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European SMEs and the choice among alternative green innovation strategies

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Abstract

How do European SMEs protect and exploit their environmental innovations on the market? In the recent years, an increasing number of SMEs have been engaged in implementing environmental management systems (EMS) and in patenting green innovations as results of alternative green innovation strategies. This paper aims at exploring whether European SMEs adopt EMSs and green patents as complements or substitutes. Relying upon a sample of 8797 firms, we estimate a Bivariate Probit Model to take into account the fact that SMEs simultaneously consider alternative green innovation strategies to protect their green innovations, and to identify sector-specific behaviors. The results provide evidence in favor of a complementarity between green patents and EMS. However, the analysis also reveals that the relationship differs remarkably according to the sector considered. In particular, firms in knowledge intensive business services and in supplier dominated services tend to use green patents and the EMS as substitutes, while knowledge-intensive manufacturing and infrastructure based sectors see them as complements.

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Keywords: EMAS, green patents, complementarity

1. Introduction

European firms are increasingly stimulated by public authorities and institutional bodies to actively engage in activities aimed at greening their productions, through different policies that encourage efficiency and sustainability. Large companies have been immediately able to associate new eco-management practices with green R&D expenditures directed at ensuring the appropriability of green investments' returns, by filing environmental management systems (EMS), green patents and eco labels. On the contrary, SMEs have been striving for allocating limited resources between the implementation of new environmental practices and the development of green innovations.

Green investments can lead to innovations and contents not easy to protect with usual protection methods such as patents, and that can be more effectively exploited on the market with trademarks and logos. Formal innovation activity is risky, it entails costs and the potential returns are uncertain and affected by a wide range of variables, but the successful green R&D ensures the exclusive exploitation of patentable eco-innovations discovered. On the other hand, environmental management practices can result in an EMS that entails lower costs if compared with R&D, and more flexible implementation mechanisms, while effectively signaling green concern to the market. The EMS can result in a signal conveying reputation; the associated logo can be exploited to customers and entails excludability of firms not committed to the same requirements.

Academic research has widely explored the role of patents as the most diffused formal instrument to protect innovation, in particular among large firms. However, other legal methods to protect the intellectual property, such as trademarks and industrial designs, have increasingly come into focus (Schwiebacher, 2010). Nonetheless, the relationship of potential complementarity between protection methods has been scarcely explored and, to our knowledge, no previous research has addressed this issue in the context of green strategies, looking at the adoption of green collective trademarks, namely EMS, and green patents. There are many empirical studies on drivers of eco-innovation (Triguero et al. 2013; Horbach et al. 2012), as well as on the adoption of EMS (e.g. Morrow and Rondinelli 2002; Frondel et al. 2008), however, literature related to identify the factors spurring the simultaneous adoption of both EMS and green patents is poor (Kesidou and Demirel 2012).

The objective of this paper is thus to empirically investigate how European firms mix EMSs and green patents and to study the complementarity between EMS and green patents, identifying the most important variables explaining the joint adoption of both the EMS and green patents.

The original contribution of the paper is twofold. First, from a conceptual perspective, we extend the traditional analysis on patents vs. trademarks (see Bhattacharya and Guriev 2006; Amara et al. 2008; Llerena and Millot 2012) to eco-innovation strategies. We investigate whether green patents are complement or substitute to the use of a green collective trademark, such as EMAS. Second, it develops the analysis of complementarity vs. substitution relationship between alternative protection mechanisms among European SMEs, enriching a debate still at the early stage. Data on SMEs are uncommon in this stream of literature that mostly concentrates on large firms. However, SMEs face human and financial resource constraints and their choice among alternative green strategies is more difficult, but at the same time even more strategic. We will also put particular attention to the role of sector specificities as important factors in determining SMEs' propensity to use different mix of green practices.

Our empirical analysis is based on a panel of 8797 European SMEs. The dataset includes financial variables, as well as information on innovative performance and green innovation strategies at firm level. We estimate a Bivariate Probit model to reflect the fact that SMEs simultaneously consider the use of EMSs to exploit the reputational effect and the registration of patents to protect green innovation. The empirical evidence suggests that 15,3% of European SMEs in the sample has implemented at least one green innovative strategy, the propensity to file green patents is low, and the prevailing green strategy adopted is the registration of an EMSs. The econometric analysis shows that European SMEs use EMAS and green patents as complements rather than substitutes when investing resources in green strategies. When deepening the analysis within sectors, the results reveal that knowledge intensive business services, together with agriculture and supplier dominated services, use EMS and green patents as substitutes, while infrastructure services, science based and high tech manufacturing sectors tend to use the EMS and green patents as complements.

The rest of the paper is organized as follows: in the next section we present the theoretical framework, section 4 describes the data and illustrates the methodology, section 5 discusses the empirical results, and section 6 concludes.

3. Alternative green innovation strategies: green patents vs. Environmental Management Systems

Green innovation is "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives" (OECD, 2009). The discovery of new technologies helps firms to reduce their impact on the environment and at the same time to cut costs. Even though it can be initially costly to implement new green technologies, in the long run a firm would significantly take advantage from the development of these innovations, making it more convenient to go green. Prior research, indeed, has confirmed that one of the most important reasons for firms to undertake eco-innovation is cost-savings (De Marchi 2012; Horbach et al., 2012; Kesidou and Demirel, 2012). Eco-innovations can be introduced in response to stakeholders and market pressure, namely when the market demands more eco-friendly products or values a green brand image (Morrow and Rondinelli, 2002; Lannelongue and Gonzalez-Benito, 2012).

