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The Relationship Between Environmental Efficiency and Manufacturing Firm's Growth

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Abstract

This paper investigates the empirical link between emission intensity and economic growth, using a very large data set of 61,219 Italian manufacturing firms over the period 2000-2004. As a measure of lagged environmental performance (efficiency) at firm level we exploit NAMEA sector for CO2, NOx, SOx data over 1990-1999. The paper tests the extent to which (past) environmental efficiency/intensity, which is driven by structural features and firm strategic actions, including responses to policies, influences firms growth. Our results show, first, a typical trade off generally appearing for the three core environmental emissions we analyse: lower environmentally efficiency in the recent past allows higher degrees of freedom to firms and relax the constraints for growth, at least in this short/medium term scenario. Nevertheless, the size of the estimated coefficients is not large. Trade off are significant for two emission indicators out of two, but quite negligible in terms of impacts, besides the case of CO2. For example, growth is reduced by far less than 0.1% in association to a 1% increase of environmental efficiency. Environmental efficiency does not seem a primary cost factor and constraint to growth if compared to other factors affecting firm targets and firm competitiveness. In addition, non-linearity seems to characterise the economic growth-environmental performance relationship. Signals of inverted U shape appears: this may be a signal that both firm strategies and recent policy efforts are affecting the dynamic relationship between environmental efficiency and economic productivity, turning it from an usual trade off to a possible joint complementary/co-dynamics, where bad environmental performances hamper firm growth and investments in greener technologies may be associated to positive economic performances of firms and sectors.

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Summary

This paper investigates the empirical link between emission intensity and economic growth, using a very large data set of 61,219 Italian manufacturing firms over the period 2000-2004. As a measure of lagged environmental performance (efficiency) at firm level we exploit NAMEA sector for CO2, NOx, SOx data over 1990-1999. The paper tests the extent to which (past) environmental efficiency/intensity, which is driven by structural features and firm strategic actions, including responses to policies, influences firms growth. Our results show, first, a typical trade off generally appearing for the three core environmental emissions we analyse: lower environmentally efficiency in the recent past allows higher degrees of freedom to firms and relax the constraints for growth, at least in this short/medium term scenario. Nevertheless, the size of the estimated coefficients is not large. Trade off are significant for two emission indicators out of two, but quite negligible in terms of impacts, besides the case of CO2. For example, growth is reduced by far less than 0.1% in association to a 1% increase of environmental efficiency. Environmental efficiency does not seem a primary cost factor and constraint to growth if compared to other factors affecting firm targets and firm competitiveness. In addition, non-linearity seems to characterise the economic growth-environmental performance relationship. Signals of inverted U shape appears: this may be a signal that both firm strategies and recent policy efforts are affecting the dynamic relationship between environmental efficiency and economic productivity, turning it from an usual trade off to a possible joint complementary/co-dynamics, where bad environmental performances hamper firm growth and investments in greener technologies may be associated to positive economic performances of firms and sectors.

Keywords: Firm growth, Manufacturing, Emission intensity, Economic performance, Environmental performance

JEL: C23, D21, O32, Q55

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1. Introduction

Over the last few years, the relationship between environmental performance (emission intensity, environmental efficiency, eco-strategies, etc.) and economic performance has received increased attention, also thanks to its role within the 'Lisbon Objectives' on growth and innovation and the 'Gothenburg priorities' on sustainable development.

Within this debate, manufacturing has received much attention, given its relatively high impacts on the environment, and higher innovation potential. The research directions of higher added value are currently three: (i) the effects of environmental performances and innovations on economic performances, given the relatively wider space the drivers of environmental innovations have occupied (Mazzanti and Zoboli, 2008a,b); (ii) an increasing attention to the dynamics of relationships in the short run and medium/long run; (iii), extending at micro and meso levels the analyses from manufacturing to other industries, as recently proposed by Cainelli *et al.* (2007) and Mazzanti and Zoboli (2009).

This paper aims at providing a contribution on points (i) and (ii) above. It focuses on manufacturing industry; nevertheless, it uses a very large data set, compared to predominant survey-based analyses relying on often small scale samples. It does not suffer from cross-sectional biases, often plaguing *ad hoc* survey data which rarely escape the 'cross section trap', if not by repeated surveys over time, since it models a dynamic relationship between *emission intensity*[1] and firm-level economic growth, in others words environmental and economic performances at the firm level.

More specifically, this paper investigates the empirical link between firms economic growth and emission intensity, using a very large data set of more than 60,000 Italian manufacturing firms. Economic data refer to the period 2000-2004. In order to circumvent the unavailability of data on environmental performance indicators at this level of microeconomic detail, we use as a measure of environmental efficiency by exploiting sector based NAMEA data, from which we recover firm based data. The Italian NAMEA provides detailed data at two digit level on main emissions, value added and employees over 1990-2003. Taking data for the periods 1990-1999 and 1992-1995 in order to impose a lag structure to the modelled relationship, we reconstruct emission per employees ratios at firm level by using sector coefficients of emissions per unit of labour and panel data on employment of firms, as a pragmatic and only available proxy of environmental efficiency from official data at firm level.

Using this approach, the paper specifically tests the extent to which (past) environmental efficiency/intensity, which is driven by structural features and firm strategic actions, including eventual responses to policies, influences firms economic growth in a short-medium term scenario if we consider the lag we are able to structure between environmental and economic performances.

[1] 'Emission intensity', namely emissions per unit of labour, is the proxy for 'environmental efficiency' we here exploit. Further analyses may be carried out by using alternatively 'emissions per unit of value added'. This is actually the inverse of 'environmental efficiency' as a ratio, but we follow this standard form, widely used in NAMEA analyses (Femia and Panfili, 2005).

The paper is organised as follows. Section 2 presents a short summary of the literature that aims at synthesising the state of the art of various research directions focusing on environmental innovation, environmental performances and economic performances at firm level. Section 3 is first addressed to the definition of the conceptual framework on which research hypotheses are based, and then consequently discusses data sources, the empirical model and the econometric methodology. Section 4 presents and comments on empirical outcomes. Section 5 concludes and suggests lines of future research.

