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Brown Sunsets and Green Dawns in the Industrial Sector: Environmental Innovations, Firm Behavior and the European Emission Trading

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Summary

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Keywords: Environmental Innovation, Industrial Sectors, ETS, Innovation Drivers, CIS Data

JEL Classification: C21, L2, O33, Q38, Q55

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Abstract

We study the driving forces behind the adoption of environmental innovations (EI) in the Italian industry over 2006-2008 through analyses of the new wave of Community Innovation Survey (CIS) data that covered for the first time environmental innovation adoptions. We investigate whether the first phase of EU ETS has exerted some effects on environmental innovations by using a bery large sample of italian manufcturing firms. Estimates show that external forces and complementarity with other management practices are particularly relevant to increase the adoption of relatively new and radical technologies: relationships with other firms and institutions, local public funding, group membership are the key factors. The role of ETS on EI seems instead to be weak: it drives

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innovation if we compare ETS and non ETS firms, but the stringency itself does not matter, due to sector idiosincratic factors and to the fact that stability of policy also matters.
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1 Introduction: environmental innovations and the European Emission Trading System

The economics and management analyses of environmental innovations (EI herafter) (Rennings, 2000; Krozer and Nentjes, 2006; Europe Innova, 2008; CML, 2008; Kemp and Pearson, 2007) are based on the evolution of various strands of empirical research on innovation drivers, and on the theoretical literature regarding the dynamics and environmental and economic performance effects of EI. Work on the dynamics of EI has developed within a theoretical literature that includes classic environmental economics research issues on the static and dynamic efficiency of regulatory instruments (economic vs command and control, fiscal tools and emissions trading) and, thus, the effects of (technological, mainly emissions abatement tools) innovation spurred by regulation (Popp, 2002, 2006; Brunnermeier and Cohen, 2003; Hahn and Stavins, 1994; Goulder and Parry, 2008; Acemoglu et al., 2011). It also includes analyses evolving within evolutionary economics (Mulder and Van den Bergh, 2001), focused mainly on the co-evolution of innovation, policy and economic dynamics in socio-bio-economic systems (Kemp, 1997). The structural theme of endogeneity in innovation is paramount and links analysis of innovation drivers to work on the effects of innovations (Pizer and Popp, 2009; Kemp and Pontoglio, 2011). The empirical literature is supported by theoretical reasoning testing hypotheses related to the efficiency (and also effectiveness, Millock and Nauges, 2006; Bruvoll et al., 2003) of the economic and policy drivers (Johnstone, 2007). Theoretical work follows both mainstream and heterodox approaches that deal with firm and sector innovation performance, as examples of the Schumpeterian tradition which emphasises 'innovation adoption' and dynamic evolution (Breschi et al., 2000; Brioschi et al., 2002; Cainelli et al., 2006; 2010; van den Bergh, 2007). The motivation for environmental innovations (Sterner and Turnheim, 2008; Mazzanti and Zoboli, 2009; Horbach, 2008; Rennings et al., 2003; Frondel et al., 2004), and the complementarity between the drivers if innovation (Mohnen and Roller, 2005; Mazzanti and Zoboli, 2008) and organisational innovations related to the environment, such as Environmental Management systems (EMS) and auditing schemes (Harrington et al., 2007; Arimura et al., 2008; Frondel et al. 2004; Wagner, 2007, 2008; Johnstone and Labonne, 2009) are investigated. On the level of the economic and environmental performance of EI, the starting point is the Porter (Porter and Van der Linde, 1995; Ambec and Lanoie, 2008; Esty and Porter, 1998) hypothesis related to the competitive advantages, which, in the long run, may derive from investment in EI (to comply with or anticipate environmental policies) or from strategies aimed at not (only) just cost reduction, but also investment in firm assets in line with the ideals of corporate social responsibility (CSR) (Reinhardt et al., 2008; Margolis et al., 2007; Benabou and Tirole, 2010). Some aspects of corporate social responsibility include techno organisational innovations, training or human capital, workers' and unions' involvement in strategic innovation decisions, working conditions related to health, safety and stress. The aim is to increase long term profitability through complementary investment in technological and human capital and the production of impure public goods linked to the innovation process (Kotchen, 2005; Rubbelke and Markandya, 2008).

Research values can be identified in the various (and new) aspects related to the synergy and integration of circumscribed analyses of EIs with the larger conceptual scenario, which at the same time is coherent with the specific features of industries in different countries (Cole et al., 2005, 2010; Mazzanti and Montini, 2010). The literature highlights several issues and hypotheses that need to be tested (Del Rio, 2009; Van den Bergh, 2007) in order to identify the added value derived from EI analyses (effects and driving forces). We highlight some of the most important ones.

Empirical work on the drivers of EI (Horbach, 2008; Horbach and Oltra, 2010) focus mainly on the factors, internal and external to the firm, that can trigger EI in national or regional systems. It highlights factors ranging from collaboration to the organisation and relationships of the organisation (Cainelli et al., 2011a). Another body of work focuses on the co-causal relationships and complementarities among various typologies of EI (techno, EMS, ISO certifications, etc (Ziegler and Nogareda, 2009; Wagner, 2008, 2007, 2009, 2003; Mazzanti and Zoboli, 2008; Cainelli et al., 2011b). Studies using German EI data assess long run policy effects (Rennings and Rexhauser, 2010), and point out that the economic and innovation effects of policies should include a 'political economy' reasoning (Aidt, 2010).

The innovation effects of the European Union (EU) Emmissions Trading Scheme (ETS) (Convery, 2009; Ellerman et al., 2010; Clò, 2008), a potentially pathbreaking event in EI dynamics in Europe, has been extensively analysed, and compared to other environmental policies at the theoretical level (see also Carraro et al., 2010). However, there has been no robust empirical investigation of ETS, including its pilot phase in 2005-2007. The studies that do exist provide some insights, but are based most on case studies and small sample sizes.

At a general level, Borghesi's (2011) conceptual study looks at the effects of ETS on innovation and describes ETS allocation and functioning based on past, current and future scenarios. Kemp (2010) and Kemp and Pontoglio (2011) comment on ETS innovation effects in their EI related work. These studies refer to the lack of empirical work and firm level data on innovation and policy although some micro studies have emerged which try to rebalance the prevalence of macro based simulation studies focusing on carbon pricing and its economic and environmental effects (Alberola et al., 2009, 2008; Tole, 2011). Taschini (2011) provides a theoretical study on the technological features of ETS developments, but it relies on simulation analysis. There are also some case based studies that include interviews with firm managers; Pontoglio (2010) investigates the paper and cardboard sector in Italy and finds very weak ETS effect on EI, and Rogge et al. (2011) study some German sectors. [1]. These authors find that the innovation impact of the EU ETS has remained limited so far because of the scheme's initial lack of stringency and predictability and the relatively greater importance of context factors. Additionally, the impact varies significantly across technologies, firms, and innovation dimensions and is most pronounced for research and development (R&D) on carbon capture technologies and organizational changes. The analysis in this paper suggests that the EU ETS on its own may not be a sufficient incentive for fundamental changes in corporate innovation activities at a level that ensures that long-term political targets will be achieved. In a study that includes 42 interviews with German power sector companies, Rogge and Hoffmann (2010) find that the EU ETS mainly affects the rate and direction of technological change in power generation technologies, in large sized coal-based power generating companies where carbon capture technologies are added as a new technological trajectory. Schmidt et al. (2010) conduct a survey of the innovation effects of ETS in the EU power sector and conclude that 'the EU ETS has limited effect on the innovation activities (adoption and R&D) of both users and producers of power generation technologies. However, the perception of long-term GHG (greenhouse gas] reduction targets has a significant influence on all innovation dimensions'.