The propensity to patent among SMEs is low and green patenting activity does not represent an exception. However, developing eco-innovation can be more easily and less costly in comparison with general innovation for two main reasons: first, within the domain of technologies for sustainability there are large margins of improvements and less prior art to be taken into account to move the technological frontier; secondly, eco-innovation is largely encouraged by institutions that might provide incentives for innovation in the form of subsidies or tax reductions. Patents protect firms' technological knowledge. The legal core of the patent is excludability of potential rivals and consequent exploitation of the granted innovation. Excludability allows patent owners to appropriate the value of the invention for all the coverage period, in order to refund the uncertainty sustained by firms. Appropriability can depend on the degree of codification of knowledge (Amara et al. 2008; Howells et al. 2003) as well as on the degree of novelty. Patents are better suited to capture profits stemming from new technological knowledge that must be protected from imitation to provide a competitive advantage. However, patents do not provide a clear signal to consumers, even when innovation is product-related. In this sense, trademarks can complement patents: the trademark is a sign that identifies origin, reputation, quality and marketing strategy of firms and associated products. It does not entail uncertainty in the result and it can be renewed indefinitely. It represents the instrument to reduce information asymmetry between producers and customers. Firms may want to protect innovations against rivals by patenting activities and may also want to diffuse new functionalities on the market by registering a trademark (Mendoca et al., 2004; Ramello, 2006). This strategic behavior is more likely to be undertaken by firms developing highly codified knowledge that can at the same time result in tangible products market side oriented (Amara et al. 2008; Miles 2008).

In the context of green innovations, it is possible to conceive environmental certifications as trademarks, as they can prolong the life of green patents: the eco-innovations protected by patents can be successfully associated with a trademark to guarantee a clear identification of products by consumers on the market. The EMS in particular is 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). As such, the EMS can be seen as a collective trademark[1]:it is linked to a logo, it conveys reputation, it is associated with an eco-friendly image and can be used exclusively by adherents paying annual fees and committed to tough requirements.

Similarly to a trademark, an environmental certification allows the firm to inform about its environmental effort and it contributes to add value to goods and services that consumers buy also for their intrinsic meanings (Lawrence and Phillips 2002). The environmental certification is represented by a recognizable registered sign that facilitates responsible consumer choice: it reduces information asymmetry because it allows for a differentiation

[1] The EMS is often considered an organizational innovation. However, even if it entails the implementation of management practices that are at least partially new in the adherent firm, it does not imply a level of novelty sufficient and original such as previously unestablished technological innovations. Indeed, an explicit signal of novelty is not needed to register a trademark. At the same time, the EMS does not imply excludability and its primary function is to signal eco-friendliness on the market, i.e. it is a sign of reputation rather than of innovation.

with respect to non green products and services. The primary function of environmental certifications is to convey reputation (Prakash and Potoski 2006) and their strength lies in the underlying standard and requisites. The reputational effect of the environmental certification increases proportionally to the visibility and to the number of adherents to the green standard: the greater the number and the size of registered firms, the wider the visibility of the logo on the market, the broader its reputational strength. As a "collective trademark", it indicates a certain quality of products and processes and it is granted after the observance of stringent requisites has been verified by impartial verifiers.

Environmental certifications contribute to create a firm's marketing assets, however an exclusion right cannot be exploited by the individual firm but needs to be pursued by the third institution responsible for the standard. The authority responsible for the environmental certification is charged with the protection against infringements related to the illegal use of the logo by non certified firms. This contributes to smooth litigation costs on all the adherents, resulting in a competitive advantage with respect to litigation costs undertaken to protect patents. A large share of investments is carried out after the certification is registered, to maintain it: this means that the intensity of the investments is more flexible and can be largely graduated by the firm as opposed to the case of patents.

The adoption of EMSs is highly diffused among SMEs, similarly to what happens with trademarks: registration and maintenance of both require the payment of fees, but the burden is smaller compared to that entailed by patenting activity (Munari and Santoni 2009). At the same time, the lack of knowledge of IPRs among SMEs mostly regards patents, while the diffusion of knowledge about EMSs is widely spread by governments which often provide support and competences through local organizations (Alberti et al. 2010). For this reason, standards like EMAS (Environmental Management and Audit Scheme) are more popular among SMEs rather than among large firms.

3.1 Complementarity and substitution among green innovation strategies

Given the above discussion, it is relevant to understand to what extent firms – and SMEs in particular - use green patents and EMS as complements or substitutes. The empirical analysis on complementarities has been successfully applied in research to the examination of alternative IPRs and other informal methods to protect innovation (e.g. Amara et al., 2008;

Munari and Santoni, 2009; Neuhausler, 2012; Llerena and Millot, 2013). Overall, there seems to be a non straightforward relationship among different IPR strategies, since some scholars do find substitution effects (Arundel, 2001), while others find complementarity between patents, trademarks and other means of intellectual property protection (Amara et al. 2008; Munari and Santoni 2009). Interestingly for the scope of this paper, as it is well documented in innovation studies, sector specificities matter in defining the extent to which different strategies might be complements or substitutes for companies (Pavitt, 1984; Tether, 2003; Malerba, 2000; Castellacci, 2008).