2. Related literature

A first main stream of research deals with the drivers of eco-innovation strategies. The seminal work by Jaffe and Palmer (1997), which studies environmental innovation (R&D and patents) at industry level, was followed by Brunnermeier and Cohen (2003), which employs panel data on manufacturing industries to provide new evidence on the determinants of environmental innovation, measured by number of patents. The European setting has recently been the source of some interesting evidence: Rennings *et al.*, (2003) exploit OECD survey data in order to investigate whether environmental auditing schemes and pollution abatement innovation are correlated, similarly to the more recent work by Arimura et al. (2008) on Japan. Mazzanti and Zoboli (2005, 2008a, b) present evidence for the manufacturing sector at a district level, focussing on an extended set of drivers (environmental R&D, policy induced costs, EMS, industrial relations, other innovations). Frondel *et al.*, (2004) use an OECD survey dataset on manufacturing firms and study internal firm-based strategies, external policy variables, and test drivers for end-of-pipe measures or integrated cleaner production processes. For a recent comprehensive analysis of all works on innovation drivers we refer to Johnstone (2007).

A second stream of research is focussed on environmental innovation and (its) employment effects. The main contributions in this stream include Rennings and Zwick (2001), Rennings *et al.* (2001), Pfeiffer and Rennings (1999). What is relevant to our study is the main hypothesis that increasing environmental efficiency by environmental innovations strengthens competitiveness and the firm performance, with or without policy stimulus. An ancillary hypothesis is that eco-efficiency investments require higher amounts of labour. The reasoning is that, on the one hand, product innovation spurs employment since it creates new demand, while, on the other hand, process innovations decrease employment since they are usually labour saving. Some employment compensation may occur as a result of indirect price/market driven effects. It should be noted that this is a two stage process in which first the firm decides whether or not to invest in innovation, and second optimizes the volume of labour following the innovation process.

Rennings and Zwick (2001) is based on a sample of eco-innovative firms for five EU countries, in the manufacturing and service sectors. This is a rather unique study which provides evidence related to manufacturing but also includes some evidence concerning eco-innovations in the service sector. They find that in most firms employment does not change as a consequence of innovation, but this may be due to the limited period covered by the survey. Econometric results show that, apart from some effects registered for product innovations, eco-innovation typologies do not influence the level of employment, though as expected (Caroli and van Reenen, 2001), according to their evidence environmentally oriented innovations seem to lead to a skills bias effect. Also, end of pipe innovations are related to a higher probability of job losses, while innovations in recycling have a positive effect on employment.

Employment effects may be thus be unevenly distributed, with strong negative effects from environmental strategies/policies on low skills intensive industries and potentially positive effects on other industries. It could also be argued that product and process eco-innovation strategies may bring about (potentially negative) net effects on employment, attributable to a destruction of the low skilled labour force (administrative staff) and a creation of high skilled positions (R&D).

Third, there is a complementary stream of literature that has focused on the various static and dynamic relationships between eco-innovation, environmental performances and firm performances[2]. Konar and Cohen (2001) investigated the effect on firm market performance of tangible and intangible assets, including two environmental performance-related elements as explanatory factors. Cohen *et al.* (1997) also analysed the relationship between environmental and financial performances. Overall, these authors found that investing in a 'green' portfolio did not incur a penalty and even produced positive returns.

Less recent works by Gray and Shadbegian (1995) used total factor productivity and growth rates for plants over 1979-1990 as performance indicators to test the impact of environmental regulation and pollution abatement expenditures. They found that $1 more expenditure on abatement is associated with more than 1$ worth of productivity losses. They found that, when analysing variation over time or growth rates, the relationship between abatement costs and productivity is not significant. Greenstone (2001) estimates the effects of environmental regulations, using data for 1,75 million observations of plants in the 1967-87 US censuses of manufacturers. Environmental regulations negatively affect growth in employment, output and capital shipments.

Finally, we would point to recent EU based studies, that focus on the (short term) effects of environmental strategies on the stock performances of corporations, using standard cross section/panel approaches (Ziegler *et al.*, 2008) and 'event' studies that analyse whether there are exogenous unexpected policy effects on the short term performance of environmentally minded firms. The latter are criticized for their intrinsic very short term focus. Although valuable, and based on official datasets,

[2] A fourth correlated stream of research focuses on the 'drivers of firm environmental performance' including, among others, Foulon *et al.* (2002), Cole at al (2005), Collins and Harris (2003). This is minor in scale given the paucity of data and the difficulty of eliciting such data on real environmental outcomes (non monetary quantification of externalities) even by surveys

we believe that the value of evidence focusing on stock market performance is limited since the majority of firms, especially in Italy, are of medium or small sized, and do not appear in stock market data. Innovation dynamics are close to productivity trends which, in the end, are the main engines of firm performance.

Our paper is embedded in the third research directions, focusing on the effects of environmental (emission) intensity on firms economic performance here measured by firms turnover growth. The possible contribution of our work stems from: the focus on a dynamic perspective, the use of real firm performance indicators, the lagged structure of the data set and the very large number of firms. The main 'limit' is the exploitation of sector data instead of micro data for proxing environmental emissions, depending on the general unavailability of real environmental performances measures at the microeconomic level, for large sample of firms in Italy. This is confirmed by the recent paper by Arimura et al. (2008) who study the ISO/EMS (voluntary agreements) effects on environmental performances on the basis of an OECD survey on environmental performance of firms. It is striking that the dependent variable 'environmental performances' is constructed by means of self reported data using an ordered format (no change, decrease or increase in emissions). Though the authors carry out some test and external validity checking for assuring data credibility, the answers seem to be affected by the typical bias that may arise when likert scale are offered, with in addition the fact that the issue is highly critical from a firm's perspective. Thus, though the first best would to use real environmental performance data at the firm level (challenge for future research in the future), and the exploitation of self reported survey data is a plausible second best, the (panel) nature of NAMEA data disaggregated at two digit level offer a robust framework that hybridize firm and sector data to analyse economic-environment relationship[3].

3. Conceptual framework, data and methodology

3.1 The theoretical framework

This section briefly sketches the main elements of the conceptual framework on which the set of hypothesis tested in the empirical part is rooted, trying to discuss what factors may support 'joint' economic-environmental performances at firm level (Mazzanti and Zoboli, 2009).

A first set of factors revolve around the 'Porter's hypothesis' (Jaffe *et al.*, 1995). Environmental regulation may influence innovation and market (rent) creation. In the long run, regulation costs, or environmental R&D expenditures, are more than compensated for by the benefits of innovation in terms of higher efficiency and/or higher value added. This conclusion seems to run counter to the conventional wisdom that environmental regulation (like any other regulation, of course) or

[3] A rare set of studies that use real environmental performances to study the co-evolutionary effects between firm performances (turnover and profits) and emission intensity of firms are by Earnhart and Lizal (2006, 2007, 2008), who exploit a 1996-98 panel for Czech firms. The panel is nevertheless limited to around 400 firms.

spontaneous investments in green firm performances impose significant direct and indirect costs on firms and industries, with the primary effect of impacting negatively on economic performance, and especially (labour and total factor) productivity.

