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Abstract

This paper aims at analyzing whether environmental management systems can spur innovation at firm level, by providing new empirical evidence on the relationship between EMAS (Eco Management and Audit Scheme) and patented innovation. In applying a Negative Binomial model with Fixed Effect, we estimate the number of granted patents using EMAS as key explanatory variable. The relationship between EMAS and innovation is studied by using an original panel database composed by 30439 European firms belonging to all sectors and size. Moreover, we use an original instrumental variable to control for potential endogeneity. The analysis reveals that EMAS is positively correlated with innovation at firm level, although the results vary across countries and sectors.

Keywords: Innovation; Environmental management systems; Patents; Eco-Management and Audit Scheme.

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1. Introduction

Environmental Management Systems (EMSs) are considered a promising type of environmental policy instrument finalized to increase the environmental awareness of firms and to reduce their environmental impact. EMSs are implemented voluntarily by private firms, however worldwide environmental authorities strongly encourage their adoption through subsidies and technical support. The European Commission provided since the 1993 the official European EMS, the Eco Management and Audit Scheme (EMAS), to certify firms adopting well defined eco-management practices.

The number of EMAS registered sites has been constantly increasing over time (about 38% over the last ten years in UE27) as well as the academic effort to explore potential impacts of its implementation at sectoral and at firm level, with particular attention to the impact on innovation (e.g. Wagner, 2007; Rennings et al., 2006; Frondel et al., 2008; Horbach, 2008; Ziegler and Nogareda, 2009; Demirel and Kesidou, 2011).

According to the existing literature, several advantages are associated with EMSs implementation: Molina-Azorín et al. (2009) analyze the literature related to the EMS' impact on firms' financial performance, noticing that studies where a positive impact of environment on financial performance is obtained are predominant. Iraldo et al. (2009) show the positive impact of EMSs on environmental performance and on self-reported technical and organizational innovations. Hering et al. (2012) demonstrate the positive impact of EMS implementation on exports; Lan et al. (2012) find a positive impact of EMS on human capital. Morrow and Rondinelli (2002) highlight the importance of the reputational effect of EMS implementation as well as the improvements in terms of energy efficiency; Dasgupta et al. (2000) provide empirical evidence that the EMS spurs regulatory compliance.

However, in some countries[1], the growing concern about the long-term profitability of EMSs on competitive markets, the perceived absence of economic returns associated to the costs of EMSs implementation and the absence of a strong signaling on the market (Hillary, 2004; Morrow and Rondinelli, 2002; Massoud et al., 2010), caused a slowdown in new registrations and in some cases provoked a drop of certified firms. Technological innovation is a key factor for achieving a better environmental

[1] German certified sites were 1830 in 2003, while decreasing up to 1212 in 2012. In Sweden, certified firms were 115 in 2003 but only 55 in 2012. A smaller decrease in Austria: from 298 in 2003 to 255 in 2012. Finally, in UK from 75 certified sites in 2003, only 48 certified sites are registered in 2012.

performance and for ensuring competitiveness of firms[2], however, it is controversial whether the EMS can spur innovation. It is not clear indeed whether the positive correlation between innovation and EMS often found in the literature is (at least partially) due to the fact that more innovative firms are also more likely to be certified because there are (unobserved) factors spurring both innovation and EMS adoption.

Existing literature often lacks of longitudinal dimension (e.g. Frondel et al., 2008; Ziegler and Nogareda, 2009) as well as cross country comparison (e.g. Horbach, 2008; Demirel and Kesidou, 2011) and mainly rely on self-assessed innovation and self-reported degree of EMS implementation. Furthermore, the empirical evidence is not conclusive: apparently, the EMS correlates differently with innovation according to specific types of innovation considered (Ziegler and Nogareda, 2009; Frondel et al., 2008) or according to the specific EMS considered.

In order to overcome at least some of the limitations of previous studies, this paper relies on a database of 30439 European firms from 24 different countries, that collects data from 2003 to 2012. We consider EMAS as a specific and highly requiring EMS for several reasons: firstly because it is the official European EMS, secondly, because it entails a number of core activities common to all firms and clearly defined, but proportioned to their size, and finally because strong empirical evidence on its impact on innovation at firm level over time is scarce.

This paper uses the count of granted patents to identify innovation at firm level (Wagner 2007). The literature on this topic makes a limited use of patent data (Wagner, 2009). Patents are a very noisy indicator of innovative activity but however they provide comparable measure of innovative outcomes (across time and countries). The results of our investigation reveal that EMAS is effective in fostering innovation at firm level.

The rest of the paper is organized as follows: Section 2 presents the relevant literature, Section 3 develops the relationship between EMAS and innovation. Section 4 concerns the data source and the methodology. We present our econometric results in Section 5; Section 6 concludes.

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[2] See for instance Costantini and Mazzanti (2012), Cainelli (2008); for a critical review on the relationship between innovation and firms' performance see Brusoni et al. (2006).