Muuls and Martin (2011) provide qualitative and quantitative empirical evidence from interviews with firm managers in six European countries as part of an extensive study. They find that 30% of firms joined the ETS, and that sector differences outweigh cross country differences. They provide econometric evidence of the effect on innovation adoption of process and product innovations related to 'ETS stringency indicators'. Their study has some similarities with our approach and mostly captures current and future stringency (mainly through expected prices). They use dummy variables for whether the firm is part or not of the ETS mechanisms. The evidence is mixed. On the one hand, there seem to be few differences between ETS and non-ETS firms in terms of 'process and product' types of innovation; on the other hand, the effect of the expected stringency of the cap is significant. This is consistent with early mover behaviour being not very apparent in the first phase, and increasing in the current phase when firms can anticipate future price rises. The most robust finding is related to 'product and process' types of innovation, where the stringency of the ETS in phase III seems to be a driver. This highlights that the choices of firms to engage in R&D and other innovation activities may be related to the allocation of allowances.

Dechezlepretre and Calel (2011) present a detailed survey of some recent work on EI. They find that 'some report that the EU ETS has had a strong positive effect on low-carbon.. For instance, Petsonk and Cozijnsen (2007) report on a few early case studies and conclude that the EU ETS has had a

[1] Tomas et al. (2010) analyse the Portuguese chemical sector and find weak evidence of increased costs and competitiveness.

substantial impact on innovation. This is one of the very few studies that shows an effect of the ETS on early moving behaviour. Uncertainty about future scenarios and price volatility hamper EI. The uncertainty is highlighted by Gronwald and Ketterer (2011) who study evolution of EU ETS prices, finding jumps and unexpected movements. This irregular pattern may be generating a postponement of abatement decisions based on excessive uncertainty.

In a rather pessimistic view of the innovation promoting properties of ETS in the first phase, some studies do find some effects, although there is no thorough ex post evaluation. An interesting paper by Di Maria and Jaraite (2011) applies ex post policy evaluation techniques such as matching estimators to analyse whether ETS has had an impact in its first phase. They find that ETS had no significant impact on CO2 emissions (implying lack of impact on innovation). Anderson et al. (2011), in a survey of Irish ETS firms find that the scheme has resulted in moderate technological change, although their study is based on a small number of firms based in Ireland and Lithuania. Dechezlepretre and Calel (2011) provide a survey of Belgium, the UK, France and Germany (a total of 233 observations), and find that firms regulated by EU ETS have innovated more than unregulated firms, both generally and in relation to low carbon technology. However, this study uses patents rather than innovation adoption.

What is lacking is a robust econometric study of EU industry. Italy is major industrial country that provides a good case study. An econometric application to a large relevant sample should highlight the existence or not of empirical regularity after controlling for size, sector and the drivers of EI.[2]

Having said that, the objective of the present paper is in a nutshell to analyse the innovation effects of EU ETS first phase by exploiting the new release of EU Community Innovation Survey (CIS) 2006-2008, which includes data on EI.

We want to assess the innovation effects of ETS, highlighting both policy and sector specific EI effects. We test the ETS effect with particular reference to the start up phase, that is the effect of the 2005 allocation of quotas on the adoption of EI over 2006-2008, the period of the fifth CIS. This captures potential anticipatory behaviour because the ETS was proposed by the EU Commission over 2000-2002 with a final 2003 Directive. The allocation procedure gave competencies to national states as far as sector quota allocation was concerned in the first phase (Clò, 2008; Woerdman et al 2008). This resulted in different levels of stringency depending on the allocated quota and the historical emissions level in each sector. We use probit and two stage Heckman models to analyse the probability that ETS triggered EI in 2006-2008. This study contributes to the literature by providing firm level evidence, which is in line with other work that uses CIS data, such as Breschi et al. (2000). Sector specificity is relevant from

[2] Rogge et al.'s (2011) study concludes that: "As we focused our analysis on the power sector, other studies will have to identify whether and how the innovation impact of the EU ETS differs across sectors. Additionally, all of our case companies were based in Germany – though often with international operations – so it might be useful to investigate whether companies with other home markets have reacted similarly to the EU ETS [...]. Finally, while our qualitative approach enabled us to study the complex causal links and feedback loops of innovation processes in the power sector and how the EU ETS is impacting them, innovation surveys allowing for statistical generalisations should complement this analysis."

both innovation (e.g. technological regimes) and policy perspectives. Conceptually and empirically, the merging of micro and meso elements enriches the analysis of sector-related structural forces with micro based heterogeneity and detail.

The present study is probably the only work on ETS effects that is based on CIS survey data, although Aghion et al., (2009) show that 'improving energy efficiency [and] reducing environmental impact or improved health and safety' are the lowest ranked motives for innovation. Given that the ETS Directive was published in 2003, their study can be seen as testing the absence of early behaviour by firms. However, we test the effect of ETS implementation in the pilot phase 2005-2007. The implementation in 2005 and the 2003 Directive are assumed to have an impact on 2006-2008 innovations. This allows for a time lag and no overlap between the 'policy dose' and the 'innovation response'.

The present study contributes to the literature on the drivers of EI, using national level EI data (CIS 2008 which covers the main EU countries) to test the innovation effects of ETS policy. Unlike other survey based studies: (i) we propose a theoretical framework to show the forces underlying the 'diffusion of innovation'[3], a typical issue in CIS based studies as opposed to studies focusing on inventions (Johnstone et al., 2011; Brunnermeier and Cohen, 2003; Jaffe and Palmer, 1997); (ii) we analyse a very large sample of manufacturing firms. We thus investigate the drivers of innovation diffusion at both theoretical and empirical levels, with the emphasis on policy related drivers. The focus on the EU ETS is original and links with and complements recent empirical work focusing on EU firms using survey based data (Caroli and van Reenen, 2001; Martin et al., 2011; Muuls and Martin, 2011) to study the link between EI and managerial and policy factors.

The paper is structured as follows. Paragraph 2 explains the rationale behind the construction of policy stringency ETS related indicators. Paragraph 3 sketches a theoretical model that depicts the innovation choice of firms between green and brown options. Paragraph 4 presents the econometric analyses of environmental innovation using CIS 2006-2008 data. Paragraph 5 contains some concluding remarks on the main results that emerge from the analysis.

2 ETS stringency indicators

We start our investigation by constructing a series of ETS policy indicators aimed at capturing the stringency of the policy in its first allocation phase. We exploit two main sources of information: NAMEA sector emissions data (Tudini and Vetrella, 2012) released by ISTAT for over 1990-2008 (we exploit 2000-2005

[3] This conceives EI as a phenomenon driven by firm behaviour and policy levers. To assess the role of policies (ETS), we construct sector level environmental policy indexes (policy stringency), using data derived from the 2005 allocation of ETS quotas by the Italian Ministry of the Environment, and emissions data derived from NAMEA (ISTAT hybrid economic environmental accounting, see on the topic Costantini et al., 2011 and the recent analysis on the US by Muller et al., 2011).

data), and information on the allocation decision derived from official documentation from of the Italian Ministry of the Environment (Ministero dell'ambiente, 2006).