Previous literature has highlighted how SMEs are less likely to carry out autonomous R&D than large companies and tend to use forms of innovation protection that are different from patents (Klepper, 1996; Shefer and Frenkel, 2005; Bordoy et al., 2007; Munari and Santoni, 2009). This is particularly true for very small companies, who cannot sustain the burden of costs associated to patent filing. Indeed, both green patents and environmental certifications provide an incentive for firms to invest in eco-innovations and green practices, but at the same time, they are both costly to implement and to enforce, their maintenance require the payment of fees and continuous sunk costs and, at least in the case of green patents, the long term commitment is associated with a high rate of uncertainty of refunding and possible costs of litigation. All these burdens can represent a significant barrier for the use of green strategies. Nevertheless, once a company has implemented at least one green strategy, it can be convenient for environmentally concerned firms to reinforce the use of the green strategy exploiting the complementarity relationship with the other one.

Therefore, we first test the following hypothesis:

Hypothesis 1: For SMEs, the joint use of EMS and green patents provide a competitive advantage and therefore green patents and EMS are complements.

Notwithstanding the difficulty of implementing composite green strategies, which include both green patenting activity and environmental certifications, scholars have pointed out that there are important sectoral differences to be taken into account when looking at the innovation strategies. Many studies show that firms' propensity to implement trademarks and patents varies across industries (Arundel, 2000; Somaya, 2004); similarly, the propensity to adopt an environmental certification and/or to file green patents differs across industries

(Horbach et al., 2012; Frondel et al., 2008; Wagner, 2008). This is because sector characteristics determine, among others, the technological content and degree of knowledge intensity and codification; the tangibility of output; the type of users (consumers vs. businesses) (Pavitt, 1984; Soete and Miozzo, 1989; Castellacci, 2008).

Following Castellacci (2008), we can distinguish sectors along two dimensions. The first refers to the function of each sector in the economic system as provider or recipient of goods and services, i.e. as provider of intermediate or final goods. This dimension also allows to identify the most important type of users for firms and, more in general, the characteristics of the demand. It is reasonable to argue that a higher need to impact on final consumers' perception increases the use of strategies that exploit reputational assets on the market, such as for example the environmental certifications. On the contrary, firms that are in the middle of the value chain may want to better protect their technological knowledge, and therefore are more likely to file patents to prevent imitation. At the same time, intra-firm trade can benefit from logos that certify environmental compliance and green reputation, and this can lead companies to simultaneously look for environmental certification together with green patents. Therefore we put forward the following hypothesis:

Hypothesis 2a Firms providing final goods and services are more likely to treat green patents and environmental certifications as substitutes than firms operating in the middle of the value chain are more likely to adopt environmental certifications and green patents as complements.

The second dimension characterizing the production of different goods and services concerns the technological content of each sector, which is defined by the technological regime and trajectory, and by the extent to which sectors are able to develop new technologies internally or must rely on the external sources. In this respect, it is possible to argue that firms in sectors with a high degree of knowledge intensity are more likely to patent and perform internal R&D activity. Furthermore, formal R&D and patents are more common in sectors with a relatively high level of output tangibility (Amara et al. 2008), while non patentable green innovations and environmental management systems are more diffused in sectors where the output more intangible. As a consequence, we put forward these two hypotheses:

Hypothesis 2b SMEs belonging to sectors with strong technological content and knowledge intensity are more likely to recur to green patents and environmental certifications as complements.

Hypothesis 2c SMEs belonging to sectors with a high degree of output tangibility are more likely to use green patents and environmental certifications as complements.

4. Data and methodology

4.1 Data collection

The analysis is based on a sample of SMEs operating in the EU15 Countries. We constructed our sample starting from a random selection on Amadeus database: this database collects administrative and financial individual data for European firms since from 2003. We started with data related to 30.000 firms from the EU15 Countries, we then identified firms with a head-count of less than 250 and a turnover less than 50 millions Euros, in order to restrict our analysis to SMEs. We integrated the data on firms' performance from Amadeus with two types of data concerning green innovation strategies. First, we collected data on Eco-Management and Audit Scheme (EMAS) accreditation, which is an environmental management instrument developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance[2]. At European level, EMAS (Eco-Management Audit Scheme) is the most important Environmental Management System; it was drawn by the European Commission with Reg. CEE 1836/93 and it consists of an environmental management standard that entails periodical internal and independent audits to verify the continuous upgrading of firm's environmental performance. EMAS is associated with a logo that can be used to signal firm's environmental care and a public register yearly updated; EMAS is more stringent with respect to other international EMSs (it overtakes ISO14001, going beyond its requisites). The European EMAS register, provided by the European Commission, is available on line and yearly updated. The EMAS register records the date and the number of the EMAS first accreditation, the year of renewal and other data on verifiers, sector and geographical origin of the firm. Second, we gathered information on patents (IPC classification, applicant, inventor, priority year), from the PATSTAT database. We considered patents as green, if

[2] http://ec.europa.eu/environment/emas/index_en.htm

their IPC class was listed in the WIPO Green Inventory[3]. We ended up with an unbalanced panel spanning from 2003 to 2010 with 8.797 enterprises observed and 50.477 observations containing information on firm's performance, environmental certifications and patent portfolio composition.

