International Journal of Sustainable Energy Planning and Management

Eco-Innovation and Emissions Trading: A Sector Analysis for European Countries

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ABSTRACT

This article aims to assess the impact of a specific regulation, namely the European Union emission trading system (EU-ETS) on the Eco-Innovation (EI) activities of the companies, to evaluate its effectiveness in changing the companies' environmental behavior. It also intends to empirically examine whether the EU-ETS and its 'stringency' are significantly related to EI, taking into account both the internal and external factors that might be correlated with EI. To this end, we develop a cross-sectional framework using the Community Innovation Survey (CIS) data and create a stringency indicator for the period between 2012-2014 for 13 European countries. We found that the EU-ETS has limited and some controversial effects. Furthermore, technology policies emerge as an important element of the policy mix complementing climate policy. Based on our findings, we make recommendations for policymakers on how to improve the existing policy mix.

Keywords

Community Innovation Survey (CIS);
Eco-Innovation;
Emissions;
European Carbon Market

http://doi.org/10.5278/ijsepm.6567

1. Introduction

In consequence of the worldwide growing concerns about the emission of greenhouse gases (GHGs) to reduce the impact of climate change, the European Union (EU) has launched a strategy that comprises several initiatives, such as the International Climate Policy (e.g. the Paris Agreement) [1], the Climate and Energy Action Framework for 2030 [2], the Renewable Energy Directive, among others. Preceding the Paris Agreement as an International Climate Pact [3], the Kyoto Protocol emerged, which was based on three mechanisms, namely the Clean Development Mechanism, the Joint Implementation, and the European Union Emissions Trading Scheme (EU-ETS). This last system acts as a cap (global limit), where a maximum of CO_2 emissions is established, determining the number of emission allowances provided. Therefore, if an installation emits more CO_2 than the licenses received, it will have to buy licenses, but if it emits less, it will be able to sell the remaining ones.

Companies, in particular those in the sectors involved in the allowances market, are subject to pressures to adopt better environmental behaviors, either compulsorily through policy measures or voluntarily through the market and competition, or simply to reduce related operating costs, concerning, for instance, energy, raw materials or waste treatment. In this way, there are several motivations for Eco-innovating. Eco-Innovation (EI) is understood as any product, process, organizational, social, or institutional innovation that can reduce environmental impact and resource use [4, 5, 6]. Several studies look for the determinants of EI. These determinants can be internal or external to the company [7, 8]. Environmental policies, namely the aforementioned EU-ETS, are within the external determinants of EI [9].

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Some authors show that environmental regulation is one of the strongest determinants of this EI [10, 11], although other authors show that its effect is not so relevant [12, 13], with no consensus in the literature.

Thus, this article intends to estimate the impact of a specific regulation, EU-ETS, on the Eco-Innovation activities of the companies involved in the market, to assess its effectiveness in changing the environmental behavior of companies. The proposed metric is effective to deliver the expected outcomes, specifically on the Eco-Innovation strategy, as caught up by the firm-level data from the Community Innovation Survey (CIS). Therefore, we intend to contribute to the existent literature by empirically examining whether the EU-ETS and its 'stringency' is significantly related to EI, taking into account both the internal and external factors that might be correlated with EI. Furthermore, we compare economic activity sectors, contributing with a different approach to analyze the relationship between EI strategies and the effectiveness of the EU-ETS market.

The rest of the article is divided as follows. Section 2 presents an overview of previous research exploring the links between EI, policy regulation and competitiveness, and the EU-ETS market. Section 3 exposes the methods and data collected for this work, while section 4 presents the empirical results and discusses some policy implications derived from these. Finally, section 5 concludes the work, pointing some future research direction needs.

2. Literature Review

In this section, a theoretical framework is provided to understand the influence of regulatory policies on eco-innovation, as well as their effect on market competitiveness. Additionally, a literature review on the origin and evolution of the European Union – Emissions Trading System (EU-ETS) together with its impacts on EI are presented, which is the aim of our study.

2.1. Eco-innovation, policy regulation, and competitiveness

Innovation has always been seen as part of the solution to environmental problems. However, before 2005 few programs at the EU level had specifically addressed the stimulation of environmental innovations. Since then, Eco-Innovation started receiving growing attention [4]. Indeed, the literature about the role of policy regulation in EI promotion is developed mainly after 2010. As the benefits of EI are undervalued in the market and because of lock-in problems of well-developed and well-embedded technologies in power supply and transport, the EI policy is stronger than the traditional innovation policy [4]. Del Río et al. [6] state that regulatory stringency affects the rate and direction of EIs and is a crucial element to encourage them, especially the radical ones. Moreover, according to the so-called Porter Hypothesis, stricter environmental regulations encourage environmental technologies that reduce both the environmental impact of production activities and the costs of complying with regulation [14].

Environmental innovative firms cooperate on innovation with external partners (suppliers and universities) to a higher extent than other innovative firms [8]. In a study applied to Spain, De Marchi [8] presents some results that suggest that the R&D cooperation is more intense for environmental innovators than for other innovators. The policy action, within the form of public grants, fosters innovations that reduce the impact on the environment to an higher extent than other innovations.

A study conducted by Borghesi et al. [15] about Italy, suggests the importance of well-designed, long-term, and time-consistent policies to promote the development of cleaner technologies for energy efficiency and CO_2 abatement. Results show that current and future expected regulations are highly correlated to EI and the policy stringency is negatively related to innovation diffusion, a result that applies to both types of EI considered, internal and external to the firm. It is also important to understand how the green system works at a regional level. A study by Antonioli et al. [16] for Emilia-Romagna, in Italy, shows that firms that share the municipality location with EI adopters are more likely to adopt EIs, which highlights the relevance of agglomeration economies and native institutional conditions in providing concrete (innovative) contents to the green economy paradigm. Moreover, at a municipal level spillovers tend to prevail over other geographical factors and to the respective economic activity sector, and, therefore, EIs may be considered as a key source of growth for regional systems, particularly when spurred by local spillovers.

