Environmental certifications and innovation in European firms

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Abstract

The last twenty years witnessed a rapid diffusion of Environmental Management Systems (EMS) and Ecolabels in most OECD Countries. It is not clear, however, if EMS and green labels affect firms' innovative performance and in what direction.
This paper aims at investigating the relationship between environmental certifications of process and product (specifically EMAS and Ecolabel) and the certified firms' innovative performance against the performance of non certified firms over a ten years period. An 2SLS model is estimated to tackle the potential endogeneity issue, and a fixed effect model is estimated to take into account the presence of unobserved characteristics of firms. The results of the econometric analysis on 30439 European firms suggest a positive impact of EMAS and Ecolabel on innovation.

1 Introduction

In recent years, many different approaches to voluntary environmental regulation have been formulated, both by countries and by public institutions, in order to improve the awareness of firms regarding their environmental impact. The most common instruments proposed are: Environmental Management Systems (EMS) and green labels.
The European Commission provided two specific policy tools in order to foster firmsâĂŹ adoption of eco-friendly practices: the Eco Management and Audit Scheme (EMAS), which is an Environmental Management System, and the Ecolabel, an international green label.

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Previous studies explore the impact of EMS and ecolabels on firms financial performance (Yang et al. 2012; Heras-Sarzaibitoria et al. 2011), on exports (Hering et al. 2012) and on human capital (Lan et al. 2012). An increasing number of studies investigate the impact of voluntary EMS on innovation (Gauthier et al. 2012; Triguero et al. 2013) but the results are not conclusive. Few studies, however, investigate the effect of EMAS, a more requiring standard with respect to other EMS (e.g. the ISO series), on European firms innovative performance (Wagner 2009). No studies so far explore the correlation between ecolabels and innovation, and thus no comparative assessment has been made of the impact on innovation induced by product vs. process environmental certifications.
The main contributions of the paper are (i) to explore the correlation between EMAS certification and innovation and (ii) to analyze the correlation between Ecolabel and innovation in European firms.
The Porter hypothesis asserts the existence of an "innovation effect" provoked by stringent environmental regulation. We argue that the acceptance of stricter environmental requirements linked to ecolabels and EMS can cause a similar innovation effect. A further contribution of this work is, therefore, (iii) to verify the existence of an innovation effect caused by environmental certifications, excluding the effect of potential self selection bias.
The results of the empirical analysis on 30439 European firms over ten years (2003-2012) suggest that the adoption of EMAS positively affects firms innovative performance, as well as the adoption of the Ecolabel certification. Furthermore, an "innovation effect" can be demonstrated because it seems that the three years after the implementation of EMAS are the most effective in spurring innovation, while no significant effect can be linked to the years before and during the certification process.
The paper is organized as follows: Section 2 introduces the European environmental certifications EMAS and Ecolabel. In Section 3 presents the relevant literature. Section 4 develops the theoretical framework. Section 5 concerns data sources and methodology. Econometric results are presented in Section 6. Section 7 concludes and suggests possible lines for future research.

2 EMAS and Ecolabel: theoretical background

An EMS can be defined as âĂIJan organizational change within firms based on the adoption of management practices that integrate the environment into production decisions, identifying opportunities for pollution and waste reductions, and implementing plans to make continuous improvements in productions methods and environmental performanceâĂİ (Khanna and Anton, 2006).
Ecolabels are trademarks that certify the eco-sustainability of finite products and services: the logo indicates the environmental preferability of a product within a particular category, based on life cycle considerations. Sometimes ecolabels are mandatory (e.g. the U.S. Blue Energy Star label), more often ecolabels are voluntary, as is the case of the European Ecolabel.

2.1 EMAS

At the European level the official EMS is EMAS: EMAS was designed by the European Commission with Reg. CEE 1836/93, in the context of the Fifth EU Environment Action Programme entitled "Towards Sustainability". EMAS was originally restricted to companies in industrial sectors but since 2001 is open to all economic sectors including public administrations. A second version of EMAS (EMAS II) was adopted by the European Commission with Reg. 761/2001, and a further implementation was designed with Reg. 196/2006. The last revision (EMAS III) has been published in 2009 (Reg. 1221/2009); it subsumes previous regulation, and entered into force on 11 January 2010.
Firms usually decide to adhere to an EMS in order to enhance their internal efficiency, to clean their public image, to claim their social responsibility and eventually to address immediate and long-term environmental issues (Rondinelli et al. 2000, Canon-de-Francia et al. 2009, Hudson et al. 2012).
Firms have to follow various steps in order to obtain and to maintain the EMAS certification, according to the cycle "plan-do-check-act". They make an initial review of their environmental impact: the outcome is a report that sheds light on the most significant direct and indirect environmental aspects and lays down a benchmark to measure future improvements. Then, the firm addresses the identified significant issues by implementing an environmental management programme. The final part of the cycle entails an internal environmental audit, to produce a so-called environmental statement.
On the basis of the final assessment, which is public, authorized verifiers can validate the organization, that becomes listed in the EMAS register and can use the EMAS logo as a signal to consumers and to public and private buyers.
EMAS is more stringent with respect to other international EMS, especially with respect to ISO series:

1. It overtakes ISO14001:2004 in the sense that the same requisites are a compulsory part of the EMAS certification but are not sufficient.

2. It requires an initial environmental review to verify the true environmental performance of the firm, in order to assess the effectiveness of the goals reached over time, since the registration.

3. It measures environmental impact through six highly requiring indicators, enabling an annual public comparison between firms.

4. The annual environmental statement is compulsory and public.

5. The environmental training of employees is a verified requisite.

The paper considers EMAS, rather than other EMSs, for its wide diffusion among European firms, for its official homogeneous regulation across the EU27 Countries, and for its environmental stringency.

2.2 Ecolabel

The European Commission launched Ecolabel in 1992, a voluntary green label that consumers could trust in order to distinguish greener products on the market. To qualify for Ecolabel, products have to comply with a set of criteria that guarantees that the main environmental impacts of finite products are lower than those of similar products on the market. [1] EU Ecolabel criteria have been formulated for 26 non-food and non-medical product groups that are reviewed every 3/5 years to keep up with technological innovations. [2] If a product meets the requirements of the Ecolabel standard, the trademark is conferred and it can be simply maintained by paying the annual fees.
The paper considers Ecolabel because it is the official green label of the European Union; its criteria are periodically revised and shared by all EU27 countries, therefore it is preferable to private national labels.[3]

3 Relevant literature

The empirical literature related to our research questions can be divided into two main branches. One strand analyzes how the environmental certifications affect firms' innovative performance, and more broadly investigates the determinants of innovation. Another branch focuses on the determinants of environmental certifications adoption.

Several papers explore the impact of EMS on innovation, finding mixed evidence. The majority of them are based on self-assessed data on innovation, thus introduces a strong element of subjectivity and heterogeneity. Furthermore, many studies cannot take into account the magnitude of introduced innovations, because they measure only the presence or not of any innovative behavior.
Demirel and Kesidou (2011) introduce a measure of the innovative effort by using the amount of the environmental investments undertaken by British firms. They investigate the determinants of different types of eco–innovation in the UK, namely the *end of pipeline pollution control technologies*, the *integrated cleaner production technologies* and the *environmental R&D*. They use an original database derived from a DEFRA's survey [4] at firm level. This government survey was carried out in years 2005 and 2006, and obtained response from 289 UK firms belonging to the manufacturing sector. The paper divides the determinants of eco–innovation in three main categories: *external environmental policy instruments*, such as environmental regulation and environmental taxes, the *internal firm–level motivations*, such as organisational capabilities, in par-

