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SMEs and Barriers to Eco-Innovation in EU: A Diverse Palette of Greens

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Abstract: Eco-innovation is an explicit aim of major EU policy strategies. Many environmental policy *de facto* require firms to eco-innovate to comply with policy requirements, while the overlap between policy-driven and market-driven eco-innovation strategies is increasingly important for many firms. Barriers to eco-innovation can then emerge as a critical factor in either preventing or stimulating EU strategies, policy implementation, and 'green strategies' by firms.

In this paper, we propose a taxonomy of EU SMEs in terms of barriers to eco-innovation. The aim is to discriminate among SMEs on how they differ in terms of perception of barriers and engagement in environmental innovation, thus highlighting the need to look at eco-innovation barriers in relation to firms' attitudes, technological and organizational capabilities, and strategies.

We identify six clusters of SMEs. These clusters include firms facing 'Revealed barriers', 'Deterring barriers', 'Cost deterred' firms, 'Market deterred' firms, 'Non eco-innovators' and 'Green champions'. The clusters show substantial differences in terms of eco-innovation adoption. We show that our proposed taxonomy has little overlap with sector classifications. This diversity should be taken into account for successful environmental innovation policies.

Keywords: eco-innovation, barriers to innovation, firm behaviour

JEL Codes: O33, Q55

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1 Introduction

In spite of a lacking precise and shared definition, eco-innovation became an explicit aim of major EU policy strategies.[4] Innovation is a priority in the implementation of the EU climate-energy strategy in place since 2007. EU funding of climate change related research is estimated at 9 billion/€ across the different themes of the 7th Framework Programme (FP) 2007-2013, compared to around 3,2 billion/€ in the 6th FP. By 2013. The EU's Environmental Technologies Action Plan (ETAP) is expected to have channelled over 12 billion/€ towards eco-innovation projects through FP6, FP7 and other EU funding programmes. Eco-innovation has been included among the missions of EACI, the European Agency on Competitiveness and Innovation. A 'Resource efficient Europe', which largely depends on eco-innovation diffusion, is one of the flagship initiatives of Europe 2020. Finally, an 'Eco-innovation Action Plan' (Eco-Ap) has been adopted by the European Commission in 2011 (see European Commission, 2011). Firms are, of course, the main actors in the implementation of these strategies.

A feature of eco-innovation is its direct link with policy. In many cases, policies addressing the environment, natural resources, and energy can explicitly (e.g. by technical standards) or implicitly (e.g. by economic instruments like taxation) require firms to adopt innovative technological or organizational solutions. As eco-innovation outcomes remain highly uncertain and can depend on uncertain innovative reactions by different industrial actors (e.g. Mazzanti and Zoboli, 2006a), firms subject to environmental policy requirements may be expected to eco-innovate even in the case this cannot provide the appropriation of net economic benefits.

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[4] A often referred definition of eco-innovation is "*The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life-cycle, in a reduction of environmental risks, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*" (UNU-MERIT et al., 2008). See also Europe Innova (2008) and CML et al. (2008).

However, a transition from policy-driven to market-driven eco-innovation is under way as a result of the increasingly strategic dimension of environmental practices at the firm level and the development of 'green markets' (e.g. Ambec and Lanoie, 2008). This transition is reflected in the debate on the Porter Hypothesis (e.g. Ambec et al., 2013; Porter, 1991; Porter and Esty, 1998; Porter and van der Linde, 1995), which suggests that better environmental performances as well as eco-innovation strategies can be a source of competitive advantages for firms.

Barriers to eco-innovation can then emerge as a critical factor in either preventing or enabling EU strategies, policy implementation, and 'green strategies' by Porterian firms. Furthermore, while eco-innovation barriers may be similar to 'conventional' innovation barriers, the evolving overlap between 'policy-driven' eco-innovation and 'market-driven' eco-innovation can give specific characteristics to eco-innovation barriers as well as to firms' reactions to them.

In this paper, we propose a clustering of EU SMEs in terms of barriers to eco-innovation and eco-innovation engagement. Our focus on SMEs is due to their potential in triggering economic development via the exploitation of emerging green business opportunities (e.g. Shapira et al., 2013).[5] We employ data from the 2011 Flash Eurobarometer on "Attitudes of European Entrepreneurs towards eco-innovation" and other sources on environmental regulatory stringency in EU countries, innovativeness and 'dirtiness' of industrial sectors. The aim is to discriminate among SMEs on the basis of their perception of barriers and actual investment in environmental innovation. In so doing we recognize that barriers perception is intimately related to the engagement in innovation (see for example D'Este et al., 2012).

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[5] SMEs represent the core of EU27 private sector, employing 66.7 percent of the workforce in non-financial business sectors in the year 2008 (source: Eurostat).

The paper is structured as follows. Section 2 reviews the relevant literature. Attention is given to eco-innovation peculiarities and innovation barriers. Section 3 describes the methodology for clustering and the data we employ. Section 4 presents the clusters emerging from the analysis, their level of eco-innovation adoption, and their characteristics related to country location and the sector they belong to. Section 5 concludes and suggests some policy implications of the analysis.

2 Literature review

There exists a broad literature investigating the drivers of eco-innovation (Horbach et al., 2012). The main aim of this literature is to identify specificities of eco-innovation with respect to innovation tout court. This is generally done by identifying the direction and relevance of a series of driving forces of eco-innovation. After some early contribution based on US data (Lajouw and Mody, 1996; Brunnermeier and Cohen, 2003), this literature has flourished in recent years, also thanks to the widespread availability of data on eco-innovation adoption contained in the 2008 wave of the Community Innovation Survey (CIS2008) (see Horbach et al., 2013 for a review).

A first important specificity of eco-innovation is found in the double externality issue (Jaffe et al., 2005). The first market failure affecting eco-innovation refers to usual positive externalities (knowledge spillovers and imitation) generated by innovation activities. As suggested by Arrow (1962), firms fail to completely internalize the returns to innovation. The second market failure is due to the fact that eco-innovation has the effect of reducing negative environmental externalities that are not valued by the market (in absence of public intervention). The absence of a monetary reward for improved environmental performance of products and production processes calls into question the need of public intervention aimed at creating markets for negative environmental externalities (e.g. environmental taxes, markets for pollution allowances, subsidies for emissions abatement or for the adoption of cleaner technologies) or at imposing the adoption of specific environmental standards (regulatory pull and push effect – Jaffe et al., 2005). The combination of these two market failures results in a substantial under-investment in eco-innovation, well below socially optimal levels.

Also Porter and van der Linde (1995) emphasize the role played by (well designed) environmental regulations. Their conceptual discussion, based on case-evidence of profitable policy-induced eco-innovations, leads to the so-called 'Porter hypothesis'. This latter highlights that the role of environmental regulation goes beyond the solution of the environmental externalities, it is crucial to reduce information asymmetries and uncertainties, and signals potentially unexploited inefficiency improvements and cost savings linked to improved environmental performance (Horbach, 2008).