4.2 Descriptive statistics

Table 1 presents the sample composition. In the sample there is a predominance of small firms (73.63%) with respect to medium size firms (26,37%). Furthremore, 50% of the sample is characterized by producers of personal goods and services. Overall, the selected SMEs, irrespectively of the industry, recur to the environmental certification rather than to green patents. Only one firm out of eight implement a green innovation strategy and among environmentally concerned companies the EMAS is the most frequent method used. In particular, 13.8% of European SMEs in the sample use the EMAS as the only strategic method to signal environmental concern on the market. The presence of the green logo is concentrated in some sectors, in particular infrastructure-based services (25%) and low and medium tech manufacturing sectors (22% and 18%). Not surprisingly, among the producers of supplier-dominated goods, 1 out of 5 firms has the EMAS certification, whereas in the scale intensive manufacturing sectors 1 out of 3 firms is certified. It seems that the market target, consumer vs. business, can orient the choice about how to effectively signal environmental concern. The highest rate of certified firms can be found in the science based manufacturing sector (slightly more than 50%). In this sector we can also observe the highest percentage of firms mixing both the environmental certification and green patents (4% of firms). Producing highly technological products spurs the adoption of patents, and in particular the association of green patents with environmental certifications. Not only the science based manufacturing sector firms shows more propensity to reinforce the EMS logo with green patents, but also the specialized suppliers manufacturing, (3.5% of firms using both green patents and environmental certifications) that have in common with the science based manufacturing sector the presence of a high tech production for business and

[3] The WIPO Green Inventory was created by the IPC Committee of Experts in order to enable searches for patent information relating to so-called Environmentally Sound Technologies as listed by the United Nations Framework Convention on Climate Change (UNFCCC). It includes all the IPC classes that are associated with environment-friendly technologies in a variety of fields. In particular, it includes six technological fields: alternative energy production, transportation, energy conservation, waste management, agriculture/forestry, administrative/regulatory as well as design aspects and nuclear power generation.

consumers. All service companies prefer registering an environmental certification rather than filing green patents.

It can be noticed that only a small number of firms in the sample recur to green patenting as the only mean to protect environmental R&D (0.4%). In the sample, 4% of firms own at least a patent, which is due to the fact that firms are small firms, whose R&D activity is limited by the scarcity of resources. Among patent owners, 16.5% file green patents. By comparison, the concentration of green patents can be found in the manufacturing sectors, with about the 50% of the green patents in the sample. More precisely, science based manufacturing and personal goods producers together have 33% of total green patents, followed by specialized manufacturing suppliers that own 16% of green patents in the sample.

The simulatenous adoption of green patents and EMAS is chosen by 28 firms in the sample, the majority of which are medium size firms, belonging to medium and low tech manufacturing sectors.

Italian and Spanish firms record the greatest propensity to simultaneously adopt green patents and the environmental certifications, followed by German firms. This can be due to cultural factors, but also to national regulation that allows SMEs to access to benefits when joining the certification program, providing substantial reliefs from costs burden.

[Table 1 about here]

4.3 Methodology

Empirical studies on complementarities have been based on three main approaches (Arora, 1996; Galia and Legros, 2004; Mohnen and Roller, 2005; Gilli et al., 2014). The first approach consists in modelling a firm's objective function with parameters that have to be tested as indicators of complementarity. This is the so called productivity approach (Amara et al., 2008). The reduced form approach (Arora, 1996) is based on the notion that "a factor which has an effect on one variable will not be correlated with another variable unless the variables are complementary". The last approach is the one we are following in the present analysis and consists in looking at the conditional correlation between two or more variables, and presents the advantage that there is no need to specify a reference outcome variable, e.g.

productivity, to identify complementarity (Gilli et al., 2014): it returns an effective test of complementarity using the choice variables as dependent variables.

Following Amara et al. (2008), we run a Bivariate Probit model that allows the simultaneous estimation of the probability to adopt the EMS and to file green patents. Estimating a Bivariate Probit model allows the evaluation of the systematic correlation between the residuals of the choice equations; the complementarity arises when the null hypothesis of absence of correlation is rejected (Wooldridge, 2002; Cameron and Trivedi, 2009). The correlation, where significant, may reveal complementarities if positive, or substitution mechanism if negative, between the green strategies.

The existing evidence about the adoption practices implemented by European SMEs make us consider the same set of explanatory variables as factors that determines the implementation of green strategies. Our analysis consists of two binary choice equations based on two binary variables: *Greenpatents* and *EMAS*. We identify four clusters of firms: companies jointly recurring to green patents and EMAS, firms registering only the environmental certification, firms recurring only to patents and finally firms not recurring at all to green strategies. Therefore, the possible combinations are Strategy (1,1), Strategy (1,0), Strategy (0,1) and Strategy (0,0). The model allows for the estimation of the joint probability related to the two binary dependent variables, as well as the pair wise correlation across the two equations (ρ). Such correlation coefficient enables to make some inference on complementarity or substitution effect between green patents and EMAS certification.

We estimate the following model:

(1)

Jointly with

(2)

4.4 Covariates

Table 2 presents the summary statistics and Table 3 illustrates the cross correlation between the continuous variables of the model.

[Table 2 about here]

[Table 3 about here]

This study measures green patents using the dummy variable *Greenpatents*, which takes value 1 if the firm reports at least one green patent in portfolio, 0 otherwise. Similarly, we proxy the variable environmental certification by accounting for the presence of EMAS certification, building the dummy *EMAS* that takes value 1 one year after the year of the accreditation. To control for the effect of firm size we introduce the variable *Employees* that reports the lagged total number of employees. Additionally we control for firms' performance by introducing the lag of firms' profit (*Profit)*: we do this as we expect that past performance affects SMEs resource availability in the subsequent period and determines firms propensity to adopt one specific green strategy rather than others. We also introduce the variable *PastInnov*, which expresses the number of non-green patents applications of the previous period, to account for path dependent innovative behavior. Concerning sectoral dummies, we introduce a set of dummies following the taxonomy of Castellacci (2008). We further elaborate this classification by organizing the sectors according three dimensions: output tangibility, knowledge intensity and consumer exposure. Figure 1 can provide an intuitive representation of the classification according to three axes. The figure represents the relative position of sectors according to three characteristics: knowledge intensity, output tangibility and consumer vs. business market.

