriented R&D are often proposed as part of the

[13] See Jaffe et al. (1995), Hemmelskamp (1997), Hemmelskamp and Leone (1998), Mazzanti and Zoboli (2005), Requate (2005) for various conceptual insights and evidence of the policy effects on innovation.

policy package. It is worth noting that most firms in our dataset do not exploit grants. This may derive from high administrative costs, informative costs, or from high opportunity costs to R&D. In a district based environment, nevertheless, networking activities involving joint efforts toward R&D and innovation may totally or partially substitute for top down governmental policy through subsidies.

(5) *Eco-Auditing schemes (AUDIT) are positively associated to environmental output innovation*[14]. We include auditing schemes for testing whether voluntary approaches (like EMAS, ISO14000) of environmental management improve, acting as driver, the likelihood of introducing environmental related innovation (acronyms are EMAS, ISO). Unlike ISO schemes, EMAS requires external communication via an environmental report. On the link between environmental innovation and auditing schemes we note the recent applied oriented contributions by Horbach (2003) and Frondel et al. (2004), who empirically verify the hypothesis of correlation between environmental process/product innovation and "environmental organisational innovation". Rennings et al. (2003) also analyse the interrelationship between various environmental related innovations, deeply focusing on EMS and associated green organisational corporate strategies innovative from an organisational point of view. Those papers provide preliminary evidence on the links between auditing, as part of a wider environmental organisational innovatory strategy, and environmental technological innovations. From a pure theoretical standpoint, Dosi and Moretto (2001) suggest that eco-labeling, which should enable firms to reap the consumer surplus linked to environmental attributes by identifying "green" products, may induce also perverse effects, such as increased investments in conventional technologies (more polluting with respect to new technologies) before the label is awarded. The effect stems from the existence of a complementarity relationship between polluting and green production lines, added to the award of labels for a subset of production lines, and not concerning all production activities.

(6) *Industrial relations play a role in favouring input/output innovations*. The local production system under investigation is historically highly unionised. Industrial relations quality, in terms of co-operative relationships between management and unions and management and employees, matters for organisational and technological innovation (Antonioli et al, 2004; Mazzanti et al., 2005). To our knowledge the link between industrial relations and environmental innovation strategies has very rarely been tested[15]. We use a vector of synthetic index capturing the quality of industrial relations and unions/employee involvement in management strategies in order to test this link for environmental innovation[16]. The sign of the relationship cannot be defined ex ante. The mere presence of trade unions is not leading to higher innovative capacity. Different schools of thought tend to see in the presence of unions at the firm level a danger for the efficiency of production processes, or an element of

[14] Since auditing and R&D are conceived as inputs for output innovations, we investigate the extent to which auditing is a driver for output innovation in a multivariate setting. The association between auditing and R&D is drawn out from simple correlation analyses. Further empirical analyses may also study the complementarity relationships between various inputs (Mohnen and Roller, 2005; Milgrom and Roberts, 1990).

[15] Frondel et al. (2003) provide some evidence on the effect of unions as a "pressure group", finding ambiguous evidence.

[16] Our indicators of industrial relations, ranging between 0 and 1 to represent intensity and quality of management/trade unions/employee relationships concerning firm strategies, are: (i) an index capturing management initiatives vs. employees in work organizations (MAN-vs-EMP), (ii) a dummy capturing workers/unions participation at decisional firm levels (PART) (iii) a synthetic index of employee involvement in decisions concerning organizational innovation management (INVOL) (iv) a synthetic index of industrial relations intensity concerning high performance practices (IND-REL). The latter is a comprehensive index enclosing various aspects of the interactions between social parties; it takes into consideration the organisation of mangers/workers joint work groups, employee participation in formal structures with decisional power.

stimulus, pressure, and active interaction with the management. At the empirical level, contrasting results have been reached about the role of unions (Addison and Belfield, 2001) and their generalisation would not be granted[17]. The quality of industrial relations, concerning the interactions between management and both union delegates and employees, may be positively associated with techno-organisational innovations of any kind. At the same time, they also implement information flows, consultation and negotiation procedures with worker representatives on work organizations, process and product innovations. Within the economic literature this "industrial relations driver" model opposes to the "management driver" model, and roots on procedures of consultation and handing over of decisional functions, from management to employees. This involvement is activated through the implementation of working groups with operative tasks, and joint commissions by managers, employees and union representatives, which aim at decentralising decisional processes. This approach may be particularly effective when the aim is to reshape a fordist-taylorist structure.

(7) *Significant correlation between organisational/technological innovation and environmental innovation*. Exploiting trends for high-performance practices/organisational innovation and process/product innovation in 1998-2001, we test whether environmental innovations are, following possible complementarities relationships[18], positively associated with other innovations. The most recent literature emphasises that the mere introduction of new technologies, without organisational innovation and new human resource management practices, does not seem to support better performances. Bundles of high-performance practices are needed (Arnal et al, 2001, OECD, 1998). The link between techno-organisational innovation and environmental innovation has never been tested to our knowledge[19]. We use diverse proxies: (i) regarding output innovation regressions, a total index of organisational innovation practices (INNO_ORG), a dummy for Total quality management (TQM), a synthetic index of technological innovation (INNO_TEC) and a dummy for process innovation (INNO_PROC); (ii) Training and/or skilled workforce measures are often hypothesized as complementary to R&D innovative input investments, for increasing firm performances. An index of formal training employee coverage (COV) is tested as driver, since training is often considered a high-performance practice linked to organisational innovations (Huselid and Becker, 1996); (iii) finally, another proxy of organisational innovation is the flatness of the organisational structure: it has been argued that flatter organizations perform better in terms of innovative dynamics, compared to more "centralized" firms (Aoki and Dore, 1994; Womak et al., 1990). Flatter firms should also move easier towards innovation flexibility dynamics rather than defensive strategies (labour cost

[17] Valenduc (2001) deals with trade unions as agents of environmental awareness. He stresses, proving anecdotal examples, that the sensitivity to environmental issues is very variable from a branch union to another. Even if there is a long-standing interest of trade unions in taking into account health, safety and environmental issues, it is not always possible to affirm that this is a highest priority. Environmental issues may be either a supplementary tool in order to improve other main areas of bargaining and negotiations (environment is a new dimension), or a specific goal, a new strategic priority, with trade unions acting as stakeholder in environmental policy at regional and local level.

[18] Complementarity may be opposed to the "substitution hypothesis" which derives from a usual neoclassic reasoning. In fact, if the firm is optimizing resource allocation in production before environmental regulations, any additional abatement cost or innovation cost deriving from policy enforcement lead, at least in the short run, to an equal reduction in productivity, since labour and capital inputs are re-allocated from "usual" production output to "environmental output" (pollution reduction). Substitution dominates under this view.