In Crespi et al. [17] the authors differentiate weak EI (e.g. incremental or radical innovation with low penetration rates) from strong EI (e.g. incremental or radical EI that have high penetration rates and thus a high environmental impact) and state that policies should be focused on the uptake of strong EI, and on radical ones, to maximize the environmental benefits.

In countries with a certain level of policy stringency, and where the choice of environmental policies is more flexible, there is a greater propensity to generate widely diffused innovations and to benefit from innovations generated elsewhere [18]. Indeed, results from Kemp and Pontoglio [19] show that flexibility has a positive impact on Eco-Innovation. However, they found that the flexibility of EU-ETS, within the banking and borrowing context, worked against the development of innovations. Furthermore, the results did not find the best instrument to foster innovative response to environmental regulations, although taxes and emissions trading systems were found to be superior in promoting innovation than regulation. Yet, this can be true for low-cost improvement innovations but does not appear to be true for radical innovation.

As it is shown by Horbach et al. [11], the regulation in Germany features a strong influence on EIs, particularly to push firms to scale back air (e.g. CO_2, SO_2, or NOx), water or noise emissions, to avoid hazardous substances, and to increase the recyclability of products. Cost savings are also of great importance as a motivation for reducing energy and material use, with the energy and raw material prices and taxation considered as drivers for EI. Another important source of EI is the customer requirements [20], especially products with improved environmental performance and process innovations that enhance material efficiency, and reduce energy consumption, waste, and therefore the use of dangerous substances.

A robust and well-functioning financial market helps investors to tap into the commercial potential of clean energy, contributes to social desires, the expansion of cleaner energy, and energy efficiency and environmental sustainability [21]. However, Al Mamun et al. [22] warn for potential key policy implications. Indeed, smoothing the availability of finances to renewable energy firms should be a key priority for governments to allow those firms to be able to increase cleaner energy production and address the threat of the increasing greenhouse gases and the achievement of intergenerational energy security. Another potential key policy appointed by the authors is the provision of tax credits to investors in stocks of cleaner energy firms, encouraging the socially faithful investors and others to invest more funds in the stocks of companies that produce cleaner energy. They also claim the development of Government policies to scale back the economic incentives to use, produce and invest in fossil fuels, through measures like the increased carbon tax, stringent usage guidelines for producing and using fossil fuels, while providing increased governmental support for cleaner energy initiatives.

Horbach et al. [7] compare France to Germany. In their study, it is possible to ascertain the relevance of the regulatory push-pull effect for EIs documented by the significance of the respective variables, which confirms the importance of regulatory instruments in stimulating EIs by industrial firms. Furthermore, the results show that eco-innovative firms tend to patent significantly more than other innovators and that EU-wide centralized policies, like the EU-ETS, seem to be capable to promote Eco-Innovation. Moreover, it is possible to observe that in Germany the cost savings, especially the material and energy savings, play an important role in triggering EIs, as well.

According to Porter and Van Der Linde [9] (p. 98), “competitive advantage rests not on static efficiency nor on optimizing within fixed constraints, but on the capacity for innovation and improvement that shift the constraints”. Taking this thought into account, Porter and Van Der Linde [9] (p.116) claimed that “the focus should be on relaxing the environment-competitiveness trade-off and the orientation should shift from pollution control to resource productivity”. Furthermore, it is asserted that success can not come from policies that proclaim that environment will triumph over the industry, nor from policies that promise that industry will conquer the environment. As an alternative, the success must involve innovation-based solutions to promote environment and industrial competitiveness.

2.2. EU-ETS

The world’s largest carbon pricing regime is the EU-ETS, a cap-and-trade system of CO_2 allowances – constrains the aggregate emissions of regulated sources by creating a limited number of tradable emission allowances, requiring those sources to surrender allowances according to their emissions. It was adopted in 2003, with a pilot phase from 2005 to 2007, a Kyoto phase from 2008 to 2012, and the third phase from 2013 to 2020 [23]. A new phase (Phase IV) has recently started in 2021 and will be extended until 2030 to fulfill the emission reduction targets as a part of the EU´s contribution to the Paris Agreement [2].

In the study of Borghesi et al. [24] for Italy, most respondents across different sectors agreed that energy costs’ factors tend to dominate specific CO_2-targeted policies in terms of EI-related impacts. Within the same study, it is stated that policy certainty and financial support are two pre-conditions to sustain initial innovation adoption. In this particular case of Italy, Borghesi et al. [15] assert that, in the first phase of the EU-ETS, the majority of the firms adopted a “wait and see” policy, using the allowances at their disposal instead of investing in new technologies to benefit from the opportunity to sell the permits.

The over-allocation (in Phase I) and therefore the economic recession (in Phase II) have reduced the direct impact of the EU-ETS on emissions, however, the combination of rigorous monitoring and awareness, as well as a positive carbon price, has driven some abatement on emissions [25]. Interviews from this study suggest that the EU-ETS has affected investment decisions in limited ways (e.g. mainly small-scale efficiency-related investments instead of being sufficiently clear to drive large, long-term investment decisions). Furthermore, pieces of evidence from Phase I and Phase II claim that significant windfall profits only endure for a limited time, as a policy can and will respond once the evidence is obvious. Thus, the EU-ETS system has been ready to deter major carbon-intensive investments and consequently to release capital that could be turned to low carbon investment, which reinforces the importance of EU-ETS in business decision-making.