[1] ec.europa.eu/ecolabel/
[2] http://ec.europa.eu/environment/ecolabel/
[3] The paper does not consider the German national eco-label "Der blaue Engel", created in 1978 (http://www.blauer-engel.de/en/index.php) because its requirements are different from the requirements of the Ecolabel. It is still largely diffused in Germany and as a consequence Ecolabel results will not be completely reliable for Germany.
[4] Department for Environment Food and Rural Affairs (UK)

ticular the presence of any EMS, and *efficiency*, for instance cost–savings from environmental improvements, and corporate image. In Demirel and Kesidou's model the dependent variable is the environmental investments normalized by the total capital of the firm; since the eco–innovation variable is censored from below at zero, they use a Tobit censored model. The control variables include external determinants of eco–innovation, such as the dummies related to environmental regulation and taxes, and internal determinants of eco–innovation (the dummies for ISO14001 and for a generic EMS).
The econometric results show that the EMS is effective both in motivating firms to invest in end of pipeline green technologies. The EMS also has a positive significant effect in motivating firms to invest in environmental R&D, but it is not effective in increasing R&D expenditure of firms that already perform green R&D. Finally, the variable EMS does not show any effect on the Integrated Cleaner Production technologies related investments.
Some limitations concerning the potential reverse causality between EMS and environmental innovation have been considered by Frondel et al. (2008), that find no effect of EMS on pollution abatement innovations.
Frondel et al. (2008) address the issue of the relationship between EMS and environmental innovation performance by modeling a recursive bivariate probit model that allows for firms' decision on innovation activities and EMS adoption to be simultaneous. The paper is based on an OECD survey conducted in 2003 among several OECD countries; the authors focus on 899 German firms of all economic sectors. While the dependent variable *ems* takes value 1 if the firm is already EMS certified or if the implementation is in progress, the other binary variable (*abate*) takes value 1 if a new technology of pollution abatement has been introduced. The model is based on dummy variables that control for reported perceived pressure of public authorities, commercial customers, environmental organization and internal/external stakeholders. Other dummies account for the desire to clean corporate image or to be environmental compliant. The econometric estimation reports no significant effect of EMS as a determinant of *abate*.
One potential limitation of this paper is the use of the variable *abate* as dependent variable, that narrows the innovative behaviour to a single possible type, underestimating the impact of *ems*.
An attempt to analyze the reverse causality between EMS and innovation is performed by Ziegler and Nogareda (2009). The paper explores the causal relationship between technological environmental innovation and EMS. It is based on a unique database composed by data derived from a questionnaire telephone survey conducted in summer/autumn 2003 regarding 368 German manufacturing firms. The aim of the paper is to analyze whether the adoption of an EMS or other environmental assessment activities in 2003 can be explained as (partially) dependent on the adoption of any technological environmental innovation implemented over the years 2001–2003. The dependent variables are therefore the dummies ISO14001, EMAS, and three other variables representing the environmental effort of the firm in terms of eco–labelling, assessment of environmental life–cycle and measures about waste disposal. Unfortunately, less than 8% of

the interviewed firms was EMAS certified, while more than 24% of them detained an ISO 14001 certification, therefore the authors consider the dependent variable ISO 14001 as a more precise proxy for EMS. The main explanatory variables concern the dummies for environmental product and process innovation, while introduced controls include several other dummies, such as non–environmental innovation, perceived pressure from consumers and competitors, sectoral dummies and export, and measure for size and age of the firm. Ziegler and Nogareda perform many uni–variate probit models, considering at first each of the dependent variables, and then a multivariate probit model in view of the strong relationship existing between them. The results demonstrate a positive effect of environmental innovation on the adoption of EMSs, but according to the authors this conclusion can be challenged because omitted underlying firm heterogeneity could not be controlled in a cross-sectional framework, i.e. their estimation could be biased by the absence of control for characteristics that affect both the adoption of an EMS and the implementation of technological environmental innovations.

Cross–sectional databases are very common in this branch of literature, though a panel approach could solve the unobserved heterogeneity problem concerning innovative and certified firms; an exception is represented by Horbach (2008).

Horbach's (2008) paper partially overtakes the difficulties related to the use of cross-sectional database, by relying on two different panel database: the establishment panel of the Istitute for Employment Research (IAB) and the Mannheim innovation panel (MIP). The IAB database covers two points in time, therefore the author is able to perform a random effects model estimation. The sample is composed by 753 German firms providing goods or services related to the reduction of environmental impact, of which 56% were environmentally innovative. The binary variable *Environmental innovation* is estimated on several covariates: age of firms, size, R&D, turnover expectations and a dummy for the introduction of generic environmental management tools. The econometric results confirm a positive role of the environmental management tools in determining the adoption of an environmental innovation in the two previous years. This analysis has some limitations in the fact that environmentally active firms are instrinsecally more likely to develop new environmentally related products. Once again, the environmental innovation is self–assessed by firms and it is limitated to a binary variable, that does not take into account the magnitude of the innovative performance of firms.

The paper reports a second analysis using the MIP panel wave 2001, collecting data for 4846 firms in the manufacturing and service sectors, running at first a probit model on the innovators sub sample (environmental innovators against other innovators), and then a multinomial logit model, to analyze the firms' choice between innovations with environmentally relevant effects and other innovations, versus the no–innovation alternative. Among the covariates (Sales, Profit situation, Size, Presence of highly trained employees, a dummy for expected increase in demand), the dummy variable *organization* represents the introduction of changes in the organizational structure (which includes the introduction of EMS, but in a generic sense, e.g. any management system, even informal). The coefficient of *organization* is significant and positive both for the environmental and other innovation variables.

Another problem often encountered in this literature is represented by the definition of EMS that is adopted. Sometimes a very inclusive definition of organizational changes is considered, like in Horbach (2008) and Frondel et al. (2008), and this introduce wide heterogeneity in the environmental effort declared by firms. Moreover, few studies consider ecolabelling as a potential determinant of innovation. To our knowledge, only Wagner (2009) explicitely considers ecolabelling among the determinants of innovation, finding a positive impact of eco–labels on product innovation.

Wagner questions whether EMS and ecolabelling affect firms' propensity to carry out environmental innovation and whether the impact is moderated by country location or by the interaction of EMS with national regulatory framework. Wagner's dataset is based on a survey carried out in 2001 across nine European countries (Belgium, France, Germany, the Netherlands, Hungary, Norway, Sweden, Switzerland and UK) and involving nearly 2100 firms. Wagner implements a multivariate probit model to assess the determinants of process and product innovation as interrelated variables. The main explanatory variables are the terms derived from the interaction between the EMS index (that measures its level of implementation: non-existent, considered, in progress and fully implemented) and the country specific dummy. The model also introduces dummy for ecolabelling activities. Furthermore, Wagner introduces an interaction between the EMS index and a measure of stringency of the national regulation (based on a Hofstede, 2001). The findings show that no significant effect can be attributed to the EMS with respect to product innovations, while some positive effect is related to the interaction of the EMS with specific country dummies (Germany, Sweden and UK). On the other hand, the variable *ecolabelling* shows a significant positive effect on process innovation. When regressing the second model, the coefficients of the interaction terms of EMS and of the measure of regulatory stringency are no longer significant, while the significativeness of the *ecolabelling* dummy is confirmed.

Rennings et al. (2006) narrow to the EMAS certified firms their analysis, trying to focus on a specific EMS and its characteristics as potential determinants of innovation. The sample considered doesn't present self–selection bias, since it is composed by certified firms only, but still doesn't allow for a comparison with non certified firms. Rennings et al. consider EMAS validated manufacturing German facilities to investigate the impacts of different characteristics of EMAS on technical environmental innovations and economic performance. 1227 firms partecipate in a telephone survey conducted in 2002. The probit model estimates the self assessed environmnetal process and product innovation as a function of different characteristics of EMAS certification. The main results concern the importance attributed by firms to the learning processes entailed by the certification and the maturity of EMAS (measured as two revalidations obtained) in determining environmental process and products innovation.

Similarly Inoue, et al. (2013) find a positive effect of the maturity of ISO 14001 on innovative performance. In particular, they analyze the impact of the ISO–

duration (how long the firms stay in ISO 14001) and the environmental R&D share on total R&D and on sales, of 1499 Japanese firms in 2003. The variable *ISOduration* shows a positive coefficient and lasts when controlling for the age of the firm.
To summarize, the main limitations of the existing literature are the following:

- The majority of the papers exploring time series relationship environmental certifications-innovation are restricted to one point in time, lacking data to assess the effect of the EMS regime over time, and to one country (mainly Germany, or UK or Japan)
- The definition of the EMS–organizational changes is wide and introduces high heterogeneity in the environmental effort considered and effectively implemented by firms
- Most previous research is based on firms' self-assessment of innovation, introducing a strong element of subjectivity, and doesn't consider, out of some exceptions, a measure of innovation magnitude.
- The literature considering eco-labels and innovation is very scarce; to our knowledge the only exception is represented by Wagner (2008)
- The endogeneity bias has not been completely solved.