[19] Florida et al. (2001) analyse the relationship between organizational resources/organizational innovativeness and EMS schemes, exploiting firm-level data, finding a positive correlation. Organizational factors may thus play a role in the adoption of green designs. In our case, EMS strategies are not correlated neither to any of organizational innovative practices nor to process/product innovations. When including all certification activities (ISO and EMS), correlations ate moderately significant with TQM and process/product innovations.

reduction, labour saving technological process). Within the specific realm of environmental innovation such hypothesis, which involves a complex reasoning over human resources, innovation and organisational strategies, is never been tested. We capture the element by an index of hierarchical levels on establishment business "functions" (hierarchy ratio): the lower the index, the flatter the firm (HYER), which might be associated both to R&D and output indicators.

(8) *Networking activities are (positively) associated to environmental innovation (through environmental R&D).* R&D generally recognised as an important innovation measure and an input for innovation output dynamics (technology invention and adoption) and firm productivity in a second stage. This extends to *Environmental R&D*.

The importance of networking relationships, in terms of voluntary agreements and spillovers is high in district industrial areas. Networking activities may partially substitute for size economies of scale in environment characterised by small and medium firms. We elicited data on the source of environmental innovation to test an important hypothesis which recently emerged from the "social capital (SC) literature" (Cainelli et al., 2005; Mancinelli and Mazzanti, 2004; Glaeser et al., 2002): the positive relationship between R&D and social capital in an impure public good framework (Cornes and Sandler, 1997), where social capital arises as an intangible assets, defined as firm investments in co-operative/networking agreements.

The necessary joint effort to establish voluntary co-operative schemes, by which achieving goals specific to the network but appropriable by participants, characterises most forms of (i) voluntary agreements, (ii) inter-firms infra district cooperation, (iii) inter-firms inter-districts cooperation. The relevance of points (i)-(iii) as engines for innovation and growth at a regional level has increased over the last decades. Market and non-market 'horizontal' networks play a major role with respect to 'vertical' and hierarchical relationships (Cappello and Faggian, 2005). Finally, social capital/networking externalities might turn over standard Marshallian externalities in explaining growth and innovation processes[20]. Network relations and high-performance oriented organizational strategies are indeed linked, since they may represent external and internal ways of innovating the organizational firm structure[21].

Empirically speaking, we use "networking" dummies (presence of cooperation with other firms and cooperation with research institutes in developing innovations for the four identified innovation areas, from emissions to energy: acronyms are NET-suffix) as explanatory variable of R&D in the innovation input regression. We also construct a total networking index ranging from 0 to 1, synthesizing the four dummies (NET-TOT): this represents the networking innovation oriented involvement of firms with other firms and research institutes across environmental realms. To our knowledge the link between environmental-oriented networking strategies (Aggeri, 1999) and R&D has never been tested for environmental innovation. The networking effect on innovation is included in R&D using a two-stage estimation procedure, where the hypothesis is networking → R&D → innovation[22].

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[20] In this sense, SC as a stock captures the idea that collective external economies of scale are realised by cooperation over input activities, such as research, technological development, organisational innovation, and training and advertising, wherein fixed costs are pooled among agents who join.

[21] See Hansen et al. (2001).

[22] It is worth noting that potential endogeneity may affect the networking-related variables. According to some contributions on industrial districts (Brusco et al., 1996; Cainelli and Zoboli, 2004), this kind of formal and informal

3.1 Methodological issues and innovation modeling

There is no shared theoretical model for studying innovation determinants both at industry and firm level. It is difficult to specify a theoretically satisfying structural or reduced form equation for both input and output innovation (Jaffe and Palmer, 1997; Brunnermeier and Cohen, 2002), as, for instance, a "production function" approach. In addition, the set of potential explanatory variables is large, ranging from firm structural characteristics and firm performances, to exogenous factors, like policies, to organisational and technological dynamics, belonging both to the specific environmental arena and to other strategic business areas which nevertheless may exert indirect influence on environmental innovations. One aim of the paper is the attempt to extend the usual core of driving forces which is often restricted to environmental-related factors and some control elements. At a conceptual level, we here extend the usual linear innovative process, which mainly link innovation to R&D as input, towards a richer and more extended "innovation production function"[23]. We claim that when studying innovation output and input proxies from an applied perspective, a feasible and plausible way is to define reduced forms which attempt to explain innovation by exploiting a theoretically consistent set of covariates. This is a usual practice within the technological and organisational innovation oriented literature, which broadly exploits the frame of a "knowledge production function". External and internal factors should both be extensively tested as possible drivers of environmental innovation; this has been enlarging the applied research perspective during recent years (Florida et al. 2001) [24].

The analysis is forced to rely on quite rough reduced forms, specifying the proper econometric model for each continuous/discrete variable under analysis. The "pillars" giving robustness to the study are sample representativeness, the quality and quantity of firm level data, and the way we cope with endogeneity, omitted variable issues and other potential flaws affecting the analysis.

A preliminary analysis must be carried out for studying the full correlation matrix, concerning all potential covariates, dropping high-correlated potential regressors. This first selection is aimed at reducing collinearity problems, selecting a limited set of covariates for testing each specific hypothesis. The outcome is a matrix of *selected* potential explanatory variables (correlation values for selected regressors are shown in tab.3[25]). Besides few variables indexes, which will be consequentially cautiously introduced, the final correlation matrix shows low figures concerning main independent variables. Concerning regression analysis, a "from general to particular" backward stepwise method is applied, which may result more consistent with the different biases arising when variables relevant variables are omitted or irrelevant ones are included: in the former case coefficient are biased, in the second case variances are inflated by using too much information and estimates are less efficient. Thus, the second problem, over fitting specifications starting from a conceptual model, is less severe and can be resolved by eventually deleting non-significant variables (i.e. t ratios less than 1,282 step by step). Further, it is worth

networking relationships may be interpreted as a quasi-fixed factor of 'production' (Brynolfsson et al., 2002), slow evolving over time, thus exogenous with respect to R&D decisions at least in the short term.

[23] For recent relevant contributions using such innovation function approach which goes back to Griliches (1979) see among the others Cassiman and Veugelers (2002) and Mohnen and Roller (2005).

[24] Hansen et al. (2001) present an analysis of case studies regarding environmental innovations in small and medium sized enterprises, for five European countries. The study reveals a great variety in factors driving the process: character of environmental innovation, regulatory setting, firm strategic orientation, network relations, sectoral influence. Innovative capability emerges as the result of the interplay between different driving forces.