2. Literature review

The EMS can be defined as "an 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 performance" (Khanna and Anton, 2006). EMAS[3] similarly to all EMSs has a core of activities, entailing the publication of a periodical environmental report, the definition of management activities finalized to establish continuous environmental improvements, and the periodical assessment of outcomes, according to the scheme "Plan-Do-Check-Act". EMAS has its own guidelines, and the third party audit allows firms to obtain the certification or its renewals over time.

A number of empirical studies have attempted to identify the determinants of innovation at the firm level, and whether an EMS could be considered one of them. Several papers indeed introduce the EMS as a key explanatory variable of innovation, however, the majority of these studies are based on self-assessed data on innovation and do not 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, such as the end of pipeline pollution control technologies, the integrated cleaner production technologies and the environmental R&D. The paper introduces among the determinants of eco innovation the internal firm level motivations, namely the organizational capabilities of firms, in particular the presence of any EMS. The econometric results show that the EMS is effective in motivating firms to undertake investments in end of pipeline green technologies and 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

[3] EMAS was drawn by the European Commission with Reg. CEE 1836/93, in the context of the Fifth EU Environment Action Programme 'Towards Sustainability'. EMAS was originally restricted to companies in industrial sectors but since 2001 it has been open to all economic sectors including public administrations. A second version of EMAS (EMAS II) was adopted by European Commission with Reg. 761/2001, and a further implementation was drawn with Reg. 196/2006. The ultimate revision (EMAS III) has been published in 2009 (Reg. 1221/2009); it subsumes previous regulation, and entered into force on 11 January 2010.

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 solved by Frondel et al. (2008) that find no effect of EMS on pollution abatement innovations. This paper addresses the issue of the relationship between EMSs and environmental innovation performance by modeling a recursive bivariate probit model that allows for 899 German firms' decision on innovation activities and EMSs adoption to be simultaneous. The econometric estimation reports no significant effect of the EMS as a determinant of abatement technological innovations.

An attempt to analyze the reverse causality between EMSs and innovation has been also performed by Ziegler and Nogareda (2009). The aim of the paper is to analyze whether the adoption of an EMS or other environmental assessment activities in 368 German manufacturing firms during 2003 can be explained as (partially) dependent on the adoption of any technological environmental innovation implemented over the years 2001-2003. The paper considers both formal and informal management systems. 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). This paper overtakes the difficulties related to the use of cross-sectional data, by relying on two different panel databases[4]. The econometric results of the first analysis confirm a positive role of the environmental management tools in determining the adoption of an environmental innovation in the two previous years. The environmental innovation is self-assessed by firms and it is limited to a binary variable that does not take into account the magnitude of the innovative performance. The paper reports a second analysis using the MIP panel

[4] The establishment panel of the Istitute for Employment Research (IAB) and the Mannheim innovation panel (MIP).

wave 2001, collecting data for 4846 firms in the manufacturing and service sectors. The paper considers any change in the organizational structure (which includes the introduction of EMS, but in a generic sense, e.g. any management system, even informal) and shows a positive effect on innovation measures.

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 introduces wide heterogeneity in the environmental effort declared by firms. Antonioli et al. (2013) study the relationship of complementarity between organizational changes and training[5] on environmental innovations, finding no complementarity when the objective considered is the adoption of EMAS/ISO standards. 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 study considers EMAS validated manufacturing German facilities to investigate the impacts of different characteristics of EMAS on technical environmental innovations and economic performance. 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 ISO14001 on innovative performance of 1499 Japanese firms in 2003.

[Table 1 about here]

3. Why EMAS should foster innovation?

This paper asks whether EMAS affects the probability of European firms to develop new patents. Recent literature seems to agree that a positive, even if weak, effect of EMSs on less tangible assets of firms such as reputation and innovativeness apply (Wagner, 2007; Rennings et al., 2006). Wernerfelt (1984; 1995) suggests that EMS adoption fosters the development of strategic resources and competitive advantages which have a positive influence on firms' innovative capabilities (Wagner, 2007). However, this positive correlation does not prove causality, and the dynamics between

[5] High Performance Work Practices (HPWP) and Human Resource Management (HRM).

EMSs adoption and innovative behavior can be better investigated with longitudinal data which allow for controlling for unobserved characteristics of firms (Ziegler and Nogareda, 2009).

The development of knowledge is a cumulative process and can have a positive impact on future innovative performance (see Baumol, 2002); Rennings et al. (2006) demonstrate the importance of learning processes by EMSs in developing environmental product innovations, though the study was limited to certified firms and does not provide a comparison with non-certified firms' performance. Indeed, EMS implementation can result in a new internal source of knowledge, and, at the same time, it can bring externally sourced knowledge, based on cooperation with other certified firms and partners. The complementarity between internal and external knowledge has been widely investigated as a determinant of innovation development (Cassiman and Veugelers, 2006; Caloghirou et al., 2004; Arora and Gambardella, 1994).