Tabella 1. Literature on EMSs and Innovation

Authors	Years	EMS	Source of data	Period of coverage	Country	Data and sectors	Main findings
Demirel and Kesidou	2011	ISO14001	DEFRA survey	2005-2006	UK	289 manufacturing firms	Not conclusive evidence: significant impact of EMS only on specific types of innovation
Ziegler and Nogareda	2009	ISO14001, EMAS	telephone survey	2003	Germany	368 manufacturing firms	Positive effect of environmental innovation on EMS adoption
Horbach	2008	organizational changes	IAB, MIP survey	2001, 2004	Germany	753 firms in environmental sectors and 4846 manufacturing and services firms	Positive effect of organizational changes innovation
Frondel, Horbach and Renning	2008	generic EMS	OECD survey	2003	Germany	899 firms, all sectors	No significant effect of ems on abatement technology innovations
Rennings, Ziegler, Ankele, Hoffman	2006	EMAS	telephone survey	2002	Germany	1227 EMAS certified firms	Positive effect of EMAS maturity on environmental innovation
Wagner	2008	EMS and Ecolabel	postal survey	2001	9 EU countris	2095 manufacturing firms	Positive effect of ecolabelling on product innovation,not clear effect of EMS interacted with national regulation indexes on innovation
Inoue,Arimura,Nakano	2013	ISO14001	OECD survey	2003	Japan	1499 firms of all sectors	Positive effect of ISO 14001 maturity on environmental R&D expenditure

The table illustrates the most relevant literature about EMSs and Innovation cited in the Literature review.
Source: authors elaboration

The literature related to the determinants of EMSs adoption is scarce but presents consistent and homogeneous results.
The EMAS certification entails consultant and registration costs, together with implementation and annual mantainance costs and fees, hence financial characteristics of firms have to be taken into account when investigating the determinants of EMAS adoption. Bracke et al. (2008) examine 436 EU-15 firms (plus Norway and Switzerland) listed in 2005 in Dow Jones STOXX 600 Monthly Selection List, of which 38 were EMAS certified. They find that solvency ratio and non-current liabilities (that reflect the interests of long term creditors) positively affect the decision of implementing EMAS, whereas the profit margin variable is negatively correlated with EMAS implementation. The capital intensity and the number of shareholders are not significant. The authors explain the negative coefficient of the profit variable as caused by the fact that in more competitive markets, where profits are moderate, the need to differentiate from competitors is higher, hence firms are more likely to certify.
Heras-Saizarbitoria et al. (2010) study the financial performance of accreditated firms before and after certification, finding that firms with better than average performance have a greater propensity to pursue accreditation but they found no evidence that improvements in performance following certification.

Morrow and Rondinelli (2002) asked to 5 German firms in the energy and gas industry their motivations for acquiring EMAS certification. According to Morrow and Rondinelli (2002) the main reason that spurs German firms to adopt EMAS is to achieve continuous improvement of environmental performance, followed by the desire to identify weaknesses and potential use of energy sources. Costs savings were not a significant incentive. A study conducted by the German Federal Environmental Agency on 1264 EMAS registered sites in 1998-1999 confirm the minor role played by the cost savings reason in the adoption of the certification.
According to Johnstone and Labonne (2009) the expectation to reduce the frequency of the inspections positively affects the decision to adopt an EMS, together with the opportunity to benefit from public financial supports and incentives. They analyze about 4000 manufacturing facilities of 7 OECD countries. By means of a postal survey they collect data on expectations and motivations to undertake an EMS. The results show that stringent environmental regulations negatively influence the probability to adopt an EMS. On the contrary, the exposure to international markets, the desire to improve corporate image, especially for listed firms, and a large number of facilities and employees are positive determinants of EMS adoption. All the proxies that capture the intention to improve reputation, together with a high visibility on the market, are positively correlated with EMS implementation.
Canon-de-Francia et al. (2009) analyze whether the ISO14001 standard is interpreted by the capital market as a sign of environmental responsibility, modifying the profitability of firms. The paper analyzes the performance of 80 Spanish firms traded on the Madrid Stock Exchange market from 1996 to 2002. They find a negative effect on the market value: the results seem to show that the Spanish market negatively views the allocation of resources to ISO14001, especially in the case of less polluting and less internationalized firms.

4 Conceptual framework

4.1 The Adoption of EMAS and Ecolabels

The adoption of an environmental certification can be motivated by several factors.
Visibility and reputation
Larger firms, with larger share of the market and/or with many facilities, have a higher visibility both to customers' eyes and to authorities' control activities. Therefore, the implementation of an environmental certification can be motivated either by reputational reasons, or by the desire to be compliant with environmental regulations. In some cases, together with the intention to fulfill regulatory requirements, there is the desire to lower the inspection rate with respect to non certified firms.
Signaling and market demand

An environmental certification can signal to consumers a firm's environmental effort and can help to meet the market demand for greener products and services. Some studies (e.g. Vloski et al., 1999) confirm that customers willing to pay more for green products than to an equivalent but not environmentally sustainable product.

Regulation

National regulations usually spur the implementation of EMS and green labels, in order to improve environmental and regulatory performance of firms, and provide benefits and national subsidies that drive also smaller firms to join EMS. The role of national regulations into spurring the EMAS or Ecolabel adoption is discountinuous over time. During the first period of EMAS regime, the population of certified firms was composed by a majority of large firms with enough resources to cope with the implementation of a costly and high requiring standard. Then, the second EMAS version (2001) obliged countries to provide policy measures that, by lowering cost burden and providing technical support from local authorities, were aimed at allowing SMEs and particular categories of firms, often in highly polluting sectors, to join EMAS. In particular, since 2000 the rate of new adherents were diminuishing, and to constrast this trend, European countries implement several regulatory and fiscal measures to facilitate EMAS introduction into more pollutant firms and SMEs. The relation of the Parliament 475/2004 summarizes the different subsidies and benefits carried out in European countries: the main instruments regard tax benefits and subsidies, technical support in the initial phase of implementation, free training within interested firms, extended authorizations and, rarely, a lower rate of inspection. Moreover, the 2004/18/CE deliberation introduces the green public procurement discipline, that establishes that a fixed share of public procurement must be green according to some criteria. These criteria are considered fulfilled automatically by EMAS certified firms, or for Ecolabel certified products. The discipline remains facultative and its implementation varies a lot across countries, but this provision can be considered as another advantage that fosters EMAS and Ecolabel adoption.

The policy subsequent to the second EMAS revision both allows for a new increase in the number of accreditations, and change the structure of EMAS population, composed by a core of large companies with long EMAS maturity, and a majority of SMEs with shorter EMAS experience.

Size and resources

Despite the increasing percentage of SMEs among EMAS certified firms, the availability of human and financial resources is necessary to implement and to mantain an environmental certification, since both require implementation costs, annual fees and the EMAS also requires human resouces devoted to its functioning and continuous improvements.

Sectors

Firms belonging to manufacturing sectors are more likely to detain an Ecolabel, since they deal directly with customers and need to use a well known logo to signal environmental concern; but also firms providing services to other firms need to prove the quality of their services through an environmental certification. Finally, firms working in environmentally concerned fields, such as waste management and recycling, or particularly pollutant sectors subjected to more stringent regulations, like refineries, can be more likely to implement EMAS. [5]

Innovation

Neither EMAS regulation, nor Ecolabel regulation, can require the implementation of practices and productive processes not available on the market, covered by patents, or of not common level of knowledge, hence there is no need to be innovative to implement EMAS or to obtain an Ecolabel, and in this sense innovative firms cannot take advantage from their innovation, with respect to non innovative firms, as the requirements to be certified are very different from those required for filing a patent.

Nevertheless, we cannot exclude that more innovative firms are also more likely to implement the environmental certification, i.e. a potential endogeneity source. We postpone the discussion of this issue in the Methodological section, in which we will try to solve it.

4.2 Why the environmental certifications should foster innovation?

It is often pointed out that the implementation of an environmental certification is costly and many firms agree upon the fact that the system is complex and demanding (UE Final Report on Emas 2009).