Furthermore, eco-innovation differs from standard innovation in terms of pecuniary incentives and importance of regulations. Eco-innovation requires additional and broader knowledge which does not belong to the core competences of firms or to the traditional industrial knowledge base (e.g. De Marchi, 2012). Resort to cooperation agreements (e.g. Cainelli et al., 2012; De Marchi, 2012) and external knowledge sourcing (e.g. Ghisetti et al., 2013) are thus particularly important and "complement" investment in organizational and technological capabilities (e.g. Horbach, 2008; Demirel and Kesidou, 2012; Horbach et al., 2012). Embeddedness in (local) production systems and complementarity between different types of (eco-)innovation are also emerging relevant factors for the patterns of eco-innovation adoption by SMEs (Mazzanti and Zoboli, 2005, 2008, 2009; Cainelli et al. 2011).

Finally, many contributions (e.g. Horbach, 2008; Demirel and Kesidou, 2012; Horbach et al., 2012) also explored the extent to which eco-innovation is affected by more classical drivers of innovation (in general) such as technology-push and market-pull factors. Similarly to general innovation activities, eco-innovation is also stimulated by the availability of capabilities (internal or external to the firm) in terms of knowledge stock, human capital and organizational features (technology-push) and by market stimuli in terms of 'responsible' demand from consumers, other firms and public procurement (market-pull) (see Horbach, 2008, for a discussion).

While the recent literature on the drivers of eco-innovation is well developed, basically no contribution tries to give a comprehensive overview of the barriers to eco-innovation. Among the few contributions in the field, Foxon and Pearson (2008) adapt from the literature on systems of innovation (e.g. Smith, 2000) some categories of 'system failures' to the field of eco-innovation. These are failures in infrastructure provision and investment, transition failure, lock-in failures and institutional failures. These failures, however, refer to systemic issues with little consideration for within-firm barriers. Del Rio et al. (2010) focus their discussion at more 'micro-level' barriers to eco-innovation (*conditions internal to firms*). However, neither Foxon and Pearson (2008) nor Del Rio et al. (2010) try to provide a comprehensive empirical assessment of barriers to eco-innovation.

On the contrary, the literature on "standard" technological innovation has devoted great attention to innovation barriers. The increasing availability of suitable data from innovation surveys (e.g. Community Innovation Survey, CIS) has led to a more extensive empirical evidence on the topic.[6] Extant literature has pursued two main lines of investigation (Iammarino et al., 2009; D'Este et al., 2012). These focus on the determinants (e.g. firm's characteristics) that affect the perception of barriers and the impact of these latter on the firm's innovation propensity and intensity. General insights

[6] The harmonized CIS questionnaire before the inclusion of the questions on environmental innovations (i.e. before the 2008 wave) was equipped with a specific section on innovation barriers.

are worth being stressed. Despite the large attention on barriers of financial nature (e.g. Hall, 2002; Savignac, 2008; Mancusi and Vezzulli, 2010; Hottenrott and Peters, 2012), literature also focuses on other types of non-financial obstacles, like factors related to market structure and regulations, knowledge, organizational and technological capabilities (e.g. Tiwari et al., 2007; Iammarino et al., 2009; D'Este et al., 2012, 2014; Blanchard et al., 2013; Pellegrino and Savona, 2013; Hölzl and Janger, 2013). Developing from the idea that innovation may be hampered by different types of obstacles, attention has been given also to the complementarities among the different types of barriers (e.g. Galia and Legros, 2004; Mohnen and Röller, 2005). This has resulted in important implications for the design of policy packages aimed to lower the obstacles that hinder firms' innovation.

Evidence on barriers to innovation has revealed an important aspect that should be taken into account when dealing with data on perceived obstacles to innovation activities. Specifically, this pertains to the counter-intuitive findings related to the positive relation between innovative performance and experienced barriers intensity. Contributions on the topic have pointed to a reverse causality issue. As claimed by Galia and Legreos (2004; 1189) "*it is plausible that certain problems are not effectively encountered until firms face them.* [...] *Innovative firms face problems and more innovative firms have more problems*". Brought to an extreme, this position might lead to consider barriers perception as a sign of how successful the firms are in overcoming innovation obstacles (e.g. Baldwin and Lin, 2002; Tourigny and Le, 2004). Recognizing this reverse causality issue, D'Este et al. (2012) propose to distinguish between two types of innovation barriers: 'revealed' and 'deterring' barriers. The former relates to those obstacles which firms face when they commit to innovation. Through the engagement in innovation activities, firms become aware of the difficulties: in turn, there emerges an experiential learning process that leads to increasing consciousness of those factors that hinder innovation. Because of their disclosing nature, revealed barriers differ from deterring ones, which, on the contrary, refer to obstacles that actually prevent firms from engaging in innovation.

3 Data and methodology

3.1 Data and variables

To perform our analysis we rely on a survey-based source of data: the Flash Eurobarometer on "Attitudes of European Entrepreneurs towards eco-innovation", conducted by the Gallup Organization on behalf of the DG Environment of the European Commission. Interviews, carried out through January and February 2011, are directed to a random and representative stratified sample of EU-27 SMEs (10-249 employees). Sectors involved in the survey are: agriculture, manufacturing, environmental industries (i.e. water supply, sewerage and waste management), construction and food services (restaurants, catering, beverage serving). Such a source of data reveals to be extremely useful for our analysis, as it specifically focuses on firms' eco-innovative activities. When compared to innovation surveys (e.g. CIS) largely used in studies on determinants and impacts of eco-innovation, Eurobarometer data have a main advantage. They include specific information on both the investment in eco-innovative activities and barriers to eco-innovation.

We focus on selected relevant sectors: manufacturing and environment-related industries. We believe these are more relevant when considering barriers to eco-innovation in SMEs. This narrow focus and the cleaning procedure of the data (i.e. dropping observations with missing values in the relevant variables) leave us with an operating sample of 2,308 firms out of the 5,222 firms included in the original sample (of which 2,948 belonging to our sectors of interest).[7]

As for the variables that we use in our cluster analysis, we take into account two aspects that emerge from the literature on innovation barriers (see Section 2). First, we do not confine our analysis to financial barriers, but we consider a larger set of obstacles that refer to costs, market and knowledge. Second, we want to account for the different nature of 'revealed' and 'deterring' barriers. To this aim, we include the actual investment in green innovation as an additional clustering variable. This help identifying firms that, while experiencing high barriers (cost, market, and knowledge), have either a strong actual engagement in eco-innovative activities (revealed barriers) or a weak engagement in eco-innovation (deterring barriers).

Variables capturing eco-innovation barriers are created as follows. We group the 14 different types of barriers included in the Eurobarometer questionnaire (Q.7 – refer to Box 1 in the Appendix), in order to reduce the number of variables. Grouping is based on the types of obstacles identified in the literature (see Section 2), and is validated through a principal component analysis.[8]

A first group of variables captures 'cost barriers' related to insufficient internal and external funding, uncertain return to eco-innovation and insufficient access to subsidies and financial incentives. A further set of variables reflects 'knowledge barriers' due to: lack of qualified personnel and technological capabilities; lack of external

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[7] Excluded firms in our sectors of interest, once controlling for country and industry characteristics, do not differ, on average, from our sample of firms in terms of size (employees and turnover), turnover growth, product eco-innovation outcome, cost and market barriers while they have slightly lower eco-innovation investment, process eco-innovation outcome and knowledge barriers.