Following the mainstream reasoning, if the firm is optimising resource in production, before the implementation of (new) environmental regulation, any additional abatement cost or innovation cost deriving from policy enforcement will lead, at least in the short run, to an equivalent reduction in productivity/performance, since labour and capital inputs are re-allocated from 'usual' or scheduled production output to 'environmental output' (pollution reduction).

This emphasis on substitution may stem from the roles in neo-classic reasoning of the assumption of optimal allocation of resources in the *status quo* and of input prices (and green taxes) as innovation levers. In fact, resource prices have been the main driver of change only in specific conditions of strong relative price changes coupled with structural economic transformations. More generally it is technology that affects prices by changing factor combinations and capital intensity. In other approaches, the development of new production processes is viewed as an ongoing process within firms and sectors less reliant on input prices, except in particular circumstances (Kemp, 1997; Krozer and Nentjes, 2006).

Economies of scale and scope are another argument leading to depart from conventional view.. Complementarity and economies of scale and scope, among other factors, might lead to states where the productivity effect of environmental investments or compliance becomes positive (plausibly in the medium long run) [4].

A more general question is whether it is possible to separate eco-innovation from other typologies of innovation. In practice it is often not easy to separate the two (Rennings, 2000). With or without policy aimed at innovations, cost-saving motivations and demand-related product market objectives could work as innovation drivers. All could be complementary in the ultimate aim of enhancing firm productivity, and no sharply defined difference between them may be possible, in that (i) eco-innovations may generate low or high eco-impacts depending on their nature and their integration with other innovations; (ii) standard innovations may also provide eco-innovations. Much of the current empirical research is aimed at disentangling intended and unintended (e.g. mere cost savings in the more general meaning) eco-effects stemming from innovations: in these approaches, only those innovations linked to intended 'proper' environmental strategies and effects are classified as eco-innovations. A broad definition of eco-innovations encompasses intentional and unintentional actions.

[4] "The choice to invest in either change in production process or end of pipe will be used to evaluate the extent to which production and abatement is undertaken jointly. End of pipe technologies are considered to reflect evidence of the existence of a separable production function, with production the conventional output and abatement of pollution as essentially separate plants within a single facility. Different resources are used for each plant. Production process is considered to reflect a production process in which abatement and production of the conventional output are integrated, allowing for the complementary use of inputs in both abatement and production" (Labonne and Johnstone, 2007, p.3).

This may lead to a framework in which economic and environmental goals are more easily identified as being complementary, and are integrated. Jaffe et al. (1995, 2003) note that firms can engage in some or a great deal of pollution control "Besides end of pipe technologies, firms usually have strong difficulties in accounting for specific capital and current environmental expenditures". As discussed above, it might also be due to the entangled nature of many environmental and 'normal' innovations.

This likely 'jointness' of 'eco' and 'normal' innovations has some connections with the evolutionary perspective on industrial dynamics, where the balance between firms' entries and exits is the main driver of development. Along these lines, environmental pressures could constitute an increasing wedge between innovative firms (sectors) and less innovative firms, which could in the end, disappear. The former may demonstrate higher performance on all-inclusive innovative grounds, positively integrating and correlating environmental and non-environmental dynamics. According to evolutionary theory, interlinked technologies evolve along a dynamic path, generating positive spillovers and effects on productivity. This discussion can also be positioned with the analysis of complementarity regarding input factors in the production of innovation and higher performance practices (Milgrom and Roberts, 1990, 1995; Mohnen and Roller, 2005; Laursen and Foss, 2003; Mazzanti and Zoboli, 2008b). Complementarity generates increasing returns and non-appropriable innovation rents.

Another motivation is related to the issue of rent generation and appropriability. The production of some 'environmental goods' is associated with rents that are appropriable, at least partially, by firms. They are in fact correctly defined as the private share of an impure public good, which encompasses other entangled pure public features. Many environmental innovations combine an environmental benefit with a benefit for the company or user. The gaps between environmentally accounted and standard productivity often emerges in the differences between natural resources and correlated externalities (Bruvoll *et al.*, 2003). Thus, the innovation potential of policies, and the associated innovative endogenous strategy of firms depend on the features of the environmental goods. Those goods may be characterised by private appropriable rents and by public good elements. This complementarity in production, i.e. a technologically-based positive correlation between the private (fully appropriable) and the public good elements is potentially linked both to the kind of externalities we are dealing with, e.g. local/global emissions, private or public product/process (Kotchen, 2005; Rubbelke, 2003; Loschel and Rubbelke, 2005), and to technological factors, e.g. the relationships existing among apparently separate technological dynamics.

Technology and externalities are in any case theoretically interrelated environments; and non-convexities in production could be an important element for the joint production of private and public values, depending on fixed costs and technological constraints (Papandreou, 2000; Boscolo and Vincent, 2003).

To sum up, the key question revolves around the possibility that firms may adopt some environmental strategies even on an endogenous market-based path. Starting with the Porter's framework we discussed elements that might enrich the set of motivations behind a possible joint path of environmental and labour productivity in the medium-long run, even in the absence of direct policy intervention. Evolutionary theories and borderline issues, such as complementarity, could constitute some conceptual pillars that extend the intrinsically static neoclassic reasoning.

The 'pessimistic' view of a trade-off between firms' environmental and non-environmental strategies may be mitigated by a framework in which those complementarities, which at heart involve different technological innovations (labour-oriented, environmentally-oriented), might explain, at least in part, why sustained increasing environmental efficiency is compatible with sustained increasing labour productivity in the *ex post* setting.

3.2 The set of tested hypotheses

We now specify the main *research hypotheses* we are testing, that arise from the above discussion.

[H.1]. The sign of the dynamic relationship between emission intensity at time *t-1* and economic performance specified as firm growth, at time *t*, is investigated, by using two different time lags: emission intensity per unit of labour averaged over 92-94 and over 95-99. We do expect the closer the lag is the more probable that environmental efficiency and economic performances are characterised by a trade off rather than complementary dynamics. Disentangled dynamics (statistical insignificance) are also a possibility if economic performance is independent on environmental elements.