Fixed costs faced by firms to implement the environmental certifications are partially correlated with size, and partially are assumed to be unrelated to dimension. These latter costs mainly entail validation and verification fees and the environmental verifiers services (e.g. the consultancy to write the first environmental report). The costs related to size of firms are the registration fees, that are different from verification costs and can vary from zero to 1500 Euros in the case of large companies, and the costs of employing external expertise to support EMAS implementation and reporting.

In terms of human resources, according to the estimation of the Euroepan Commission [6], depending on the organisationâĂŹs size, number of sites, previous experience with management systems and the complexity of environmental impacts, the typical personal commitment to implement EMAS varies from a few persons per month in a small company in the service sector to several persons per year in large corporations with many sites.

The highest costs are carried out during the first period of implementation because firms need time to learn EMAS requirements and to establish the necessary management and administrative systems. Once EMAS is implemented, system maintenance needs fewer resources, since many activities required for the first

[5]An example of this can be found in Italian regulation, where the AIA-Autorizzazione Integrata Ambientale, a permits that involves some kind of industries, like refineries and cokeries, has to be renewed every five years, but for EMAS firms become renewable after eight years and can be done using the same documentation of EMAS (D. Lgs. 152/2006).

[6]http://ec.europa.eu/environment/emas/documents/kit-en.htm/costs

registration are no longer needed. It can be noticed that the consultancy costs show the largest reduction, followed by costs for the first assessment and the first report. Once EMAS comes into regime, firms can start to take advantage from its implementation.
The EMAS efficacy can be intuitively assessed by verifying the profile of the certified firms under the six key indicators introduced by the latest EMAS version (EMAS III, Reg. CE 1221/09). These indicators are:

1. Energy efficiency
2. Raw material efficiency
3. Water (use)
4. Waste
5. Bio diversity
6. Emissions

Under the first indicator, the certified firm through the implementation of the Emas should demonstrate constant improvements each year of Emas maturity, and this gain in efficiency must be reported in the annual environmental report, that is mandatory. The persistent gain in efficiency is a challenging achievement, and forces firms to take advantage from the best technologies available on the market, and eventually to develop innovation to provide the improvements needed by the EMAS. The duty to comply with the EMAS requirements can be assimilated to the duty to comply with mandatory environmental regulation imposed by public institutions. Thus, we expect a similar effect on innovation: prior research has proved the existence of a positive relationship between stringent environmental regulation on eco innovation at the firm level (Porter and van der Linde 1995, Rennings 2000, Horbach et al. 2012, Rennings and Rammer 2011).
In parallel, firms' gain in efficiency means to increase savings, and new financial resources can be invested in the maintanance of the system and in environmental R&D. This can produce technological environmental innovations. This can be a competitive advantage especially for SMEs that usually do not carry out R&D because of the scarcity of resources.
Indeed, the estimated average costs of a typical EMAS organisation amount to around 48,000 Euros for the first year and 26,000 Euros annually for subsequent years; however, from the simulation of the European Commission can be seen a wide varieties among Emas generated expenditure. For instance, for a small firm the annual costs of implementation are about 10.000 Euros, whereas a large company spends about 39.000 Euros to implement annually Emas certification [7]. Nevertheless, it has been estimated a potential annual efficiency energy savings amount of 3000 up to 10.000 Euros for micro firms, and a costs savings up

[7] In the âĂIJEMAS ToolkitâĂİ, the European Commission estimates the financial resources spent on setting up an environmental management system, including external consulting fees and associated communication and registration costs, to be on average:

to 400.000 Euros per year for large companies.
Similar observations can be done also for the second indicator regarding raw materials. We expect that enhancing input efficiency leads at first to a better exploitation of the existent technological knowledge, and, as a subsequent step, to the introduction of innovative solutions to improve their environmental performance. For instance, one of the firms awarded by the Emas Award 2014 is a large engineering company from Austria, the Voestalpine VAE, Weichensysteme and HYTRONICS GmbH, through intensive research and development work, has optimised its use of materials and logistics, as well as the recycling of turnouts. Similarly, the HR BjÃűrkmans EntrÃĺmattor AB (Sweden), working in the floor mat rental and laundry market, has developed an innovative mat washing system to better comply with indicators on the input efficiency and water use reduction. The use of its new closed system, with its low washing temperatures, special detergents and a water reuse rate of up to 98%, has resulted in sizeable energy and water savings. It has also led to significant reductions in the volume of used and contaminated water entering the municipal waste water treatment cycle [8].
It is on waste recycling that eco-innovation can help certified firms to better comply with the EMAS requirements. The application of the EMAS program fosters firms to recycle from the 60% up to the 99% according to the reports of certified firms (see http://ec.europa.eu/environment/emas/casestudies/index-en.htm for some examples). Eco innovation is required to find other ways to improve recycling, and in imposing a constant improvements leads to innovation. Another case of successful implementation of EMAS and eco innovation, is the Belvas Organic Chocolate (Belgium) that adopts an innovative waste management process that incorporates separation of organic waste and its use in biomethanisation plants. A unique energy retrieval system is used to melt chocolate.
A better waste management, with particular attention to packages, is also a requisite imposed by the Ecolabel certification. The Ecolabel evaluates the whole life cycle of the production of certified products and services; this means that also the input must be controlled, the materials used cannot be toxic and must be less polluting than the average environmental impact of similar products. The immediate implication is the research of alternative and eco-friendly outputs, for this reason we expect Ecolabel spur innovations. EU Ecolabel minimises the use of hazardous substances that may be harmful to the environment. Substances contained in the products must be also highly biodegradable, so they are less damaging when they flow into the waste water system.
Among the innovative stories of Ecolabel certified firms, we can mention also the Azko Nobel coatings company that introduced many end of pipe line eco innovations to accomplish with the solvent-free cleaning market.

Euros 10,000 for very small companies ($<$ 10 employees)
Euros 20,000 for small companies ($<$ 50 employees)
Euros 35,000 for medium companies (50 $<$250 employees)
Euros 50,000 for large companies ($>$ 250 employees)

[8] http://ec.europa.eu/environment/emas/emasawards/winners.htm

4.3 Factors affecting innovative behavior

The propensity to innovate strongly depends on industry sector and markets characteristics. Firms' technological capabilities are more likely to be highly developed in science based and production intensive sectors (Greenhalgh and Rogers, 2006), in which innovative mechanisms can represent a competitive opportunity to gain market share. Moreover, in these sectors the possibilities of technological improvements are higher than in other industries, and this allows for a concetration of high skilled employees and a higher R&D expenditure.

The development of knowledge and of innovative routines is a cumulative and can have a positive impact on future innovative performance; "innovation breeds innovation" (Baumol, 2002) and we expect that the knowledge stock and the human capital, together with a previous innovative history, makes firms more likely to innovate in the future (Arundel and Kabla, 1998; Horbach, 2008). A major problem when investigating the driving forces of innovation is to introduce measures that proxy for the unobservable firms characteristics. We partially solve this issue by introducing a variable for the innovative history of firms.

Many studies confirms the positive impact of size on innovation (Demirel and Kesidou, 2011; Rennings et al., 2002, among others). The firms' size determines the availability of human resources. Larger firms are also more familiar with scale economies and patenting routines associated with innovation and with appropriability dynamics.

Firms' financial dynamics affect innovation, because R&D requires resources as well as to file a patent. It is uncertain, nonetheless, whether the impact is positive, because it largely depends on the capacity of firms to exploit past and present economic resources. Moreover, previous positive turnover and profits form positive expectations on future selling performance of firms. An expected increase in future demand could trigger innovation.

Finally, how firms can exploit their intagible assets, such as patents and trademarks, can be determinant for future implementations of patents and environmental certifications.

Organizational structure of firms can make the introduction of innovations more likely or more difficult, and the adoption of an EMS could improve innovative performance, but this depends not only on the implementation or not, but also on the characteristics of the implemented EMS. The degree of implementation is firm-specific and the environmental stringency is EMS specific, therefore the impacts on innovation can differ, nonetheless an EMS can spur innovation both by requiring environmental improvements and efficiency increasing, and by leading to cost-savings that means more resources (also) to R&D expenditure.