In an Italian-based study of Pontoglio [26], it is possible to observe that the EU-ETS scheme is not able to award and stimulate investments, having been scarcely favorable to innovations. This study refers to the investment and the limited span of the allocation periods as a long-term problem since they resulted not be sufficient to provide a predictable long-term signal for investments. The author states that carbon dioxide emitted by energy-intensive industries can not be reduced using low-cost end-of-pipe abatement solutions. In contrast, it requires improvements in energy efficiency and investments in renewable resources, whose adoption is influenced both by energy and carbon prices. Furthermore, the actors involved in their development and diffusion are machinery suppliers who are fundamental actors in the innovation system.

Nevertheless, theoretically, it is expected that environmental policies can stimulate the adoption and diffusion of carbon-friendlier technological solutions. In this study, it is shown that its potential in the EU-ETS Phase I was sharply weakened due to some flaws in its design, more precisely in the allocation principles, new entrants and closures rules, and issues related to its time profile, which depart the Phase I of EU-ETS from an ideal trading mechanism. In fact, in the first two phases of the EU-ETS allowance prices were volatile and sometimes very low, therefore resulting in a weak incentive to implement energy efficiency and innovation [27]. But, despite an imperfect design, it has managed to incite an increase in the adoption of emitting technologies [28]. Even in the third EU-ETS phase, which was more stringent, it only had limited effects on the rate and direction of corporate research, development, and demonstration (RD&D) and its adoption [28]. In this study, the authors state long-term emission reduction targets as an important trigger of RD&D. Furthermore, it was found that technology policies, in the form of demand-pull and technology-push instruments, have significant effects on low carbon technological change, and are therefore an important factor compensating for the insufficient effect of emissions trading. The Porter Hypothesis states that a policy like the EU-ETS can incite EI and improve the financial performance of regulated firms. However, according to Osses [29], the policy did not enhance the financial performance of regulated companies, which can be further expounded by the time lag associated with the profitability of EIs. In this study, it is shown, by a comparison among the eco-patent output, that EU-ETS only induced innovation in its second implementation phase, which can be a result of a higher degree of regulatory stringency and an increased level of certainty compared to phase one. Thereby, policymakers should enact EU-ETS reforms focused on decreasing the emission cap, introducing means to stabilize the allowance price, carefully assessing if the scheme can be extended to other sectors, and launching other EI enhancing instruments.

Innovation risks and the related high initial investment costs of technological boundaries limit investments in technological innovation to reduce carbon emissions, and thus investments tend to focus mainly on market-available technologies for core processes [27]. The study of Gasbarro et al. [27] for the Italian pulp and paper industry concludes that, since financial uncertainties usually deter both technical and organizational innovation, it is necessary to highlight and maintain the commitment to improving environmental performances. As a consequence, it is strictly crucial to stimulate the investment in innovation through regulation enforcements, which will potentially affect the international competitiveness of pulp and paper companies.

In the Rogge and Hoffmann [30] study, for the sectoral innovation system of power generation technologies, it is possible to see that the EU-ETS has impacted at four levels: (i) knowledge and technologies; (ii) actors and networks; (iii) institutions; and (iv) on-demand. Regarding the first impact, EU-ETS accelerates the innovation process, being an additional driver for RD&D on higher efficiency levels (materials, components) and indirectly benefiting RD&D on renewables. Actors and networks include the regulatory pull from power generators to technology providers, the increased corporate RD&D spending, especially of larger players, and the heterogeneity of actors. On institutions, EU-ETS fosters changes in thinking, including in top management, and promotes the distribution of CO_2 policies across the organization through its integration in procedures, structures, and corporate innovation routines. Finally, on-demand was impacted especially because of new plants, with a temporary spike in pre2012 interest in investments, and due to the incentives provided for fuel switching and cogeneration, and the measures improving energy efficiency that raised plants' profitability.

In the study of Rogge and Hoffmann [30], it can also be found that the EU-ETS scheme mainly affects the rate and direction of technological change of power generation technologies within the large-scale, coal-based power generation technological regime, to which carbon capture technologies are added as a new technological trajectory. For the German pulp and paper industry, Rogge et al. [31] found that the EU-ETS and the international climate policy had barely affected their innovation activities. Instead, RD&D decisions and companies' adoption tend to keep them on established and primarily market-factor-driven technological business-as-usual trajectories. Low prices for CO_2, a high share of free allocation, and regulatory uncertainty are some of the likely reasons for the low relevance of the EU-ETS. Therefore, increasing the stringency and predictability of the current policy mix would be expected to contribute towards a decarbonization path [28, 31].

3. Methods

The data collection matched the same period and sectors of both the CIS database and the EU-ETS database. The sample is composed of 11524 firms answering the CIS (sectors C, H, and D, see Table 2), from 13 European countries (BG-Bulgaria; CY-Cyprus; CZ-Czech Republic; DE-Germany; EE-Estonia; EL-Greece; HR-Croatia; HU-Hungary; LT-Lithuania; LV-Latvia; PT-Portugal; RO-Romania; SK-Slovakia), belonging to the sectors that participate in the EU-ETS and that are also included in CIS. These include the Thermoelectric Plants, Ceramics, Cement and Lime, Cogeneration, Combustion Plants, Iron Metals, Pulp and Paper, Refineries, Glass and Aviation.