[25] Among all covariates presented in tab. 3, high correlations pertain to clusters of conceptually similar covariates, which are then introduced one at a time in regressions.

noting that the omitted variables issue is one of the main causes of endogeneity (correlation between explanatory variables and errors), often due to data unavailability (Woolridge, 2002, p.50-51).

Econometric analysis focuses on (a) estimation of the determinants for specific environmental innovation (emission-related, waste-related, and energy related); (b) estimation for a synthetic index of innovations (c) estimation of regression for R&D investments relating to environmental innovation.

(a) Innovation output for specific innovations

In order to perform this exercise, we estimate a sort of 'knowledge production function' (Griliches, 1979). The knowledge production function expresses the relationship between innovation output and innovation inputs within the 'conceptual' framework of a production function. The reduced form is as it follows:

(1) $INN_{i,t} = \beta_0 + \beta_{1,t}(\text{structural firm features}) + \beta_{2,t/t-1}(\text{environmental policy proxies}) + \beta_{3,t}(\text{environmental R\&D}) + \beta_{4,t}(\text{environmental grants}) + \beta_{5,t}(\text{techno-organisational innovation}) + \beta_{6,t-1}(\text{industrial relations}) + \beta_{7,t-1}(\text{performances}) + e_i$

where INN_i represents the environmental innovation output of firm i, and e_i the error term with usual properties. β_0 is the constant term, β_{1-8} the set of coefficients associated to explanatory variables, where (t) stays for 2003-2001 and (t-1) for 2001-1998. Econometrically speaking, this *knowledge production function* is estimated by means of a Logit/probit specification[26].

From the econometric point of view, the estimation poses at least two problems. First, heteroskedasticity, as it is often found when cross sectional data are used, may reduce the efficiency of econometric estimates. Thus, all estimates are carried out adopting a 'robust' estimator which addresses such source of distortion. Secondly, there is a potential endogeneity when investigating the determinants of innovation. Panel dataset may be a better framework to cope with it. Nevertheless, the nature of techno-organisational innovation, intangible assets, networking and policy-related data, all potential drivers of innovations, often prevent the setting up of proper panel dataset given most factors are definable quasi-fixed or slow evolving (Huselid, 1996; Brynolffson et al., 2002). A way to deal with the problem is by introducing a vector of 'lagged' term into the regression (thus specifying an hybrid cross sectional model) for all relevant covariates (for an example see Khanna and Anton, 2002). Exploiting the two survey waves, most of our drivers are temporally preceding innovations (2001-2003). For R&D, we use both the elicited 2001-2003 value and the predicted values stemming from a first stage R&D regression, in order to cope with endogeneity between R&D and innovation. Though the direction of causality is not ambiguous in this case (from R&D to innovation)[27], the use of a two stage procedure may help making estimates more robust.

(b) *Synthetic index of Innovation output*

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[26] Since we may expect different predictions from the two models when the mix of 1s and 0s is skewed, the choice over which model to use is less relevant with our data. To test this hypothesis, alternatively to the normal distribution, we also specify a logit specification: logit outcomes (not shown) are not different from probit in terms of both coefficients sign and significance and regression measures of fit.

[27] When data are purely cross sectional and two-way causal relationships between variables are a critical issues, applied analyses may only aim at highlighting "correlations" rather than causal processes (Michie and Sheehan, 2005).

When estimating the total innovation index, ranging between 0 and 1, we face a limited but continuous variable. We deal with *fractional variables* (Papke and Woolridge, 1996), continuous but limited. It is possible to affirm that there is not an "optimal" econometric model for studying fractional variables. Although OLS estimates in this case may suffer from the same distortions characterising the use of linear models for binary variables, the often used one limit or two-limits Tobit models (Rosett and Nelson, 1975; Tobin, 1958) are not a panacea, and often it is possible to verify that estimates deriving from OLS, OLS based on (log) transformations (when this is possible given the observed "0s") and Tobits do not differ significantly as far as coefficient signs and "relative" statistical significances are concerned (Pindyck and Rubinfeld, 1991), although coefficient "levels" are different across models. Since the aim is not (here) the estimation of elasticity, this may be considered a less severe flaw. Thus, OLS corrected for heteroskedasticity is used as econometric tool for estimation.

Other statistical models could be exploited for testing the validity of results and specifications. We here do not deal with patent-like data (Brunnermeier and Cohen, 2003), which obviously require a (Poisson-based) model for count data. We argue that a (synthetic) index on different innovation adoptions ranging from 0 to 1 is a preferable alternative to count-like specifications of the dependant variable *when* we observe a number of innovation typologies over a range (necessarily) defined by the researcher (we are not counting an intrinsic discrete real phenomenon, like patents or specific innovations per se). In addition, as said above, using innovation intensity indexes, the aim is not estimating elasticities but finding a ranging over explanatory factors. Thus, the variable "number" of innovation typologies does not properly and necessarily fit within a count model (conceptually, we are not effectively facing a discrete count variables) and even less with ordered probit frames (Khanna and Anton, 2002)[28]. Nevertheless, a final test using count models (specifying as dependant variable the number of typologies of innovations adopted) is carried out, in order to compare outcomes (Woolridge, 2002, ch.19). The methodological issue is in any case open to and worth of further investigations.

(c) *R&D Innovation input*

We estimate a simple reduced form equation for R&D investments per employee (Jaffe and Palmer, 1997):

(2) Log(R&D/per employee)= $\beta_{1,t}$*(structural firm features*[29]*)* + $\beta_{2,t-1}$*(techno-organisational innovation)* + $\beta_{3,t-1}$*(industrial relations)* + $\beta_{4,t-1}$*(firm networking)* + $\beta_{5,t-1}$*(performances)* + e_i

The log value is often used as dependant variable. Nevertheless, environmental R&D is not positive for many firms, which report a zero corner value. This is plausible with other evidence (Horbach, 2003). Thus, R&D equations are first estimated by means of OLS corrected for heteroskedasticity: OLS is nevertheless generally inconsistent when facing "corner solution models", both using the entire sample and a subset of it. Those models arise when y takes on the value zero with positive probability but it is a roughly continuous random variable over positive values. As discussed in length by Woolridge (2002, ch.16-17), those models are often wrongly labeled censored regressions, though the issue is not data observability as in censoring and truncation. Corners solutions models refer to a hypothetical economic model where the zero value is the "optimal", and

[28] The point is critical in methodological terms and quite unresolved. In our opinion, ordered models are appropriate when we face ratings, voting and other ordinal observed phenomenon. Count models fit data which effectively represent a discrete counting of a variable going from 0 to infinite. Concerning innovation adoptions, the number of innovations is defined by the researcher: setting up an index is one of the ways to capture a sort of "innovation intensity", leading to fractional variable frameworks.