[8] We grouped barriers by considering factor loadings obtained by means of a principal component analysis. Results confirm, in line with the theoretical expectations, the three-variable grouping we implement. However, due to the relatively low explained variance (about 55 percent), we do not use the resulting principal components in our clustering procedure.

information; lack of suitable business partners; lack of collaboration with research organizations and technological lock-ins. The final group of variables refers to 'market barriers' caused by: uncertain demand; lack of incentives to reducing material use; lack of incentives to reducing energy use; dominated market and existing regulations not providing incentives to eco-innovate. Cronbach’s alpha values (i.e. 0.74, 0.74, 0.66 for the three groups, respectively) support the internal consistency of the grouping of barriers.[9]

After the grouping, we create our variables for cost, knowledge and market barriers. We sum the score (deriving from a 4-point likert scale) of each item in the three groups and divide by the number of items in each group[10]. The resulting values are then normalized to have mean equal to 0 and variance equal to 1 (Z-scores). The fourth variable included in the cluster analysis reflects the engagement in eco-innovative activities. The variable *EI investment* is obtained through the normalization (Z-score) of an ordinal variable (Q.6 in the Eurobarometer questionnaire) reflecting the percentage of investment in eco-innovation over the total of innovation expenditures.[11]

In addition to these clustering variables, we use variables on eco-innovation adoption at the firm level. We employ a series of dummies taking values 1 if the firm adopted eco-innovation. *Product or process EI* captures whether the firm introduces either a product or process innovation. *Product EI* refers to product innovations, while *Process EI* to process innovations. These variables are not used in the 'internal profiling' of the clusters; instead, they are used to check if and how clusters match green innovation

[9] Among the alternatives, our grouping of the barrier variables maximize the internal consistency scores.
[10] Scores are expressed by means of a 4-point likert scale related to importance of each barrier. The scale is as follow: 1 not at all serious; 2 not serious; 3 somewhat serious; 4 very serious.
[11] 0: 0%; 1: less than 10%; 2: between 10% and 29%; 3: between 30% and 49%; 4: more than 50%. Note that this variable does not refer to absolute engagement in EI investment but rather the relative orientation of innovation investment towards green innovation.

adoption. This can provide an 'external profiling' of the clusters that reveals actual behavioural difference between the clusters in terms of expected eco-innovation adoption.

Finally, we create a set of variables upon which we can characterise how firms in different clusters are distributed across countries with different levels of environmental regulatory stringency, and sectors with different emission intensity and R&D intensity.

Information on country-level environmental regulatory stringency stems from the Executive Opinion Survey managed by the World Economic Forum – The Global Competitiveness and Benchmarking Network. For each country we calculate the 2006-2011 average of the perceived stringency levels.[12] Three groups of countries are created using thresholds given by the 33th and 67th percentile of the stringency levels distribution.

Information on emission intensity of sectors to which firms belong is taken from Eurostat NAMEA (National Accounting Matrix including Environmental Accounts) data. We consider the sectoral intensity of emission of CO_2, SO_2 and NO_x over the sectoral value added and calculate a single sectoral emission score that equals the sum of the three standardized (from 0 to 1) intensity averages over the period 2008-2010. 'Green', 'grey' and 'brown' sectors are then defined on the basis of the 33th and 67th percentile of the sectoral emission score distribution.

Finally information from sectoral R&D intensity stems from Eurostat 2006-2008 CIS data. We calculate the sectoral R&D intensity in the last year available (2008) as the ratio between R&D investment and turnover. Also in this case the 33th and 67th percentile of the sectoral R&D intensity distribution are used to define three groups of sectors.

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[12] In the survey business executives are asked to rate on a 7-point Likert scale (where 0 stands for "very lax" and 7 for "among the world most stringent") the stringency of their country's environmental regulations.

3.2 Methodology

We build a taxonomy of barriers to eco-innovation by means of cluster analysis techniques. As suggested by Hair et al. (2009), in a first step we cluster our firms through a hierarchical clustering method and identify the optimal number of clusters. In a second step, starting from the centroids obtained in the hierarchical clustering, we use a non-hierarchical method to assign firms to clusters. Finally, we validate the clustering solution.

We use the average-linkage method[13] as our preferred algorithm for the hierarchical clustering. The average-linkage method compares all individual belonging to a cluster with all individuals in other clusters. This method minimizes the influence of outliers (Hair et al., 2009). In a reasonable and tractable range of cluster solutions (between three and eight clusters) we choose a six-clusters solution based on the Duda-Hart stopping rule.[14] Finally, the centroids of the hierarchical clustering have been used as the starting point for the non-hierarchical clustering. Non-hierarchical clustering further reduces the influence of outlying observations and allows firms to be reassigned to more suitable clusters once the number of clusters is chosen.

The six-clusters solution has been validated by splitting the full sample of 2,308 firms into fifty random samples of 1,154 firms each. We replicated the same steps (hierarchical clustering with average-linkage to obtain the centroids and non-hierarchical clustering to assign the firms to the clusters) for the random sub-samples. We then

[13] Similarity is measured by means of the squared Euclidean distance.

[14] The six-clusters-solution has the minimum level of pseudo T-squared statistics (16.57 compared to 22.68 of the five clusters solution and 54.21 of the seven clusters solution) and the maximum level of Je(2)/Je(1) statistics (0.97 compared to 0.9 of the five clusters solution and 0.8 of the seven clusters solution). The Calinski-Harabasz pseudo F does not suggest any other specific clustering solution. Moreover, internal and profiling and eco-innovation adoption analysis for cluster solutions with a different number of clusters was generally less satisfactory in terms of balance between the within-cluster homogeneity and between-clusters differences.

compared the distribution of firms across clusters in the original clustering with the one obtained for the fifty random sub-samples separately. On average, 81.93 percent of firms were assigned to the correct original cluster, confirming the robustness of our clustering.

Another robustness check of our clustering comes from the analysis of the variance (ANOVA) in which we use as dependent variables our clustering variables (EI investment intensity and cost, market and knowledge barriers) as well as all original indicators of perceived barriers and indicators of eco-innovation output. Further support comes from the Scheffe's tests. These are aimed to test for the significance of the difference between all pairs of clusters in terms of clustering variables, single barrier-items and eco-innovation outcome. Finally, another validation of our methodological approach comes from the analysis of eco-innovation adoption in the clusters (see Section 3.1), on which we comment in Section 4.1.

4 A proposed taxonomy

The evidence emerging from the cluster analysis is presented in **Table 1**. Further insights come from the analysis of eco-innovation adoption in the clusters (**Table 3**) and the characterization of countries and sectors to which our firms belong (**Table 4** and **Table 5**).