We employ two measures of stringency, adapted to a sensitivity analysis. The use of multiple indexes allows different perspectives.

The first indicator is the following:

$$s_1 = T * s_i - EUA_i \quad (1)$$

where EUA_i = tradable permits (European Union Allowances) of sector i; T = national emission target (Kyoto target: given that we use 2005 as pivotal year, we have weighted the Italian -6.5% reduction accordingly, thus taking in the calculation 2/3 of the total target of Italy); $s_i = e_i / \sum e_j$ = emission share of sector i; e_i = emissions of sector i; $\sum e_j$ = total emissions

The second indicator that can be used as an alternative to the first one is the following:

$$s_2 = e_i / EUA_i \quad (2)$$

To highlight the connection between the indicators s_1 and s_2, notice that the former may also be rewritten as follows:

$$s_1 = [T * s_2 * EUA_i] / \sum e_j - EUA_i$$

or, equivalently:

$$s_1 = EAU_i[(T * s_2) / \sum e_j - 1] \quad (3)$$

As far as s_2 is concerned, we have constructed three alternatives: (i) 2005 NAMEA emissions / allocated quotas, (ii) 2000-2005 average NAMEA emissions / allocated quotas (iii) Ministry of the environment reported 2000 emissions / allocated quotas; (i) is chosen as main indicator.

Concerning s_1, we have defined a version taking 2005 as benchmark year for the Kyoto target (2/3 of total reduction) and a version with the proper final Kyoto target of -6.5%. Like the other stringency indicator s_2, also s_1 was calculated, moreover, taking both NAMEA 2000-2005 average emissions and the Ministry of the environment emissions.

In the econometric analysis that follows we will run regressions using a dummy variable that takes value 1 for sectors under the ETS (DE1 – paper and cardboard without printing branch; DF, DI, DJ) and value 0 for all other sectors. When the dummy takes value 1, we then compute stringency indicators mentioned above. The use of both the ETS dummy and the stringency indicators among the EI regressors allows to distinguish the impact on the EI deriving from the presence of the ETS from the effect generated by the stringency of the regulation. The values of all stringency indicators by sector are available upon request. The definition of various indexes is also a way to carry out 'sensitivity tests' from an empirical point of view, namely observing whether the eventual significance is variant or not with respect to the selected index.

[3] One can reasonably expect that the most polluting sectors show the highest stringency

3 The theoretical model

Let us consider a population of firms whose number is normalised to 1. Each firm has to choose whether: (i) to use an old, polluting technology or (ii) to shift to a new, pollution-free technology. Let us assume, for the sake of simplicity, that the firm's output and revenues R remain unchanged whatever the adopted technology. Stated differently, we assume that in the present context environmental-innovation consists of a cleaner process technology which does not imply higher production efficiency (i.e. higher output per unit of input). Finally, let us assume that the cost of the new, non polluting technology (c_{NP}) is higher than the cost of the old, polluting technology (c_P):

$c_{NP} > c_P > 0$

Each firm has, therefore, to choose between two alternative strategies:

1) keep on using the old technology that requires pollution permits to operate

2) invest in the innovation technology which implies higher costs but sets the firm free from having to purchase the pollution permits.

Let the variable $x(t)$ denote the share of firms choosing strategy 1 (i.e. that need pollution permits to operate) at time t, $0 \leq x(t) \leq 1$.

Indicating with π_k $k = 1, 2$ the correspondent pay-offs, we have:

$\pi_1 = R - c_P - P_p(x)\left(Q_P - \bar{Q}\right)$

$\pi_2 = R - c_{NP}$

where: $P_p(x)$ indicates the price of the pollution permits, which is a strictly increasing function of the number of firms that demand them, Q_P denotes the quantity of permits required by the firm that keeps using the old technology to carry on its activity and $\bar{Q}$ the amount of emission permits originally received by the firm. It follows that the term $\left(Q_P - \bar{Q}\right)$ obviously indicates the amount of permits sold (when $Q_P < \bar{Q}$) or bought (when $Q_P > \bar{Q}$) by the firm.

The process of adopting strategies is modelled by the so called *replicator dynamics* (Weibull, 1995), according to which the strategy whose expected pay-offs are greater than the average payoff spread within the populations at the expense of the alternative strategy:

$$\dot{x} = x\left(\pi_1 - \overline{\pi}\right)$$

where

$$\overline{\pi} = x \cdot \pi_1 + (1 - x) \cdot \pi_2$$

is the average payoff of the population of firms.

From the equations above, it turns out that the replication dynamics can be written as follows:

indicators. This seems to be confirmed by the available data: as a matter of fact, the most polluting sector (DI) is besides one case the sector that presents the most stringent allocation in our dataset, as well as metallurgy, with respect to lower indexes associated with coke & refinery and paper industry.

$$\dot{x} = x(1-x)(\pi_1 - \pi_2) = x(1-x)\left[c_{NP} - c_P - P_p(x)\left(Q_P - \bar{Q}\right)\right]$$

Notice that if $\left[c_{NP} - c_P - P_p(x)\left(Q_P - \bar{Q}\right)\right] > 0$, then the payoff of strategy 1 is higher than that of strategy 2, so that a higher number of firms will decide to keep on using the old technology ($\dot{x} > 0$). If firms need to buy permits to use the old technology (i.e. $Q_P > \bar{Q}$),[4] this will increase in its turn the price of pollution permits, thus reducing the gap between the payoffs of the two strategies. If, on the contrary, $\left[c_{NP} - c_P - P_p(x)\left(Q_P - \bar{Q}\right)\right] < 0$, strategy 2 is more remunerative than strategy 1. In this case, therefore, a higher number of firms will shift towards the innovative technology ($\dot{x} < 0$), which decreases the pollution price. The process will go on as long as $\left[c_{NP} - c_P - P_p(x)\left(Q_P - \bar{Q}\right)\right] < 0$ until the term between square brackets get to zero, so that each firm is indifferent between the two alternative strategies.

From the replication dynamics above, it follows that three possible equilibria can occur in the model, namely the two extreme steady states:

(i) $x = 0$ in which all firms adopt the innovative technology

(ii) $x = 1$ in which no firm adopts the innovative technology

and an internal equilibrium in which some firms adopt the new technology while others keep on using the old technology. More precisely, the latter case will occur if:

(iii) $\exists x^*$ such that $c_{NP} - c_P = P_p(x^*)\left(Q_P - \bar{Q}\right)$

Observe that the internal equilibrium x^* is a sink (attractor), while the two extreme equilibria $x = 0$ and $x = 1$ are sources (repellors). As a matter of fact, as it can easily verified:

if $0 < x < x*$ then $\dot{x} > 0$, while $x > x*$ we have $\dot{x} < 0$.

It follows that, whatever the initial share of firms that buy the pollution permits, the system will always converge towards the stable internal equilibrium x^*.