The organizational structure of firms can make the introduction of innovations more likely or more difficult, and the adoption of well-designed EMSs can improve innovative performance. A characteristic of EMSs is that they provide permanent incentives for further reductions of the environmental impact. Even though EMAS has been defined a "medium swords" program (Potoski and Prakash, 2005) because it does not sanction shirkers, it nonetheless entails periodical monitoring and annual public disclosure of the environmental performance of adherents[6]. Certified firms have to monitor their activities and improve their performance under several indicators. In particular EMAS firms monitor six key indicators introduced by the latest EMAS version (EMAS III, Reg. CE 1221/09): 1. Energy efficiency; 2. Raw material efficiency; 3. Water (use); 4.Waste; 5. Bio diversity; 6. Emissions[7].

[6] See for example the environmental performance (Iraldo et al., 2009; Daddi et al., 2011), or the economic performance, among others, Khanna and Damon (1999) that analyze the impact of another "medium sword" program (the "33/50 US Program") and its impact on short and long run profitability of firms, finding a positive effect on long run profitability.

[7] The EMAS specific technical indicator are: Total direct energy use: total annual energy consumption, expressed in MWh or GJ. Total renewable energy use: percentage of total annual consumption of energy (electricity and heat) produced by the organisation from renewable energy sources. Annual mass-flow of different materials used (excluding energy carriers and water): in tonnes. Total annual water consumption: in m3. Total annual generation of waste: in tonnes. Total annual generation of hazardous waste: in kilograms or tonnes. Use of land: in m2 of built-up area. Total annual emission of greenhouse gases (incl. at least emissions of CO2, CH4, N2O, HFCs, PFCs and SF6): in tonnes of CO2 equivalent. Total annual air emission (incl. at least emissions of SO2, NOx and PM): in kilograms or tonnes.

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 required compliance with the EMAS can be assimilated to the duty to comply with mandatory environmental regulation. A broad strand of the literature analyzes the relationship between stringent environmental regulation and innovation, partially driven by the theoretical framework of the Porter hypothesis (Porter and van der Linde, 1995; Horbach et al., 2012, Rennings and Rammer, 2011). Jaffe and Palmer (1997) find that increasing the environmental regulatory compliance expenditure influences positively general technical innovation. Similarly, Brunnermeier and Cohen (2003) find that environmental innovation responds to increases in pollution abatement expenditures.

Rennings et al. (2006) argue that, even though market-based instruments are generally considered those with the highest dynamic/innovation efficiency with respect to command and control regulation, standards can be more effective in stimulating environmental innovation in situations characterized by strategic behaviors of firms (i.e., when the impact of one's own activities on other firms are taken into account).

Although EMAS is a non-mandatory policy instrument, it is a standard; it entails environmental expenses and can be assimilated to stringent environmental regulations. Therefore, we expect a positive effect of EMAS on innovation.

This analysis uses patent data to address the research question, namely whether EMAS improves innovative performance of European firms. The count of patented innovations captures an objective and comparable measure of innovation and reveals how much a firm is innovative. So far, the use of patent data to investigate the relationship between EMSs and innovation is still limited; to our knowledge only Wagner (2007) addresses the issue of the link between EMSs and environmental innovation performing a patent analysis.

4. Database and methodology

4.1 Database

The analysis is based on a unique database originating from different sources. We started from Amadeus database that provides us a random sample of 40000 European (EU27) firms. We then merged the list of 40000 firms with those contained in the

EMAS Register[8], updated to 2012, in order to identify certified firms, merging at first tax code and company name information and then checking the complete correspondence with the full address. At the end of 2012 it was made up by 4502 firms and contains information on registered sites, number of employees, date of the first registration, NACE code and environmental verifiers responsible for the accreditation. From the EMAS register we excluded public administrations. We also use data on Environmental Expenditure on GDP from Eurostat[9].

We merged financial data for the whole list of firms from 2003 to 2012 and patent portfolio data from the Amadeus database. We obtained a final panel spanning from 2003 to 2012, reporting observations on 30439 European firms.

The sample is composed by firms from eight different industries plus a residual category: 1. Infrastructure, 2. Trade 3. General Services, 4. Knowledge Intensive Business services (Kibs), 5. High Tech Manufacturing, 6. Medium Tech Manufacturing, 7. Low Tech Manufacturing, 8. Agriculture and 9. Others.

Table 2 shows the sample composition by sector. SMEs among EMAS are prevalent (about 53% of small firms and about 30% medium size firms). Table 3 displays the composition by country. It can be underlined that EMAS certified firms in the sample are mainly in Spain (38.48%) Germany (25.34%) and Italy (12.91%). Table 4 shows that the highest concentration of EMAS certifications is in medium and low tech manufacturing sectors.