[Table 1 about here]

Table 1 allows us to profile the clusters, considering the mean values of the key variables employed in the procedure (see Section 3.2). We report the mean of the 4 groups of clustering variables that capture cost, market, and knowledge barriers together with EI investment. We also report the mean values of the single variables that contributed to generate the three barrier categories (see Section 3.1).

The inclusion of the EI investment variable allows us to investigate the extent to which barriers combine with the actual engagement in green innovative activities in generating different clusters.

In particular, there are firms with high perceived barriers that can have either high or low EI investment, and the same applies in the case of low perceived barriers. This highlights the different behaviour of different firms in front of similar barriers and thus the need to discriminate among them. As we will see, while these differences point to the role of firm's capabilities and strategies in front of eco-innovation, consistently with an evolutionary reasoning, they also point to the need to target policy interventions to the different types of SMEs, abandoning a “one fits all” approach when implementing innovation and environmental policies.

Specifically, our analysis discriminates among six clusters.

First, we identify a 'Revealed barriers' cluster. Firms in this group perceive the whole spectrum of obstacles to eco-innovation as highly relevant. Nevertheless, EI investment is relatively high. These firms perceive barriers along the innovation path, as they become aware of the difficulties related to the engagement in eco-innovative activities. In other terms, barriers for this group of firms can be seen as part of an experiential learning process.

The second cluster that is singled out in our analysis includes SMEs that face 'Deterring barriers'. These firms are characterized by relevant obstacles related to costs, market and knowledge. Differently from the firms belonging to the previous cluster, SMEs facing deterring barriers are characterized by a low EI investment. Hence, in this second cluster barriers act as obstacles that prevent firms from engaging in eco-innovation.

These two clusters seem to mirror, in the green realm, the results of the research literature on the obstacles to innovation in general (see Section 2). Nevertheless, specific features of eco-innovation can emerge from these two clusters. Firms belonging to these two clusters experience not-too different levels for almost all the barriers (single and groups) while they have an extremely different level of EI investment (**Table 1**). This difference can mark either a strong divide (or, dynamically, a bifurcation) of reactions, capabilities, and strategies for green innovation, or they may reflect different environmental regulation requirements that lead to divergent pressure to perform EI investment.

'Cost deterred' firms constitute the third cluster of SMEs we identify. These firms report relatively high obstacles related to eco-innovation financing and costs, while relatively low barriers related to market and knowledge. EI investment is lower than the sample average. These firms seem to fall within the conventional view about the opportunity costs of environmental regulation to firms and the limited appropriability of eco-innovation benefits, which can be public goods to a large extent ('double externality' arguments, see Jaffe et al., 2005). This cluster can correspond to a failure of the Porter Hypothesis from the supply side: even though to eco-innovate might create gains of competitive advantages (low market and knowledge barriers), firms do not perceive enough net benefits (due to the high costs) from this strategy.

The fourth group of firms emerging from our analysis is that of SMEs with a relative higher perception of 'Market barriers', with relatively low cost barriers and knowledge barriers. Such a barrier profile is associated to an engagement in EI investment which is lower than the average. In this case, in spite of the potential capacity of eco-innovation, the market mechanisms do not provide enough opportunities because of either the lack of markets or the limited capacity of appropriation of the positive externality related to eco-innovation ('double externality' issue). This cluster can correspond to a failure of the Porter Hypothesis from the demand side: firms can have opportunities to gain competitive advantages from eco-innovation (low costs and knowledge barriers) but there are not enough perceived market opportunities (low market demand) to justify this strategy.

The fifth cluster we identify is made of SMEs that we define 'Non eco-innovators'. These firms are characterized by low levels of perceived obstacles (all groups) but have a very low level of EI investment. Their low engagement in spite of low barriers is probably due to the lack of intrinsic incentives (e.g. little relevance of environmental regulation for them). In addition, the group includes also those firms that are not interested in carrying out innovative activities (e.g. Savignac, 2008), regardless their "green tone".

Finally, our cluster analysis distinguishes a group of SMEs that manage to achieve a high EI investment while reporting medium-level obstacles to eco-innovation. Whereas these firms face far higher barriers than ‘Non eco-innovators’ their profile is generally characterized by lower perceived obstacles than the other clusters.[15] However, they perceive cost barriers similar to ‘Market deterred’ firms, and market barriers similar to that of ‘Cost deterred’ SMEs. We define them as 'Green champions': opportunities and capabilities related to eco-innovative products and processes are a fundamental component of their core business strategy and make them able to engage heavily in eco-innovation even though they may face certain non-negligible barriers.

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Table 2 resumes the clusters in terms of the combination between the level of perceived barriers and the level of EI investment with reference to data in **Table 1**.

[

Table 2 about here]

The results emerging from the cluster analysis can be looked at in a different perspective. Investment in eco-innovative inputs (i.e. EI investment) is not the only aspect that affects the eco-innovative profile of EU SMEs. These differ also in the extent to which they perceive barriers. For all our clustering variables as well as for each specific barrier, the ANOVA (analysis of variance) suggests that differences in these variables across clusters are jointly statistically significant. Moreover, pairwise comparisons based on the Scheffe's test suggest significant differences also for most pairs of clusters for all variables. In the last column of **Table 1** we report only the few pairs for which the Scheffe's test indicated a statistically insignificant difference between two specific cluster for a given variable[16].

4.1 Eco-innovation adoption in the clusters

We validate the profiling based on clustering variables ('internal profiling') by investigating the extent to which clusters differ with respect to variables representing actual undertakings along eco-innovation strategies, that is the adoption of product and/or process eco-innovations (see Section 3.1). The results of this analysis are presented in **Table 3**.

[Table 3 about here]

[16] This means that all unreported pairs are characterized by pairwise significant differences. As we found significant differences in clustering and external variables for the large majority of pairs, our clustering can be deemed robust.

We expect ex ante that different combinations of perceived barriers and EI investment intensity will result into different rates of eco-innovation adoption. We consider three different outcomes: i) the firm adopts either a product or a process eco-innovation; ii) the firm adopts a product eco-innovation; iii) the firm adopts a process eco-innovation. ANOVA suggests that our clusters are characterized by jointly significant differences in eco-innovation adoption. Moreover, Scheffe's tests highlight statistically significant differences for most pairs of clusters in variables related to eco-innovation adoption. At a first sight there seems to be a strong relation between EI investment intensity and innovation adoption, with the ranking of clusters based on the two measures being basically identical (with the only exception of the 'Non eco-innovators' and 'Deterring barriers' clusters). However, barriers matter for successfully adopting eco-innovations, once EI investment orientation of the firms is controlled for.[17]

The most successful clusters in terms of eco-innovation adoption are the 'Revealed barriers' and the 'Green champions' clusters, which are also the ones with higher intensity of EI investment. However, we observe that, despite the substantially (and statistically different) higher effort in terms of EI investment of firms in the 'Green champions' cluster as opposed to firms in the 'Revealed barriers' cluster, the eco-innovative adoption rate is not statistically different between the two clusters. Probably because of firm-specific features and intentional green strategies, firms in the 'Revealed barriers' cluster can have the same rate of eco-innovation adoption of 'Green champions' firms with a lower engagement in EI investment. Moreover, it seems that facing revealed barriers is intrinsically connected to an experiential learning process (D'Este et al., 2012),

[17] In unreported regressions we estimate the extent to which belonging to a specific cluster affects eco-innovation outcome once controlling for sector, country and, more importantly, intensity in EI investment. For all measures of eco-innovation outcome we find that cluster dummies are jointly significant.

which positively affects the return on EI investment in terms of eco-innovation performance.

