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# Environmental certifications and innovation in European firms

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Abstract
This paper aims at analyzing whether environmental certifications 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, the relationship is studied by using an original database composed by 30439 European firms belonging to all sectors and size. The analysis tries to solve several methodological issues and reveals that EMAS affects innovation at firm level, although the results vary across countries and sectors.

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### Abstract

This paper aims at analyzing whether environmental certifications 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, the relationship is studied by using an original database composed by 30439 European firms belonging to all sectors and size. The analysis tries to solve several methodological issues and reveals that EMAS is positively correlated with innovation at firm level, although the results vary across countries and sectors.


### 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 encouraged 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. 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 performance and for ensuring competitiveness of firms, 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.

[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.

One major gap that was identified in the literature on this topic is the limited use of patent data (Wagner 2009), even though it would address the issue of defining a comparable innovative outcome, since only innovation that exceed a certain degree of novelty can be patented. Therefore this paper uses the count of granted patents to identify innovation at firm level. 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 theoretical framework. Section 4 concerns the data source and the methodology. We present our econometric results in Section 5; Section 6 concludes.

## 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[2] 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.

[2] 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 ad-ministrations. 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.

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 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 partially overtakes the difficulties related to the use of cross-sectional data, by relying on two different panel database: the establishment panel of the Istitute for Employment Research (IAB) and the Mannheim innovation panel (MIP). 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. This analysis has some limitations in the fact that environmentally active firms are intrinsically more likely to develop new environmentally related products. Once again, 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 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 introduce wide heterogeneity in the environmental effort declared by firms.

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. Conceptual framework**

This paper aims at clarifying 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. 2003, 2005, 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 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[3]. Those characteristics are effective in improving the certified firms' performance under several indicators (for instance the environmental performance, Iraldo et al. 2009; Daddi et al. 2011; or the economic performance, see 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).

[3] EMAS firms can be intuitively compared by verifying their profile 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

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. 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. The major drawback of using this kind of data for such analysis, represents also its major advantage: the count of patented innovations capture only the innovative activity that exceed a certain level of novelty with respect to prior art, thus excluding innovations that do not significantly innovate on the existent technologies. Patent data provide an objective and comparable measure of innovation and, in addition, the count of patents reveal how much a firm is innovative.

**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 sample of 40.000 randomly selected European (EU27) firms. We then merged the list of 40.000 firms with those contained in the EMAS Register, 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. The European EMAS Register, provided by the European Commission, is available on line and yearly updated[4]. 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 environmental verifiers responsible for the accreditation. From the EMAS register we excluded public administrations.

We merged financial data for the whole list of firms from 2003 to 2012 and patent portfolio data that we retrieve both from the Amadeus and from the PATSTAT database (applicants, priority date, application year and the International Patent Classification code).

We end up with a final panel spanning from 2003 to 2012, reporting observations on 30439 European firms.

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 randomly selected was too large (e.g., data related to eight years out of ten were not available).

It can be noticed that the highest concentration of EMAS certifications is in medium and low tech manufacturing sectors. In particular, EMAS certified firms in the sample are mainly in Spain (38,48%) Germany (25,34%) and Italy (12,91%); SMEs among EMAS are prevalent (about 53% of small firms and about 30% medium size firms).

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[4] http://ec.europa.eu/environment/emas/register/

[Table 2 about here]

[Table 3 about here]

Innovative firms represent 10.36% of the sample, 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 the control group, as the percentage of EMAS with at least one patent in their portfolio is 23.7% against 9.6% of innovative firms in the control 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 control group, 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, or a case of simultaneity, 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 as well as Patents 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 the explanatory variable EMAS, we introduce fixed effects, we control for dynamic country and sector specific trends, and we use an instrumental variable.

The dependent variable *Patents* 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*; 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 is lagged. 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. 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 past innovation of firms, calculated with the perpetual inventory method (Greenhalgh and Rogers 2007)[5].

We include other control variables such as the number of employees (*Employees*) and past profits (expressed as share of turnover, *Profit*) 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*), 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.

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.

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 (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 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 per years interaction term.