[Table 2 about here]

[Table 3 about here]

Innovative firms represent 10.36% of the sample (firms with at least one granted patent), among them, more than a half is concentrated in the Medium tech and Low tech manufacturing sector. Not surprisingly, the sector in which the percentage of innovators is the highest is the High tech manufacturing sector. EMAS certified firms seems to be more innovative with respect to non certified firms, as the percentage of EMAS with at

[8]The European EMAS Register, provided by the European Commission, is available on line and yearly updated (http://ec.europa.eu/environment/emas/register/)

[9] http://ec.europa.eu/eurostat/data/database.

least one patent in their portfolio is 23.7% against 9.6% of innovative firms in non certified firms group.

[Table 4 about here]

[Table 5 about here]

In our sample, 1082 EMAS firms obtained EMAS certification before 2003, while 810 became EMAS during the period 2003-2012. Table 6 summarizes the number of new registrations per year. The peak of new certifications is between 2006 and 2009. In the same years, as shown by Graph 1, the growth rate of patents of EMAS group has a fall, after which there is an increase. One possible explanation can be that the majority of EMAS firms are SMEs, with limited resources, and it could be that while investing in the new implementation of EMAS, no or few resources were devoted to R&D and patenting activities. However, once EMAS is established, it can affect positively innovative performance and spurring the growth rate of patents over the growth rate in patented innovations of the non EMAS, as well as the whole sample trend.

[Table 6 about here]

[Graph 1 about here]

4.2 Variables and methodology

The positive correlation between EMAS and innovation does not automatically imply causality. A reverse causality problem can be identified: innovation can spur the implementation of EMSs, or the decisions of firms to develop innovation and to adopt EMAS are considered at the same time. Some characteristics of firms affecting $EMAS_{i,t-1}$ as well as $PATENTS_{i,t}$ variables are likely to be correlated with unobserved factors relegated into the error term. The endogeneity source resides therefore in omitted firm specific variables.

To deal with these issues, we use panel data, we lag of one year the explanatory variable $EMAS_{i,t-1}$, we introduce fixed effects, we control for dynamic country and sector specific trends, and we finally use an instrumental variable.

The model we estimate is:

$$PATENTS_{i,t} = \alpha_i + \beta_1 EMAS_{i,t-1} + \beta_2 Z_{i,t-1} + \varepsilon_i \quad (1)$$

where $PATENTS_{i,t}$ is the dependent variable, $EMAS_{i,t-1}$is the key explanatory variable and $Z_{i,t-1}$ represents several control variables.

The dependent variable $PATENTS_{i,t}$ report the number of granted patents in the year by each firm in the sample. The independent variables have been chosen for the analysis on the base of prior empirical literature, provided their availability on our database (see for instance Wagner, 2008; Demirel and Kesidou, 2011; Horbach et al., 2008; Frondel et al., 2008). The explanatory variable related to our research question is the dummy $EMAS_{i,t-1}$; it 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 covered by the panel, or stays equal to 1 from the first year of the panel if the accreditation has been obtained before the 2003.

Wagner (2007) argued that a certification dummy is a relatively weak measure for EMS implementation, especially because it contributes to raise the reverse causality issue. Unfortunately, our data do not include a measure of implementation degree; however EMAS implementation presents a minimum level of implementation irrespective of size and sector of activity, guaranteed by local environmental authorities that support private environmental verifiers in conceding the accreditation. This should ensure comparability of the effort and of the degree of implementation.

As a further attempt to control for the reverse causality, $EMAS_{i,t-1}$ is lagged of one year[10]. According to Rehfeld et al. (2007), using a lag of the explanatory variable seems of limited effectiveness; they find a high correlation of environmental innovations carried out in the past and planned for the future. Thus there should be high correlation between plans related to past and future environmental innovation and EMSs adoption.

[10] As a further attempt to test the effect of the adoption of EMAS we introduce several lags in the Negative Binomial model. Here we report the coefficients (st. err. in parenthesis): $EMAS_{i,t-2}$: 0,091* (0,021); $EMAS_{i,t-3}$: 0,607* (0 .286) and $EMAS_{i,t-4}$: -0.350 (0.244).

However, this is not automatically true for generic innovation that appears to be less correlated with environmental expenditure planned and linked to the implementation of EMSs. Nonetheless, we control for $PASTINNO_{i,t-1}$ of firms, calculated with the perpetual inventory method (Greenhalgh and Rogers, 2007)[11].

We include several control variables ($Z_{i,t-1}$) such as the number of employees ($EMPLOYEES_{i,t-1}$) and past profits (expressed as share of turnover, $PROFIT_{i,t-1}$) to take in account size and past financial performance of firms. We also introduce the share of GDP devoted by countries each year to the environmental expenditure ($ENV\ EXP_{i,t-1}$), as an attempt to control for country specific effects on innovation. This index should help controlling the trend in new certifications that could be generated by country specific environmental regulation. All these variables are lagged of one year.