The implementation of an EMS is strongly related to financial performance, but at the same time, once it is fully operating, can lead to cost-savings, as a consequence of the increased efficiency, establishing a virtuous cycle, in which as far as the EMS works, improvements and innovations are carried out bringing an increase of efficiency that in turns leads to cost-savings that could be invested

in R&D and EMS.
Horbach (2008) and Triguero et al. (2013), regarding the specific case of environmental innovation, acknowledge the importance of the demand side factors: in particular the market share and the pressure exerted by consumers. Environmental innovation is a type of innovation that can be implemented also for reputational reasons, and it could be connected with visibility and firms corporate responsibility that are linked with size.
Moreover sectors are also relevant into identifying the stakeholders environmental awarness and pressure, as well as the pressure exerted by consumers. Manufacturing firms, in this sense, can be more receptive of the instances of environmentally concerned customers with respect to firms not facing directly with final consumers, i.e. not producing final goods.
Regulation can play a role regarding incentives and protection of innovation provided to domestic firms; also the general trend of the economy matters in determining R&D success of countries. The development of patents is negatively correlated with high litigation rates and difficulties to enforce encountered in the national context. The incentive to innovate can be also linked to the possibility to limitate or minimize spillovers mechanisms: shorter imitation time on the market of reference can discourage R&D expenditure, hence innovation (Cohen et al., 2000).
Wagner (2008) tries to recover an effect of EMS interacted with country dummies, but does not find any significant impact. Nevertheless, a cultural impact on the diffusion of EMAS and Ecolabel must be taken into account: it could be that certified firms contribute to clean the supply chain asking for certified products and exerting pressure on other firms of the same market.
According to Horbach (2008), the environmental innovations are less market-drive than other innovations; environmental policy and institutional pressures can act on environmental innovations by directly incentivizing environmental improvements or by forcing the adoption of environmental certifications that in turns bring innovation (Demirel and Kesidou, 2011).

5 Database and descriptive statistics

Our analysis is based on a unique database originating from different sources.
We started from Amadeus database that provides us a sample of 40.000 randomly selected European firms (EU27). We then merged the list of 40.000 firms with those contained in the EMAS Register, in order to identify certified firms, merging at first anagraphical information and then checking the complete correspondence. The European EMAS register, provided by the European Commission, is available on line[9] and yearly updated. At the end of 2012 it was made up by 4502 firms linked to information on registered sites, number of employees, date of the first registration, NACE code and verifiers. From the EMAS register we excluded public administrations.

[9] ec.europe.eu/environment/emas/register

Subsequently we associate to each certified firm the date of the first registration in EMAS, in order to build to further identify EMAS firms registered before the 2003, thus before the starting point of our panel, and firms that obtain the certification during the years covered by the database, namely from 2003 to 2012.
Finally we merged financial data for the whole list of firms from 2003 to 2012 and patent portfolio data that we retrieve both from Amadeus and from PATSTAT database (applicants, priority date, application year and the International Patent Classification, from now on IPC).
Among the firms belonging to the same initial random selection we identify firms with at least one Ecolabel certified product, by merging the firms name and address with a list we built starting from the Ecolabel Catalogue. The Ecolabel Catalogue, at the end of 2012, was composed by 1357 licenses, with information on the name and category of registered products and services, producers, retailers and economic sectors. We chose to exclude services in order to focus on Ecolabel as a product green label. Unfortunately, we don't know the data of the first Ecolabel obtained by each firm, therefore the dummy variable that we could associate in order to capture the presence of Ecolabel is time-invariant.
We end up with a final panel spanning from 2003 to 2012, reporting observations of 30439 European firms, with information on 1.697 EMAS certified firms, and 233 firms with at least one Ecolabel product.
The sample is composed by firms from nine different industries: we distinguish Infrastructure, Trade and General Services from knowledge intensive business services (Kibs), we then divide the manufacturing sector according to three levels of knowledge intensity, High, Medium and Low technology manufacturing sectors. Finally, we introduce the Agriculture sector and we identify the residual category Others that collects household activities and some firms with unknown nace code.
Despite we started with countries from the EU-27 group, the sample includes only firms from 24 countries. This is due to the fact that for some countries the quantity of missing data related to the firms rendomly selected was too large (e.g., data related to eight years out of ten were not available), thus we decide to exclude those countries.
Table 1 provides information about the sample composition, in particular the number of firms divided by sector and the percentage of EMAS and Ecolabel certified firms. Table 2 illustrates the distribution of the sample across the countries.
The first column indicates the sector name, while the second column provides a description of the activities included. The following columns report the number of firms and the percentage out of the sample, the number of EMAS and Ecolabel certified firms in the sector and the percentage out of the sector's firms.
It can be noticed the high concentration of EMAS and Ecolabel firms in medium and low tech manufacturing sectors. In particular, Ecolabel firms are concentrated in manufacturing sector for about the 90%, mainly from Italy (23%), France (21%) and Spain (17,6%). The EMAS certified firms in the sample are mainly from Spain (38,48%) from Germany (25,34%) and from Italy (12,91%);

SMEs among EMAS are prevalent (about 53% of small firms and about 30% medium size firms) and concentrated in manufacturing sector.

Table2. Sample composition by sectors

Sector	Description	N firms	%	N emas	%	N Ecolabel	%
Infrastructure	Electricity, gas supply, water supply and waste management, construction, transportation and storage, real estate activities	6223	20,4%	370	5.9	5	0.08
Trade	Wholesale and retail trade	7713	25,3%	184	2.4	40	0.5
Kibs	Telecommunications, R&D	2423	8%	101	4.2	3	0.1
Other services	Accomodation and food services, financial and insurance activities, administrative and support services, PA and defence, education, human health, arts and entertainement	7240	23.7%	220	3.0	12	0.2
High tech manufacturing	Aerospace , Pharmaceuticals Computers, office machinery , Electronics-communications Scientific instruments	402	1.3%	39	9.7	2	0.5
Medium tech manufacturing	Electrical machinery, Motor vehicles Chemicals, excluding pharmaceuticals, Other transport equipment ,Non-electrical machinery, Coke, refined petroleum products and nuclear fuel, Rubber and plastic products, Non metallic mineral products, Shipbuilding , Basic metals, fabricated metal products	2571	8.6%	380	14.8	100	3.9
Low tech manufacturing	Other manufacturing and recycling, Wood, pulp, paper products, printing and publishing , Food, beverages and tobacco, Textile and clothing.	3208	10.6%	372	11.6	68	2.1
Agriculture	Agriculture, forestry and fishing Mining and quarring	410	1.3%	15	3.6	3	0.7
Others	Households and extraterritorial organizations, residuals (nace unknown)	249	0.8%	16	6.4	0	0
Total		30439	100%	1697	5.6	233	0.7

Table 2 provides the distribution of the sample across countries. The first column indicates the country ISO code, the second column indicates the number of firms from each country, the following columns the number of EMAS and Ecolabel certified firms with the percentage out of the number of firms from the same country.

Table3. Sample composition by countries

Country	N firms	%	N EMAS	%	Ecolabel	%
AT	916	3.0	43	4.6	6	0.6
BE	592	1.9	16	2.7	9	1.5
BG	1	0.0	1	100	0	0
CH	3	0.0	3	100	0	0
CY	23	0.0	23	100	0	0
CZ	21	0.0	21	100	0	0
DE	8905	29.2	396	4.4	18	0.2
DK	652	2.1	31	4.7	19	2.9
EE	2	0.0	2	100	0	0
ES	5271	17.4	651	12.3	40	0.7
FI	7	0.0	5	71.4	4	57
FR	6038	19.8	69	1.0	47	0.7
GB	1351	4.4	43	3.1	15	1.1
GR	15	0.0	12	0.8	0	0
IE	995	3.3	44	4.4	0	0
IT	2497	8.2	229	9.1	54	20
LT	9	0.0	9	100	1	11
NL	305	1.0	10	3.2	7	2.2
NO	385	1.3	18	4.6	0	0
PL	21	0.0	18	86	0	0
PT	2426	7.9	49	2.0	8	0.3
RO	2	0.0	2	100	0	0
SE	1	0.0	1	100	0	0
SI	1	0.0	1	100	0	0
Total	30439		1697		233	

Table 3 provides some information on the presence of innovative firms in the sample, divided by sectors and by group, EMAS, Ecolabel and control group, with the percentage calculated out of the sectors. Further details on innovative firms are provided in the table summarizing number and percentage of innovative firms by group. The innovative firms are the 10.36% of the sample, i.e. 3156 firms out of 30439. Among them, more than a half is concentrated in the medium and low tech manufacturing sector. Not surprisingly, the sector in which the percentage of innovators is the highest is the high tech manufacturing sector.