A similar evidence is found for the 'Cost deterred' and 'Market deterred' clusters, for which an intermediate rate of eco-innovation adoption, similar in the two clusters, is accompanied by significant differences in EI investment intensity (higher in the 'Cost deterred' cluster). No matter the EI investment, pecuniary barriers, either cost or market ones, seem to have the same effect on eco-innovation adoption.

Moreover, despite the significant difference in EI investment intensity between firms in the 'Non eco-innovators' and 'Deterring barriers' clusters (higher in the case of the 'Non eco-innovators'), no such difference is found in terms of eco-innovation adoption by the two clusters.

Finally, looking at the only two clusters for which no significant difference is found in terms of EI investment intensity ('Non eco-innovators' and 'Market deterred'), we observe significant differences in adoption. Disinterest and lack of orientation towards eco-innovation, make 'Non eco-innovators' firms having a significantly worse adoption performance.

All in all, eco-innovation adoption confirms the difference between clusters in line with expectations. The two best performing clusters in terms of adoption are 'Revealed barriers' (high barriers, high EI investment, and high eco-innovation adoption) and 'Green champions' (medium barriers, very high EI investment, and very high eco-innovation adoption). At the other extreme, the two worse performing clusters for adoption are 'Deterring barriers' (high barriers, low EI investment, and very low eco-innovation adoption) and 'Non eco-innovators' (low barriers, very low EI investment, and low eco-innovation adoption). In the middle there are the other two clusters: 'Cost deterred' and 'Market deterred', both having (with differences) medium level barriers, medium EI investment engagement, and medium-level eco-innovation adoption. The overall picture seems to be, therefore, self-consistent.

4.2 Sectoral and geographical distribution of clusters

As a final step of our analysis, we want to investigate if and how our clusters are related to the institutional environment of the countries and to the classification of sectors (see Section 3.1). The aim is to verify if the country (institutional features for environmental regulation) or the sector (innovativeness and emission intensiveness features) of the firms could be a good predictor of the cluster they belong to. This analysis is important to verify if our clustering is non-trivial, i.e. countries and/or sector features do not perfectly explain perceived barriers and green innovative attitudes.[18]

[Table 4 about here]

Table 4 reports absolute and relative frequencies of firms by cluster and by country (first block) and sector (second and third blocks). Countries are grouped according to the perceived stringency of environmental regulations. Table A1 reports the countries belonging to each of the three groups we identify (top regulated, mid regulated, low regulated) according to their position in the ranking created from the World Economic Forum data (see Section 3.1). Sectors are aggregated according to two alternative criteria (Table A2). First, we distinguish sectors according to their average emission intensity. 'Green sectors' are the ones with lower emission intensity, 'grey

[18] In unreported analysis we explored the relationship between our clustering and firm size. The only information available in the survey about firm size refers to the distinction between small firms (10-49 employees) and medium firms (50-250 employees). This is a quite rough distinction, especially if we consider the fact that the firm size distribution is substantially skewed, making the size class '50-250 employees' extremely heterogeneous. Nevertheless, evidence suggests that medium firms tend to be over-represented in the 'Green champions' cluster while small firms are relatively more concentrated into the 'Deterring barriers' and 'Market deterred' clusters. Results are available upon request.

sectors' are the ones with intermediate emission intensity, 'brown sectors' are the most emission intensive sectors. Second, we distinguish sectors according to their average R&D intensity (low, mid, and high technology sectors). Table A2 reports the correspondence of each NACE sector to these rankings of emission intensity and R&D intensity.

If clusters are over-represented (under-represented) in specific countries or sectors, relative frequencies (square brackets) in Table 4 should be higher (lower) than their column total.

First, it is interesting to notice that SMEs that are characterized by high and diversified barriers profiles (i.e. firms in the 'Revealed barriers' and 'Deterring barriers' groups) are located in countries with low regulations. The lack of a supportive environmental-oriented institutional framework seems thus to be related to a higher perception of barriers across the whole spectrum of possible eco-innovation obstacles. To be sure, whereas 'Revealed barriers' firms are somewhat evenly distributed across sectors, 'Deterring barriers' companies are slightly more concentrated in 'grey' and 'medium-tech' sectors.

'Cost deterred' firms are likely to be found in 'mid-regulated' countries, 'brown' and 'mid-tech' sectors. This is not surprising given that mid-tech and brown sectors are represented by paper manufacturing, rubber and plastics, and basic metals (see Table A2), which can face high costs for green strategies that give rise mostly to pubic goods (pollution abatement).

Firms in the 'Market deterred' cluster are likely to belong to 'top' and 'mid regulated' countries, 'green' sectors and both 'high-tech' and 'low-tech' sectors. This picture seems to be consistent with the low cost and knowledge barriers these firms do face: limited market opportunities can be the most important perceived barrier, given a highly regulated, and then highly demanding, institutional environment.

Firms in the 'Non eco-innovators' cluster are relatively more likely to be found in 'top regulated' countries, 'green' sectors (i.e. low emission intensity) and 'high-tech' sectors, which can be reasonable given that low-emission high-tech sectors include pharmaceutical products, computers, electrical equipment and other sectors that are relatively little sensitive to environmental issues even in top regulated countries.

Finally, 'Green champions' firms are more likely to be found in 'top regulated' countries and both 'green' sectors and 'brown' sectors, either 'high-tech' or 'low-tech'. This internal diversity of 'Green champions' is interesting because it points purely to the features of the firm in determining green strategies, given 'extreme' industrial situations and a highly regulated institutional environment.

All in all, **Table 4** reports the country-level institutional and sectoral features that correspond the clusters we have identified. This is also reflected in the value and significance of the Pearson χ^2 tests reported on the right column of **Table 4**. From the tests, we notice that the distribution of the firms in the six clusters is not independent from the distribution of firms across classes of countries and sectors based on regulation stringency, R&D intensity and emission intensity. In other terms, the χ^2 tests point to joint cross-cluster differences in terms of country-level institutional features and sector-level technological and environmental characteristics. To be sure, the difference is slightly weaker when we look at the emission intensity of sectors (p-value of the χ^2 test equals 0.01).