The simple analytical framework proposed above can be easily extended to examine the innovation choices performed at the sector level and their relationship with the stringency indicators introduced in the previous section. Consider, for instance, a generic sector i that is included in the EU-ETS. Let us assume that the ratio between emissions level (thus also permits needed Q_P) and the permits originally at disposal $\bar{Q}$ is the same for each firm j belonging to sector i. If this is the case, it follows that the stringency ratio s_2 of the whole sector i holds for each firm j, namely:

$s_2 = e_i/EUA_i = (Q_P/\bar{Q})_j \; \forall j$

From the equation above, it yields:

$Q_P = s_2 * \bar{Q} \; \forall j$

[4] See below for a discussion of the case $Q_P \leq \bar{Q}$.

Substituting this expression into π_1, we get:

$\pi_1 = R - c_P - P_p(x)\bar{Q}\,(s_2 - 1)$

so that the difference between the payoffs of the two strategies becomes:

$\pi_1 - \pi_2 = c_{NP} - c_P - P_p(x)\bar{Q}\,(s_2 - 1)$

Notice that if $s_2 = 1$, namely, if each firm originally receives exactly the amount of permits that are needed to carry on its activity, then the payoff differential becomes:

$\pi_1 - \pi_2 = c_{NP} - c_P > 0$

In this case, therefore, from the replication dynamics it follows that

$$\dot{x} = x(1-x)(c_{NP} - c_P) > 0$$

In other words, if $s_2 = 1$ strategy 1 will always be more remunerative than strategy 2 and no firm will innovate at the equilibrium ($x^* = 1$).

If $s_2 < 1$, namely, each firm in sector i needs less permits than those at disposal, then it is:

$\pi_1 - \pi_2 = c_{NP} - c_P - P_p(x)\bar{Q}\,(s_2 - 1) > 0 \rightarrow \dot{x} = x(1-x)(\pi_1 - \pi_2) > 0$

Stated differently, if the ETS is not stringent ($s_2 < 1$) the system will eventually converge towards the equilibrium in which no firm innovates ($x^* = 1$).

Finally, if the ETS is stringent ($s_2 > 1$), then from the replication dynamics it yields:

$\dot{x} = x(1-x)[c_{NP} - c_P - P_p(x)\bar{Q}\,(s_2 - 1)]$

which admits both the extreme repulsive equilibria ($x^* = 0$ and $x^* = 1$) and the inner attractor $x^* \in (0,1)$ in which both strategies coexist.

Observe that, ceteris paribus, an increase in the stringency indicator s_2 makes strategy 1 less remunerative with respect to strategy 2. As one would reasonably expect, it follows that a more stringent ETS will tend to increase the share of firms that decide to invest in the new non-polluting technology at the equilibrium.

Given the positive relationship between the stringency indicators s_1 and s_2 identified in the previous section, a similar result obviously emerges also if we measure the ETS stringency in terms of s_1. From equation (3), in fact, we can express s_2 in terms of s_1 as follows:

$s_2 = \left[(\frac{s_1}{EAU_i} + 1) \sum e_j \right] / T$

Substituting the equation above to s_2 in the payoff differential, we get:

$\pi_1 - \pi_2 = c_{NP} - c_P - P_p(x)\bar{Q} \left\{ \left[(\frac{s_1}{EAU_i} + 1) \sum e_j \right] / T - 1 \right\}$

It follows that -ceteris paribus- the higher the stringency indicator s_1, the higher the firms' incentive to innovate (strategy 1 becoming progressively less remunerative with respect to strategy 2). The same result, moreover, occurs if the amount of permits at disposal of sector i (EAU_i) decreases and/or the government sets a lower and more restrictive emissions target (T), which is consistent with what one would reasonably expect.

In what follows we will use the model as a reference to test the ETS effect (presence and stringency) on manufacturing firm based innovation, analysing the extent to which innovation diffusion at firm level is driven by structural features and policy effects of sector level.

4 The empirical framework

4.1 The data and the model

In order to analyse the drivers of EI in the Italian manufacturing industry and test the innovation effect of ETS, we exploit diverse sources of data. The main source is represented by the CIS dataset. CIS2008, the 5th wave, was the first wave that covered EI adoption in line with the definition of EI developed by the Measuring EI (MEI) project funded by the European Commission's 6th Framework Programme (Kemp and Pearson, 2007).[5]

In order to set define our ETS policy stringency indicator, we also use NAMEA emissions data (2005, and 2000-2005 to capture medium run trends) and the Italian allocation of ETS quotas by sector. The three sets of data were merged. This is standard procedure when there is an absence of firm level data, e.g. Cole et al. (2009) merge individual data on wages and firm pollution data (see also Cainelli et al., 2010). Cluster correction is needed in such cases.

We use dprobit as our estimator tool to study the probability of adoption, given that our EI variables are specified as dichotomous indexes. Dprobit fits with maximum-likelihood probit models and is an alternative to probit. Rather than reporting the coefficients, dprobit reports the marginal effects, that is, changes in the probability of an infinitesimal change in each independent, continuous variable and, by default, reports discrete changes in the probability of the dummy variables. Tables 1 and 2 provide a brief explanation of the main dependant variables we test. The appendix reports further specifcations about the sectors under investigation.

Our econometric model is based on the following probit specification:

$\Pr(Y_i = 1/X) = \Phi(X'\beta)$

where Φ is the cumulative distribution function of the standard normal distribution and Y_i is a dummy variable taking the value 1 if firm i introduces an EI and 0 otherwise. The full set of covariates described in Table 3.

4.2 Econometric evidence

We present the results for the drivers of EI focusing on the two main specifications of EI adoption related to the direct effects of carbon pricing, in our case ETS: EI related to 'reduction in CO2 emissions' and 'energy use per unit of output' (benefits arising in the production phase). This is the main level at which we test the hypothesis that ETS stringency eventually can lead to innovation effects, given that ETS should be aimed at reducing carbon dioxide emissions

[5] We thank ISTAT for the provision of data and the possibility to have access to original sources to carry out estimates. The dataset is highly representative of the italian industrial system.

through abatement technologies and/or energy reprocessing and changes to the energy structure.[6].

4.2.1 *Environmental innovations for energy efficiency*

Tables 4 and 5 present the outcomes for the adoption of EI for energy efficiency, which is related to but more extensive than CO2 abatement on which we comment further below. We describe the internal (e.g. R&D), external to the firm (e.g. cooperation) and policy correlated factors, including ETS policy stringency. The rich set of covariates is aimed at mitigating problems of omission of relevant variables, which, on their own, might produce endogeneity in cross section environments (we follow the consolidated literature on EI drivers, Horbach, 2008), although we avoid the inclusion of strongly correlated factors.

In relation to 'internal sources', we note that the presence of R&D expenditure is never significant (confirming the results in Cainelli et al., 2011a, b and Horbach and Oltra, 2010). Specific environmental R&D is probably needed as an input, whereas the lack of significance of R&D, in our view, is related to the fact that R&D is ultimately a proxy for general innovative-related absorptive capacity[7]. Training activities are positively correlated to EI, which confirms the evidence found in the above cited studies[8]. Productivity (at 2006 levels), as expected, is a determinant of innovation in the next period: high performance firms reinforce their advantage through new investment activating virtuous circles, while less productive firms may experience vicious circles. This again confirms the existence of virtuous circles: EI is driven by positive core economic performance and may contribute to further enhancing the firm's economic and environmental performance.