[29] Size, market features (national market share, subcontracting share), sector, district membership, etc...

observed, corner solution for most agents. As a consequence, more appropriate Tobit (Type I Tobit model, following Amemya's definition) and two stage heckit/two-tiered models are used and compared. Finally and alternatively, a probit model specifying as "1" firms with positive R&D is also tested.

3.3 Econometric results

We present and comment results for the set of hypothesis formulated above. Different regressions are investigated (tab.4a-b). We examine various environmental-related output innovation equations (5), environmental R&D equations[30].

For output innovations, given that data innovations, R&D, environmental costs and auditing schemes are all elicited as trends over 2001-2003), potential endogeneity should be tested, though, as we remarked above: (i) emphasis is on trends; this is plausible given the slow-evolving nature of such variables; (ii) the causality nexus is clear in this case, if compared to innovation-performances links, which are intrinsically subject to the reverse causality conceptual problem. In fact, R&D and costs are conceptually inputs, auditing schemes may be correlated to but hardly "explained" by innovations. Nevertheless, endogeneity is properly tested by implementing a Wu-Hausman test (Woolridge, 2002, p.118-20), which is a regression-based form of the Hausman test: fitted residuals or predictions estimated from a first stage regression using *all* instruments for the potential endogenous variable (x) are used as covariate in a regression of y on x and all the previous used instrument, including a constant (remember that all exogenous variables are used as instruments for themselves). The usual t test statistic on the targeted variable is a valid test of endogeneity. In other words, if the "object" variable is not significant we may assume its exogenity and IV estimation is not needed. In our case, a significant coefficient emerges only for environmental costs in some of the regressions, and never for R&D and auditing. The outcome confirms ex ante expectations, since costs were, relatively speaking, the most likely factor to present endogeneity problems. We then introduce in those cases the associated fitted values as a further two-stage estimation attempt in this case (Millock and Nauges, 2005)[31]. We note that standard errors deriving from two-stage procedures have a tendency to be rather large, larger than OLS. This depends on the quality of instruments used. Thus, often we should manage a trade off between possibly inconsistent OLS coefficients with relatively small standard errors and a consistent but imprecise estimator. The problem is harsher in relatively small datasets; since the Wu-Hausman tests preliminary carried out highlight potential endogeneity for costs only, this issue is only partially touching our frame of analysis. Further, R&D and costs are introduced both separately and jointly as explanatory variables, to check whether their positive correlation may lead to distortions in estimates.

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[30] Acronyms for the various dependant variables are: INNO-EM (adoption of process/product environmental innovation related to emissions), INNO-WA (adoption of process/product environmental innovation related to waste), INNO-EN (adoption of process/product environmental innovation related to energy inputs), and INNO (adoption of any environmental innovation). Those are dummies. We do not exploit firms that adopted all four innovations since the number (12) is too limited. Then, we have INNO-TOT (synthetic index of the adoption of the four environmental innovation), and environmental R&D (R&D).

[31] See Woolridge (2002, pp.90-93) for a comprehensive discussion on "two-stage least squares". He notes that the first stage regression producing the fitted values must contain all instruments for x and all exogenous variables then included in the second stage regression. Otherwise, inconsistent estimators of relevant coefficients may arise. A further note: given our innovation proxies are in some cases binary variables, we refer to Woolridge (2002, p.474-5) for the 2SLS procedure in probit analysis, which is still one of the ways to cope with potential endogeneity on a continuous explanatory variable.

3.3.1 Input innovations

We begin commenting the outcomes for the *input innovation* equations, for R&D and environmental investments, following a logical consequential reasoning starting from input and then moving to innovation outputs.

Concerning both input proxies, two analyses are attempted: one using the log-value per employee as dependant variable in a “corner solution/censoring model” and the other, given the high number of “zero”, using a probit model where positive values are associated to one. In the first case (continuous R&D variable), Tobit and two-stage procedures are used as estimation tools.

Probit analysis on environmental R&D shows the following outcome. Ceramic and chemical sectoral effects are the only structural features associated to the firm which result to significantly drive R&D. Size-related effect do not emerge. In addition, the share of final market production tends to positively explain the amount of resources devoted to R&D. Other firm related factors affect R&D, all with a positive sign: the quality of industrial relations within the firm (proxied by the index IND-REL, which derive from information on the trade unions involvement in internal labour markets, organisational practices, and participative / consultation processes), the number of hierarchical levels (which represent a proxy of “organisational flatness”, read in the opposite way), and to a lesser extent organisational innovation (number of innovative organisational practices). The positive sign attached to the number of hierarchical levels poses a problem: in fact innovative dynamics are often more likely to be positively correlated to flat organisational structures[32] (see below for opposite results on innovation output indexes)[33].

It is worth noting that the covariate capturing the firm involvement in operative and networking activities specifically devoted to environmental innovation (NET-TOT) exerts a positive effect on R&D, though significant only at 10% level (quite close to the 5% threshold). The index concerning the total networking effect across all environmental innovation realms actually hides possible different links: in fact only networking for emission-related innovation arises highly significant if indexes are separately introduced. All in all, networking effects turn over size effects, highlighting a theoretically defined complementarity between R&D and networking investments as “inputs” of innovative outputs.

Among policy drivers, the dummy concerning emission policies is the only significant driver, and reduces the t value attached to networking when included. Auditing schemes and grants do not affect the probability of R&D being positive. Training activities, which are often claimed to be associated to R&D for high-performance and more innovative firms, never show to be significant, as well as organizational practices.

When specifying R&D/employees as dependant variable, we note that the OLS estimates perform poorly in terms of overall regression fit and coefficient robustness. The censored nature of the variable may be the underlying reason. We thus adopt a Tobit model which is more consistent with a R&D censored distribution having a significant bulk of zero observations.

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[32] See Aoki and Dore (1994) and Womak et al. (1990). Most authors stress the innovative properties of flat organisations. Nevertheless, though this is a shared and plausible hypothesis, other elements should be taken into account. The role of flatness as driving force for innovation may vary by sector.

[33] The analysis of correlations confirms the opposite signs: while is (weakly) negatively correlated to all innovation proxies, the ratio index of hierarchical levels/firm functions is more significantly and positively related to R&D and investments.

Tobit results (not reported) slightly less robust than probit, are: the networking effect increases its significance level, although within a 10% statistical threshold. Among sector and size dummies, only the chemical industry seems to positively influence R&D. R&D is also positively correlated to past productivity. We also attempted to use only firms with positive R&D values (61 units out of 140). The outcome is not statistically satisfactorily; the reason could be that discarding limit observations leads to a truncated regression setting, "which is no more amenable to least squares than the censored data models" (Greene, 2000, p.908).