[Table 7 about here]

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

$$PastInnovation = (1-\delta)patent\ stock_{t-1} + patent\ flow_{t-1} \qquad \delta=0.10$$

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

## 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[6].

The first model presents the Negative Binomial[7] 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. We further replicate the model for countries subsamples and for sectoral based subsamples, in order to exploit possible heterogeneities. For these models we calculate the Incidence Rate Ratios as well as the marginal effect. A variation of one unit in the EMAS variable, i.e. from 0 to 1 in the case of EMAS, is associated with a count increase of 1.299 in the dependent variable for the first regression, an increase of 1.2101 in the count dependent variable in the second estimation and an increase of 1.276 in the third estimation. 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 8 about here]

[Table 9 about here]

[6] Compared with the random effects model, the Hausman test confirms that the model is consistent.

[7] The Negative Binomial model seems to fit better if compared with the Poisson model, because the variance of the dependent variable shows sign of sufficient overdispersion (the variance of Patents is twenty times larger than the mean). However, the Poisson model with Fixed Effects confirms a positive and significant coefficient of the key variable EMAS.

[Table 10 about here]

However, with the approach followed so far, the simultaneity issue has not been completely ruled out. We expect the variable EMAS to be correlated with the error term of the main regression. To produce a consistent estimation of the EMAS coefficient therefore we introduce an instrumental variable. 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 environmental verifiers over the period covered by the panel[8].

The EMAS regulation establishes that in each country there must be private counselors or companies charged with public environmental authorities to verify the existence of EMAS requisites to grant the certification. Since they are private counselors, 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 certified. Therefore, they foster EMAS adoption and spread the information among local firms. Their presence in European countries has been constantly increasing over time. A larger number of environmental verifiers means a greater promotion on the territory of EMAS, a greater availability of means to start the procedure of accreditation and, eventually, a larger number of firms that decide to adopt the certification.

The variable Verifiers Trend 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 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 try to exploit it on the market. The instrumental variable appears to be not correlated with the error term of our main regression, since there are no unobserved factors able to influence both Verifiers Trend

[8] This growth trend is country specific. Data have been provided by the EMAS Helpdesk, that we would thank.

and the number of granted patents (Instrument exogeneity requisite), but at the same time is plausibly correlated with the decision to join the EMAS standard (Instrument relevance requisite)[9].

[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 coverage of ten years (from 2003 to 2012).

A Negative Binomial FE model has been run on the whole sample and on subsamples based on countries and sectors. The main model includes country per year interaction terms and sector per year interaction terms, with the aim to control for country and sector specific unobserved dynamics. In addition, an instrumental variable has been introduced as a further attempt to, at least partially, rule out potential bias coming from omitted variables affecting both innovation and EMAS adoption.

The negative binomial performed on the whole sample reveals a positive impact of the EMAS certification on granted patents; the result is confirmed in all the three models on the whole sample and is consistent with that part of the literature that positively links EMSs and innovation. However, among the country based subsamples analysis only the regressions 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. 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.

[9] The first step of our model therefore estimates EMAS as a function of the number of Veriers Trend. The F statistics is large enough to guarantee that the instrument is not too weak. Then, we add the predict EMAS hat along with the residuals from first stage to the structural regression. This two stage residual inclusion estimation guarantees that the result is consistent. For an example see Terza et al. 2008.

Past innovation, as well as firms' size, positively influences innovation, confirming a large strand of the literature, while it seems that previous period financial performance does not exert any significant impact.

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 estimation with EMAS hat confirms the findings of the main model. The estimated coefficient of EMAS hat is significant, positive and only slightly different with respect to the first three models.

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 |

Table 2. Sample composition by sectors

| 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 |

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 | |

Table 4. Innovative firms across sectors

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

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 |

Table 6. Patents trend over the period 2003-2012

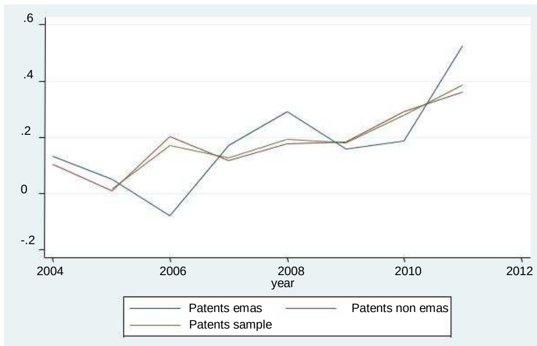


Table 7. Summary statistics

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Dependent variable | | | | |
| Patents | 0.208 | 2.098 | 0 | 100 |
| Explanatory variables | | | | |
| EMAS | 0.035 | 0.185 | 0 | 1 |
| Control variables | | | | |
| Turnover | 17234 | 22734.8 | 0 | 64719 |
| N of employees | 76.774 | 159.777 | 1 | 4609 |
| Pro t | 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. Negative binomial FE