The EMAS certified firms seems to be more innovative with respect to the control group, as the percentage of EMAS firms with at least one patent in portfolio is the 23.7% against the 9.6% of innovative firms in the control group. Similarly, Ecolabel firms present a higher percentage of innovative firms than the control group (12.4%). The distribution of innovation across sectors is not different between the two subsamples; the peak of patents is in medium and low manufacturing sectors.

Table 4. Innovative firms by sector

Sector	N innovators	%	Emas	%	Ecolabel	%	Control	%
Infrastructure	247	3.9	51	20.6	0	0	196	79.4
Trade	364	4.7	32	8.8	1	0.2	331	91
Kibs	220	9.0	4	1.8	0	0	216	98.2
Other services	283	3.9	8	2.8	1	0.3	274	96.9
High tech manufacturing	226	56	26	0.8	1	0.3	199	98.9
Medium tech manufacturing	1168	45.4	148	12.6	2	0.1	1018	87.3
Low tech manufacturing	619	19	111	18	24	3.8	484	78.2
Agriculture	19	4.6	2	10.5	0	0	17	89.5
Others	10	4.0	1	10	0	0	9	90
Total	3156	10.36	403	12.7	29	0.9	2724	86.4

The table reports the number of innovative firms by sector. The percentages refers to the share of innovative firms in EMAS, Ecolabel and control group. Source: authors elaboration

Table 5. Innovative firms by group

	INNOVATORS	NON INNOVATORS	TOT
EMAS	403 (23.7%)	1294 (76.3%)	1697
ECOLABEL	29 (12.4 %)	204 (87.6 %)	233
CONTROL GROUP	2724 (9.6%)	25989 (90.4%)	28509
TOT	3156 (10.3 %)	27283 (89.6 %)	30439

The table summarizes the share of innovative firms by groups. It can be noticed that the percentages are higher in the case of EMAS and Ecolabel certified firms. Source: authors elaboration

In the sample 1082 EMAS firms obtained EMAS certification before the 2003, while 810 have become EMAS during the period 2003-2012. Table 6 summarizes the number of new registrations per year. Among them, the peak of new certifications happens between 2006 and 2009. New registrations in the first part of the panel, from 2003 to 2005 come from large firms, while after 2005 the average number of employees of new certified firms decreases, hence the new entrances are smaller. Probably this is because of the delay in the adoption of European regulations concerning the policies to advantage SMEs in entering EMAS in Spain and Italy. Indeed, almost all the new accreditations over this period regard SMEs.

Table 6. Registrations over time of new EMAS firms

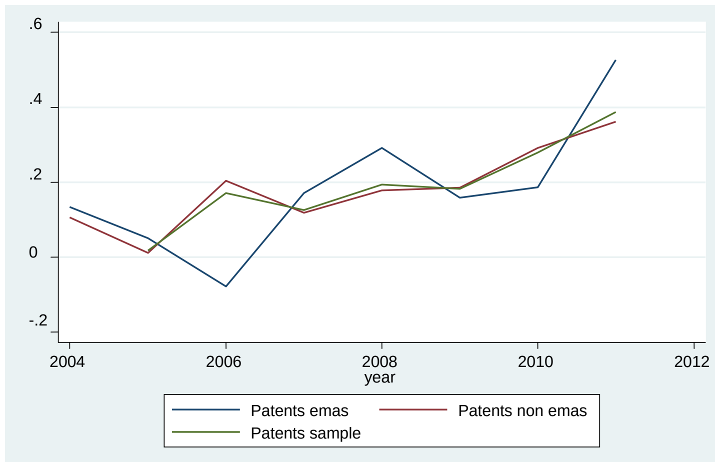
Registration year	N emas	Percentage
2003	40	4.94
2004	90	1.11
2005	50	6.17
2006	150	18.52
2007	110	13.58
2008	140	17.28
2009	70	8.64
2010	60	7.41
2011	60	7.41
2012	40	4.94
Total	810	100

Source: authors elaboration

Figure 1 shows the growth rate of patents over the years 2004 to 2011 for EMAS certified firms, for the control group and for the whole sample. The increasing overall trend reflects the behaviour of the control group trend, while the EMAS trend seems much more complex.

In particular, in correspondence of 2006 the graphic shows a steep fall, after which there is an increase and again a fall in 2009. One possible explanation can be the fact that the majority of EMAS firms are small and medium firms, with limited resources, and a major part in the new accreditations happens between 2006 and 2009. Hence it could be that while investing in the implementation of EMAS, no or few resources were devoted to R&D and patenting activities.

Figure 1. Patents trend



6 Variables

Dependent variable
The dependent variable we consider is the innovation patented by certified and non certified firms, in order to capture the effect of environmental certifications on innovative performance. We therefore build the dependent variable *Patents*. This is a variable reporting the number of patents filed per year by each firm. Despite some drawbacks [10], we choose as dependent variable the number of patents because this allows us to deal with an objective measure of innovation, and to capture the dynamics of the patents flow over time.
The distribution of this variable is skewed and left-censored at zero, and does not provide information about non patentable innovation, but has the advantage to compare a more similar innovative effort, thus we prefer to use an objective measure of innovative output, rather than let assess innovation by firms and adopt a more subjective index of innovative effort.
Explanatory variables
The variables that proxy the adoption of an environmental certification of products or process are *EMAS* and *Ecolabel*. The dummy *EMAS* equals zero for never EMAS firms and it becomes equal to 1 for certified firms, from the year of the accreditation if this happens during the ten years spanned by the panel, or stays equal to 1 from the first year of the panel if the accreditation has been

[10]

obtained before the 2003. The dummy *Ecolabel* is equal to 1 in presence of at least one certified product and 0 otherwise.

While EMAS represents an environmental certification of process, Ecolabel is an environmental certification of product. Even though the effort required by EMAS is higher than other environmental standard, once implemented it could vary over years and across sectors and firms; moreover, it takes some months before entering into full regime, hence we use one year lag of this variable.

Each Ecolabel, on the contrary, requires the same human and financial resources irrespective of size of the firm and product to be certified. Unfortunately, the dummy Ecolabel accounts only for the presence of at least one Ecolabel, but does not take into account if the firms cumulate a greater number of Ecolabel certifications.

Control variables

We control for firm size introducing the variable *N of employees* that represents the number of employees hired by each firm every year, and for firms financial performance by using the variable *Profit*, both are one year lagged.

The analysis controls also for industrial sectors,(*Agriculture Infrastructure Trade Kibs Other services High tech manuf Medium tech manuf Low tech manuf Others*) and for countries (*Country dummies*). We build the Country*year interaction terms, in order to capture the heterogeneous dynamics across countries.

The variable *Environmental expenditure* is an index that reports the share of GDP yearly devoted by the countries to environmental investments, and should reflect the environmental awarness of the country itself and its policy tightness (*Env. Expenditure*).

Finally, we control for the stock of accumulated knowledge of each firm with the perpetual inventory method (*past Innovation*) (Greenhalg and Rogers 2007).