In relation to external sources, we show that they matter a great deal and provide information on the multiple sources of EI adoption. While innovation oriented cooperation (CO) does not matter at the aggregate/average level, there are a number of specific 'information sources' that are relevant for increasing innovation capabilities and innovation adoption. For example, receiving information from other firms in the group (SENTG) is relevant for energy efficiency and reinforces the advantages of being part of a business group (GROUP). This is an interesting finding and confirms that EI is heavily embedded in network relationships.

[6]Further research could exploit EI information on technology adoptions that reduce impacts at the level of 'use of goods': 'reduction in energy consumption', 'reduced emissions and water and soil pollution', 'Material, waste, water recycling'. An extension to the second use oriented perspective is in line with a life cycle approach that focuses not just on production, but takes a 'from cradle to grave' view of EI and environmental performance.

[7]The evolutionary economics and innovation studies literature shows that R&D is often a factor embodying innovative (absorptive) capacity rather than a strong internal firm efforts for a comprehensive and environment-specific productivity enhancement. Therefore, it cannot be a determinant of more radical forms of innovation and performance (Breschi et al., 2000).

[8]We note that the non significance of export is coherent with Cainelli et al.'s (2011a,b) findings which also highlight the role played by FDI and foreign ownership among the international drivers of EI.

Suppliers are a source of EI (and see also Cainelli et al. 2011a, b) as are attendance at fairs and conferences.

To achieve consistency with the studies in the literature we include 'environmental related controls' in order also to avoid omitting relevant variables. We find high significance for environmental management systems (EMS) introduced before 2006 (we select this form to avoid endogeneity) and sector energy expenditure per unit of value. Both covariates show positive coefficients for the correlation with EI, which is a plausible and expected result.

Finally, we investigate the important role of policy variables (ETS). 'Public' support is necessary for coping with CO2 externalities and firms that receive public funding are more likely to adopt EI. This applies especially to energy efficiency, but also applies to CO2 (see below).

The evidence on ETS effects is mixed. When we test (Table 4) the ETS/non ETS effect by including a dummy in the full sample, the coefficient is significant and positive. ETS sectors, as expected, are more innovative: they respond to their structural higher energy intensity and polluting performance by innovating.

The proposal for an ETS system predates the Kyoto Protocol. The Directive was proposed in 2001-02, and confirmed in 2003. At the time of our analysis, firms had had time to behave as early movers and anticipate the policy, The diachronic innovation adoption with respect to the ETS Directive and start phase confirms that this EI effect is dependent on structural factors, but also on the ETS as a driver of innovation. Further analysis might test for medium long run effects; here, the significance and sign of the dummy is stable and not dependent on the exclusion/inclusion of additional covariates. It is robust to the inclusion of two main EI correlated factors, EMAS and sector energy expenditure per unit of value, both significant with a positive sign of the coefficient.

The evidence on the effects of ETS stringency indicators is more counterintuitive (Table 5). First, we carry out estimates on the sub sample of ETS firms (four sectors), which includes more than a thousand firms. We find that ETS stringency - captured by the proxies described in Section 3 for the sensitivity tests - is negatively correlated with EI. [9]. . Looking in more depth at the findings, the distribution of EI by sector and inductive evidence from the interviews with stakeholders (industry association representatives, see also the Conclusions section), this result is in line with the current situation. The share of firms adopting energy efficiency EI is higher in the paper and cardboard (18%), coke and refinery (32%), and metallurgy (21%) sectors, while ceramics, the sector with the strictest ETS allocation based on our indexes, has an EI adoption rate of 17%. We interpret this as related to idiosyncratic sectoral weaknesses that affect management and policy efforts, since ceramics is one of the most polluting sectors (Marin and Mazzanti, 2011). The econometric evidence should be complemented by case studies and interviews with managers (Martin et al., 2011). An interview with the body responsible for implementing the ETS in Italy (Confindustria) confirmed that the ceramics and cement

[9] Note also that the proxies implemented give the same econometric result, a sign of robustness (sensitivity test of the policy index).

industries have experienced problems in trying to comply with the ETS system (see also Martin et al., 2011). These are related on the one hand to the fragmented structure of these sectors (many small and medium sized firms organised in districts) and on the other hand to their pollution intensity. Most firms initially aimed only at being compliant by buying and keeping allowances, and adopted a precautionary approach, including efforts devoted to 'lobbying' activities (Aidt, 2010). Cooperative (district based) behaviour could compensate for such weaknesses, for example some ceramics districts adopted EMS at district level to reduce organisational costs. Given the relation between EMS and EI, integrated approaches to EI within the ETS may be useful. ETS firms in Italy, on average, are low level EI adopters compared, for example, to firms in Germany. Thus, the effect we capture using the ETS stringency indicator, which is driven by latent structural factors and by different capabilities to respond to a new policy, should be interpreted as marginal. Steel and paper firms are higher level EI adopters but their share is still low at around 20%. Regarding paper and cardboard, interviews with managers [10] highlight that in the first phase of ETS the effects on innovation were negligible due to policy uncertainty and price volatility. This confirms other interview related evidence. In addition to uncertainty, interviewees stressed that SME firms suffer from oligopoly market power and difficulties in accessing the market. Evolution of market demand is recognised as a significant driver compared to carbon pricing, at least in the current framework. Interviewees were of the view that more attention should be devoted to the typology of innovations. Sectors are highly idiosyncratic with paper producing firms having shifted to gas from oil many years ago and cogeneration occurring in most firms (although not recognised in the ETS scheme). Also, reuse of sub products improves efficiency. Perhaps funding could target specific EI in the form of funding and trusts based on the revenue derived from carbon taxes or ETS non-free allowances (which will apply to future EU ETS scenarios). A general stimulus to EI through pricing might not be effective due to high sector technology idiosyncrasies. It appears that the low price of ETS has slowed innovation. It is worth noting that some countries, such as the UK, will support the ETS price through a complementary carbon taxation applied on top of the ETS pricing system (prices will move from 13£ per tonne in 2013 to 30£ in 2020).Overall, the evidence is mixed. On the one hand ETS firms are stimulated to innovate on the basis of the structural environmental and the incentive offered by the new ETS, and on the other hand stringency does not matter. Sector structural factors have tended to influence the path-dependent patterns among firms. Negative lock in effects characterise the ceramic sector, a leading part of the Italian industry with low historical environmental performance. Ceramics firms have reacted by adopting defensive, not innovative behaviour, buying quotas and 'waiting to see' how ETS develops, but if they do not increasing their EI generation and adoption efforts, they risk very high costs as soon as the system becomes more stringent.

[10] Transcripts of interviews are available upon request.

4.2.2 *Environmental innovations for carbon abatement*

We next focus on CO2 abatement technology adoption (see Tables 6 and 7). We highlight the evidence for and against the more general CO2 abatement strategy of increasing energy efficiency, and the specific action of curbing CO2.

Not that the 'information'/relational factor is more relevant for CO2 abatement: external sources dominate for relatively more radical types of technology adoption. External sources of innovation related content and new skills and competences are important. This is coherent with the 'public good' nature of CO2 abatement which requires of breakthrough technologies which are beyond the capabilities of individual firms. The relevance of suppliers as sources of technology is complemented by the support provided by industry associations (SPRO).