[*H.2*]. The shape of the relationship is also investigated by specifying quadratic forms for emission intensity. Non-linearity is a real world feature that is analysed in both mainstream and alternative perspectives, but that assumes special relevance in dynamic scenarios. Were the relationship is non-linear, that is not only the cross-section (sector) heterogeneity and the lag difference between the two 'productivities' that matter, but also the level of the environmental performances matters. Critical thresholds may exist, and we do expect non-linear dynamics to represent the real world situation of many environmental-economic co-dynamics. It is nevertheless difficult to assess *ex ante* which shape is the more likely one, given empirical evidence is still scarce. If the non linear relationship assumes a U shape, this would mean that at low emission intensity the relationship with economic performance is associated to a complementary content, then trade off emerge when the environmental efficiency worsen. Otherwise, in presence of an inverted U shape, the trade off between economic and environmental performances is mitigated at higher environmental intensity. Further increases in environmental intensity hampers growth and leads to a co-dynamics between the two sides of firm objectives. In other words, it may be that only at quite high, or comparatively high, environmental pressures, firms (sectors) endogenously implement (innovative) strategies or are subject to policies, that help achieving a joint dynamic relationship between environmental and economic performances.

Summing up, we carry out various tests on whether environmental efficiency, deriving from innovation and structural changes leading to emission reduction is, following technology-based and externality-based complementarities relationships (Mazzanti and Zoboli, 2008a, b), positively associated with firms growth. The hypothesis we implicitly assume in the empirical model is that environmental impacts (environmental efficiency) are also dependent on the core dynamics of innovation, driven by structural factors (e.g. firm size), policy levers, and idiosyncratic strategic factors (R&D). In other words, we explicitly test whether the two objectives of the firm: environmental and economic performances, are disentangled (no significant correlation), positively related (correlation/complementarity between the two), or negatively correlated (substitution or trade-off framework).

As discussed in Section 3.1, this 'complementarity' may be opposed to the 'substitution hypothesis' which often derives from a usual neoclassic reasoning, which tends to hide the possibility that firms adopt environmental innovation in a non policy scenario. 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 leads, at least in the short run, to an equal reduction in productivity. .

3.3. The data set

3.3.1. Economic performances

The data-set used in this paper was drawn from AIDA: a commercial database collected by Bureau Van Dijck. This large data set of Italian joint stock companies reports balance sheets data such as sales, value added, number of employees, labour cost, technical assets, etc. Using this statistical source, for the period 2000-2004, we built a panel composed of more than 61,000 Italian manufacturing firms. For all these firms we have the following information: (i) the industry in which they operate; (ii) the geographic location; (iii) a size variable measured through the number of employees over the period 2000-2004. In addition, we have, for a sub-sample of these firms, other two information: i.e., (i) sales and (ii) age. This second sample is composed of 36,312 firms. We use these two data sets in relation to the stage of the Heckman procedure we consider below. Specifically, the first larger data set is used to estimate the selection equation where the dependent variable is constituted by a dummy variable that takes the value 1 whether all information on sales and age are available for the period 2000-2004 and the value 0 otherwise. The second smaller data set is used to estimate the growth equations which allow us to investigate on the empirical link between environmental and economic performances, respectively emission per employees and turnover. In Tables 1-3 we report the distribution of firms and employees refereed to the second data set by geographic areas (Table 1), employees classes (Table 2) and industry (Table 3).

A potential problem with these kinds of samples is that firms are not randomly chosen (Cingano and Schivardi, 2004). However, a comparison with the whole population in terms of frequency distribution both by industry and by geographical areas show that our sample is not far from being representative.

Table 1 – Distribution of sample firms by geographic areas

	Firms		*Employees*	
	N.	*%*	*N.*	*%*
North-West	15,164	41.8	1,182,367	50.3
North-East	11,214	30.9	702,696	29.9
Centre	6,968	19.2	355,228	15.1
South	2,966	8.2	110,993	4.7
Total	**36,312**	**100.0**	**2,351,284**	**100.0**

Table 2 – Distribution of sample firms by employee classes

	Firms		*Employees*	
	N.	*%*	*N.*	*%*
0-19	15,607	43.0	169,333	7.2
20-49	12,260	33.8	377,556	16.1
50-249	7,149	19.7	733,364	31.2
>249	1,296	3.6	1,071,032	45.6
Total	**36,312**	**100.0**	**2,351,284**	**100.0**

Table 3 – Distribution of sample firms by industry (see keys in Appendix)

	Firms		*Employees*	
	N.	*%*	*N.*	*%*
DA	2,584	7.1	158,617	6.7
DB	3,976	10.9	235,098	10.0
DC	1,398	3.8	54,027	2.3
DD	903	2.5	30,123	1.3
DE	2,306	6.4	118,442	5.0
DF	127	0.3	14,069	0.6
DG	1,633	4.5	189,105	8.0
DH	2,003	5.5	118,953	5.1
DI	2,179	6.0	143,185	6.1
DJ	6,895	19.0	365,674	15.6
DK	5,308	14.6	365,321	15.5
DL	3,205	8.8	289,120	12.3
DM	895	2.5	151,985	6.5
DN	2,900	8.0	117,564	5.0
Total	**36,312**	**100.0**	**2,351,284**	**100.0**

3.3.2. Emission intensity (environmental technical efficiency performance)

Environmental performances are taken from the NAMEA source[5]. The Italian NAMEA provides detailed data at two digit level on main emissions, value added and employees over 1990-2003. Here we focus on 1990-1999 for establishing a lagged structure to the analysis (see below).

Taking data for the period 1990-1999 in order to impose a lag structure to the modelled relationship, and focusing on some primary environmental efficiency measures of industries (tons of emission for CO2, SOx, NOX per unit of labour, full time equivalent jobs (FTEJ)), we reconstruct *environmental technical efficiency* ratios at firm level by using sector-level coefficients of emission/FTEJ, i.e. the only available proxy for environmental efficiency at sector level, and our AIDA data on firm employees[6]. This is the only plausible way to recover firm-level data on environmental performances in order to exploit the very rich information contained respectively in the Italian NAMEA and AIDA.

We set up average emission/employee for the two periods 1992-1994 and 1995-1999 for assessing relationships at different lag distances between environmental performances and firm's growth[7]. Years 1990 and 1991 were in the end discarded given problems with sector comparability over time within different NAMEA. Average values are taken both for testing the technical efficiency effects using two different time periods, and since emission data are characterised by yearly-specific volatility that is mitigated and smoothed by taking averages.

Table 4 presents summary estimates for the main variables we use in the econometric analysis.