As a final analysis, we use a two stage procedure (hurdle model), finding no evidence of a two-tier process (last column tab.4b). The model fit is nevertheless good. Networking, organisational factors (flatness), industrial relations elements and productivity performances affect R&D as shown in tab.4b. A positive role of training (COV) also emerges, though the coefficient significance depends on the inclusion of other positively correlated "high-performance" practices and industrial relation proxies, thus is not robust. Auditing schemes do not matter. As far as networking is concerned, when dummies for specific environmental realms are included, it emerges that energy-related cooperation is the only and most significant, maybe driving the total networking effect. Summing up for networking, this preliminary evidence highlights the role of cooperation with other firms and research institutes, with specific evidence on emission and energy contexts. The regression including energy-related networking dummy is associated to higher fit measures.

3.3.2 Output Innovations

As far as *output Innovation* proxies are concerned, we observe the following outcomes deriving from binary probit analysis[34]. As a preliminary analysis, we focus on the INNO (adoption of *any* environmental innovation) index. Results (not shown) are not highly satisfactory in terms of fit, probably depending on the rough measure of environmental innovation (innovate/not innovate): analyses using more specific indexes is needed.

When disaggregating by "environmental issues", outcomes are the followings (tab.4a).

First, environmental innovation concerning emission-reduction shows to be positively influenced by the presence of voluntary auditing schemes[35]. Concerning policy-related explanatory factors, we note that the (reported) presence of emission-related policy is positively related to innovation; nevertheless, quite interestingly, the probability of adopting emission innovations is inversely proportional to the number of years the firm has been subject to the policy. This number of years, reported by firms themselves, may depend on historical, productive and institutional reasons. The outcome is somewhat counterintuitive and will be confirmed below: following this evidence it seems that policy effects are stronger in the first phase of policy implementation,

[34] As measures of goodness of fit, we report the value of the log-likelihood test comparing the maximised value of the log-L function and the log-L computed with only a constant term. Furthermore, an analogue of the R^2 in conventional regressions is McFadden likelihood index, which has an intuitive appeal since it is bounded by 0 and 1 (Greene, 2000, pp.831-833). The index increases as the fit improves, though values between 0 and 1 have no natural interpretation. Other fit measures have been suggested by various authors (Greene, 2000, p.832). Among the others, we Estrella (1998), who propose a measure that takes into account the share of correct predictions (higher or lower than 0,5) on the basis of observed 0 and 1 values. Greene (2000) nevertheless points out that all in all it is important to place limited emphasis on diverse measures of goodness of fit when dealing with discrete dependant variable models.

[35] Those schemes may be sometimes policy driven. Some firms may adopt EMAS and other schemes to comply with existing sector or district guidelines; we are aware of firms adopting EMAS to avoid even the shutting down of the establishment. EMAS may be legally binding in some situations. Voluntary schemes may be also ways to circumvent more stringent and direct policy actions.

fading away with time. A possible reason may be that firms reporting lower years of policy experience are newer firms: thus environmental innovation is stronger in newer firms. The positive effect of R&D arises only when specifying a dummy variable as explanatory factor (R&D/employees instead is not significant, as well as environmental costs[36] and investments). Size and sectoral controls do not influence adoption. The index of "participative innovation oriented" industrial relations is a positive driver. Finally, firm performances do not matter.

Secondly, waste-management related innovation is primarily affected by policy proxies, as reported by firms. As above, we note in fact that while the "policy dummy" is positively significant, the probability of adopting waste management innovations is inversely related to the years of policy implementation. Although the number of firms exploiting grants is low, the factor is here significant. Then, policy effects may also pass through the positive influence of environmental costs, which are moderately significant. Nevertheless, we note that though the Wu test highlighted potential endogeneity, even for waste the fitted values are not significant. Waste innovation also shows to be positively influenced by the presence of voluntary auditing schemes and by a flatter organisational structure. While size is still not significant, with Group membership turning over size effects, some sectoral influence emerges (Ceramic).

Third, turning to innovation in the realm of energy efficiency, we observe that R&D is significant among the endogenous firm drivers when included as dummy variable. In this case, investments are more significant in explaining energy innovations: this is plausible given the high technological fixed costs and the low relevancy of end of pipe solutions in these environmental realms. In addition, size effects are here more influential, although they do not emerge as strongly statistically significant. Industrial relations dynamics confirm their already noted positive effects. Finally, sectors do influence innovation: this may appear not surprising given the differences in energy intensity across manufacturing sub-sectors. Ceramic is the most significant driving sector.

Finally, but not least important, we examine the 0-1 continuous index capturing all four realms of innovation (INNO-TOT[37]). OLS corrected estimates show (tab.4a, last columns) that (i) R&D and costs are significant while investments are not (regression 4[38]); (ii) Policy drivers, like grants, in addition to policy driven environmental costs (which we may intend as a proxy of indirect effect of policy) are also significant[39]. Auditing schemes are significant (with EMAS dominating over ISO14000). Sectors and size do not influence the adoption of innovation measured in terms of "intensity". Scale economies emerge through the effect of "group membership". Finally, confirming an already mentioned evidence for specific realms, innovative activity is more intense in flatter organizations and in firms where the quality of industrial relations is good in terms of workers and unions participation to decisional processes on high-performance and organisational strategies. Performances confirm not to influence environmental innovation[40].

[36] Predicted values of costs are included following the endogeneity test, but they do not arise significant.
[37] The specific binary regression for material innovation is highly not robust and is not presented.
[38] This regression is eventually affected by the positive correlation between such drivers (around 0,35). R&D and costs are still significant when investments are omitted and the overall fit also improves (5,6).
[39] Even omitting GRANT, regressions keep overall and coefficient significances.
[40] Count data models (see also par. 3.1) do not provide a striking different evidence. Signs do not change while statistical significance is slightly changing with respect to OLS: flatness decreases its impact, the chemical sector increases its role. R&D and costs are significant both when separately included; and when included together. Though there is no natural counterpart to R^2, goodness of fit may be measured by various fit measures, some bounded between and 1 and reported in

3.3.3 Main outcomes

We sum up the main outcomes. As far as firm structural features are concerned, size effects are significant only when considering innovative inputs. Market features also do not matter. By sector, effects on innovation are not strong but more evident: the chemical and ceramic sector emerges as moderately important drivers in some cases.