Other control variables included are *YEAR* dummies, to capture period trend effects, and the interactions between years and country dummies for the major countries in the sample. Wagner (2008) tries to reveal an effect of EMS interacted with country dummies, but does not find any significant impact. Nevertheless, a dynamic effect of country specific characteristics, such as regulation, domestic market characteristics, intellectual property rules and enforcement, and many others, cannot be excluded therefore we include *COUNTRY*YEAR* interaction term.

Finally we control for sector specific dynamics by interacting years and sector dummies. We do not have information on R&D carried out by companies, but, on one hand we know from the literature that for SMEs the R&D missing data should be more correctly read as zero R&D expenses, since R&D investments are strictly correlated with size (Brunneimer and Cohen, 2003; Shefer and Frenkel, 2005). On the other hand, we know that the propensity to innovate strongly depends on industries. Firms' technological capabilities are more likely to be highly developed in science based and production intensive sectors, 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

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[11] Past innovation is estimated using the perpetual inventory method:

$$\text{Past Innovation}(t) = (1-\delta)\text{patent stock}(t-1) + \text{patent flow}(t) \quad \delta=0.10$$

where patent stock denotes the patents portfolio of firms and patent flow is the number of patents granted in year t.

allows for a concentration of high skilled employees and a higher R&D expenditure. Therefore we try to control at least at sector level for R&D effort by introducing the dynamic *SECTOR*YEAR* interaction term.

[Table 7 about here]

4.3 Instrumental Variable

With the approach followed so far, the endogeneity issue has not been completely ruled out. We expect the variable $EMAS_{i,t-1}$ to be correlated with the error term of the main regression. To produce a consistent estimation of the $EMAS_{i,t-1}$ coefficient therefore we introduce an instrumental variable. A valid instrument lets us isolate a part of $EMAS_{i,t-1}$ 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 *VERIFIERS* as instrument: it represents the number of private environmental verifiers per country over the period covered by the panel. This instrumental variable has never been used before to our knowledge and represents an innovative contribution of this study.

The EMAS regulation establishes that in each country there must be private experts or companies charged with public environmental authorities to verify the existence of EMAS requisites to grant the certification. Since they are private consultants, 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 competences, by presenting the advantages to become EMAS certified. Therefore, they foster EMAS adoption and spread the information among local firms. Their presence in European countries has been overall increasing over time, even. At the end of 1998 environmental verifiers were 262; at the end of 2014 they reached the number of 411 operating in European Union. A larger number of environmental verifiers means a greater promotion on the territory of EMAS, a greater availability of opportunities to start the procedure of accreditation and, eventually, a larger number of firms that decide to adopt the certification.

The variable *VERIFIERS* is correlated with the decision of firms to implement EMAS, however it is not correlated with the decision to develop or not patentable innovation. It can be noticed that the number of verifiers and its trend it's exogenous to country specific innovation policies, since it is not determined by any public incentives or subsidy and it is totally dependent on the voluntary choice of private experts that obtain a specific environmental qualification and try to exploit it on the market. Therefore we estimate the model:

$$PATENTS_{i,t} = \alpha_i + \beta_1 \hat{E}MAS_{i,t-1} + \beta_2 Z_{i,t-1} + \varepsilon_i \quad (2)$$

where $\hat{E}MAS_{i,t-1}$ is the predicted value obtained using the instrument *VERIFIERS*. We estimate the IV Poisson model, whose results are shown in Table 11. The model estimates the parameters of a Poisson regression model in which some of the regressors are endogenous and it is suitable to model nonnegative count outcome. We use the Control-function estimator that, as described by Wooldridge (2010), uses functions of first-stage parameter estimates to control for the endogeneity in the second stage.

5. Empirical results

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 effects model, in particular we rely on the Negative Binomial Fixed effects estimation.

Table 8 presents the Negative Binomial[12] performed on the whole sample as well as the Poisson model. The most important finding of this analysis is that the variable $EMAS_{i,t-1}$ shows a positive and significant coefficient, being therefore effective in spurring innovation at firm level. The result holds when controlling for *COUNTRY*YEAR* and *SECTOR*YEAR* interaction terms, as robustness check. For these models we calculate the Incidence Rate Ratios. A variation of one unit in the $EMAS_{i,t-1}$ variable, i.e. from 0 to 1 in the case of EMAS, is associated with a patent count increase of 1.299 in the dependent variable for the first regression, an increase of 1.2101 in the count dependent

[12] The Negative Binomial model seems to fit better if compared with the Poisson model, for some reasons. The sample mean is 0.21 whereas the sample variance is 4.32, so there is overdispersion. The test for overdispersion confirms it (coeff. 7.66*** SEs 1.77).

variable in the second estimation and an increase of 1.276 in the third estimation. Past innovation, as well as firms' size, positively influences innovation, while it seems that previous period financial performance does not exert any significant impact.