Table 4 – Descriptive analysis of variables

Variable and acronym	*Description*	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Y	Turnover growth 2000-2004	0.120	0.590	-6.689	10.137
Turnover 2000	Value of sales in 2000	15.250	1.208	5.860	23.081
Age	Age of the firm in years	3.089	0.496	1.386	4.955
CO_2	Environmental efficiency (CO_2 on FTEJ, average value 1995-999)	12.779	1.655	7.826	21.658
NOx	Environmental efficiency (NO_x on FTEJ, average value 1995-1999)	6.640	1.489	2.079	15.797
SOx	Environmental efficiency (SO_x on FTEJ, average value 1995-1999)	6.184	1.776	0.693	16.781

All variables are to be intended in logs

[5] The main source of data on sectors-pollutants is NAMEA, published by ISTAT (Italian National Statistical Institute, www.istat.it). The NAMEA is deriving from real observations carried out on point emission sources year by year. The first NAMEA, referring to 1990 data, was published in ISTAT (2001).

[6] Average units of the pollutant produced per employee in the branch. Being based on quantity, and not value, it can be taken as an indicator of 'technical emission efficiency', thus reflecting the production technology of the branch. Given the level of aggregation of NAMEA production branches, E/N can also reflect composition effects, i.e. the combination of different E/N in, for example, different industries in the branch DK 'Machinery' of NAMEA.

[7] This is a proxy of technical efficiency. As alternative, for future research or further test on same data, we might use emissions on value added as a proxy of environmental economic efficiency (Mazzanti and Zoboli, 2009). The latter may grow less than the former if labour productivity increases more than emission per employee (and vice versa). It signifies that more value added is generated out from the same or lower emissions. We may then face very different dynamics regarding Emissions/employees and E missions/VA depending on the labour productivity dynamics.

3.3. Empirical model and methodological issues

The empirical specification used in this paper is within the established and well developed literature based on Gibrat's law on proportionate effects. This hypothesis states that the probability of a given proportionate change in size during a specified period of time is the same for all firms in a given industry, regardless of their size at the beginning of the period (Mansfield, 1962). Following Evans (1987a, b), we adopt a 'growth version' of this model, specifying the dependent variable as firm size growth and not firm size at time *t*. The independent variable remains size at time *t-1*. We test this hypothesis for sales/turnover[8]. Although most studies focus on employment as a proxy for size, there are an (increasing) number of investigations on the literature based on other measures of size and performances, from profitability to asset value[9].

We opt for the Gibrat model for a variety of reasons. In absence of a panel of data framework, we deal with a hybrid cross section environment with a lag structure in the empirical model that circumvents endogeneity. Instead of relying on a simple cross section specification, we prefer using such model given that it has shown good performances in previous studies (Cainelli *et al.*, 2007) and are related to a well developed and consolidated literature, mainly established in the evolutionary economics environment. Panel analyses may be scope for future (more valuable) research though we remark that our lagged model is specifically aimed at coping with endogeneity that would be a methodological and conceptual issue in a panel world.

According to this literature, it is also relevant to deal with exit/entry flows over the period. Gibrat's law could also be valid for certain defined sub-samples of firms (young, innovative, etc.). From a methodological point of view, this calls for econometric techniques that tackle sample selection bias.

Finally, some recent papers (Lotti *et al.*, 2007) argue that while the law may fail on an *ex ante* basis (that is on the total firms) since small and medium sized firms (SMEs) grow faster, in an *ex post* 'equilibrium', after the market has cleaned the industry through competition pressures, this law may hold for the core of survivor firms. Short run and long run differences in the validity of Gibrat's law may thus occur, and they can be associated with exit/entry flows and the evolution of industry towards a core set of firms. The period of observation is generally not so long as to detect these differences in the short to long run. In any case our study is not primarily focused on testing Gibrat's law, which is the framework in

[8] We use turnover instead of productivity (turnover / employees) for two reasons. First, it is coherent with most Gibrat's literature. Secondly, though it might be of interest an investigation between environmental and economic efficiency correlation (Mazzanti and Zoboli, 2009), the period 2000-2004 is atypical, witnessing in Italy a decrease or a stagnation of labour productivity for many industrial sectors, partly due to an increase of the workforce and employment (mainly women, immigrants, atypical contracts) in association with a low growth of value added.

[9] For a recent work which like ours uses size measures such as real gross output, employment and real value added, see Harris and Trainor (2005), who analyse manufacturing sectors in a panel framework to study the relationship between growth and size, rejecting the law in all observed cases. Other recent works dealing with measures other or in addition to employment size are Dunne and Hughes (1994), Delmar *et al.* (2003), Audretsch *et al.* (2004), Del Monte and Papagni (2003), who deal with Italian manufacturing firms in 1989-1997. A very detailed and comprehensive survey in this literature is presented by Santarelli *et al.*, (2006), to which we refer the reader.

which we test out hypotheses. Nevertheless, our result should be interpreted as biased towards the short to medium term[10].

The specification we used to empirically test the relationship between emission intensities and firms size growth is (Evans, 1988a, 1988b):

$$\text{(1)} \qquad \Delta_4 \ln(Y_{i,t}) = \ln(Y_{i,2004}) - \ln(Y_{i,2000}) = \alpha_i + \gamma_i \ln(Y_{i,2000}) + \delta_i \ln(age_i) + \mathbf{X}_{g,\mathbf{i}}{}' \boldsymbol{\beta}_g + v_i$$

where $Y_{i,2004}$ and $Y_{i,2000}$ are sales of firm *i* in 2004 and 2000, age_i denotes firm age, $\mathbf{X_i}$ is a set of variables, including the emission intensity at sector level, and finally v_i is the error term with the usual statistical properties.

It is worth noting that this relationship is also investigated by specifying quadratic terms both for sales and age and for emission intensity indicators. This is done in order to capture potential non-linear effects among these covariates and the dependent variable.

To overcome potential selection bias, we estimated equation (1) using the Heckman two-step procedure (Cainelli *et al.*, 2007)[11]. In the first step we estimate a selection equation where the dependent variable is constituted by a dummy variable taking value 1 whether all information on sales and age are available for the period 2000-2004 and the value 0 otherwise. As explanatory variables of this selection equation we use four geographic (*North_West*, *North_East*, *Centre* and *South*) and four size (*D19*, *D20_49*, *D50_249* and *D250*) dummies. The residuals of this regression were used to construct a selection bias factor, which is equivalent to the Inverse Mill's Ratio. This factor accounts for the effects of all unmeasured characteristics which are related to the selection variable. The Inverse Mill's Ratio is introduced as an extra explanatory variable in the second stage of the Heckman procedure, which consists of estimating the growth equation (1) using Maximum Likelihood estimators and using the selection bias control factor as an additional independent variable. In this way, we obtain efficient and consistent estimates of the unknown coefficients of the equations. Finally, since emission intensity data are calculated at firm level by exploiting emissions/employees ratio from the industry level, we estimate

[10] Here we cannot directly assess the role of policies as the driver of innovation, or consequently performance. Nevertheless, if we exclude anticipation strategies, the period under observation is one when major policies were still not implemented at EU and national levels. We can assume therefore that such innovation strategies are purely endogenous and depend on firms' strategic management, as (discussed) in Mazzanti and Zoboli (2009). This could explain in part the coherent but reduced number of first mover firms focussing on innovation for environmental purposes.