The CIS survey is a three years survey, where only 2008 (2006-2008) and 2014 surveys (2012-2014) directly asked firms if they had adopted any eco-innovation strategy and if these were related to the product, process, marketing, or organizational innovations. To have a common period of analysis among both datasets, we have collected data from the period 2012-2014.

For the EU-ETS the total number of available firms reporting allowances allocation and total emissions during the 2012-2014 period was 2727 (see Table 1). Both datasets were joined by computing averages, considering the values reported by each firm in each economic activity sector.

In the analyzed countries, it was considered the individual data of all companies participating in the EU-ETS, regarding their level of emissions and the number of licenses allocated, available on the European Commission's website (https://ec.europa.eu/clima/ets/), in millions of tonnes. The observed emissions and received allowances per company were aggregated by sector, and following [15] we constructed an EU-ETS policy indicator to capture policy stringency that will be used as an explanatory variable in the econometric analysis to be performed in the following section.

The indicator s is a ratio between the emissions (e) of sector i and the EU-ETS allowances allocated to that sector (EUA), as presented in equation (1).

$$S_i = \frac{e_i}{EUA_i} \tag{1}$$

The more emissions the sector i produces and the lower the level of its allowances, the more stringent is the ETS policy. If $s_i > 1$, it means the number of allowances at disposal to sector i is lower than its emissions level, therefore the ETS policy is stringent for that sector. If, in contrast, $s_i \leq 1$ then the permits allocated to sector i are equal or lower to its emissions, so the ETS policy is not stringent.

Table 2 presents the available CIS data in the period 2012-2014, especially considering the EI strategies implemented.

Table 1. Number of available firms on CIS 2014 and EU-ETS by country and sector

CIS		Countries													
		BG	**CY**	**CZ**	**DE**	**EE**	**EL**	**HR**	**HU**	**LT**	**LV**	**PT**	**RO**	**SK**	**Total**
Sectors	17	155	34	106	83	109	115	135	90	129	98	80	102	28	1264
	19	179	28	124	182	29	135	54	100	60	47	140	151	30	1259
	23	336	75	153	132	106	168	147	134	141	52	299	181	56	1980
	24	92	55	106	119	85	149	271	79	117	56	64	119	26	1338
	25	779	55	250	353	85	149	271	634	117	56	583	339	205	3876
	35	123	1	116	150	54	27	32	116	49	36	41	149	60	954
	51	20	67	8	7	96	200	158	9	146	95	27	16	4	853
	Total	1684	315	863	1026	564	943	1068	1162	759	440	1234	1057	409	**11524**

EU-ETS		Countries													
		BG	**CY**	**CZ**	**DE**	**EE**	**EL**	**HR**	**HU**	**LT**	**LV**	**PT**	**RO**	**SK**	**Total**
Sectors	7	5	0	6	127	2	12	0	4	0	2	22	6	6	192
	2+3	64	3	230	874	35	20	20	124	52	72	48	115	76	1733
	6+7+8	30	9	61	233	3	39	15	33	6	9	40	29	19	526
	5	9	0	7	66	1	19	5	4	0	1	1	21	10	144
	4	3	0	7	34	0	5	4	3	1	0	2	12	1	72
	1	1	0	1	8	1	0	1	3	0	1	0	5	2	23
	Aviation	4	1	4		2	7	1	3	2	1	9	2	1	37
	Total	116	13	316	1342	44	102	46	174	61	86	122	190	115	2727

Notes: 17 (7 on EU-ETS) Manufacture of paper and paper products; 19 (2+3 in EU-ETS) Manufacture of coke and refined petroleum products; 23 (6+7+8 in EU-ETS) Manufacture of other non-metallic mineral products (cement, ceramics, and glass); 24 (5 in EU-ETS) Manufacture of basic metals; 25 (4 in EU-ETS) Manufacture of fabricated metal products, except machinery and equipment; 35 (1 in EU-ETS) Electricity, gas, steam, and air conditioning supply; 51 (Aviation in EU-ETS) Air transport.

Table 2. Variables description

	Environmental benefits obtained within the enterprise	
Ecoeno	Reduced energy use or CO_2 footprint (reduced total CO_2 production)	1 = yes; 0 = no
	Environmental benefits obtained during the consumption or use of a good or service by the end-user	
Ecoenu	Reduced energy use or CO2 footprint	1 = yes; 0 = no
	Factors driving the enterprise's decisions to introduce innovations with environmental benefits	
Enereg	Existing environmental regulations	High = 3; Medium = 2; Low = 1; Not relevant=0
Enetx	Existing environmental taxes, charges, or fees	High = 3; Medium = 2; Low = 1; Not relevant = 0
Enregf	Environmental regulations or taxes expected in the future*	High = 3; Medium = 2; Low = 1; Not relevant = 0
Engra	Government grants, subsidies, or other financial incentives for environmental innovations	High = 3; Medium = 2; Low = 1; Not relevant = 0
	Other variables	
SIZE1	If the number of employees under 50	1; 0 otherwise
TG	Turnover growth between 2012 and 2014	(%)

Notes: *For example preparing environmental audits, setting environmental performance goals, ISO 14001 certification, ISO 50001 certification, etc.

Although CIS is referred to the entire period 2012-2014, the period of analysis was reduced to just one average year to avoid reducing the number of observations further. The EU-ETS data was reduced to the period average, as well. Provided both dependent and independent variables are in average terms for one year only, we used cross-section regression analysis. All estimations have been performed using the Stata software.