'Public funding support' has so far been insufficient to encourage decarbonisation across the economy. The higher significance of energy efficiency may be related to the inadequacy of Italian public policy and prioritisation of more general objectives such as energy efficiency, and the mixed public good nature of energy efficiency. Public support could stimulate private investment and higher 'appropriation of rents (Corradini et al., 2011). The weaker significance of CO2 may justify efforts to increase public support.

The results for the set of 'environmental' covariates all have positive and highly significant coefficients. The drivers of or factors correlated to EI adoption seem to differ between CO2 and energy efficiency goals, depending upon the different implications of the 'technology adoptions'. However, these differences highlight the role of external sources of knowledge.[11]

The restriction on CO2 abatement (Table 7) presents similarities and differences in the comparison with ECOEN drivers (Table 5). Again, the set of stringency indicators is negatively related to EI. Personal contacts with representatives of the Italian industry association and a close look at the sector adoption shares for CO2 abatement (18% paper and cardboard, 25% coke and refinery, 13% ceramics and cement, 18% metallurgy) highlight that ceramic/cement firms have the most stringent ETS allocation and are the least innovative. The relatively lower average size of these firms is evidently not counterbalance by support from networking and 'external sources of knowledge'. This weakness should be the focus of policy and management.[12] The issue is crucial for both environmental and economic policy since the ceramics sector is a heavy polluter, but is also competitive (Costantini et al., 2010). Absence of innovation could mitigate the possibility to achieve a win win situation (Costantini and Mazzanti, 2012). Interviews with managers of ceramics firms highlighted that: the ETS first phase did not work to stimulate innovation, although they indicated that stringent caps might induce greater energy efficiency. In the 1980s, the ceramics sector introduced some major technological innovations (e.g. new tile 'heating procedures'). In the modern ceramics industries, CO2 abatement inno-

[11] Energy expenditure is not introduced given the high correlation with policy indexes.

[12] However, this captures the Italian average. For example, in the Emilia Romagna region, where a core cluster of ceramic district firms operates, EI is higher than the average for Italy.

vations are more likely in the pre production phase (e.g. new technologies for the preparation of dust material as input for tiles). Quite interestingly and somewhat counterintuitively, managers in the ceramics and paper sectors indicated that a carbon tax implemented homogeneously across sectors is more reliable, less market distorting (fairer for ETS involved firms) and more manageable (by SMEs).

Finally, in line with the more circumscribed nature of CO2 innovations, the set of more general significant factors is reduced (e.g. training and group membership are no longer correlated with to ECOECO as in the case of ECOEN), and EMAS is significant in all the regressions. This is as expected given the quite radical content of EMAS as an organizational strategy that is correlated with CO2 abatement decisions in the sub set of ETS sectors. This played a role before and at the time of ETS introduction (2002-2005). The link between technological and organizational EI has been assessed robustly in the literature (Ziegler and Nogareda, 2009; Wagner, 2007,2009).

5 Conclusions

We provide some preliminary micro econometric evidence on the EI effects of EU ETS exploiting newly available CIS data for Italian manufacturing firms. We investigated the policy induced EI effects of ETS in an usual 'innovation function' adoption approach that built on (i) a theoretical evolutionary model that provides a simple analytical framework to analyse what influences the probability of adoption of EI - energy efficiency and CO2 abatement in the production phase - for firms in the manufacturing sector, and (ii) the related construction of sector specific ETS stringency indicators,. We extended the set of (typical) drivers of EI, internal and external to the firm.

Estimates show that EI is driven by a multiple factors, internal and external to the firm. External forces, that is, knowledge acquisition, seem to matter most, with some differences between energy efficiency and CO2 abatement and the radicalness and content of the innovation. For example, the informed support of industry associations is relevant for CO2. If on the one hand internal R&D does not influence EI, on the other hand sources of EI such as local public funding, and also less emphasised correlated elements as group membership and training are key factors. The policy arena, the networking and internal organizational/management sources direct environmental technical change. This is new evidence that also confirms previous findings.

In relation to ETS, it seems that its role in promoting innovation is mixed. Though further econometric and case study evidence is needed to analyse medium long run innovative reactions (to the development of EU ETS), our findings show that ETS is - ceteris paribus – one of the drivers of EI for energy efficiency and CO2 abatement in 2006-2008. Although sectoral structural factors play a role, this effect is robust and consistent with the results of other case studies. ETS has promoted EI. Although this innovation is not necessarily radical in nature (and our data do not allow is to identify this) we find that 'ETS firms' adopt more EI in the areas of energy efficiency and CO2 abatement.

Within the core set of ETS firms, we see that the stringency of the policy - produced emissions on received allowances - does not promote more innovation. In fact, the more the stringency, the lower the level of EI which we interpret as signalling sector weakness in the specific cases of the ceramics and cement firms. Among the generally low share of firms adopting EI even in polluting sectors, ceramics demonstrates the lowest innovation intensity. This should be confirmed for other countries, and should be considered by managers and policy makers.

An interview with the Italian industry association responsible for implementation of the ETS showed that there is a small impact of policy on innovation dynamics. Within a framework characterised more by compliance than innovative behaviour in sectors other than the energy sector, firms have adopted 'wait and see' strategies. Most firms have bought quotas and, so far, tended not to sell them in the face of uncertainties about targets, mechanisms and prices. Great effort has been put into lobbying actions for inclusion in the 'free auction' share of firms in the new ETS phase. This behaviour is due mostly to the small size of firms, for example, in the ceramic and paper and cardboard sectors. There is a need for a collaborative strategy to tackle ETS (e.g. to reduce sunk costs and information costs), similar to what happened in the case of district based EMAS implementation. Lack of innovation adoption (diffusion) depends mainly on the structural features of the Italian economy (e.g. SMEs), which increases uncertainty about future ETS developments. Some features of Italian industry could mitigate this behaviour, for example, collaboration and pooling of policy related management costs, including financial intermediation services.

The pooling of sunk costs might help with the international carbon market, as clean development mechanisms. Industry associations tend to support those markets given both the enhanced investments possibility in emerging countries and the lower carbon abatement prices they would allow to experience. EI can be promoted and transferred through the formation of international links, though the resulting lower prices of quotas may be a barrier. The need of an EU 'Linkage Directive' testimonied this risk. Future work should study the ETS innovation effect and include the role of international markets and firm/sector openness.

Overall, the findings from work on the role of the EU ETS and evidence from case studies are confirmed by our micro econometric analysis: ETS has had some effects on innovation, but we need to disentangle sector structural effects that depend on path-dependent innovative patterns and specific isolated policy effects. The evidence provided in this paper on ETS is robust from an econometric view point and refers to a large sample of firms.