Table 7. Summary statistics. Obs 304390

Variable	Mean	Std. Dev.	Min	Max
Dependent variable				
Patents	0.208	2.098	0	100
Explanatory variables				
EMAS	0.035	0.185	0	1
Ecolabel	0.024	0.154	0	1
Control variables				
Turnover	17234	22734.8	0	64719
N of employees	76.774	159.777	1	4609
Profit	3.97	14.768	-100	100
Agriculture	0.013	0.114	0	1
Infrastructure	0.22	0.414	0	1
Trade	0.242	0.429	0	1
Kibs	0.075	0.263	0	1
Other services	0.231	0.421	0	1
High tech manuf	0.012	0.111	0	1
Medium tech manuf	0.077	0.267	0	1
Low tech manuf	0.098	0.298	0	1
Others	0.031	0.173	0	1
Env expenditure	0.323	0.135	0.11	1.31

Table 8. Comparison between EMAS and Control groups

	Control Group				EMAS			
Variable	**Mean**	**Std. Dev.**	**Min**	**Max**	**Mean**	**Std. Dev.**	**Min**	**Max**
Patents	0.19	1.96	0	100	0.51	3.56	0	96
Turnover	17234	22734.7	0	64719	11540	2064.0	0	21716
N of employees	72.4	155.4	0	4609	154.2	208.4	0	3959
Profit	3.9	14.8	0	100	4.2	13.4	0	100

7 Does the adoption of EMAS foster innovation?

In order to assess the impact of EMAS on innovation, we need to take care of three main problems: sample selection, endogeneity and unobserved (correlated)

individual heterogeneity. Moreover, we want to take into account the dinamics over time allowed by the panel database.
The decision to undertake an environmental certification is a deliberate choice of firms and does not have the characteristics of a randomly assigned variable. It could be that highly productive firms can have enough resources to result into both patents and environmental certifications.
Therefore, we control for unobserved time invariant individual heterogeneity by using a fixed effect model, in particular we rely on the Negative Binomial fixed effect estimation compared with the random effect model. We then check with the Hausman test whether the model is consistent and it turns out it is. To control for time varying country related unobserved factors we introduce the country dummies interacted with year dummies for the main countries.
Unfortunately, since the Ecolabel variable is not time varying, we can perform this model for the EMAS environmental certification only the fixed effect panel analysis, while we run a Negative Binomial for estimating the Ecolabel variable coefficient.
The first model presents the Negative Binomial performed on the whole sample, as well as the second model, that includes the trends country-years related to the major countries represented in the sample, (hence, we reduce the sample to the countries for which we were able to build the country-years interaction). Both the models show a significant and positive coefficient for the variable EMAS. Table 9 provides also the Negative Binomial reporting the Ecolabel variable, revealing a positive effect also for this variable.
We further replicate the model for countries subsamples and for sectoral based subsamples, in order to exploit possible heterogeneities. Models from 3 to 6 illustrate the results obtained for Italy, France, Germany and Spain, singularly considered. Models from 7 to 11 show the results for the following sectors: High tech manufacturing, Medium tech manufacturing, Low tech manufacturing, Kibs and Other services.

Table 9. Negative Binomial. EMAS

	(1)	(2)
Patents		
$EMAS_{t-1}$	0.233*	0.186*
	(0.0936)	(0.0986)
past Innovation	0.0387***	0.0381***
	(0.00149)	(0.00154)
$Nofemployees_{t-1}$	0.0479***	0.0381***
	(0.0103)	(0.0106)
$Profit_{t-1}$	0.0108	0.0212
	(0.0197)	(0.0209)
Env. exp	-0.541+	
	(0.308)	
Years dummies	Y	
Country*Year dummies		Y
Constant	-0.0832	0.306***
	(0.161)	(0.0624)
Observations	304390	251370

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Wald chi2(12)= 1353.95 Prob > chi2 = 0.0000 Log likelihood = -8137.9498

Wald chi2(43) = 1345.55 Prob > chi2 = 0.0000 Log likelihood = -8088.8942

Table 9. Negative Binomial. Ecolabel

	Negative Binomial. Ecolabel
Patents	
Ecolabel	0.727***
	0.186
past Innovation	0.896***
	0.047
N of employees	0.002***
	0.000
Profit	0.008***
	0.002
Infrastructure	0.433
	0.262
Trade	0.941***
	0.257
Kibs	1.330***
	0.270
Other services	-0.055
	0.266
High tech manuf	3.469***
	0.334
Medium tech manuf	2.588***
	0.257
Low tech manuf	1.843***
	0.261
Constant	-4.511***
	0.247
Year dummies	Y
lnα	
	3.022***
	0.045

Number of obs = 300063 Prob > chi2 = 0.0000

Log likelihood = -6512.1929 Pseudo R2 = 0.1334

Table 10. Negative Binomial Country subsamples

	(3) IT	(4) FR	(5) DE	(6) ES)
Patents				
$EMAS_{t-1}$	0.243*	0.0900	0.707***	0.0765
	(0.463)	(0.669)	(0.188)	(0.209)
past Innovation	0.0490***	0.0296*	0.0386***	0.0271***
	(0.00890)	(0.0122)	(0.00164)	(0.00664)
$Nofemployees_{t-1}$	0.0551	0.136	0.0324**	0.0590
	(0.0476)	(0.115)	(0.0115)	(0.0365)
$Profit_{t-1}$	0.0117	0.0109	-0.000117	0.00842
	(0.00722)	(0.0113)	(0.00235)	(0.00721)
Env. exp	-0.8316	5.466	2.123***	2.631
	(0.9282)	(4.295)	(1.961)	(2.516)
Year dummies	Y	Y	Y	Y
Constant	5.805	-7.012	-10.69***	-6.892
	(7.266)	(5.023)	(1.013)	(6.447)
Observations	24970	60380	89050	52710

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Wald chi2(12) = 60.46 Prob > chi2 = 0.0000 Log likelihood = -496.25846

Wald chi2(12) = 30.82 Prob > chi2 = 0.0021 Log likelihood = -233.71496

Wald chi2(12) = 1211.64 Prob > chi2 = 0.0000 Log likelihood = -6691.572

Wald chi2(12) = 38.94 Prob > chi2 = 0.0001 Log likelihood = -650.07903

Table 11. Negative Binomial Sectors subsamples

	(7) high tech m	(8) medium tech m	(9) low tech m	(10) kibs	(11) other services
Patents					
$EMAS_{t-1}$	0.0164	0.0259	1.172***	-1.005	2.187 **
	(0.308)	(0.155)	(0.301)	(0.672)	(0.7192)
past Innovation	0.0487***	0.0414***	0.0430***	0.0350***	0.0319***
	(0.00568)	(0.00235)	(0.00412)	(0.00572)	(0.00375)
$Nofemployees_{t-1}$	0.00539	0.00108	0.109***	-0.0108	0.0505*
	(0.0313)	(0.0183)	(0.0264)	(0.0416)	(0.0237)
$Profit_{t-1}$	-0.000487	0.00847*	0.00100	0.00150	-0.00384
	(0.00569)	(0.00413)	(0.00608)	(0.00652)	(0.00354)
Env. exp	-2.822+	-0.774	0.118	-21.18	-4.548
	(1.589)	(0.750)	(1.813)	(18.06)	(3.023)
Country*Years	Y	Y	Y	Y	Y
Constant	1.923*	0.801*	0.111	11.68	2.710+
	(0.865)	(0.392)	(0.944)	(9.399)	(1.597)
Observations	960	19260	15550	1695	22960

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Wald chi2(37) = 170.57 Prob > chi2 = 0.0000 Log likelihood = -778.56761

Wald chi2(36) = 551.16 Prob > chi2 = 0.0000 Log likelihood = -3034.7504

Wald chi2(36) = 261.96 Prob > chi2 = 0.0000 Log likelihood = -1328.7994

Wald chi2(36) = 117.89 Prob > chi2 = 0.0000 Log likelihood = -512.72605

Wald chi2(36) = 187.50 Prob > chi2 = 0.0000 Log likelihood = -877.60243

7.1 Instrumental variable

The main question addressed by this paper is whether environmental certifications such as EMAS and Ecolabel spurs innovation at firm level. To answer this issue we test the model:

$$Innovation_{i,t} = \alpha_i + \beta Environmental\ \ Certification_{i,t} + \beta Z_{i,t} + \epsilon \qquad (1)$$

The econometrical approach followed so far, the Negative Binomial estimation, allows for the fixed effects introduction that control for unobserved heterogeneity of firms. The estimation results holds also when controlling for country specific period trends. However, this approach does'n take into account the potential endoeneity provoked by the fact that unobseverd factors affecting innovative behavior can also affect the likelihood to adopt an environmental certification. Furthermore, a simultaneity issue cannot be excluded, leading to a simultaneous causality bias (EMAS spurs innovation, innovative behavior affects EMAS adoption). We thus expect the variable EMAS to be correlated with the error term of the main regression.