Equations (2) and (3) were estimated to understand how the chosen factors drive the company's decisions to introduce Eco-innovations according to the variables in Table 2. The two dependent variables are the environmental benefits obtained within the enterprise, ecoeno, meaning reduced energy use or CO_2 footprint (reduced total CO_2 emissions), and the environmental benefits obtained during the consumption or use of a good or service by the end-user, ecoenu, meaning reduced energy use or CO_2 footprint.

$$ecoeno_i = \alpha_i + \beta_j X_{i,j} + \beta_j W_{i,j} + \beta_7 s_i + \varepsilon_i \qquad (2)$$

$$ecoenu_i = \alpha_i + \beta_j X_{i,j} + \beta_j W_{i,j} + \beta_7 s_i + \varepsilon_i \qquad (3)$$

Where i refers to the economic activity sector, α is the regression constant, β the coefficients associated with each independent variable, X the vector of factors driving the enterprise's decisions to introduce innovations with environmental benefits, namely, enereg (existing environmental regulations), enetx (existing environmental taxes, charges or fees), enregf (environmental regulations or taxes expected in the future), engra (government grants, subsidies or other financial incentives for environmental innovations), and W the vector of control variables composed by SIZE1 (if the number of employees in the firm is under 50) and TG (turnover growth between 2012 and 2014). The variable s_i is the average EU-ETS stringency policy indicator of firms that traded in this market during the 2012-2014 period and ε is the random component of the linear relationship between X and $ecoeno_i$/$ecoenu_i$.

4. Results

The number of available firms on CIS has been associated with the companies in the EU-ETS and the results are discussed based on the interaction between the two groups. In this section, we will present the empirical results and discuss some policy implications derived from them.

4.1. Empirical Findings

As can be observed in Table 3 all variables have the same observation number (91, which corresponds to 7 sectors in 13 countries), except the ETS stringency policy indicator, which has a lower sample, presenting 78 cases, for the same countries and sectors. Nevertheless, there were countries with missing data for some sectors, meaning, there are sectors with available data in CIS that were not present in EU-ETS and vice versa, which made us match both sets of information, not being able to work with complete data for all sectors in all countries. In the descriptive statistics table, Table 3, we can also observe that the mean values are all positive, with s_i representing the highest value in contrast to the ecoeno and ecoenu that present the lowest ones, while the others have similar values between the ecoenu and s_i. Regarding the deviation, we can observe that the values are quite close and similar, except for ecoeno and ecoenu that are lower. It is also important to refer that the values are within the expected range, with all of them presenting null or positive values, except for TG suggesting the possibility of negative values for turnover growth, between 2012 and 2014.

Provided that on average $s_i \leq 1$, more specifically, $s_i = 0.709$, then the permits allocated to sector i on average are higher to its emissions, meaning that jointly for all sectors considered, the EU-ETS policy is not stringent. Moreover, the two dependent variables (environmental benefits obtained within the enterprise, and the environmental benefits obtained during the consumption or use of a good or service by the end-user), present very low average values, being those with the lowest standard deviation as well. Thus, on average the firms answering the CIS survey during 2002-2004 have stated to introduce

Table 3. Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ecoeno	91	0.180	0.149	0.000	1.000
ecoenu	91	0.115	0.094	0.000	0.469
enereg	91	0.524	0.444	0.000	3.000
enetx	91	0.424	0.399	0.000	3.000
enregf	91	0.430	0.409	0.000	3.000
engra	91	0.260	0.216	0.000	1.122
SIZE1	91	0.553	0.232	0.000	1.000
TG	91	0.307	0.449	–0.333	2.750
s_i	78	0.709	0.338	0.268	2.419

very few environmental benefits, which may be explained by the low incentives they had to perform eco-innovations, representing higher imposed costs. However, this would as well imply that higher amounts of licenses need to be bought or lower emissions need to be released by these same firms. With a weak stringent EU-ETS policy (on average) and low stated EI measures, it is reasonable to state that the EU-ETS policy implications are not producing the desired effects within these sectors, and they need to be reformulated to be more stringent and produce the environmental desired effects effectively.

The Pearson correlation analysis (Table 4) provides clear evidence, for a significance level of 1%, that there is a very large and positive relationship between enetx and enereg (0.977), enregf and enereg (0.986), and enregf and enetx (0.985), which reflects a very regulated market, potentially damaging corporations that do not have a strong financial background, especially if the stringency ratio is higher than 1 (Table 3). This means that the corporations emit more than the allowances allocated, and therefore there is a more stringent policy, and the innovation in this particular field is lower. These high values of correlation among explanatory variables might also conduct to multicollinearity issues, demanding that these should be inserted individually in the regression performed to avoid spurious regressions. This might be because we have a small number of observations within the sample. Even so, the VIF values computed do not reveal multicollinearity issues.

It is also important to note that for a significance level of 1%, the correlation between the indicators ecoeno, ecoenu, enereg, enetx, enregf and engra is positive and has a moderately weak relationship (namely, between enetx and ecoenu, 0.404). On the other hand, for all the remaining indicators with a statistically significant correlation, some with a level of 5% (for example, between TG and ecoene) and others with a level of 10% (such as SIZE1 and ecoenu), there is a negative and considerably weak relationship. It should also be noted that the indicator s_i does not present any significant correlation with the other variables, for the tested significance levels, namely at 1%, 5%, and 10% significance.

Table 5 presents the cross-section regression results where both Enetx (existing environmental taxes, charges, or fees) and Enregf (environmental regulations or taxes expected in the future) reveal to have a negative impact over ecoeno, the latter in a nonsignificant way, thus turning harder to reduce energy usage or CO_2 footprint.