Further research could investigate whether subsequent ETS phases produce more intense EI adoption. This is an urgent issue given that the current allowance price (2011) is 8€ (a reduction of 40% since 2010), which is evidence of uncertainty about future developments. The EU is launching a new energy Directive on a mixed energy/CO2 tax, which might be aimed also at setting a floor to ETS prices. Analysing the second phase of ETS which overlaps the

2008-2009 recession and the fragile, post crisis economic environment, will be problematic. CIS 2008 was not affected by the recession, which did not occur till late that year. The economic and policy dynamics that characterized the first 5 years of 2000 showed their effects on EI in 2006-2008. Further research should test merged Italian and other EU countries' CIS data to enlarge the datasets and the set of testable implications. EI for 'sustainable consumption' benefits could be investigated to understand whether firms have adopted EI to provide benefits occurring along the life cycle of a product.

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Table 1 – Distribution of firms by geographic area

	ECOEN		ECOCO		Total	
	N.	%	N.	%	N.	%
North-West	478	42,0	365	39,9	2654	40,9
North-East	416	36,5	318	34,8	2188	33,7
Center	128	11,2	107	11,7	839	12,9
South	89	7,8	93	10,2	602	9,3
Islands	28	2,5	32	3,5	200	3,1
Total	**1139**	**100,0**	**915**	**100,0**	**6483**	**100,0**

ECOEN (adoptions of environmental innovations for energy efficiency),
ECOCO (adoptions of environmental innovations for CO2 abatement)

Table 2 – Distribution of firms by industry

Manufacturing Industry code	ECOEN		ECOCO		Total	
	N	%	N	%	N	%
10	70	6,1	62	6,8	467	7,2
11	23	2,0	24	2,6	107	1,7
12	1	0,1	1	0,1	1	0,0
13	49	4,3	41	4,5	305	4,7
14	34	3,0	34	3,7	397	6,1
15	26	2,3	22	2,4	204	3,1
16	53	4,7	41	4,5	339	5,2
17	41	3,6	35	3,8	190	2,9
18	50	4,4	40	4,4	415	6,4
19	18	1,6	14	1,5	56	0,9
20	39	3,4	36	3,9	149	2,3
21	18	1,6	11	1,2	76	1,2
22	79	6,9	52	5,7	445	6,9
23	63	5,5	51	5,6	379	5,8
24	54	4,7	46	5,0	252	3,9
25	131	11,5	89	9,7	736	11,4
26	32	2,8	27	3,0	162	2,5
27	46	4,0	34	3,7	195	3,0
28	100	8,8	88	9,6	458	7,1
29	37	3,2	29	3,2	118	1,8
30	16	1,4	14	1,5	65	1,0
31	56	4,9	43	4,7	283	4,4
32	49	4,3	35	3,8	277	4,3
33	54	4,7	46	5,0	407	6,3
Total	**1139**	**100,0**	**915**	**100,0**	**6483**	**100,0**

See Code reference in the appendix

Table 3 – Descriptive statistics

	Mean	*Std.Dev*
Ecoen	0.175	0.380
Ecoco	0.141	0.348
Sentg (information relationships – enterprise group)	0.432	0.495
Ssup (information relationships - suppliers)	0.365	0.481
Scli (information relationships – clients)	0.284	0.451
Scom (	0.151	0.358
Sins	0.209	0.406
Suni ((information relationships – university)	0.078	0.268
Sgmt	0.039	0.195
Scon (information relationships – conferences)	0.214	0.410
Sjou ((information relationships – journals)	0.144	0.351
Spro (information relationships –industrial association services)	0.125	0.331
Co (innovation related cooperation actions)	0.113	0.317
Rtr (training programmes in the firm)	0.259	0.438
Group (membership to business groups)	0.297	0.457
lprod06 (labour productivity in 2006)	11.881	0.816
Rd (R&D programmes in the firm)	0.305	0.460
Fund (public funding to innovation)	0.125	0.331
ets-Stringe (firm subject to ets)[1]	0.248	0.432
ln(en-exp) (energy expenditure per unit of value)	-3.682	0.665
emas (presence of emas before 2006)	0.154	0.361

[1] Detailed information on the continuous policy stringency indexes presented in par.3 and used in table 5 is available upon request).

Table 4 – ECOEN – all industry sectors

Estimation method: dprobit	[1]		[2]		[3]		[4]	
	dF / dx	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*
SENTG	0.035**	2.24	0.035**	2.24	0.034**	2.17	0.032**	2.05
SSUP	0.028**	2.14	0.028**	2.14	0.029**	2.14	0.028**	2.07
SCLI	0.019	1.47	0.019	1.47	0.017	1.36	0.019	1.52
SCOM	0.001	0.17	0.001	0.17	0.001	0.13	0.001	0.09
SINS	-0.008	-0.57	-0.008	-0.57	-0.007	-0.52	-0.007	-0.48
SUNI	0.004	0.24	0.004	0.24	0.005	0.27	0.008	0.40
SGMT	0.032	1.24	0.032	1.24	0.029	1.13	0.026	1.02
SCON	0.029*	1.92	0.029*	1.92	0.030**	1.99	0.032**	2.12
SJOU	-0.012	-0.78	-0.012	-0.78	-0.014	-0.89	-0.016	-1.00
SPRO	0.015	1.26	0.015	1.26	0.014	1.21	0.018	1.49
CO	0.011	0.58	0.011	0.58	0.011	0.55	0.012	0.59
RTR	0.036***	3.20	0.036***	3.20	0.036***	3.15	0.036***	3.12
GROUP	0.038***	3.91	0.038***	3.91	0.037***	3.69	0.039***	3.87
LPROD06	0.023***	3.19	0.023***	3.19	0.022***	3.00	0.022***	2.93
RD	-0.002	-0.26	-0.002	-0.26	-0.003	-0.36	-0.006	-0.60
FUND	0.039***	3.37	0.039***	3.37	0.039***	3.41	0.040***	3.47
ETS-STRINGE	…	…	0.054***	6.81	0.051***	6.41	…	…
EMAS	…	…	…	…	0.047***	3.25	0.046***	3.17
EN-EXP	…	…	…	…	…	…	2.068***	108.87
Size dummy	Yes		Yes		Yes		Yes	
Geographic dummy	Yes		Yes		Yes		Yes	
Industry dummy	Yes		Yes		Yes		Yes	
N. obs.	6,483		6,483		6,483		6,483	
Pseudo R^2	0.055		0.055		0.057		0.057	

*** significant at 1%; ** significant at 5%; * significant 10%;
Note: standard errors are clustered at industry level (24 sectors)