[Figure 1 about here]

KIBS i.e. knowledge intensive business services, are characterized by low output tangibility, high technological intensity and are considered in the middle of the value chain. *Science-based manufacturing* firms are characterizes by strong technological contents, high output tangibility and consumers orientation. *Scale-intensive manufacturing* firms are identified by an orientation towards business users, high output tangibility and scarce technological contents. *Supplier dominated goods* are consumer oriented, with strong output tangibility and low knowledge intensity as well as *Suppliers dominated services* but for output tangibility. *Network infrastructures* and *Physical infrastructures* are both connoted by low output tangibility, they address to both consumers and business, but they differentiate for knowledge intensity, i.e. network infrastructure firms show advanced knowledge with respect to physical infrastructure firms.

Finally, we introduce country dummies to control for national specificities, and time dummies.

5. Results and discussion

The empirical results are summarized in Table 4, Table 5 and Table 6. A first assessment of the quality of the model fit is given by the reported Likelihood Ratio Index, which compares the Log Likelihoods' values related to the unrestricted model and to a simplified model containing only an intercept for each of the choice equations. The LR test suggests that the null hypothesis that all the coefficients are all zeros can be rejected. The second LR test suggests that the null hypothesis, that the correlation between the two choice equation is zero, is rejected, proving also that a BiProbit is appropriate to estimate the model. Therefore our hypotheses is confirmed.

[Table 4 about here]

[Table 5 about here]

[Table 6 about here]

The econometric results of the Bivariate Probit model on the whole sample indicate that environmental concern is positively affected by the size of firms and, in the case of EMAS registration, also to previous positive financial performance, represented by the variable

Profit. Though the majority of SMEs do not undertake any green strategy, it is also true that larger firms are more likely to implement at least one between green patenting activity and the environmental certification, compared to their smaller counterparts; the impact of size is greater in the case of the green patents development. As expected, past innovative history affects positively green patenting activities, whereas has not a significant effect on EMAS adoption.

Differences across sectors are remarkable: the probability to be EMAS certified is affected positively by being in scale intensive manufacturing and science based manufacturing sectors. The fact that the dummies representing the manufacturing sector are positive corroborates previous findings of a high trademark adoption propensity among sectors that needs more signaling towards customers. *Infrastructure* and *Supplier-dominated services* negatively affect the adoption of *EMAS*; it can be noticed indeed that EMAS, even though it is a process certification, can be more easily exploited on consumers market, when associated to a product rather than a services, that is the characteristic shared by infrastructure firms (that are only partially consumers oriented) and *Supplier-dominated services*. The belongings to *Science-based manufacturing* and *Specialized-suppliers manufacturing* is also positively correlated with the adoption of green patents; confirming previous findings, the econometric analysis also reveals that services and infrastructures, even when characterized by a high level of knowledge intensity, as the case of *KIBS*, are negatively associated with green patenting activities.

As noticed when examining descriptive statistics, we can infer that environmental investments is costly and rarely implemented by SMEs. Only a small part of the sample, indeed, is involved in at least one green strategy: this can explain the negative coefficients associated with many sectoral dummies in the main regression. Nonetheless, while investing in green strategies, European SMEs try to capture the benefits from environmental investments on the consumers market, as well as on business market reinforcing EMAS impact with green patenting activities. Concerning the relationship between different green strategies, we obtain a positive and significant ρ from the main regression. This means that there is complementarity between *EMAS* and *Greenpatents*, as SMEs when patenting are also likely to register an environmental certification and when investing in EMAS have the propensity to dedicate other resources to green R&D and to reinforce the effect of EMAS on the market. This result allows us to deny the existence of a trade-off between environmental certifications and patents confirms the intuition of Munari and Santoni (2009), that find that SMEs use trademark and patents as complements.

We then run the model on sector-based subsamples. The main contribution deriving from this further exercise is to identify the existence of different complementarity strategies across sectors that are due to the different levels of output tangibility and knowledge intensity that characterizes different sectors, as well as to different markets. The analysis provides similar results for the variables concerning size and financial performance, but gives interesting insights on the behaviour of firms within different sectors with reference to the joint use of EMAS and green patents.

Concerning the Hypothesis 2a, the findings are mixed. Regarding the group of firms in the middle of the value chain (*Scale-intensive manufacturing* and *Specialized-suppliers manufacturing*), we obtain a significant ρ, indicating complementarity among environmental strategies. The same result holds for *Infrastructure services*, that serve both consumers and business. *Supplier-dominated goods* producers produce final goods for consumers: however, the high level of output tangibility determines a positive and significant ρ indicating complementarity and confirming the Hypothesis 2b.
Supplier-dominated services firms, due to the low tangibility of their output and to their orientation towards consumers, show a negative ρ confirming both our Hypothesis 2a and 2b. *KIBS* are characterized by low output tangibility, are positioned in the middle of the value chain and are defined by a high level of knowledge intensity. As expected in this case, the ρ we obtained is significant and negative, indicating a substitution relationship between EMAS and green patents. Unlike the *KIBS*, however, the other sectors with strong technological contents and high levels of output tangibility prefer to follow a complementarity strategy: the ρ of the regression of the *Science-based manufacturing* sectors is positive and significant.