[11] In our case, the dependent variable in the first stage takes the value 1 if all information (including sales and age) on firm *i* are available, and 0 otherwise. The covariates used in the first stage to estimate the selection equation are the following: (i) a constant term, (ii) four geographic dummies (*North-West*; *North-East, South* and *Centre*), (iii) four size dummies (D19, D20_49, *D50_249* and *D250*), and finally (iv) nine industry dummies.

standard errors, that are robust to *arbitrary cluster correlation*. This procedure allows us to account for clustering in emission intensity data derived from NAMEA (Wooldridge, 2003, 2006) [12].

4. Empirical results

We sum up the main results of our investigations. First, we find expected result in the first step, that shows the relevant influence by size, industry and geographic location.

Secondly, we focus on the core aspects of second stage regressions, where the proper Gibrat model is investigated (tables 5-7 for the three different categories of emissions).

As far as the regressions without environmental performances (not shown) indicates significant and negative signs attached to age and turnover: firm growth is more likely to be experienced by small firms, an expected plausible result, and by younger firms, again as expected.

The relationship appears to be nevertheless non-linear: quadratic forms show U shapes for both factors. This may signify that (very) young and (very) old firms are the ones experiencing higher growth over 2000-2004[13]. The same holds regarding the scale/size of firms: low and high turnovers per employee are associated to higher growths. All in all, non-linearity is empirically relevant. Those outcomes do not change when we include environmental efficiency indicators (see below).

As a third step, regarding the core analyses of environmental – economic relationships, we first note that linear forms in tables 5-7 seem to support a positive and significant coefficient for all the three emission categories. Thus, recalling H1, we would be in front of a (usual) 'trade off' between different kinds of performance: the higher emission intensity per employee (over 1995-99), the higher firm growth is (over 2000-2004). Firm growth thus appears 'not constrained' by bad environmental performances; on the reversal side, more environmental efficient firms (perhaps within greener sectors) do not touch with hand the payoffs of 'greener investments'.

Motivations may be many and various. In part this evidence may be linked to weak policy pressures on more polluting firms, mainly when focusing on a global externality like CO_2 which has been regulated from early-2000s on through the IPPC directive and the emission trading (EU ETS) scheme for CO2. In any case we do not find here evidence of proactive co-dynamics between environmental and economic realms[14]. A positive sign in the estimated coefficient here means that increasing environmental efficiency leads to some economic costs in terms of lower growth. Those are the 'implied cost' of eventual improvements in environmental performances, that should be weighted

[12] As additional analysis, in order to circumvent the problem of exploiting as source emission sector data, we estimated fitted values of environmental efficiency for firms, using as regressors in the first stage R&D expenses, size and sector dummies. In the end, looking at methodological oriented literature and comparing results of the two estimation techniques, which here do not differ much, we opted for the specific cluster correlation technique for estimation of parameters, that is offering more robust estimates.

[13] We note that this period is one of the most critical, in negative terms, for the Italian economy.

[14] We stress this is the 'average' figure regarding manufacturing firms.

against market (appropriable) and non market benefits accruing from such improvements. Viceversa, being less environmentally benign relax the constraints to growth.

It is worth noting, nevertheless, that the size of the estimated coefficients is not large, besides that for CO_2: trade off are statistically significant, but quite negligible in terms of impacts for SOx and NOx. Since also the size of coefficients ('economic significance') matters as well as its statistical significance (Ziliak and Mcloskey, 2004), environmental performance does not seem a primary cost and constraint to growth if compared to other factors affecting firm targets[15]. The result for CO2 emissions seems to highlight that, by being CO2 emission related to energy consumption and end-of-pipe solutions for CO2 emissions being limited, to reduce CO2 emissions may result in a stronger negative effect on firm growth compared to other air pollutants.

Those outcomes also do not mirror the environmental-economic 'efficiency' co-dynamics found by Mazzanti and Zoboli (2009) who use panel NAMEA data over 1990-2001 for emission intensity of value added and value added per employee at the NAMEA-sector level. Nevertheless, the two studies, though conceptually close, are hardly comparable from an empirical point of view: We here exploit a lagged model instead of a panel, with some differences in the considered period, and the analysis was there on the all macro NAMEA sectors, not just manufacturing. Both studies point out the importance of non-linear paths characterising the links and evolution of economic and environmental performances.

Finally, the 'non linear' (quadratic models at right hand columns of tables 5-7) analyses on the income-environment relationship here envisaged tells us additional insights {H2}. In fact, regarding CO_2, a robust inverted U, or bell shaped[16], endogenous dynamics seem to signal the possibility of experiencing a reduction of growth after a threshold is reached. The income-environment relationship is not similar across the range of environmental performances/efficiency. Very inefficient performances in terms of emissions per unit of labour penalise firms even in the core performances. An explanation among others may be that pollution effects are (fully) externalized up to a point, then, when a threshold is surpassed, bad environmental performances present negative effects on firm performances. A linked argument is that of 'diminishing marginal returns' of the 'input' emission, related to energy use and capital intensity. Returns that may also become negative as shown here, even from a private persctive, without accounting the social cost of emission production[17].

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[15] At least for SOx and NOx, the growth decrease that 'follows' an environmental improvement of 1% in efficiency is less than 0.1%, but half percentage point of growth when considering CO_2..

[16] We remark that the estimation of standard errors, that are robust to arbitrary cluster correlation has improved CO_2 results. The bell shape was just weakly significant without such a correction. Even for NOx, the quadratic specification was completely insignificant.

[17] The bell shaped curve also recall the possibility of envisaging an 'optimal' growth, associated to the turning point. This optimal growth is still not reached here, and is close for SOx and NOx. We nevertheless stress that also external costs should be accounted for when determining such optimal growth of firms. A balance of private and social costs/benefits of pollution is needed. Given that estimates for the abatement costs and external costs of emission are available in the UE,

Putting it under a different perspective, a potential co-dynamics between economic and environmental performances emerges when the relationship is non-linear. The negative sign of the quadratic term means that higher emissions per unit of labour hamper growth potential, and vice versa, thus, improvements in environmental performances are associated to higher growth for firms. We remark that the non-linear shape is here to be interpreted, though embedded in a dynamic relationship, on the basis of the cross section dimension. The weight is thus on cross firm/sector heterogeneity, not temporal heterogeneity that could be captured in panel analysis (Mazzanti and Zoboli, 2009; Mazzanti *et al.*, 2007).