Moreover, Enereg (existing environmental regulations) and Enegra (government grants and subsidies) have a significant and positive impact on energy and CO_2-related EI, which can evidence the effectiveness of this kind of policy. Size has a significant and negative impact on the dependent variable, which means that small enterprises (in particular, with a number of employees under 50) have more difficulties on eco-innovating in energy and emissions fields. Nevertheless, concerning turnover growth, evidence shows that companies with a higher TG, eco-innovate less. The stringency indicator (s) revealed only to be significant in explaining Ecoenu, with a negative coefficient sign, which means that the more stringent the EU-ETS policy is, the fewer EIs activities are pursued.

Results point for some interesting policy directions to be pursued as will be discussed in the next subsection. Similar to the results presented by Madaleno et al. [32],

Table 4. Pearson correlation analysis

	ecoeno	**ecoenu**	**Enereg**	**enetx**	**enregf**	**engra**	**SIZE1**	**TG**	s_i
ecoeno	1								
ecoenu	0.652***	1							
enereg	0.791***	0.481***	1						
enetx	0.782***	0.404***	0.977***	1					
enregf	0.791***	0.428***	0.986***	0.985***	1				
engra	0.449***	0.727***	0.650***	0.591***	0.602***	1			
SIZE1	–0.074	–0.205*	0.068	0.076	0.092	–0.119	1		
TG	–0.253**	–0.184*	–0.188*	–0.174*	–0.198*	–0.109	–0.151	1	
s_i	–0.132	–0.159	–0.064	–0.057	–0.082	–0.059	0.039	–0.135	1

Note: *, **, *** statistically significant at 10%, 5% and 1% respectively

Table 5. Cross-section regression results

	Coef.	**Std. Err.**	**T**	**P > t**	**F(7, 70) =**
Dependent: ecoeno					
Enereg	0.499	0.181	2.75	0.008	12.3
Enetx	–0.343	0.183	–1.88	0.064	Prob > F =
Enregf	–0.177	0.215	–0.83	0.411	0.000
Engra	0.240	0.142	1.69	0.095	R-squared
SIZE1	–0.099	0.044	–2.24	0.028	0.5515
TG	–0.050	0.024	–2.12	0.038	Adj R-squared
s_i	–0.041	0.030	–1.36	0.178	0.5067
_cons	0.165	0.038	4.33	0.000	
Dependent: ecoenu					
	Coef.	**Std. Err.**	**t**	**P > t**	**F(7, 70) =**
enereg	0.218	0.122	1.78	0.079	15.44
enetx	–0.192	0.123	–1.56	0.124	Prob > F =
enregf	–0.063	0.145	–0.44	0.665	0
engra	0.272	0.096	2.84	0.006	R-squared
SIZE1	–0.041	0.030	–1.38	0.173	0.6069
TG	–0.034	0.016	–2.1	0.039	Adj R-squared
s_i	–0.035	0.020	–1.74	0.087	0.5676
_cons	0.094	0.026	3.64	0.001	

Table 6. Cross-section regression results with robust standard errors

	Coef.	**Robust Std. Err.**	**T**	**P > t**	**F(7, 70) =**
Dependent: ecoeno					
enereg	0.499	0.196	2.55	0.013	14.59
enetx	–0.343	0.193	–1.78	0.079	Prob > F =
enregf	–0.177	0.175	–1.01	0.316	0.000
engra	0.240	0.123	1.95	0.056	R-squared
SIZE1	–0.099	0.043	–2.30	0.024	0.5515
TG	–0.050	0.016	–3.06	0.003	Root MSE =
s_i	–0.041	0.028	–1.45	0.150	0.087
_cons	0.165	0.050	3.28	0.002	
Dependent: ecoenu					
ecoenu	**Coef.**	**Robust Std. Err.**	**T**	**P > t**	**F(7, 70) =**
enereg	0.218	0.145	1.50	0.138	14.81
enetx	–0.192	0.120	–1.60	0.115	Prob > F =
enregf	–0.063	0.158	–0.40	0.691	0.000
engra	0.272	0.096	2.83	0.006	R-squared
SIZE1	–0.041	0.030	–1.35	0.182	0.6069
TG	–0.034	0.012	–2.80	0.007	Root MSE =
s_i	–0.035	0.018	–2.00	0.050	0.059
_cons	0.094	0.032	2.89	0.005	

size exerts a particular influence over the adoption of EI strategies. Indeed, smaller companies support higher costs and have lower access to government grants and subsidies preventing them from having higher investment levels, as well as preventing them from the desirable future sustainability that should be achieved. Therefore, policymakers should provide more incentives, lower taxes, and ensure that smaller firms' participation in the EU-ETS market will be fair and properly weighted (prioritizing these is important for the future sustainability of the EU market).

To perform a robustness check, estimation results have been repeated to decrease the possible effects of heteroskedasticity that may be presented by the data. Regarding Table 6, where robust standard errors are used in the estimation, the differences that distinguish it from Table 5, for example, a change in the standard error values and a non-significant change in some of the values of $p > t$, do not change the overall interpretation of the study. The exception is the effect of environmental regulations (enereg) whose impact is no longer significant (up to a 10% level) in reducing energy use or CO_2 footprint during consumption or use of a good or service by the end-user.

Looking at both Tables 5 and 6, we also confirm the overall significance of the results achieved provided the F-stat results and considering the adjusted R squared obtained from estimations. From the results, it may be as well inferred that existing environmental regulations are important to justify a firm's implementation of EI strategies. However, existing environmental taxes, charges, or fees seems not to be significant to force companies to pursue these strategies (depending on the EI strategy). The same happens when we consider the impact of environmental regulations or taxes expected in the future, which could lead policymakers to increase taxes in the future, as for now, they do not represent a concern. Since in this phase 4 (2021-2030), and based on the current legislation, scope changes have not been agreed, but yet considered as part of the review of the ETS foreseen (under the 2030 Climate Target Plan), it leaves room for stricter policies and perhaps the inclusion of more economic activity sectors in the EU-ETS scheme.