Table 5 – ECOEN – only ETS industries

Estimation method: dprobit	[1] dF / dx	[1] t-value	[2] dF / dx	[2] t-value	[3] dF / dx	[3] t-value	[4] dF / dx	[4] t-value
SENTG	0.022	1.02	0.022	1.02	0.022	1.02	0.022	1.02
SSUP	0.025*	1.84	0.025*	1.84	0.025*	1.84	0.025*	1.84
SCLI	0.059***	4.48	0.059***	4.48	0.059***	4.48	0.059***	4.48
SCOM	-0.005	-0.15	-0.005	-0.15	-0.005	-0.15	-0.005	-0.15
SINS	-0.032	-0.89	-0.032	-0.89	-0.032	-0.89	-0.032	-0.89
SUNI	0.078	1.46	0.078	1.46	0.078	1.46	0.078	1.46
SGMT	-0.050	-0.77	-0.050	-0.77	-0.050	-0.77	-0.050	-0.77
SCON	0.078***	3.19	0.078***	3.19	0.078***	3.19	0.078***	3.19
SJOU	-0.025	-1.18	-0.025	-1.18	-0.025	-1.18	-0.025	-1.18
SPRO	0.029	0.79	0.029	0.79	0.029	0.79	0.029	0.79
CO	0.026	0.83	0.026	0.83	0.026	0.83	0.026	0.83
RTR	0.024**	1.97	0.024**	1.97	0.024**	1.97	0.024**	1.97
GROUP	0.033**	2.15	0.033**	2.15	0.033**	2.15	0.033**	2.15
LPROD06	0.022*	1.79	0.022*	1.79	0.022*	1.79	0.022*	1.79
RD	-0.003	-0.11	-0.003	-0.11	-0.003	-0.11	-0.003	-0.11
FUND	0.004	0.27	0.004	0.27	0.004	0.27	0.004	0.27
ETS-string-proxy1	-0.014***	-6.76	…	…	…	…	…	…
ETS-string-proxy2	…	…	-0.014***	-6.76	…	…	…	…
ETS-string-proxy3	…	…	…	…	-0.014***	-6.76	…	…
ETS-string-proxy4	…	…	…	…	…	…	-0.013***	-6.76
Emas	0.048	1.56	0.048	1.56	0.048	1.56	0.048	1.56
Industry_code-19	0.070***	5.33	0.072***	5.41	0.070***	5.33	0.072***	5.42
Industry_code-23	-0.014***	-4.03	-0.014***	-3.98	-0.014***	-4.03	-0.016***	-4.71
Industry_code-24	0.005	0.91	0.005	0.91	0.005	0.91	0.005	0.91
Size dummy	Yes		Yes		Yes		Yes	
Geographic dummy	Yes		Yes		Yes		Yes	
N. obs.	1,613		1,613		1,613		1,613	
Pseudo R^2	0.052		0.052		0.052		0.052	

*** significant at 1%; ** significant at 5%; * significant 10%;

Note: standard errors are clustered at industry level (5 sectors)

Table 6 – ECOCO – all industry sectors

Estimation method: dprobit	[1]		[2]		[3]		[4]	
	dF / dx	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*
SENTG	0.001	0.13	0.001	0.13	0.0005	0.04	0.003	0.27
SSUP	0.029**	2.30	0.029**	2.30	0.030**	2.34	0.030**	2.33
SCLI	0.009	0.91	0.009	0.91	0.007	0.75	0.006	0.59
SCOM	-0.018	-1.59	-0.018	-1.59	-0.018	-1.63	-0.019*	-1.67
SINS	0.005	0.39	0.005	0.39	0.006	0.45	0.005	0.37
SUNI	-0.005	-0.27	-0.005	-0.27	-0.004	-0.20	-0.001	-0.07
SGMT	0.056**	2.27	0.056**	2.27	0.052**	2.18	0.050**	2.10
SCON	0.036***	3.41	0.036***	3.41	0.037***	3.59	0.039***	3.75
SJOU	-0.026**	-1.96	-0.026**	-1.96	-0.027**	-2.11	-0.028**	-2.10
SPRO	0.045***	3.73	0.045***	3.73	0.044***	-2.11	0.045***	3.63
CO	0.003	0.25	0.003	0.25	0.003	0.21	0.003	0.24
RTR	0.028***	2.67	0.028***	2.67	0.027***	2.58	0.026**	2.50
GROUP	0.028**	2.27	0.028**	2.27	0.027**	2.14	0.028**	2.21
LPROD06	0.026***	4.83	0.026***	4.83	0.025***	4.51	0.025***	4.33
RD	0.018*	1.69	0.018*	1.69	0.017	1.59	0.014	1.34
FUND	0.025*	1.90	0.025*	1.90	0.025**	1.97	0.025**	2.02
ETS-STRINGE	…	…	0.035***	3.56	0.031***	3.12	…	…
EMAS	…	…	…	…	0.053***	3.45	0.052***	3.30
EN-EXP	…	…	…	…	…	…	1.684***	103.4
Size dummy	Yes		Yes		Yes		Yes	
Geographic dummy	Yes		Yes		Yes		Yes	
Industry dummy	Yes		Yes		Yes		Yes	
N. obs.	6,483		6,483		6,483		6,483	
Pseudo R^2	0.059		0.059		0.063		0.063	

*** significant at 1%; ** significant at 5%; * significant 10%;
Note: standard errors are clustered at industry level (24 sectors)

Table 7 – ECOCO – only ETS industries

Estimation method: dprobit	[1]		[2]		[3]		[4]	
	dF / dx	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*	*dF / dx*	*t-value*
SENTG	-0.020	-1.13	-0.020	-1.13	-0.020	-1.13	-0.020	-1.13
SSUP	0.0003	0.03	0.0003	0.03	0.0003	0.03	0.0003	0.03
SCLI	0.053***	4.72	0.053***	4.72	0.053***	4.72	0.053***	4.72
SCOM	-0.045**	-2.34	-0.045**	-2.34	-0.045**	-2.34	-0.045**	-2.34
SINS	0.024	0.66	0.024	0.66	0.024	0.66	0.024	0.66
SUNI	0.028	0.79	0.028	0.79	0.028	0.79	0.028	0.79
SGMT	0.043	0.63	0.043	0.63	0.043	0.63	0.043	0.63
SCON	0.064***	3.56	0.064***	3.56	0.064***	3.56	0.064***	3.56
SJOU	-0.036	-1.57	-0.036	-1.57	-0.036	-1.57	-0.036	-1.57
SPRO	0.059**	2.17	0.059**	2.17	0.059**	2.17	0.059**	2.17
CO	0.003	0.17	0.003	0.17	0.003	0.17	0.003	0.17
RTR	0.025	1.62	0.025	1.62	0.025	1.62	0.025	1.62
GROUP	0.001	0.07	0.001	0.07	0.001	0.07	0.001	0.07
LPROD06	0.030***	4.18	0.030***	4.18	0.030***	4.18	0.030***	4.18
RD	0.022	0.095	0.022	0.95	0.022	0.95	0.022	0.95
FUND	-0.021	-0.94	-0.021	-0.94	-0.021	-0.94	-0.021	-0.94
ETS-string-proxy1	-0.025***	-5.35	…	…	…	…	…	…
ETS-string-proxy2	…	…	-0.025***	-5.35	…	…	…	…
ETS-string-proxy3	…	…	…	…	-0.025***	-5.35	…	…
ETS-string-proxy4	…	…	…	…	…	…	-0.023***	-5.35
Emas	0.081**	1.97	0.081**	1.97	0.081**	1.97	0.081**	1.97
Industry_code-19	0.002	0.43	0.004	0.70	0.002	0.43	0.004	0.72
Industry_code-23	0.020***	4.77	0.020***	4.81	0.020***	4.77	0.017***	4.22
Industry_code-24	0.013	1.50	0.013	1.50	0.013	1.50	0.013	1.50
Size dummy	Yes		Yes		Yes		Yes	
Geographic dummy	Yes		Yes		Yes		Yes	
N. obs.	1,613		1,613		1,613		1,613	
Pseudo R^2	0.072		0.072		0.072		0.072	

*** significant at 1%; ** significant at 5%; * significant 10%;
Note: standard errors are clustered at industry level (5 sectors)

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