Other firm characteristics instead influence the adoption of innovation more evidently: organisational flatness is generally emerging a driver of innovative output, and the variables concerning industrial relations, mainly the synthetic index IND-REL, exerts overall a positive influence on adoption. Though the correlation between size and this industrial relations index is not extremely high, the positive value may suggest that some size effects are better captured, in our estimates, by industrial relations dynamics occurring in medium-large firms. Nevertheless, more specific variables of employee involvement do not result significant. More research is needed on the role of trade unions and employee participation concerning environmental innovation dynamics[41].

Concerning Policy divers, direct and indirectly conceived, we find significant effects across regressions. Policy-related proxies are relevant for emission and waste policies, with a somewhat counterintuitive negative effect in relation to the "number of policy years" effect. Given that the historical experience with environmental policy is in Italy relatively recent, further evidence is needed. Environmental costs (current expenses and policy related expenses) instead arise as a core driver for most innovative output specifications. Environmental grants are exploited by a very limited number of firms, thus their positive statistical effect is to be cautiously interpreted.

Turning back to R&D, we observe that it arises as a primary driver for most innovation output realms.

Overall, technological and organisational innovations and high performance practices, including training, seem not to be correlated to environmental innovation[42]. The hypothesis that firms adopting high performance practices and techno-organisational innovations also present higher innovation concerning environmental issues is here not validated. Nevertheless, the relative flatness of the firm seems to influence both more innovative environmental strategies and non environmental techno-organisational ones (see evidence using same data in Antonioli et al., 2004). Thus, though a direct link is not emerging, environmental and non environmental innovation realms may be driven by the same innovative-oriented structural dynamics (flatness, participatory schemes, and good industrial relations) characterizing the firm.

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tables. A critical issue is the assumption that the variance of y equals the mean in the Poisson model. In effect, the test on dispersion would suggest the use of a negative binomial model, which nevertheless may present convergence estimation problems when facing numerically limited samples. In our case, the number of iterations in the negbin model sharply changes with the inclusion/omission of some variables. Using the same covariates of the Poisson model above, some coefficients lose significance. Our data also present a 28% of zero observations and an upper bound at four innovations. Thus, censoring (4) and especially truncation (0 cases) specifications may be tested even in the count data framework. As expected, fit measures and overall significance favours the truncated model, which presents better fit measures compared to the standard count specification. The vector of significant covariates nevertheless shrinks to industrial relations, auditing schemes (jointly taken), and chemical sector. R&D does not emerge significant, while costs do when predicted values are introduced. Regressions estimates are not shown.

[41] See Menezes-Filho and van Reenen (2003) for an overview of empirical works concerning trade unions role in triggering innovation dynamics.

[42] Instead, training and techno/organisational innovations are positively correlated. This reinforces the present evidence: environmental innovation seems, accordingly to our data, disentangled from other innovation and high-performance practices, at least if we observe their direct relationship.

Within the realm of “organisational innovations”, a clear positive association is shown to exist between all output innovations and voluntary auditing schemes. When considering the total innovation index (INNOTOT), EMAS certification emerges as primary factor. This is consistent with the “incremental” nature of EMAS with respect to ISO14000 (though we note that EMAS-certified firms are currently not many).

Finally, we stress again that it is difficult to assess a clear ex ante theoretical hypothesis concerning the effect of firm performance on innovation. Evidence here suggests that performances (profits, productivity) do not constitute a driver for environmental innovation, if not in rare cases concerning productivity (but never significant).

4. Concluding remarks

The paper provides new empirical evidence on the determinants of environmental-linked innovation at a microeconomic level. We exploit a recent and rich survey based datasets covering market and non market firm features. The focus is on local production system grounding on industrial districts, which is a quite unexplored case in the literature on environmental innovation. The paper adds new insights on the complex analysis concerning the driving forces of environmental performance at firm level, since it explicitly considers the relevancy of networking dynamics, techno-organizational innovations, environmental R&D and industrial relations, as long as the more usual policy-related and structural variables, among the potential driving forces of innovation in district-oriented industrial systems. The investigation has shown that environmental innovation drivers, at both input and output levels, are to be found within (i) exogenous factors, (ii) endogenous dynamics concerning the firm and its activities/strategies within and outside its boundaries, and (iii) both environmental and non environmental structural elements of the firm.

Empirical evidence has shown that policy drivers exert some effects on innovation, although results differ by innovation typologies. Voluntary eco-auditing schemes also appear to play a strong role in favoring innovation output dynamics, even more than input factors as R&D.

Firm size is never significant, while sectoral/district influence is somewhat positive, but impact is weaker with respect to other drivers. More than size, group membership and networking arise as positive innovative drivers, respectively for innovation output and R&D: this means that “horizontal economies of scale” and cooperative agreements/strategies might matter more than internal economies of scale, which are instead more relevant for non environmental techno-organizational innovation dynamics. Those latter are in fact not here correlated to environmental innovations and R&D, validating this statement. This evidence is new and it is possibly representing an added value for understanding innovation environmental dynamics and for orienting policy actions in local systems. Given the high percentage of small-medium sized firms (with less than 100 employees), this may represent good news for environmental performance of the local system: standard economies of scale are not a priority for the environment, although trade offs may emerge with other realms, since size appears relevant for techno-organizational innovation and high-performance practices like training. Another view would instead focus on the role of J-firm characteristic like a less hierarchical structure and a participatory environment in favoring the adoption of both environmental and non environmental innovations. This is the evidence arising from the industrial environment here analyzed. Trade offs could be mitigated under this perspective.

It is then highly important to investigate, for any innovation typology, what the drivers are in terms of "internal" structural firm features and external networking relationships. Our investigation suggests that networking relationships aimed at building up a social capital, instrumental to creating and introducing innovations, and "membership" to a district or a group, are factors as much as important, if not more, than firm structural characteristics. It is worth noting that a three-factor link might emerge: networking "investments" and research-oriented relationships are possibly influencing (and theoretically being complementary to) R&D/environmental investments. Then, and consequently, R&D is one of the inputs driving the adoption of innovative output. Further applied research is suggested on this key new topic to provide some generalization.

Summing up, the "innovative driver box" may consist of the following main factors: (i) firm involvement in groups and networking activities, (ii) "innovative oriented" industrial relations and a less hierarchical organization. These driving factors contribute to drive environmental innovations, together with environmental (policy related) costs, R&D and, not less important, voluntary environmental schemes. External-oriented firm behavior, environmental specific R&D, the reshaping of organization structures and management-employees relationships along more flexible and innovative scenarios, and policy-related elements all may induce innovations impacting firm strategies and firm behavior. Although specific to districts and to the industrial system here studied, our results may represent a first attempt to assess a comprehensive framework of innovation drivers in the environmental arena. The analysis also opens some new research directions, widening the vector of potential driving forces of environmental innovation when dealing with complex and evolving industrial systems.