[Table 8 about here]

We replicate the model for countries subsamples and for sector based subsamples, in order to exploit possible heterogeneities. Models from 3 to 6 (Table 9) illustrate the results obtained for Italy, France, Germany and Spain, singularly considered. Only the regressions related to Italy and Germany show a positive and significant impact of $EMAS_{i,t-1}$, while the regressions on Spanish and French firms seem overall less significant. These results are worth of further consideration; in particular, the analysis related to such countries can be deepened with the introduction of the national regulatory framework in the model, to better understand the factors that differentiate German and Italian firms among the other European firms.

Table 10 (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.

An interesting hypothesis can be put forward by looking at the sector based analysis: $EMAS_{i,t-1}$ 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. A possible explanation for this can be 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. Firms with low level of internal R&D could take advantage from EMAS by adding competences and routines to their existent knowledge, as a source of external knowledge with potential complementarity or substitution effects with other sources of knowledge creation.

[Table 9 about here]

[Table 10 about here]

This study corroborates the results on the relationship between EMAS and innovation introducing an original instrumental variable (Table 11). The estimation with $\hat{EMAS}_{i,t-1}$ confirms the findings of the main model: $\hat{EMAS}_{i,t-1}$ is significant, positive and comparable with the estimations using not instrumented $EMAS_{i,t-1}$. In this case the Incidence Rate Ratio for ÊMAS i,t-1 is 1.82. The result is robust to the introduction of the *COUNTRY*YEAR* and *SECTOR*YEAR* interaction terms, even if the magnitude of the coefficient progressively reduces.

The model is just-identified, and this does not allow to test over identifying restrictions, however we test the weakness of the instrument that rejects H0 of weak instrument (Wald: chi2(1) = 62.71 , p-value= 0.0000). The parameter ρ measures the strength of the endogeneity of $EMAS_{i,t-1}$; in our estimation ρ =19.45*** (robust s.e. 1.32) confirming the endogeneity of $EMAS_{i,t-1}$.

[Table 11 about here]

6. Discussion and conclusions

This paper analyzes the impact of EMAS on patented innovation in European firms. The panel analysis has been performed on a sample composed by 30439 European firms, and considers a period of ten years (from 2003 to 2012).

We find that EMAS positively affects the number of granted patents; however, this result is particularly strong in Italy and Germany and in low tech manufacturing sectors and services. We address the issue of endogeneity with an instrumental variable estimation, and the results are confirmed.

In term of policy implications this result show that EMAS is effective instrument to raise innovativeness of certified firms while improving their environmental performance. This positive effect of EMAS justifies environmental authorities' financial and technical support to spur EMAS adoption, as well as certified firms' effort. However, as highlighted by our analysis, EMAS is more convenient for low technological sectors and in some countries, providing support for the hypothesis that some regulatory frameworks are more EMAS and innovation friendly than others, and that some sectors are more suitable to exploit all the advantages of EMAS. In this period of scarcity of resources to devote to the environment, policymakers should consider to exploit EMAS potentialities adopting strategic improvements of regulation. On the one hand concentrating benefits and subsidies for those sectors in which EMAS is more effective would maximize the returns from firms and environmental authorities' efforts. Additionally, innovation friendly regulations should be enriched with specific provisions for EMSs, as they can be considered innovation friendly as well.

This paper provides new empirical evidence on the impact of EMAS on patents and our findings can further stimulate the debate on the relationship between EMSs and innovation. Our results can be improved in many directions. For example The number of granted patents does not capture the all the possible innovations developed by firms and probably underestimate the innovative activity of the certified firms. In addition the dummy $EMAS_{i,t-1}$does not provide a measure of the degree of EMAS implementation, thus allowing for some measurement errors.

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Table 1. Literature review

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 countries	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

Source: authors' elaboration

Table 2. Sample composition by sector

Sector	Description	N firms	%	Employees (mean)	S.D.	Turnover (mean)	S.D.
Infrastructure	Electricity, gas supply, water supply and waste management, construction, transportation and storage, real estate activities	6223	20,4%	62	145.42	154.11	123.06
Trade	Wholesale and retail trade	7713	25,3%	49	109.39	128.63	204.47
Kibs	Telecommunications, R&D	2423	8%	61	136.34	152.67	188.06
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%	173	182.77	177.88	195.68
High tech manufacturing	Aerospace , Pharmaceuticals Computers, office machinery , Electronics-communications Scientific instruments	402	1.3%	185	193.80	154.21	164.62
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%	213	188.22	124.25	177.12
Low tech manufacturing	Other manufacturing and recycling, Wood, pulp, paper products, printing and publishing , Food, beverages and tobacco, Textile and clothing.	3208	10.6%	158	153.56	166.67	193.92
Agriculture	Agriculture, forestry and fishing Mining and quarring	410	1.3%	50	88.98	77.89	206.60
Others	Households and extraterritorial organizations, residuals (nace unknown)	249	0.8%	65	106.29	172.07	201.81
Total		30439	100%	99	150.43	169.24	196.48