In contrast, government grants, subsidies, or other financial incentives for environmental innovations justify increased measures of EI within the firms considered in the sample, leaving them highly dependent on the government, which opens room for the discussion of the effectiveness of these supports. Further, it may impact future competitiveness in the market, imposing additional costs to the desired sustainability goals [17-19; 28-30].

4.2. Results Discussion

In this subsection, we raise some discussion about the empirical findings obtained in the previous subsection.

Industrial competitiveness has an important role in consumer effectiveness, especially in achieving sustainability targets [33]. In the literature, it is pointed that the industry's environmental reputation is related to the adopted sustainability strategies [33-34]. Consumers are becoming more aware of the need to save the planet and to adopt sustainable practices, starting with household responsible consumption patterns adoption. Industries should then take the needed steps in adopting these behaviors keeping themselves competitive in a globalized market while keeping answering the consumers' demand [33]. This can only be done with improved technologies [34], changes in energy demand, and increased consumption [20]. The literature also highlights that industries' environmental reputation increases sustainability strategies while considering customers' environmental concerns and keeping financial and market performance [33].

Individuals will continue consuming and population consumption needs will continue to rise. Industries will have to follow the growing pattern and provide goods at an accelerated rate. This will certainly increase the environmental impact and imply sustainability goals patterns to be rethought and reformulated. The best solution, from our viewpoint, will be to favor the necessary conditions for industries to be able to answer the growing needs patterns while attending simultaneously to sustainability goals, which can only be achieved at the expense of renewable energy technologies [35], thus favoring the adoption of EI strategies in firms. Additionally, we should be aware of the possible cost pass-through identified in the literature [36] from firms in the EU-ETS to consumers in some sectors.

The EI strategies explored in this article are actions based purely on returns over investments realized by the firms considered in the sample (or stated, since the data has strived from the CIS survey). Even with low governmental support, which turns the new desired green world unrealistic thus far, both businesses, consumers, and the environment can win by working jointly. This can only be ensured if being green is no longer a cost of doing business, but a result of innovation, new market opportunities, advanced technologies, and wealth creation [37,38]. Policymakers are required to devise mechanisms and offer incentives as to the adoption of EI strategies within firms, or even government intervention to support the EU-ETS scheme to lower the cost burden supported either by firms and consumers [36,38]. These pursued strategies have to be done especially in those industries where there is evidence that paying to be green is ambiguous, or where environmental management practices investments in EI are not evident. Thus, incentives to encourage the enhancement and adoption of environmental initiatives in economic activity sectors should be offered, as proved in our results and as highlighted by Postula and Raczkowski (2020) [39].

For these policies to be pursued there should be a clear distinction among firm dimensions [32] and risk exposure [21]. In Madaleno et al. [32] there is clear evidence that additional costs are imposed by the final consumer. Smaller firms should thus benefit from higher government support since image issues are harder to maintain, adopt and adapt, provided turnover growth is reduced in these firms if greater EI strategies are to be followed [32]. Therefore, and considering that most firms in the European markets are SMEs (small and medium enterprises) [40], investors and subventions should be prioritized for smaller firms, even if the largest firms are more capable of minimizing the risk perception [34- 32].

Concerning EU ETS phases, and the replicability of our results, some considerations can also be made. As mentioned before, this study focuses on the period 2012-2014, including the last year of the second EU ETS trading period (2008-2012) and two years of the third trading period (2013-2020). The results presented for this period can be easily extended for the complete third period, as the main distinctive feature of phase 1 and phase 2 is the number of allowances to be allocated for free to the industry. Nevertheless, for the following phases, our results should be rather conservative. For instance, for the third period, as the main difference between the first two phases and phase 3 is that no free allocation for electricity production exists and the free allocation to the industry is based on EU harmonized rules, we believe that conclusions could be different and thus EU-ETS could reveal to be a strong incentive to EIs and to affect the financial performance of regulated companies. Moreover, as the main aim of the fourth period (2021-2030) is to increase even more the pace of emissions cuts, to establish a better-targeted carbon leakage framework, and to provide funds for low-carbon innovation and energy sector modernization, we believe these impacts (on innovations, emissions, and finance) could even be more empathize.

Most of the well-succeeded industries, like the petroleum companies, have shown to fail to be fully committed to climate change mitigation, only willing to pay off their emissions. Therefore, only with the promotion of the investment in breakthrough technologies, such as carbon capture, will be possible to meet the Paris Agreement goals. The literature provides several policy suggestions to help to promote the investment in these technologies. A primary requirement provided by Bataille et al. [41] is to make the decarbonization of energy-intensive industries a priority at all levels, i.e. from the international to the sectoral level, incorporating it in each country's climate policy. Stakeholders are also important drivers to communicate, coordinate and legitimate transitions. They can create a common vision among government, industry, and society while defining long-term strategies for the whole innovation chain. Another crucial measure would be the elimination of subsidies for fossil fuel production and use, and the internalization of carbon content, through carbon pricing, at all stages of the material's life cycle, from production to end-use, with more stringent regulation. Research into supporting institutions and business models should also be prioritized. Other authors (e.g. Wesseling et al. [42]) claim that changes in user behavior, culture, and industry strategies help decarbonizing industries. This can be attained by a well-designed consumer education program to help some already developed technologies to be introduced more rapidly into the market [43]. Moreover, the government should become less risk-averse in its support for investment in breakthrough technologies and both risks and costs should be shared between industry and governments [42]. Therefore, a globally coordinated policy approach would be crucial.