To sum up:

1. **Hypothesis 2a**: firms belonging to consumer-oriented sectors are more likely to adopt substitution strategies when the final products are services (*Supplier-dominated services*), whereas consumer-oriented firms characterized by high output tangibility show instead complementarity among alternative environmental strategies (*Supplier-dominated goods*).

Business-oriented firms are more likely to protect their environmental investments and to reinforce the environmental certification with green patenting activities, irrespectively of the knowledge intensity. In the case of *scale-intensive manufacturing* and *specialized supplier manufacturing* sectors we have complementarity between the two types of green strategies.

2. **Hypothesis 2b**: sectors characterized by a strong technological content such as *science-based manufacturing*, *specialized suppliers* and *infrastructure* services are more likely to present complementarity among alternative green strategies.

3. **Hypothesis 2c**: the low tangibility of output matters hence *KIBS*, despite a high level of knowledge intensity, presents a strong propensity to substitution among alternative environmental strategies.

The inference about the complementarity across green innovation strategies has been based on the observation of the correlation among the disturbances, that does not allow to identify the key explanatory factors for the adoption of each strategy. Therefore, to provide an intuition on the main determinants of the complementarity adoption, we perform a further econometric exercise and perfom a Probit regression to estimate the probability to jointly adopt EMAS and green patents, as compared to all the other possible strategies. When investigating the determinants of the complementarity strategy, we do obtain results that are consistent with previous findings, even though overall less significant. The complementarity is likely to be chosen by innovative firms, and it is weakly fostered by size and profits. The most interesting results refers to the sectoral dummies. Being in *KIBS* and *supplier-dominated services* negatively affect the probability to jointly adopt EMAS and green patents. However, the marginal effect is quite small (about 1% less of probability of choosing the complementarity strategy for *KIBS* with respect to other sectors, and 0.7% for *supplier-dominated services*). The likelihood to have complementarity across innovation strategies increases of about 0.5% if firms belong to *science-based manufacturing* sectors and a similar result holds for the *supplier dominated goods* produces. None of the other sectoral dummies appear to be significant.

6. Conclusions

The aim of this paper was to shed light on how European SMEs mix environmental certifications and green patents to exploit their environmental investments. The fact that environmental certifications and green patents have different implementation costs and convey different protections, jointly with the fact that firms belongs to different industries, induces firms to carefully select the strategic green innovation mix to be used. This study has also stressed the importance of this choice for SMEs. On the one hand the resource constraint poses some limitations to the environmental investments that can be undertaken. On the other hand, national and European regulations largely spur the adoption of environmental certifications such as EMAS, introducing fiscal benefits and technical supports dedicated to European SMEs, while the incentives to green patents have been more difficult to implement. The stronger incentive to register an environmental certification rather than to file patents concur to further lower the already limited costs of implementation of the first type of green innovation strategy. This explains why SMEs more frequently tend to opt for environmental certifications than for patents, which is a common result in the literature on the relationship between alternative innovation protection mechanisms.

First, our analysis shows that most European SMEs does not recur to any green innovation strategy, which suggests that there is room for policy intervention to raise awareness among SMEs about the advantages deriving from green investments. Second, we show that size, innovative performance and profitability are important determinants of adoption of green innovation strategies, even though financial variables have a larger effect on EMAS, while past innovative activity affects mostly the filing of green patents, while it has no effect on the implementation of EMAS. Third, and most importantly, although EMAS and green patents overall shows complementarity, different mixings of green innovation strategies emerge within different sectors. In particular, for *KIBS* and *supplier-dominated services* sectors green patents and EMAS stands as substitutes, while *science-based* and *scale-intensive manufacturing* sectors, as well as *infrastructure* services use them as complements.

We believe that the investigation of the use and exploitation of alter-native green strategies represent a promising field for future research. In particular, the empirical analysis of complementarities among different green innovation practices could be extended to large firms and to other green instruments (e.g. Ecolabels). Finally, additional investigation about the parallelism between green strategies and IPRs among SMEs could suggest concrete policy interventions.

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Table 1. Sample composition

Sector	Description	N firms	%	EMAS (% on sector)	Green Patents (% on sector)
Agriculture	Agriculture, forestry and fishing Mining and quarring	102	1.2	13 (12.7)	1 (0.0)
Knowledge-intensive business services	Computer and related activities, research and development; otherbusiness activities	1301	14.8	134 (10.3)	2 (0.0)
Specialized suppliers manufacturing	Machinery and equipment; medical, precision and optical Instruments	140	1.8	32 (22.8)	9 (6.4)
Science-based manufacturing	Chemicals; office machinery and computers; electrical machinery and apparatus; radio, TV and communication equipment	205	2.5	123 (0.6)	9 (4.3)
Scale-intensive manufacturing	Rubber and plastic products; other non-metallic mineral products; basic metals; fabricated metal products; motor vehicles; other transport equipment	548	6.7	169 (30.8)	7 (1.3)
Network infrastructure	Post and telecommunications, financial intermediation; insurance and pension funding; acitivity auxiliary to financial intermediation	853	9.7	37 (4.3)	5 (0.6)
Physical infrastructure	Wholesale trade and commission trade; land, water and air transport; supporting and auxiliary transport activities	392	4.7	53 (13.5)	0 (0)
Supplier dominated goods	Food and beverages; textiles; wearing; leather; wood and related; pulp and paper; printing and publishing; furniture; recycling	2164	26.3	423 (19.5)	10 (0.5)
Supplier dominated services	Sales, maintenance and repair of motor vehicles; retail trade and repair of personal and household goods; hotels and restaurants	2572	31.3	182 (7.0)	6 (0.2)
Others	Households and extraterritorial organizations, nace unknown	520	5	8 (1.5)	7 (1.4)