Source: authors' elaboration

Table 3. Sample composition by country

Country	N firms	%	N EMAS	%
AT	916	3.0	43	4.6
BE	592	1.9	16	2.7
CY	23	0.0	23	100
CZ	21	0.0	21	100
DE	8905	29.2	396	4.4
DK	652	2.1	31	4.7
ES	5271	17.4	651	12.3
FR	6038	19.8	66	1.0
GB	1351	4.4	43	3.1
GR	15	0.0	12	0.8
IE	995	3.3	44	4.4
IT	2497	8.2	229	9.1
NL	305	1.0	10	3.2
NO	385	1.3	18	4.6
PL	21	0.0	21	100
PT	2426	7.9	49	2.0
Other countries	26	0.0	24	92
Total	**30439**		**1697**	

Source: authors' elaboration

Table 4. Innovative firms across sectors

Sector	N. of innovators (a)	% of innovators on total sample	N. of innovators and EMAS (b)	(b)/(a)
Infrastructure	247	3.9	51	20.6
Trade	364	4.7	32	8.8
Kibs	220	9.0	4	1.8
Other services	283	3.9	8	2.8
High tech manufacturing	226	56	26	0.8
Medium tech manufacturing	1168	45.4	148	12.6
Low tech manufacturing	619	19	111	18
Agriculture	19	4.6	2	10.5
Others	10	4.0	1	10
Total	3156	10.36	403	12.7

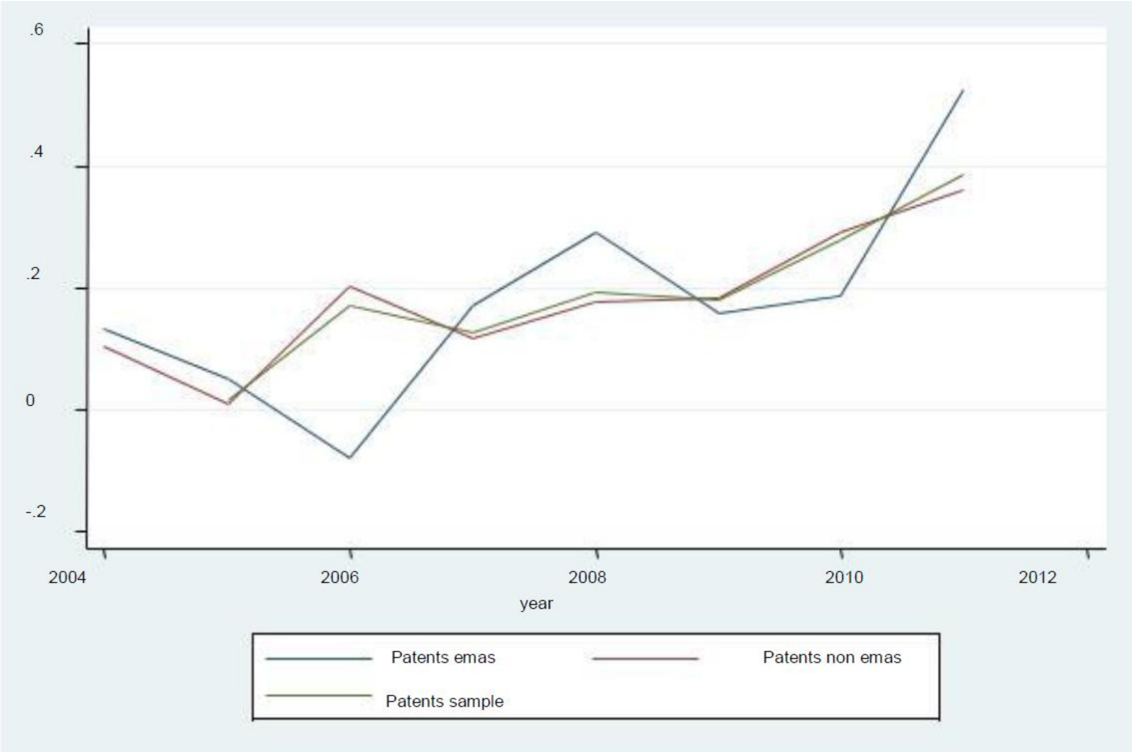
Source: authors' elaboration

Table 5. Registration over time of new EMAS firms

Registration Year	N EMAS	%
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

Table 6. Patents trend over the period 2003-2012



Source: authors' elaboration

Table 7. Summary statistics

Variables and description		Mean	Std. Dev.	Min	Max
Dependent variable					
PATENTS i,t	Number of granted patents per year	0.208	2.098	0	100
Explanatory variable					
EMAS i,t-1	Equal to 1 if firm is certified and 0 otherwise	0.035	0.185	0	1
Control variables					
EMPLOYEES i,t-1	Number of employees	76.774	159.777	1	4609
PROFIT i,t-1	Share of profit on past revenues	3.97	14.768	-100	100
PAST INNO	Patent stock calculated with perpetual inventory method	0.066	0.632	0	67.98
ENV EXP t-1	Share of GDP devoted to environmental expenditure	0.323	0.135	0.11	1.31
Instrumental Variable					
VERIFIERS	Number of environmental verifiers in the country each year	67.32716	96.04062	0	239
Sectors (dummies)					
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 manufacturing		0.012	0.111	0	1
Medium tech manufacturing		0.077	0.267	0	1
Low tech manufacturing		0.098	0.298	0	1
Others		0.031	0.173	0	1