It is difficult for emerging technologies, like electric and fuel cell vehicles, to compete in a market with mature technologies, like internal combustion engines. Indeed, when some incumbents perceive climate-related concerns as a threat rather than an opportunity, they tend to lobby to avoid the threatening of their competitors [44]. These lobbying groups comprise industry associations that have political influence. The new technologies, in turn, are perceived as risky, costly, and unable to compete with the economies of scale of established technologies. To thrive in such an unjust scenario Bataille et al. (2018) [41] propose these firms engage in research collaborations and cooperations with other stakeholders to help developing economies of scale for green procurement. Furthermore, governments should stop giving in to pressure from lobbies by eliminating the subsidies for fossil fuel-related technologies and adopt more stringent carbon-related regulations.

5. Conclusions

This paper provides new evidence on the role of the EU-ETS for innovation in energy efficiency and CO_2 abatement. Our estimates show that EIs are associated with various factors, both internal and external to the firm. External forces, as the existence of environmental regulations and financial incentives for environmental innovations (e.g. government grants and subsidies), have a positive impact on reducing energy use or CO_2 footprint within the enterprise and during the consumption or use of a good or service by the end-user. In contrast, environmental taxes, charges or fees, and the stringency of the EU-ETS revealed not to be an incentive for this kind of EIs. We find that future expected regulation is not significant for explaining EI. Different authors have studied the possibility to apply carbon taxation or other market policies to share the emissions responsibilities between consumers and producers, but the conclusions are not consensual. For instance, Jakob et al (2021) [45] proposed an "Economic Benefit Shared Responsibility" scheme to account for carbon emissions associated with the production of traded goods and services. The authors suggest the use of the economic benefits producers and consumers derive from being able to generate emissions-free of charge, as a measure to share responsibility for trade-related emissions, through a carbon price. By contrast, other studies apply alternative approaches, based on the counterfactual perspective of the absence of trade, evaluating a country's imports and exports either relative to the average global emission intensity for the respective goods and services [46], or from the perspective of how a country's trade specialization contributes to meeting global consumption in a carbon-efficient way [47]. These last authors proposed a scheme for assigning credits and penalties. In this sense, reductions in global emissions resulting from cleaner exports can be accounted for. Combining such schemes with accounting schemes for shared producer and consumer responsibility in dashboards for "multiple carbon accounting" [48] could help to create a broad depiction of the responsibility for trade-related emissions. Several authors view the fulfillment and reinforcement of the Paris Agreement as the next steps in the global response to climate change [49]. Any international negotiation about assigning burdens (or distributing efforts, or sharing responsibilities) should be subject to basic considerations, as criteria for equity and fairness, historical responsibilities, and the countries' capacity to pay [47].

Internal factors, as the size, have a significant and negative impact on the dependent variable, which means that small enterprises have more difficulties in eco-innovating. Nevertheless, the turnover growth coefficient evidence that companies with a higher TG eco-innovate less.

Our results are aligned with the literature, once EU-ETS has barely affected companies innovation activities and did not enhance the financial performance of regulated companies [28, 29, 31]. In this sense, policymakers should focus on decreasing the emission cap, introducing means to stabilize the allowance price, carefully assessing whether the scheme can be extended to other sectors. They should also launch other eco-innovation enhancing instruments, and increase the stringency and predictability of the current policy as part of a policy mix aiming to steer the rate and direction of technological change towards low carbon emissions, a non-linear process characterized by lock-ins [28, 29, 31]. As the regulatory conditions for the EU-ETS are determined up to the last phase, in the short to medium term, policy-makers should rely on complementary policies like innovation, and thus on technology-push policies to guide RD&D activities towards low carbon production technologies at competitive costs. Besides, a good complementary step would be the achievement of a globally binding climate deal that would set long-term reduction targets. Utopically, such a treaty would lead to a global carbon price and hence at the same time address producers' concerns about competitiveness, leading to a larger international demand for low-carbon technologies by technology providers [31].

This study has, however, some limitations. The period of our selected data was short due to the small CIS survey period, which has prevented us from performing a more complex estimation. Moreover, a wider range of countries should have been considered to minimize the error of this European study that has encompassed 13 countries only, and we should have used more recent data, which was not possible due to the lack of recently available data. Furthermore, we needed to use average values by economic activity sector, since there is no possibility to cross-check data for each company between CIS and the EU-ETS, due to confidentiality issues. Thus, in future studies it would be interesting to study the impact of these measures on individual companies' financial performance, using more recent data, expanding the countries' range and variables, and exploring different regression models.

Acknowledgments

We acknowledge the support by the Research Unit on Governance, Competitiveness and Public Policy (UIDB/04058/2020), funded by national funds through FCT - Fundação para a Ciência e a Tecnologia. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Thanks are due to the comments received from participants of the 5th Annual Conference of the Portuguese Association of Energy Economics (APEEN), held online during 21-22 January 2021, where a first version of the article was presented. The 5th Annual APEEN Conference was organized by CENSE (Center for Environmental and Sustainability Research) from NOVA School of Science and Technology, Lisbon, Portugal. The authors thank, as well, the opportunity to submit the article to the International Journal of Sustainable Energy Planning and Management (Special Issue: Energy Systems Sustainability) and to the valuable comments of the editorial [50], which helped us improve the article to its current version.

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