Table 2. Summary statistics

Variable	**Mean**	**Std. Dev.**	**N**	**Min**	**Max**
Dependent variables					
EMAS	0.123	0.329	50477	0	1
Green patents	0.006	0.079	50477	0	1
Control Variables					
Employees	17.651	32.701	50477	0	249
Turnover	3.282	7.084	50477	0	49.967
Profit	3.369	17.139	50477	-89	100
pastInnov	0.043	1.006	50477	0	44
Kibs	0.129	0.335	50477	0	1
Spec suppliers manuf	0.016	0.125	50477	0	1
Science based manuf	0.024	0.152	50477	0	1
Scale intensive manuf	0.066	0.248	50477	0	1
Network infr	0.092	0.289	50477	0	1
Physical infr	0.047	0.211	50477	0	1
Supplier domin goods	0.247	0.431	50477	0	1
Supplier domin services	0.301	0.459	50477	0	1

Table 3. Cross-correlation table

Variables	Turnover	numberofemployees	Profit	pastInnovation
Turnover	1.000			
Employees	0.698	1.000		
Profit	0.035	-0.013	1.000	
pastInnov	0.084	0.076	0.003	1.000

Table 4 BiProbit estimation

	Green patents	EMAS
PastInnov	0.125***	-0.00849
	(0.00712)	(0.00780)
Agriculture	-0.755*	-0.0856
	(0.0660)	(0.327)
Supplier domin services	-0.430***	-0.441***
	(0.0902)	(0.0372)
Supplier domin goods	-0.365***	0.0412
	(0.0846)	(0.0357)
Physical infr	-4.674	-0.152**
	(447.6)	(0.0495)
Network infr	-0.715***	-0.428***
	(0.145)	(0.0462)
Scale intensive manuf	-0.145	0.178***
	(0.0959)	(0.0417)
Science based manuf	0.234*	0.995***
	(0.103)	(0.0528)
Spec suppliers manuf	0.321**	-0.0248
	(0.113)	(0.0646)
Kibs	-0.513***	-0.0633
	(0.113)	(0.0407)
Employees	0.00565***	0.0134***
	(0.000433)	(0.000235)
Profit	-.0004221	.0037548 ***
	(.0018966)	(.0005922)
Country dummies	Y	Y
Year dummies	Y	Y
Constant	-2.333***	-8.936
	(0.137)	(654.0)
ρ	0.159***	
Observations	50477	
Log likelihood	-14887.569	Wald chi2(58) = 7408.05
LR test: unrestr Vs. only intercept	chi2(58) = 12899.91	Prob > chi2 = 0.0000
LR test: $\rho = 0$	chi2(1) = 23.4889	Prob > chi2 = 0.0000