Much of it may depend on our eyes on complementarity between 'private and public elements' of the emission abatement that could be targeted by the same technological dynamics. Environmental innovations often give rise to a 'dual externality', providing the typical R&D spillovers and also reducing environmental externalities (Jaffe *et al.*, 2003; Rennings, 2000). Therefore, innovation aimed at reducing environmental impact may spur positive innovation spillovers. This element of complementarity could explain why environmental efficiency may be linked to turnover dynamics.

Another joint motivation is the issues of rent generation and appropriability as well as complementarity in production between environmental and economic (technological) objectives we discussed in section 3. The latter may depend on the features of the environmental 'goods' we deal with (Bruvoll *et al.*, 2003; Kotchen, 2005; Rubbelke, 2003; Loschel and Rubbelke, 2005).

We may note that for CO_2 this threshold, or turning point of the income environment bellàshaped curve, is nevertheless outside the range of observed values for turnover growth over 2000-2004[18]. It is then a signal of a potential future reversal of the trade off into co-dynamics even for mixed pubic goods ,like carbon dioxide, whose abatement benefits are not always fully appropriated by firms.

The situation for NOx is just slightly different: recalling that the coefficient in the linear form is negligible in size, turnover dynamics appear as being associated to a trade off for a certain part of the relationship. Then a joint dynamics, as before, could characterise the relationship with win win gains. If we estimate the turning point of the bell curve, we note that the NOx one is lower with respect to CO2. This is plausible. Though this threshold is still outside the range of observed values, thus predominating the trade off between economic and environmental performances, the 'fruits' of a joint dynamics seem here closer (in time), given the higher appropriability of rents from innovations improving the NOx-related efficiency.

Finally, results for SOx are similar to those for NOx. All in all, all three main environmental indicators tell a similar story. The short-to-medium term relationship is characterised more by trade off between

some cost benefit analysis may be carried out, balancing the losses (benefits) of manufacturing (de) growth, in the portion of the relationship where a trade off emerges, and the benefits (costs) of emission reduction (increase).

[18] It is then relevant to calculate the turning point to observe whether this is within the observed range of values. Since it is well within the range, it means that besides a share of firms for which the relationship is not constituted by a trade off, the real dynamic is driven by an opposite trajectory wherein environmental productivity and economic productivity diverge.

environmental efficiency and firm growth in opposition to co-evolutionary dynamics that nevertheless appear 'at the horizon' through the non linear relationships robustly emerging from the exploitation of a correction procedure for 'cluster correlation'. For SOx the threshold turning point show the closest value to real observed ones. Co-efficiency dynamics are close to be achieved[19]. Innovation and policy levers, though not directly investigated here, probably drive stronger trajectories of co-efficiency for SOx, which is the emission that has witnessed the strongest decrease in the last 20 years.[20]

Table 5 – The impact of environmental efficiency on firms' growth: estimates

Dep. Var: $\Delta_4 \ln(Y_{i,t})$	Heckit[(a)]		Heckit[(a)]	
	Coeff.	*t values*	*Coeff.*	*t values*
SELECTION EQ.	[1]		[2]	
North_West	0.663**	8.05	0.067**	8.28
North_East	0.032**	2.38	0.033**	2.42
Centre	Ref.	Ref.	Ref.	Ref.
South	-0.147**	-6.59	-0.150**	-6.84
D19	Ref.	Ref.	Ref.	Ref.
D20_49	0.569**	20.11	0.563**	19.03
D50_249	0.645**	12.23	0.638**	11.96
D250	0.322**	5.05	0.330**	5.21
Industry dummies (13)	Yes	Yes	Yes	Yes
SECOND STAGE EQ.				
$\ln(turnover_{2000})$	-2.559**	-21.32	-2.639**	-24.69
$\ln(age)$	-0.820**	-14.22	-0.852**	-15.43
$\ln(turnover_{2000})^2$	0.075**	18.08	0.078**	22.02
$\ln(age)^2$	0.108**	12.31	0.112**	13.95
$\ln(cox_{1995\_1999})$	*0.536***	*2.64*	*0.253***	*2.58*
$\ln(cox_{1995\_1999})^2$	…	…	*-0.007***	*-2.37*
Lambda	-0.340**	-6.93	-0.330**	-6.60
N. Obs.	61,219		61,219	
Censored Obs.	24,907		24,907	
Uncensored Obs.	36,312		36,312	
Clustering	14 industries		14 industries	

[19] Mazzanti and Zoboli (2009) note that in the case of air pollutants, provided their emission can improve as a by-product of innovations in energy efficiency and inter fuel substitution (i.e. 'ancillary benefits' of reducing GHGs), there may also be *specific* capital stocks capable of reducing some of them, e.g. end-of -pipe technologies reducing SO_x, and the new plant/equipment may be both more capital intensive and less air emissions intensive compared to GHG intensity. This may also take place because of regulation. It should be noted that prior to the Integrated Pollution Prevention Control (IPPC) directive and Europe Union's Emissions Trading Scheme (ETS), GHGs were not regulated directly, whereas most air pollutants have been closely regulated since the 1970s in most countries. It is likely that regulation has been the spur for increasing capital-labour ratio to reduce these pollutants.

[20] The results do not change if we use average emission intensity over 1992-1994 instead of 1995-1999 {H1}. The two series 'average' are highly correlated. This may mean that more than by the dynamics of emission efficiency, the relationship between economic and environmental objectives is affected by structural and sectoral features, that are affected only in the medium/long run scenario.