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Tab.1a: Total firm population

Sector	no. of employees						
	50-99	100-249	250-499	500-999	> 999	Total (%)	*Total (Absolute value)*
Food	0,78%	1,95%	1,17%	0,78%	0,78%	5,45	14
Other Industries	0,78%	0,00%	0,00%	0,00%	0,00%	0,78	2
Paper-Publishing	1,56%	0,00%	1,17%	0,00%	0,00%	2,72	7
Chemical	3,11%	2,72%	0,78%	0,00%	0,39%	7,00	18
Wood	0,00%	0,78%	0,00%	0,00%	0,00%	0,78	2
Machineries	28,02%	15,95%	5,06%	2,72%	3,50%	55,25	142
Non-Metal Minerals (Ceramic)	9,73%	6,61%	1,95%	2,72%	0,78%	21,79	56
Textile	1,56%	1,56%	2,72%	0,00%	0,39%	6,23	16
Total (%)	45,53	29,57	12,84	6,23	5,84	100,00	
Total (absolute value)	117	76	33	16	15		257

Tab.1b: Interviewed firms (2004 survey)

Sector	no. of employees						
	50-99	100-249	250-499	500-999	> 999	Total (%)	*Total (Absolute value)*
Food	0,00%	0,00%	1,43%	1,43%	0,71%	3,57	5
Other Industries	0,71%	0,00%	0,00%	0,00%	0,00%	0,71	1
Paper-Publishing	2,14%	0,00%	2,14%	0,00%	0,00%	4,29	6
Chemical	3,57%	2,86%	0,00%	0,00%	0,71%	7,14	10
Wood	0,00%	0,00%	0,00%	0,00%	0,00%	0,00	0
Machineries	27,14%	17,14%	4,29%	2,86%	5,00%	56,43	79
Non-Metal Minerals (Ceramic)	10,00%	8,57%	2,86%	1,43%	0,71%	23,57	33
Textile	2,14%	1,43%	0,71%	0,00%	0,00%	4,29	6
Total (%)	45,71	30,00	11,43	5,71	7,14	100,00	
Total (absolute value)	64	42	16	8	10		140

Tab. 2a- Environmental innovation, R&D and environmental costs

Indicators						R&D	Inv-env	Env-Costs	Environmental Patents	Auditing voluntary certification Schemes
Acronyms in regressions	Inno	Inno-em	Inno-wa	Inno-en	Inno-tot					
range	Dichotomous 0/1	Dichotomous 0/1	Dichotomous 0/1	Dichotomous 0/1	between 0-1	% turnover, all firms*	% turnover, all firms*	% turnover, all firms*	Dichotomous 0/1	Dichotomous 0/1
Mean value	0,79	0,49	0,42	0,46	0,41	0,55%	0,78%	0,67%	0,02	0,26

*including all firms, with positive and zero values.

Tab. 2b- Core Variables and time period of reference

Variables	Time period
Environmental innovations, R&D, environmental costs and investments	2001-2003
Techno-organisational innovations, industrial relations, other organisational practices and production dynamics	1998-2001
Firm performances	1995-2000

Tab. 2c- Dimensional and sectoral effects: descriptive summary (mean values)

	Innovation (at least one form)	emissions	waste	energy	material	Four innovations Composite index (0-1)	R&D*	R&D>0	Investments*	Investments>0	Costs*	Networking index (0-1)
<100 employees	71,88%	39,06%	34,38%	37,50%	25,00%	0,340	0,71%	37,50%	0,70%	42,19%	0,47%	0,152
100-249	80,95%	47,62%	50,00%	42,86%	21,43%	0,405	0,32%	45,24%	0,75%	61,90%	0,90%	0,208
250-499	**93,75%**	**75,00%**	50,00%	68,75%	31,25%	**0,563**	0,42%	**56,25%**	0,85%	**68,75%**	0,42%	0,172
500-999	87,50%	62,50%	37,50%	**87,50%**	**50,00%**	**0,594**	**0,73%**	37,50%	**2,15%**	62,50%	0,19%	**0,281**
> 999	80,00%	60,00%	50,00%	50,00%	**50,00%**	0,525	0,56%	60,00%	0,23%	30,00%	**1,81%**	0,225
Chemical	80,00%	**60,00%**	50,00%	50,00%	50,00%	**0,525**	**1,30%**	60,00%	**1,36%**	40,00%	0,58%	**0,350**
Machinery	79,75%	49,37%	35,44%	44,30%	29,11%	0,396	0,48%	40,51%	0,44%	49,37%	0,47%	0,184
Ceramic	81,82%	42,42%	**57,58%**	**60,61%**	21,21%	0,455	0,64%	60,61%	1,29%	66,67%	**1,20%**	0,182

* % firm turnover, all firms included; the first five columns report the share of firms adopting such innovations.