Standard errors in parentheses

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

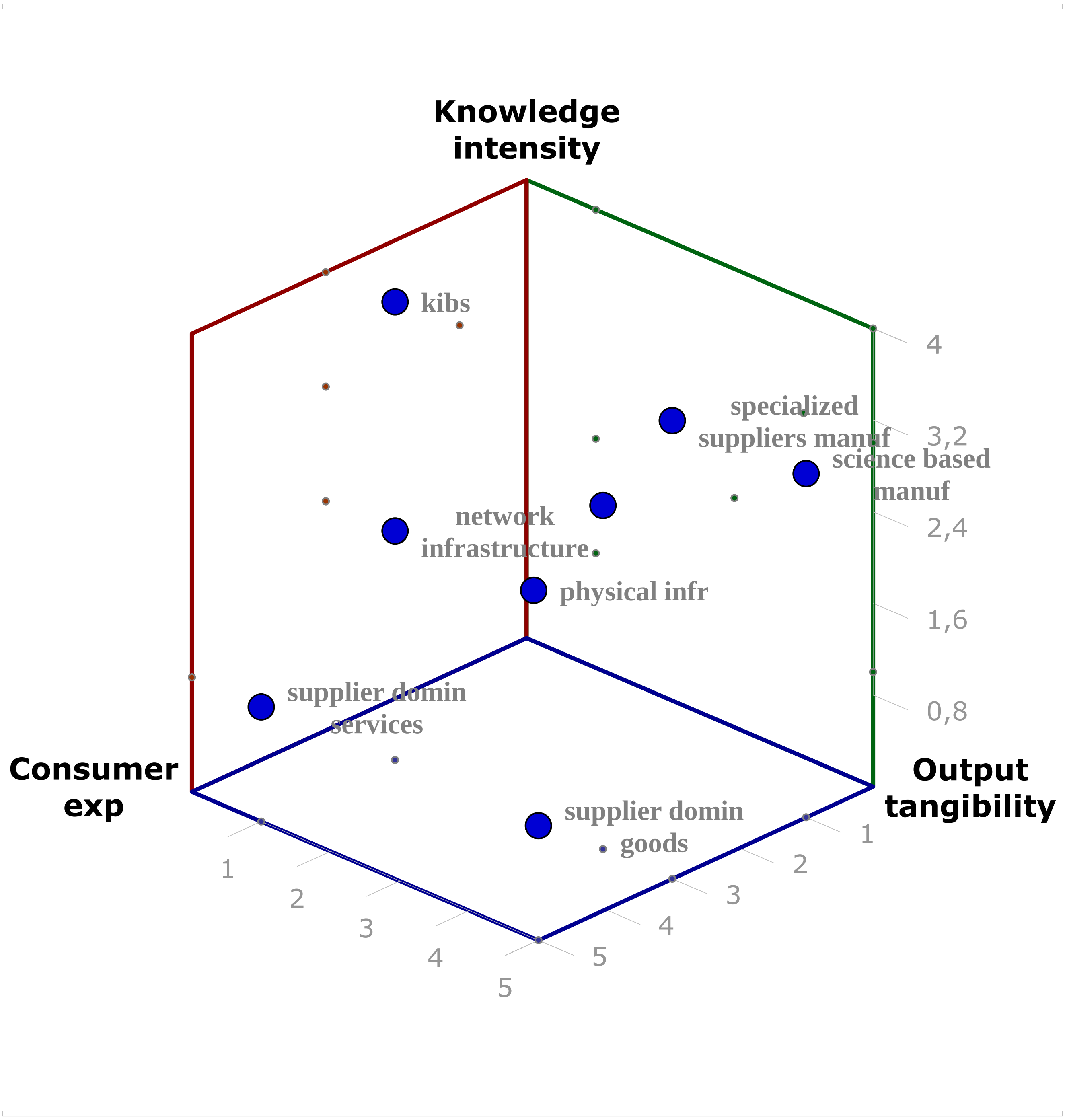
Table 5 BiProbit	Sectors			
	Kibs	Spec suppliers m	Science based m	Scale intensive m
EMAS				
PastInnov	-0.731***	0.0223	-0.0104	0.131*
	0.0335	(0.0158)	(0.0174)	(0.0662)
Profit	-0.000972	-0.0119**	0.00169	-0.00198
	(0.00243)	(0.00425)	(0.00471)	(0.00206)
Employees	0.0153***	0.00498***	0.00514**	0.0105***
	(0.00288)	(0.00124)	(0.00173)	(0.000598)
Constant	-1.058***	-0.861***	-0.901***	-0.940***
	(0.0542)	(0.0698)	(0.130)	(0.0328)
Green Patents				
PastInnov	1.276***	0.0992**	0.184***	0.159***
	(0.0403)	(0.0335)	(0.0536)	(0.0298)
Profit	0.00561**	0.00729	-0.00360	0.00364
	(0.00211)	(0.00759)	(0.00566)	(0.00616)
Employees	0.00427	0.00843***	0.00429*	0.00660***
	(0.00411)	(0.00170)	(0.00216)	(0.00104)
Constant	-2.942***	-2.200***	-1.558***	-2.655***
	(0.234)	(0.143)	(0.181)	(0.102)
ρ	-0.542***	0.102	0.479**	0.185*

Standard errors in parentheses. Country and year dummies included
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Log likelihood -318.144, Wald chi2(28) = 142.31;
Log likelihood -1068.21, Wald chi2(28) = 461.30;
Log likelihood -2517.413, Wald chi2(28) = 979.43;
Log likelihood -386,65 Wald chi2(28) = 186.65

Table 6 BiProbit	Sectors			
	Network infr	Physical infr	Supplier d goods	Supplier d serv
EMAS				
PastInnov	0.286+	-0.000997	0.0132	-0.0248
	(0.168)	(0.220)	(0.0139)	(0.0531)
Profit	-0.000293	0.00211+	0.00264**	0.00319*
	(0.00158)	(0.00108)	(0.000870)	(0.00139)
Employees	0.00729***	0.00967***	0.0152***	0.0127***
	(0.000620)	(0.000414)	(0.000430)	(0.000507)
Constant	-1.548***	-1.497***	-1.193***	-1.846***
	(0.0354)	(0.0221)	(0.0179)	(0.0217)
Green Patents				
PastInnov	-0.0170	-0.388	0.130***	0.225***
	(1.001)	(4.602)	(0.0140)	(0.0642)
Profit	-0.00166	-0.00380	-0.00224	0.00780
	(0.00713)	(0.00671)	(0.00318)	(0.00529)
Employees	0.00463*	0.00521**	0.00665***	0.00795***
	(0.00197)	(0.00169)	(0.000795)	(0.00122)
Constant	-3.057***	-3.345***	-2.855***	-3.170***
	(0.152)	(0.145)	(0.0667)	(0.0881)
ρ	0.331*	0.187	0.168**	-0.135*

Standard errors in parentheses.Country and year dummies included
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Log likelihood -1587.6008, Wald chi2(28) = 760.21;
Log likelihood -949.684, Wald chi2(28) = 434.98;
Log likelihood -2843.22, Wald chi2(28) = 737.89;
Log likelihood -15923.4 Wald chi2(28) = 4941.54

Figure 1



Knowledge intensity
kibs
specialized suppliers manuf
science based manuf
network infrastructure
physical infr
supplier domin services
supplier domin goods
Consumer exp
Output tangibility
4
3,2
2,4
1,6
0,8
1
2
3
4
5
1
2
3
4
5