| | (1) | (2) | (3) |
|---|---|---|---|
| Patents | | | |
| $EMAS_{t-1}$ | 0.233* | 0.186* | 0.190* |
| | (0.0936) | (0.0986) | (0.0975) |
| past Innovation | 0.0387*** | 0.0381*** | 0.0359*** |
| | (0.00149) | (0.00154) | (0.0015) |
| $Nofemployees_{t-1}$ | 0.0479*** | 0.0381*** | 0.0412*** |
| | (0.0103) | (0.0106) | (0.0108) |
| $Profit_{t-1}$ | 0.0108 | 0.0212 | 0.0209 |
| | (0.0197) | (0.0209) | (0.0203) |
| Env. exp | -0.541+ | | |
| | (0.308) | | |
| Years dummies | Y | | |
| Country*Year | | Y | |
| Sector*Year | | | Y |
| Constant | -0.0832 | 0.306*** | -0.6111 |
| | (0.161) | (0.0624) | 0.5409 |

Observations 183847 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
Wald chi2(60) = 1284.37 Prob > chi2 = 0.0000 Log likelihood = 7887.1883
Incidence Rate Ratios for EMAS: 1.26; 1.20; 1.21

Table 9. Negative Binomial FE Country subsamples

| | (3)<br>IT | (4)<br>FR | (5)<br>DE | (6)<br>ES) |
|---|---|---|---|---|
| Patents | | | | |
| $EMAS_{t \ 1}$ | 0.243*<br>(0.463) | 0.0900<br>(0.669) | 0.707***<br>(0.188) | 0.0765<br>(0.209) |
| past Innovation | 0.0490***<br>(0.00890) | 0.0296*<br>(0.0122) | 0.0386***<br>(0.00164) | 0.0271***<br>(0.00664) |
| $Nofemployees_{t \ 1}$ | 0.0551<br>(0.0476) | 0.136<br>(0.115) | 0.0324**<br>(0.0115) | 0.0590<br>(0.0365) |
| $P\ rofit_{t \ 1}$ | 0.0117<br>(0.00722) | 0.0109<br>(0.0113) | -0.000117<br>(0.00235) | 0.00842<br>(0.00721) |
| Env. exp | -0.8316<br>(0.9282) | 5.466<br>(4.295) | 2.123***<br>(1.961) | 2.631<br>(2.516) |
| Year dummies | Y | Y | Y | Y |
| Constant | 5.805<br>(7.266) | -7.012<br>(5.023) | -10.69***<br>(1.013) | -6.892<br>(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 10. Negative Binomial FE, Sectors subsamples

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

Table 11. Negative Binomial FE with IV

| | (1) | (2) | (3) |
|---|---|---|---|
| Patents | | | |
| EMAS hat | 0.792*** | 0.113*** | 0.052*** |
| | (0.013) | (0.0222) | (0.0113) |
| Residuals | -0.449*** | 0.236+ | -0.0340 |
| | (0.117) | (0.128) | (0.0953) |
| pastInnovation | 0.0250*** | 0.0354*** | 0.0505*** |
| | (0.00253) | (0.00153) | (0.00110) |
| NoIemployees t 1 | 0.00620*** | 0.000338** | 0.0000894 |
| | (0.000159) | (0.000110) | (0.0000573) |
| P rofit t 1 | 0.00787*** | 0.00242 | -0.00350*** |
| | (0.00188) | (0.00213) | (0.00104) |
| Constant | -1.073*** | -0.487** | 1.120*** |
| | (0.0921) | (0.170) | (0.0713) |
| Years dummies | Y | | |
| Country*Year | | Y | |
| Sector*Year | | | Y |

Standard errors in parentheses

+ p < 0:10, * p < 0:05, ** p < 0:01, *** p < 0:001

Wald chi2(12)= 4148.35 Prob > chi2 = 0.0000 Log likelihood = -6600.5881

Wald chi2(43) = 1290.05 Prob > chi2 = 0.0000 Log likelihood = 7770.3443

Wald chi2(60) = 1213.21 Prob > chi2 = 0.0000 Log likelihood = 30652.173

Incidence Rate Ratios for EMAS hat:2.20; 1.11; 1.05