To further investigate the possible correspondence between sectors or countries and our clusters, we run a series of regressions in which we estimate the probability of belonging to a cluster as a function of both sectoral and country dummies. Probit regressions employ NACE Rev. 2, R&D and emission intensity sector dummies, respectively, together with EU27 country dummies.[19]

[Table 5 about here]

Tests on the joint significance of sector and country dummies are reported in **Table 5**. On the one hand, the nationality of firms seems to matter in predicting to which cluster firms do belong: there are jointly significant differences across countries in the probability of belonging to a specific cluster. However, it can be noted (Table A3) that the conventional view about green leader and laggard countries does not find a good correspondence with our clusters. For example, as expected 'Green champions' are a high share of total firms (higher than EU average) in Sweden, Finland, the Netherlands, and partly Austria, i.e. environmentally leading and top regulated countries. However, the share is high also in Poland and Malta, which are low-regulated countries, and the share is lower than EU average in Germany and especially in Denmark, which is unexpected being both countries green leaders and top regulated. In a similar way, the share of 'Non-innovators' cluster is relatively high (compared to the EU average) in some 'laggard' Eastern and Southern European 'low/mid regulated' countries, but it is high also in Germany and the UK, as well as in Denmark and Sweden, all green leaders (with the exception of the UK) and top regulated. Each country seems to have a specific profile with respect to the weight of different clusters. For example, Germany has a high share of total firms (with respect to EU average) in the 'Market deterred' and 'Non eco-innovators' clusters, while it has one of the lowest shares of firms in the 'Deterring barriers' cluster.

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[19] Results are robust when, instead of these latter, we use dummies for country-level regulation stringency. For sake of brevity we do not report these results which are available upon request.

The statistical significance of the country dummies in **Table 5** suggests, on the one hand, that the location in a given country is generally strongly related with the firm's probability to belong to a certain cluster. On the other hand, however, there is not a correspondence between leader/laggard - or top/low regulated - countries (see **Table 4**) and the specific clusters their firms do belong to.

Contrary to country location, belonging to a given sector (either captured by the standard NACE classification or by our macro-sectors definitions based on emission intensity or R&D intensity), does not (generally) significantly affect the probability to belong to a given cluster once controlling for the nationality of the firms. The only exceptions are the 'Deterring barriers' and 'Green champions' groups: the probability to belong to these cluster is affected by the emission-intensity sectoral variables.[20] Hence, according to our test on the joint significance of the dummies, there is not a strong correspondence between sectoral classifications and our clusters. Combining this evidence with that emerging from **Table 4**, we can conclude that even in presence of cross-cluster differences in terms of sectoral characteristics, these do not systematically predict the probability to belong to a given cluster.[21]

All in all, our clusters reflect something different, in terms of berries to eco-innovation and firm's reaction to them, compared to sectoral classifications, be the latter based on standard NACE classification or based on innovativeness and emission intensity.

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[20] The tests report only weakly significant values for joint significance of R&D intensity dummies in predicting 'Deterring barriers' cluster belonging. Similarly weakly significant is the test of the joint significance of emission intensity dummies in predicting the probability to belong to the 'Market deterred' cluster.

[21] This result seems to partly contradict the Pearson tests reported in Table 4. It should be noted, however, that: i) we are now controlling for country-specific characteristics, and ii) we now consider the role of sector specificities ‘cluster-by-cluster’ The results of the Pearson tests reported in Table 4 could be actually driven by strong sectoral components in one or few clusters (e.g. in the ‘Green champions’ cluster) and/or by country-specific concentration of firms in specific sectors, thus making the Pearson test partly misleading.

The limited overlap between our clusters and sectors classifications confirms that our clusters cannot be trivially predicted by looking at the sectors to which the firm belongs. Instead, it is the combination of the firms' characteristics (strategic perceptions, capabilities, knowledge), their revealed behaviour in terms of EI investment and eco-innovation adoption generate different profiles of firms, a conclusion consistent with those of van den Bergh (2013).

5 Conclusions

While barriers emerge in all innovation processes, barriers to eco-innovation are particularly important because innovation can be the main course of action to comply with environmental policies and because eco-innovation is an important objective of recent EU-level strategies. As a consequence, not only firms' barriers to eco-innovation can discourage green strategies of companies but they can also hinder the implementation of important EU macro policies.

In the paper, we proposed a taxonomy of EU SMEs based on barriers to eco-innovation by exploiting data from a sample of 2.308 firms in manufacturing and environmental service industries (water and waste management). We identified six statistically robust clusters based on the combination of different types of perceived barriers (cost, market, knowledge) and the declared engagement in EI investment. The inclusion of this latter variable allow us to identify a wider diversity of firm eco-innovation profiles. In particular, high levels of all types of perceived barriers can correspond to either a high EI investment engagement ('Revealed barriers' cluster) or a very low engagement ('Deterring barriers' cluster). Similarly, low- or medium-level barriers of all types can give rise to either high engagement in EI investment ('Green champions' cluster) or very low engagement ('Non eco-innovators' cluster). Intermediate situations in which certain types of barriers do prevail (cost, knowledge, market) can give rise to differentiated intermediate levels of EI investment engagement ('Cost deterred' and 'Market deterred' clusters).

The analysis of eco-innovation adoption in the clusters pointed to a robust correspondence of our taxonomy with the rate of eco-innovation adoption. In other terms, the eco-innovative profile based on the clustering procedure (i.e. on eco-innovation barriers and engagement in green innovative activities) is strongly related to the firm's adoption performance.

We also considered national and sectoral characteristics of our clusters. In particular, we tested the overlapping of clusters with respect to conventional NACE sectors classification and the nationality of the firms. Geographical location (country) can significantly predict the cluster to which firms do belong. However, the country-level combination of clusters does not match the conventional view about the 'green leadership' of the countries themselves with, for example, green leading countries (Germany and some Nordic countries) having the 'Green champions' cluster less represented than the EU average and the 'Non innovators' cluster relatively more represented. An even more limited overlapping emerges between the clusters and the sectors (captured through NACE classification, R&D and emission intensity): generally, sectoral characteristics do not match cluster belonging.

Hence, our taxonomy robustly highlights something different from what can be expected from geographical and sectoral coordinates of the firms: it reflects the firm's perception, capabilities, and willingness to eco-innovate in front of eco-innovation barriers. In a way it confirms the idea that for analytical and policy purposes, attention to "eco-innovators" should go beyond the sectoral and geographical dimensions, provided that firm-level information is available (see Cainelli et al., 2011).

There are three main policy implications emerging from our results. The first is that EU strategies for eco-innovation (see Section 1) should look at barriers in a more specific way. To avoid conventional approaches based on pure regulation and/or pure incentives that expect eco-innovation as an automatic induced outcome, eco-innovation related strategies should embody instruments to deal with the different barriers (and their combination within and between types) that can hider differently the innovative reaction of firms. For example, market barriers seem to be relevant across almost all our clusters with high hindering consequences, whereas cost barriers seems to be more relevant for more specific types of firms.

The second implication is that, in addition to barriers diversity and possibly barriers hierarchy, eco-innovation strategies should take into account the diversity of the firms that are expected to undertake - or pushed to pursue - eco-innovation. Even SMEs in a similar industrial environment in the same country can perceive barriers and react to them in a specific way, thus reducing the predictability of eco-innovation outcomes at the meso and macro-level. Taking into account this diversity can reduce the risk of unsuccessful business strategies and policy actions.