Tab. 3- Correlation matrix- independent variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	NETW-TOT	1,00																								
2	AUDIT	0,21	1,00																							
3	POL-WAS	0,16	0,00	1,00																						
4	POL-EM	0,20	-0,01	0,56	1,00																					
5	R&D	0,03	-0,06	0,03	0,17	1,00																				
6	ENV-INV	0,05	0,09	0,11	0,15	0,36	1,00																			
7	ENV-COST	0,02	0,01	0,09	0,08	0,35	0,37	1,00																		
8	GRANT	0,20	-0,06	0,02	0,15	-0,02	0,16	0,07	1,00																	
9	SIZE	0,06	0,26	-0,04	-0,05	-0,07	-0,01	-0,03	-0,09	1,00																
10	CHEM	0,19	0,03	0,02	0,06	0,08	0,08	0,02	0,19	-0,02	1,00															
11	MACHIN	0,02	0,01	-0,11	-0,07	-0,04	-0,16	-0,22	0,01	-0,04	-0,30	1,00														
12	CERAM	0,00	0,02	0,07	0,03	0,04	0,08	0,21	-0,13	0,00	-0,15	-0,61	1,00													
13	INT-REV	0,02	0,01	-0,07	-0,01	0,00	0,04	0,03	0,22	-0,06	0,17	-0,25	-0,04	1,00												
14	FIN-MKT	-0,01	0,02	0,02	-0,04	0,07	0,09	0,09	-0,21	-0,06	-0,01	-0,08	0,18	-0,29	1,00											
15	GROUP	0,05	0,14	0,05	0,10	0,00	-0,13	0,08	-0,08	0,43	-0,06	0,02	-0,04	-0,02	-0,04	1,00										
16	LIVGER	-0,04	-0,06	0,13	0,09	0,17	0,14	0,14	0,14	-0,11	-0,06	0,06	0,04	0,11	-0,16	-0,12	1,00									
17	%DIP-FORM	0,06	0,20	0,20	0,11	-0,02	-0,18	0,06	-0,01	0,10	0,07	0,00	-0,16	0,07	0,00	0,24	-0,14	1,00								
18	INNO-ORG	-0,06	0,02	0,04	0,08	-0,01	0,01	-0,04	0,11	0,03	-0,04	0,13	-0,17	-0,07	0,08	0,11	-0,20	0,23	1,00							
19	INNO-TEC	0,01	0,16	0,04	-0,04	-0,05	-0,09	0,11	-0,03	0,05	-0,04	-0,05	-0,04	-0,11	0,03	0,11	-0,11	0,11	-0,01	1,00						
20	MAN-vs-EMP	0,04	0,05	-0,14	-0,16	0,11	0,05	0,16	0,00	0,10	0,10	0,04	-0,14	0,15	0,09	0,21	-0,06	0,31	0,23	0,05	1,00					
21	PART	0,01	-0,02	-0,14	-0,01	0,05	0,10	0,00	0,15	0,07	0,01	0,10	-0,12	0,08	-0,15	0,05	0,03	-0,05	0,08	-0,02	0,20	1,00				
22	IND-REL	0,05	0,22	0,07	0,12	-0,08	-0,11	-0,12	-0,09	0,27	-0,19	0,00	0,11	0,01	-0,02	0,23	-0,16	0,01	0,03	0,07	-0,04	0,19	1,00			
23	PROF_95-00	-0,06	0,13	0,09	0,12	0,06	0,18	0,00	0,09	-0,12	0,04	0,20	-0,09	-0,07	0,14	-0,11	-0,03	0,21	0,25	0,05	0,05	0,03	-0,02	1,00		
24	PROD-95-00	-0,13	0,20	0,06	0,08	0,20	0,33	0,12	0,03	0,10	-0,02	0,04	-0,06	-0,03	0,23	0,05	-0,08	0,21	0,22	-0,02	0,16	0,02	0,03	0,65	1,00	
25	INV_N-95-00	-0,04	0,25	0,15	0,17	0,15	0,29	0,08	-0,04	0,37	0,02	-0,30	0,18	0,01	0,12	0,23	-0,12	0,15	0,06	-0,02	0,02	0,03	0,32	0,16	0,54	1,00

The table presents the complete set of potential covariates.

Tab. 4a- Econometric regressions (output innovation)

Dependant variable	INNO-EM	INNO-WA	INNO-EN	INNO-TOT	INNO-TOT	INNO-TOT
Regression	1	2	3	4	5	6
Covariates/Methodology	Probit corrected for heteroskedasticity	Probit corrected for heteroskedasticity	Probit corrected for heteroskedasticity	OLS corrected for heteroskedasticity	OLS corrected for heteroskedasticity	OLS corrected for heteroskedasticity
Constant	-0,945	-1,392	-2,676***	0,941	0,135	0,083
Log-Size	-0,229	-0,754	1,514	0,416	0,196	0,272
CHEM	0,456	0,605	1,846*	1,668*	1,778*	1,579
MACH	-0,149	0,256	1,645*	0,619	0,720	0,547
CERAM	-1,678*	1,822*	2,234**	1,186	1,223	1,318
GROUP		1,971**		1,515	1,758*	1,982**
HYER		-2,078**	-1,125	-1,892*	-1,831*	-1,786*
IND_REL	2,397**		2,546**	2,477**	2,492**	2,293**
POL-WA/EM	2,090**	2,857***				
POL- WA/EM (YRS)	-2,243**	-2,304**				
Grant		1,916*		3,707***	3,194***	3,670***
ENV-INV			(dummy) 2,115**	-0,975		
ENV-COST		1,752*		2,794***	2,397**	
ENV-COST (pred values)	Not significant when included	Not significant when included			Not highly significant when included	
R&D				2,131**		2,535**
R&D dummy	2,081**		Significant at * when included			
AUDIT	2,185**	2,768***		3,076***	2,951***	3,038***
EMAS				EMAS significant at *** when included separately		
ISO_{14000}						
$PROD_{9800}$		1,302				
McFadden pseudo R^2	0,158	0,216	0,154			
Estrella fit	0,213	0,282	0,206			
Adj R^2				0,192	0,200	0,194
Log-L	-81,56	-81,75	-81,75			
Chi-squared LR test (prob chisq>value)	0,0006	0,00004	0,0002			
F test (prob)				3,21 (0,0002)	4,17 (0,0000)	4,05 (0,0000)
Correct prediction: actual 1s and 0s correctly predicted	70%	75%	67%			
N	140	140	140	140	140	140

Notes on regressions

1. fitted values of environmental costs not significant when included
2. fitted values of environmental costs not significant when included; when direct policy proxies are omitted, ENV-COST is significant at **
3. R&D dummy significant at *, regression not shown.
4. EMAS drives the significant of AUDIT
5. fitted values of environmental costs not highly significant when included

Tab.4 presents t ratios (only covariates emerging as significant in final form specifications are shown).
We emphasise coefficients which arise significant at 10%, 5% and 1% (*, **, ***).

Tab. 4b- Econometric regressions (Input Innovation)

Dependant variable	R&D	Ln(R&D)	Ln(R&D)
Methodology	Probit	Two-stage procedure	Two-stage procedure
Constant	-4,22***	-2,42**	-2,694**
Log-Size	1,10	-1,37	-1,259
CHEM	2,24**	-0,53	-1,10
MACH	0,99	-1,39	-2,146**
CERAM	2,10**	-0,19	-0,471
FIN-MKT	2,68***		
HYER	2,78***	1,74*	2,188**
IND-REL	2,03**		
MAN-EMP		1,24	
INNO-ORG	1,64		
COV		0,77	2,325**
NET-TOT	1,83*	1,87*	3,972*** (NET-EN)
PROD9800		3,016***	3,418***
GRANT		-2,03**	-1,514
Inverted MIlls Ratio		1,06	0,985
McFadden pseudo R^2	0,157		
Estrella fit	0,209		
Adj R^2		0,192	0,32
Log-L	-80,74	-93,66	-89,34
Chi-squared LR test (prob chisq>value)	30,26 (0,0003)	38,74 (0,0001)	47,37 (0,0000)
F test		2,30 (0,02)	3,91 (0,0006)
Correct prediction: actual 1s and 0s correctly predicted	66%		
N	140	61	61

Tab.4 presents t ratios. We emphasise coefficients which arise significant at 10%, 5% and 1% (*, **, ***).