Wald chi2(1)	54.35	50.44
Prob>chi2	0.000	0.000

(a) Regressions also include a constant term. Standard errors are robust and adjusted for 14 clusters. ** significant at 5%; * significant at 10%

Table 6 – The impact of environmental efficiency on firms' growth: estimates

Dep. Var: $\Delta_4 \ln(Y_{i,t})$	Heckit[(a)]		Heckit[(a)]	
	Coeff.	*t values*	*Coeff.*	*t values*
SELECTION EQ.	[1]		[2]	
North_West	0.067**	7.92	0.068**	7.62
North_East	0.033**	2.34	0.034**	2.41
Centre	Ref.	Ref.	Ref.	Ref.
South	-0.150**	-6.37	-0.156**	-6.51
D19	Ref.	Ref.	Ref.	Ref.
D20_49	0.564**	18.21	0.554**	17.64
D50_249	0.634**	11.32	0.619**	11.00
D250	0.308**	4.69	0.317**	4.92
Industry dummies	Yes	Yes	Yes	Yes
SECOND STAGE EQ.				
$\ln(turnover_{2000})$	-2.527**	-22.23	-2.635**	-27.01
$\ln(age)$	-0.820**	-13.89	-0.859**	-15.04
$\ln(turnover_{2000})^2$	0.074**	18.45	0.078**	23.28
$\ln(age)^2$	0.107**	11.86	0.113**	13.15
$\ln(nox_{1995\_1999})$	*0.070***	*2.40*	*0.234***	*4.78*
$\ln(nox_{1995\_1999})^2$	…	…	*-0.011***	*-4.27*
Mills lambda	-0.330**	-6.60	-0.311**	-5.55
N. Obs.	61,219		61,219	
Censored Obs.	24,907		24,907	
Uncensored Obs.	36,312		36,312	
Clustering	14 industries		14 industries	
Wald chi2(1)	48.18		33.68	
Prob>chi2	0.000		0.000	

(a) Regressions also include a constant term. Standard errors are robust and adjusted for 14 clusters. ** significant at 5%; * significant at 10%

Table 7 – The impact of environmental efficiency on firms' growth: estimates

Dep. Var: $\Delta_4 \ln(Y_{i,t})$	Heckit[(a)]		Heckit[(a)]	
	Coeff.	*t values*	*Coeff.*	*t values*
SELECTION EQ.	[1]		[2]	
North_West	0.065**	7.79	0.065**	8.01
North_East	0.032**	2.36	0.032**	2.40
Centre	Ref.	Ref.	Ref.	Ref.
South	-0.144**	-6.40	-0.146**	-6.52
D19	Ref.	Ref.	Ref.	Ref.
D20_49	0.574**	21.31	0.567**	20.17
D50_249	0.654**	12.46	0.646**	12.24
D250	0.332**	5.14	0.334**	5.29
Industry dummies (13)	Yes	Yes	Yes	Yes
SECOND STAGE EQ.				
$\ln(turnover_{2000})$	-2.582**	-20.82	-2.648**	-23.99
$\ln(age)$	-0.818**	-13.12	-0.845**	-14.61
$\ln(turnover_{2000})^2$	0.076**	17.79	0.079**	21.19
$\ln(age)^2$	0.108**	12.15	0.112**	13.14
$\ln(sox_{1995\_1999})$	*0.041***	*2.20*	*0.122***	*2.37*
$\ln(sox_{1995\_1999})^2$	…	…	*-0.006***	*-2.13*
Lambda	-0.348**	-7.25	-0.340**	-6.66
N. Obs.	61,219		61,219	
Censored Obs.	24,907		24,907	
Uncensored Obs.	36,312		36,312	
Clustering	14 industries		14 industries	
Wald chi2(1)	60.00		52.34	
Prob>chi2	0.000		0.000	

(a) Regressions also include a constant term. Standard errors are robust and adjusted for 14 clusters. ** significant at 5%; * significant at 10%

5. Conclusions

This paper presents evidences on the empirical link between firm size /economic performances in terms of sales/turnover growth and emission intensity indicators capturing environmental technical efficiency, by originally using a very large firm based data set of thousands of Italian manufacturing firms. This data set refers to the period 2004-2000 for turnover growth and to 1992-1999 for environmental efficiency performances. We test the extent to which (past) environmental efficiency/intensity, which is driven by structural features and firm strategic actions, including eventual responses to policies, influences firm's growth. The main added value of the paper is the use of real environmental performances data merged with economic performances indicators for a very large sample of firms in a dynamic perspective. The evidence we provide is basically 'policy-free' for carbon dioxide since Italy did not experienced policies over the 90's. Though policy valuation will be an interesting point to be added in the future, evidence on how firms behave without regulatory interventions is also of high interest to understand the relationship between economic and environmental performances, as a food for thought for management and policy making.

First, a typical trade off generally appears to emerge for the three environmental emission categories we analyse here, when focusing on a linear specification of the income-environment relationship: less environmental oriented productions allow higher degrees of freedom and less constraint for growth. We do not find evidence of current pro-active co-dynamics between environmental and economic realms. Increasing environmental efficiency leads to some economic costs in terms of lower firm growth, at least for our manufacturing firms and in this short/medium run oriented empirical scenario. Viceversa, being less environmentally benign relax the constraints to growth. However, the size of the estimated coefficients is not large besides CO_2: trade off are statistically significant but quite negligible in terms of effective average impacts. As example, for SOx and NOx growth is reduced by less than 0.10% for a 1% increase of environmental efficiency; the percentage move up to half a point of growth for CO_2 'abatements'. All in all, then, the 'environmental factor' does not seem a primary cost and constraint to growth, if compared to other factors affecting firm targets and firm competitiveness.

In addition, and highly important, non linear analyses of the relationships, nevertheless, tell us to some respect a different story. Results show that the link between emission efficiency and firm growth is in fact robustly non linear. Inverted U shapes appear for all three emission efficiency indicators: this may be a signal that both firm strategies and recent policy efforts, are affecting the relationship between environmental efficiency and economic performance, possibly turning it in the near future from a trade off to joint complementary/co-dynamics. Though our evidence is of cross sectional nature capturing sector heterogeneity more than time dynamics, we might affirm that the potential co-dynamics between environmental and economic performances appears close from the evidence, and more likely to be achieved in the next future for NOx and SOx. This evidence is plausible with the higher appropriability of (higher) environmental performances deriving from innovation actions of manufacturing firms.

The story we discuss here for Italy over the 1990s is a sort of 'policy free' scenario; it is thus consistent that CO_2 appears as the environmental factor less likely to be associated to *win win* complementary income-environment dynamics in the next future. The endogenous evolution of income and environmental factors linked by the web of firms-based and sector-specific innovation contents may not suffice, as highlighted by other studies, for coping with this externality. The relatively less significant evidence for carbon dioxide also calls for policy advices in favour of more stringent policies for emission that are characterised by a largest part of public good (not appropriable) content.

Our results could open a new window of empirical evidence that supports the existence of a dynamic and evolving of trade-off between environmental and economic strategies of industrial firms, up to achieve a complementarity between the two.

Further research rooting on this paper may be provided in the future both by using panel data analysis over 2000-2004, exploiting new updated NAMEA data, and estimating the reverse causal effects (economic performance → environmental performances) when emission data after 2004 are available. In the context of this century, some analysis of policy effects may be introduced, among others those deriving from the European emission trading scheme for carbon dioxide operating since 2005.

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Appendix

Table A.1 – Classification of manufacturing activities

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

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