Table 8. Negative binomial FE and Poisson FE

	Negative Binomial	Poisson	Neg bin	Neg bin
PATENTS				
EMAS i,t-1	0.233*	0.278*	0.186*	0.190*
	(0.093)	(0.111)	(0.098)	(0.097)
PASTINNO i,t-1	0.0387***	0.037***	0.0381***	0.0359***
	(0.0014)	(0.0013)	(0.0015)	(0.0015)
EMPLOYEES i,t-1	0.0479***	0.0481***	0.0381***	0.0412***
	(0.0103)	(0.0108)	(0.0106)	(0.0108)
PROFIT i,t-1	0.0108	0.006	0.0212	0.0209
	(0.0197)	(0.001)	(0.0209)	(0.0203)
ENV EXP t-1	-0.541+	0.009		
	(0.308)	(0.004)		
Years dummies	Y	Y		
Country*Year			Y	
Sector*Year				Y
Constant	-0.0832		0.306***	-0.6111
	(0.161)		(0.0624)	0.5409
Observations	183847	183847	183847	183847
Wald chi2	1353.95	1323.16	1345.55	1284.37
Log likelihood	-8137.9498	-8006.1166	-8088.8942	-7887.1883
Alpha : 20.05994 Likelihood-ratio test of alpha=0: chibar2 = 9.3e+04 Prob>=chibar2 = 0.000				
IRR for EMAS:	1.26	1.32	1.20	1.21

Standard errors in parentheses + p < 0:10, * p < 0:05, ** p < 0:01, *** p < 0:001

Table 9. Negative Binomial FE Country subsamples

	(3) IT	(4) FR	(5) DE	(6) ES
PATENTSt				
EMAS i,t-1	0.243*	0.0900	0.707***	0.0765
	(0.463)	(0.669)	(0.188)	(0.209)
PASTINNO i,t-1	0.0490***	0.0296*	0.0386***	0.0271***
	(0.00890)	(0.0122)	(0.00164)	(0.00664)
EMPLOYEES i,t-1	0.0551	0.136	0.0324**	0.0590
	(0.0476)	(0.115)	(0.0115)	(0.0365)
PROFIT i,t-1	0.0117	0.0109	-0.000117	0.00842
	(0.00722)	(0.0113)	(0.00235)	(0.00721)
ENV EXP t-1	-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
Wald chi2	60,46	30,82	1211,64	38,94
Log likelihood	-496.25846	-233.71496	-6691.572	-650.07903

Standard errors in parentheses + p < 0:10, * p < 0:05, ** p < 0:01, *** p < 0:001

Table 10. Negative Binomial FE, Sectors subsamples

	(7) high tech	(8) medium tech	(9) low tech	(10) kibs	(11) other serv
PATENTS t					
EMAS i,t-1	0.0164	0.0259	1.172***	-1.005	2.187 **
	(0.308)	(0.155)	(0.301)	(0.672)	(0.7192)
PASTINNO i,t-1	0.0487***	0.0414***	0.0430***	0.0350***	0.0319***
	(0.00568)	(0.00235)	(0.00412)	(0.00572)	(0.00375)
EMPLOYEES i,t-1	0.00539	0.00108	0.109***	-0.0108	0.0505*
	(0.0313)	(0.0183)	(0.0264)	(0.0416)	(0.0237)
PROFIT i,t-1	-0.000487	0.00847*	0.00100	0.00150	-0.00384
	(0.00569)	(0.00413)	(0.00608)	(0.00652)	(0.00354)
ENV EXP t-1	-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
Wald chi2	170,57	551,16	261,96	117,89	187,50
Log likelihood	-778.56761	-3034.7504	-1328.7994	-512.72605	-877.60243

Standard errors in parentheses + p < 0:10, * p < 0:05, ** p < 0:01, *** p < 0:001

Table 11. IV Poisson

	First stage	Second stage
EMPLOYEESi,t-1	0.000***	0.003***
	(0.000)	(0.000)
PROFIT i,t-1	0.006**	0.016**
	(0.000)	(0.005)
PASTINNO i,t-1	0.002***	0.837***
	(0.001)	0.066
VERIFIERSt-1	0.401***	
	(0.002)	
EMAS i,t-1		0.607***
		(0.050)
Years dummies	Y	Y
Country dummies	Y	Y
Constant	0.091***	0.683***
	(0.003)	(0.037)
R-squared	0.4048	
LR chi2		1650.33

Standard errors in parentheses + p < 0:10, * p < 0:05, ** p < 0:01, *** p < 0:001