The third implication is the need to overcome policy interventions devised on a solely sectoral basis. In fact, industrial sectors - or sector related issues - are still the usual scope of EU environmental, energy, and resource policies (see EEA 2013) in spite of the wishful efforts towards 'policy coherence and integration' (the 'Cardiff Process'). In the many cases of sectoral environmental policies calling for - or de facto imposing - firm-level eco-innovation (from invention to adoption), one cannot expect homogeneous eco-innovative response by firms because of their different perception of barriers and obstacles, even in the same sector and country. Even very specific and sector-focused policies can face implementation problems or incomplete effects unless industrial actors' diversity is taken into account.

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Tables

Table 1 – Internal profiling

	1 Revealed barriers (N=447)	2 Deterring barriers (N=434)	3 Cost deterred (N=408)	4 Market deterred (N=463)	5 Non eco-innovators (N=331)	6 Green champions (N=225)	Total (N=2,308)	ANOVA (F test)	Insignificant pairs (Scheffe's Comparison)
Internal funds	2.441	2.537	2.238	1.179	0.486	1.262	1.775	354.83***	6-4; 2-1
External funds	2.36	2.341	2.069	1.017	0.311	1.209	1.63	353.48***	6-4; 2-1
Uncertain return	2.385	2.456	2.029	1.551	0.653	1.516	1.835	219.68***	6-4; 2-1
Subsidies	2.43	2.438	2.039	1.214	0.387	1.231	1.708	337.53***	6-4; 2-1
Cost barriers	2.404	2.443	2.094	1.24	0.459	1.304	1.737	1119.04***	6-4; 2-1
Qualified pers & tech capabilities	2.085	2.175	1.27	1.378	0.553	1.071	1.497	160.13***	2-1; 4-3; 6-3[#]
External information	2.065	1.97	1.051	1.121	0.314	0.858	1.31	235.4***	2-1; 4-3; 6-3[#]
Business partners	1.975	2.012	1.11	1.166	0.299	0.876	1.319	204.22***	2-1; 4-3; 6-3[#]
Research partner	1.814	1.797	0.887	0.924	0.193	0.822	1.14	180.42***	2-1; 4-3; 6-3[#]; 6-3[#]
Technological lock in	2.177	2.258	1.414	1.436	0.459	1.173	1.565	200.39***	2-1; 4-2; 6-3[#]
Knowledge barriers	2.023	2.042	1.147	1.205	0.364	0.96	1.366	703.66***	2-1; 4-3
Uncertain demand	2.385	2.369	1.561	1.894	0.722	1.64	1.827	170.85***	2-1; 6-3
Material priority	2.013	1.933	0.922	1.395	0.453	1.116	1.37	158.41***	2-1; 6-3
Energy priority	2.21	2.136	1.186	1.633	0.662	1.302	1.589	143.88***	2-1; 6-3
Market dominated	2.087	2.09	1.091	1.544	0.483	1.062	1.473	178.45***	2-1; 6-3
Regulations	2.304	2.371	1.404	1.631	0.468	1.436	1.675	228.95***	2-1; 6-3; 6-4[#]
Market barriers	2.2	2.18	1.233	1.619	0.558	1.311	1.587	815.67***	2-1; 6-3
EI investment	2.566	0.691	1.216	1.037	0.934	3.569	1.532	888.69***	5-4

[#]Difference between pairs for the specific barrier is insignificant while it was significant for the aggregate barrier indicator

Table 2 - Clusters in terms of the combination between barriers and EI investment engagement

		EI investment		
		Low (<1)	**Medium (>1, <2)**	**High (>2)**
Barriers	**Low (all groups)**	'Non eco-innovators'		
	Medium (cost or market)		'Cost deterred' 'Market deterred'	'Green champions'
	High (all groups)	'Deterring barriers'		'Revealed barriers'

Table 3 – EI adoption performance by firms in the clusters

	1 Revealed barriers	2 Deterring barriers	3 Cost deterred	4 Market deterred	5 Non eco-innovators	6 Green champions	Total	ANOVA (F test)	Insignificant pairs (Scheffe's Comparison)
Product or process EI	0.619	0.26	0.399	0.387	0.231	0.731	0.422	57.53***	6-1; 4-3; 5-2
Product EI	0.407	0.163	0.216	0.176	0.097	0.498	0.246	44.98***	6-1; 3-2; 4-3; 4-2; 5-2; 5-4
Process EI	0.492	0.175	0.295	0.311	0.182	0.604	0.328	45.99***	6-1; 4-3; 5-2

Table 4 – Clusters with respect to country and sector features

		1 Revealed barriers	2 Deterring barriers	3 Cost deterred	4 Market deterred	5 Non eco-innovators	6 Green champions	Total	Pearson χ^{22} test
Environmen. regulatory stringency (by country)	Top regulated	116	82	112	162	143	90	705	Chi2=90.5646 d.f.: 10 p-value=0.000
		[16.45]	[11.63]	[15.89]	[22.98]	[20.28]	[12.77]	[100]	
	Mid regulated	184	194	190	203	120	75	966	
		[19.05]	[20.08]	[19.67]	[21.01]	[12.42]	[7.76]	[100]	
	Low regulated	147	158	106	98	68	60	637	
		[23.08]	[24.8]	[16.64]	[15.38]	[10.68]	[9.42]	[100]	
Emission intensity (by sector)	Green	91	70	82	106	88	53	490	Chi2=23.2021 d.f.: 10 p-value=0.01
		[18.57]	[14.29]	[16.73]	[21.63]	[17.96]	[10.82]	[100]	
	Grey	197	212	166	195	131	79	980	
		[20.1]	[21.63]	[16.94]	[19.9]	[13.37]	[8.06]	[100]	
	Brown	159	152	160	162	112	93	838	
		[18.97]	[18.14]	[19.09]	[19.33]	[13.37]	[11.1]	[100]	
R&D intensity (by sector)	High-tech	97	78	84	120	89	59	527	Chi2=29.1168 d.f.: 10 p-value=0.001
		[18.41]	[14.8]	[15.94]	[22.77]	[16.89]	[11.2]	[100]	
	Mid-tech	259	274	250	248	190	106	1,327	
		[19.52]	[20.65]	[18.84]	[18.69]	[14.32]	[7.99]	[100]	
	Low-tech	91	82	74	95	52	60	454	
		[20.04]	[18.06]	[16.3]	[20.93]	[11.45]	[13.22]	[100]	
	Total	**447**	**434**	**408**	**463**	**331**	**225**	**2,308**	
		[19.37]	**[18.8]**	**[17.68]**	**[20.06]**	**[14.34]**	**[9.75]**	**[100]**	

Absolute frequency of firms by cluster and country or sector group. Percentage frequencies between brackets.