To produce a consistent estimation of the EMAS coefficient on innovation we perform a 2SLS model. A valid instrument lets us isolate a part of EMAS that is uncorrelated with the errors in our main regression, and that part can be used to estimate the effect of a change in EMAS on innovation. We use the variable *VerifiersTrend* as instrument: it represents the growth in the number of private EMAS verifiers over the period covered by the panel.

The EMAS regulation establish that in each country there must be private counselors or organizations of consulence encharged by national public environmental authorities to verify the existence of the EMAS requisite before to grant the certification. Since they are private couselors, they are interested in proposing their services to firms: they attend a specific training to become verifiers, and after that they propose to firms their service, by presenting the advantages to become EMAS or Ecolabel certified. Therefore, they foster the environmental certification and spread the information among local firms. Their presence in European countries has been constantly increasing over time, and their promotion of the environmental certification is complementary to that implemented by public environmental authorities. A larger number of verifiers means a greater promotion on the territory of EMAS certification, a greater availability of means to start the procedure of accreditation and, eventually, a greater number of firms that decide to adopt the certification.

The variable *VerifiersTrend* is correlated with the decision of firms to implement the EMAS certification, however it is not correlated with the decision to implement or not innovation. It can be noticed that the number of verifiers and its trend it's totally exogenous with respect to country specific innovation trends, since it is not determined by any public incentives and it is totally dependent on the voluntary choice of private experts that get a qualification and want to exploit it on the market.

Therefore the instrumental variable is not correlated with the error term of our

main regression, since there are no unobserved factors able to influence both *VerifiersTrend* and the number of patents filed by firms (Instrument exogeneity requisite), but at the same time is plausibly correlated with the decision to join the EMAS standard (Instrument relevance requisite).
The first step of our model therefore estimates EMAS as a function of *VerifiersTrend*. The F statistics is large enough to guarantee that the instrument is not too weak. The second step estimates the main regression replacing the EMAS estimation retrieved by the first step.
The model is:

$$Innovation_{i,t} = \alpha_i + \beta Environmental\ \ Certification_{i,t} + \beta Z_{i,t} + u_i \tag{2}$$

Corr(*VerifiersTrend*, EMAS)$\neq$ 0
Corr(*VerifiersTrend*, u_i)= 0

First step:

$$EMAS_{i,t} = \alpha_i + \beta VerifiersTrend_t + u_i \tag{3}$$

Second step:

$$Innovation_{i,t} = \alpha_i + \beta EMAS\ \ hat_{i,t} + \beta Z_{i,t} + u_i \tag{4}$$

The Hausman test confirms that EMAS is an endogenous variable (we compare the OLS against the 2SLS), but we cannot perform another test to verify the goodeness of the instrument since the model is just identified.

Table 12

2SLS estimation: IV=VerifiersTrend

	first_step	second_step
VerifiersTrend	0.041***	
	0.009	
N of employees		0.001***
		0.000
Profit		0.003***
		0.001
Infrastructure		-0.197**
		0.067
Trade		-0.097
		0.067
kibs		0.024
		0.075
Other services		-0.170*
		0.068
High tech manuf		2.172***
		0.280
Medium tech manuf		0.890***
		0.092
Low tech manuf		0.183*
		0.075
Others		-0.175**
		0.067
Country*years		Y
EMAS hat		0,931***
		0,152
_cons	0.046***	-4.210***
	0.000	0.694

Number of obs = 300048 F(1,250046) = 19.65 Prob > F = 0.0000
F(51, 98182) = 30.41 Prob > F = 0.0000 R-squared = 0.0449
Root MSE = 2.663

It can be that firms become innovative and file patents only when they exceed a certain threshold of innovativeness. We, nevetheless, take into account the number of patents, introducing a proxy for the magnitude of the innovation carried out by firms. We propose therefore a further attempt to correct potential selection bias due to the fact that there are factors influencing the likelyhood of firms to be innovative or not, imposing a first selection of the sample in innovative and not innovative firms, and factors the determine how much innovative firms are innovative. Thus, we perform a two step Heckman model, maintaining in the main regression our intrumental variable, namely, the main regression is the same as previous model, but we select firms between innovative and not innovative by controlling for sectoral dummies in the first step.
The selection equation (Probit) estimates the probability of being innovative or not, while the second step estimates how much innovative firms are innovative, including as an additional explanatory variable the inverse MillâĂŹs ratio derived by the first step equation (Heckman, 1979; Dubin and Rivers, 1989; Wooldridge, 2002) and the EMAS estimation as derived by the first step of the previous model (See Amemiya 1985)[11].

[11]The selection equation is a Probit:

$$Z_i^* = W'\alpha_i + \epsilon, \qquad with Z_i^* = \begin{cases} 1 & if z_i^* > 0 \\ 0 & otherwise \end{cases} \tag{5}$$

The second step is a linear outcome equation:

$$Y_i = \alpha + \beta_i Environmental\ \ certification\ \ hat + \beta_i \lambda + u$$

(6)

Table 13

Heckman twostep estimation

	heckman
Patents	
N of employees	**0.001*** **
	0.000
Profit	**0.003*** **
	0.001
EMAS hat	**1.002*** **
	0.149
Country*years	**Y**
_cons	**-4.648*** **
	0.717
Select	
Infrastructure	**0.241*** **
	0.053
Trade	**0.257*** **
	0.052
Kibs	**0.478*** **
	0.055
Other services	**0.282*** **
	0.052
High tech manuf	**1.517*** **
	0.058
Medium tech manuf	**1.271*** **
	0.051
Low tech manuf	**0.756*** **
	0.052
_cons	**-2.680*** **
	0.050
Mills	
λ	**-0.369*** **
	0.095
ρ	**-0.35059**
σ	**11.563**

Number of obs = 274764
Censored obs = 270282 Uncensored obs = 4482
Wald chi2(38) = 262.49
Prob > chi2 = 0.0000

8 Results and discussion

The panel analysis perfomed on different subsamples allow us to control for individual unobserved heterogeneity: the negative binomial models were performed on the whole sample and on subsamples based on countries and sectors.
The negative binomial performed on the whole sample reveals a positive impact of the EMAS certification on innovation; the coefficient however becomes smaller when controlling for all the period trends combined with countries. Past innovation as well as size positively affect innovation, while it seems that the financial performance does not exert any significant impact.
Among the country based subsamples only the regression related to Italy and Germany show a positive and significant impact of EMAS, while the regressions on Spanish and French firms seem overall less significant.
An interesting hypothesis can be put forward by looking at the sectoral based analysis: EMAS is positive and significant for sectors characterized by low knowledge intensity, while it does not have any impact on firms belonging to high (and medium) technological sectors. From this, we can suppose that EMAS exerts a different impact across sectors and that does not spur innovation "per se", but it is effective in fostering innovation mainly for those sectors in which the R&D expenditure is originally low and not very frequent. While the impact is not significant whenever the sector is characterized by strong R&D activities.
The 2SLS confirms the positive impact of EMAS on innovation, as well as the Heckman two step estimation. Sectoral dummies are significant and control for the positive impact of manufacturing and the negative impact of services on innovation. The results are robust to the introduction of country specific trend periods.

9 Conclusions and future research

The paper investigates the impact of EMAS and Ecolabel environmental certifications on innovation using a database of 30439 European firms, and analyzing the innovative performance of certified and non certified firms over a panel spanning from 2003 to 2012. We examine the impact of the environmental certifications on innovation by performing several econometric attempts, in order to solve the main methodological issues.
We try to take into account the unobserved firm heterogeneity and to control to some extent the endogeneity issue. The mains findings of this paper concern the positive impact exerted by the environmental certifications on innovation; in particular, the analysis reveals stronger effect for sectors characterized by low knowledge intensity, namely for low tech manufacturing and general services sectors, and for two out the four main countries considered (Italy and Germany).
Further investigation on sectoral based subsamples will help to clarify not only whether EMAS fosters innovation but also when and at what conditions. This can be a promising attempt to better understand the role of the environmental

certifications across sectors.
Further investigation is also needed to complete the comparison between environmental regulation and environmental certification effects on innovation at firm level, and whether sectors react differently to mandatory or voluntary environmental regulations.

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