Table 5 - Relevance of country and sectoral dummies on the probability of belonging to clusters

	1 Revealed barriers	2 Deterring barriers	3 Cost deterred	4 Market deterred	5 Non eco-innovators	6 Green champions
Detailed NACE classification						
Chi sq (country dummies)	103.4***	113.9***	42.37**	124.6***	108.5***	65.86***
p-value (country dummies)	3.47E-11	5.76E-13	0.0164	7.73E-15	4.79E-12	1.56E-05
Chi sq (sectoral dummies)	16.59	12.55	19.04	20.07	10.7	54.94***
p-value (sectoral dummies)	0.279	0.637	0.212	0.169	0.774	1.83E-06
R&D intensity sector classification						
Chi sq (country dummies)	99.5***	115.1***	40.32**	121.2***	111.3***	64.5***
p-value (country dummies)	1.55E-10	3.55E-13	0.027	3.02E-14	1.56E-12	0.0000244
Chi sq (sectoral dummies)	0.12	5.097*	1.399	0.813	2.698	3.452
p-value (sectoral dummies)	0.942	0.0782	0.497	0.666	0.259	0.178
Emiss intensity sector classification						
Chi sq (country dummies)	99.55***	120***	40.71**	121.5***	110.8***	66.37***
p-value (country dummies)	1.53E-10	5.02E-14	0.0246	2.68E-14	1.92E-12	1.31E-05
Chi sq (sectoral dummies)	0.00354	7.093**	3.106	4.623*	2.121	11.45***
p-value (sectoral dummies)	0.998	0.0288	0.212	0.0991	0.346	0.00327
N	2299	2308	2298	2308	2308	2298

Probit estimates of the probability of belonging to a specific cluster. Chi sq and p-values of the test of joint significance of country and sectoral (various aggregations) dummies.

Appendix

Box 1 - Question on barriers to eco-innovation in the Eurobarometer survey

Q7. I will list you some barriers that could represent an obstacle to accelerated eco-innovation uptake and development for a company. Please tell me for each of them if you consider them a very serious, somewhat serious, not serious or not at all serious barrier in case of your company?

a. Lack of funds within the enterprise
b. Lack of external financing
c. Uncertain return on investment or too long payback period for eco-innovation
d. Lack of qualified personnel and technological capabilities within the enterprise
e. Limited access to external information and knowledge, including lack of well developed technology support services
f. Lack of suitable business partners
g. Lack of collaboration with research institutes and universities
h. Uncertain demand from the market
i. Reducing material use is not a innovation priority
j. Reducing energy use is not a innovation priority
k. Technical and technological lock-ins in economy (e.g. old technical infrastructures)
l. Market dominated by established enterprises
m. Existing regulations and structures not providing incentives to eco-innovate
n. Insufficient access to existing subsidies and fiscal incentives

Table A1 – EU27 countries by perceived environmental regulation

Top regulated		Mid regulated		Low regulated	
Rank	**Country**	**Rank**	**Country**	**Rank**	**Country**
1	Sweden	10	France	19	Hungary
2	Germany	11	Czech Republic	20	Italy
3	Denmark	12	Ireland	21	Latvia
4	Finland	13	Estonia	22	Poland
5	Netherlands	14	Slovenia	23	Cyprus
6	Austria	15	Slovak Republic	24	Malta
7	Luxembourg	16	Portugal	25	Romania
8	Belgium	17	Lithuania	26	Greece
9	United Kingdom	18	Spain	27	Bulgaria

Source: own elaboration on World Economic Forum data

Table A2 – Sectors by R&D intensity (CIS2008) and emission intensity (NAMEA 2008-2010)

Description	NACE rev 2	R&D intensity	Emission intensity
Manufacture of food products; beverages and tobacco products	10-12	Low-tech	Grey
Manufacture of textiles, wearing apparel, leather and related products	13-15	Mid-tech	Grey
Manufacture of furniture; other manufacturing; wood; repair and installation	16, 31-33	Mid-tech	Grey
Manufacture of paper and paper products	17	Mid-tech	Brown
Printing and reproduction of recorded media	18	Low-tech	Grey
Manufacture of coke and refined petroleum products	19	Low-tech	Brown
Manufacture of chemicals and chemical products	20	High-tech	Brown
Manufacture of basic pharmaceutical products and pharmaceutical preparations	21	High-tech	Green
Manufacture of rubber and plastic products and other non-metallic mineral products	22-23	Mid-tech	Brown
Manufacture of basic metals and fabricated metal products, except machinery and equipment	24-25	Mid-tech	Brown
Manufacture of computer, electronic and optical products	26	High-tech	Green
Manufacture of electrical equipment	27	High-tech	Green
Manufacture of machinery and equipment n.e.c.	28	High-tech	Green
Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	29-30	High-tech	Green
Water collection, treatment and supply	36	Low-tech	Green
Sewerage, waste management, remediation activities	37-39	Low-tech	Brown

Source: own elaborations based on CIS 2008 data and EU NAMEA 2008-2010 data.

Table A3 - Ratio between the country-level share of the cluster and the EU average share of the same cluster (> 1: higher share in the country)

	Revealed barriers	Deterring barriers	Cost deterred	Market deterred	Non eco-innovators	Green champions
BE	1.15	1.11	0.39	1.18	1.16	1.00
CZ	0.60	0.23	1.44	2.49	0.37	0.33
DK	0.68	0.44	1.08	1.07	2.24	0.61
DE	0.90	0.52	0.99	1.44	1.21	0.93
EE	0.73	0.75	1.06	0.82	1.80	1.09
EL	1.74	1.79	0.95	0.35	0.12	0.73
ES	1.37	1.60	1.00	0.57	0.49	0.73
FR	0.19	1.13	1.41	1.28	1.44	0.38
IE	1.13	0.61	0.65	1.51	0.80	1.39
IT	0.94	1.40	0.83	0.76	1.27	0.75
CY	2.58	0.53	0.00	1.50	0.70	0.00
LV	0.43	0.63	1.53	1.41	1.15	0.84
LT	1.59	1.88	0.70	0.54	0.43	0.47
LU	1.61	1.00	0.35	1.56	0.44	0.64
HU	0.84	1.33	1.50	0.22	1.23	1.06
MT	0.23	1.45	1.54	0.45	0.95	1.87
NL	0.52	0.69	0.82	1.30	1.21	1.93
AT	1.44	0.87	0.99	1.04	0.49	1.07
PL	1.54	0.66	0.58	0.87	0.72	2.01
PT	1.06	1.00	0.86	1.20	0.81	1.01
SI	1.29	1.06	1.32	0.62	0.64	1.03
SK	1.41	1.31	1.03	0.84	0.54	0.53
FI	0.51	0.42	1.05	1.42	1.03	2.11
SE	0.55	0.16	1.03	0.45	2.32	2.64
UK	0.86	0.75	0.80	0.83	2.23	0.66
BG	1.37	1.99	0.68	0.60	0.50	0.49
RO	1.15	1.42	1.13	0.72	0.54	0.91
Tot EU	1.00	1.00	1.00	1.00	1.00	1.00