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ABSTRACT

Innovation is now expected to play an important role to overcome difficult issues of climate change more than ever. To examine how to induce innovation, the relationship between environmental policy and innovation has been focused on. Still few researches, however, have examined the impact of the EU emission trading scheme on innovation based on econometric analysis. This study scrutinises how corporate responses towards the EU ETS influence R&D investments of EU major corporations. Using firm-level panel data, which is constructed based on the data of corporate responses to the Carbon Disclosure Project, EU Industrial R&D Investment Scoreboard, and corporations' CSR reports, I estimate two dynamic panel models using system GMM estimator. Endogeneity issue is addressed in these models. The results show that corporations which have a policy or a strategy to comply with the EU ETS or to react proactively before being regulated by the EU ETS are more likely to encourage R&D investment. The process of reacting towards the EU ETS may provide an opportunity for corporations to recognise the importance of R&D investment for their future strategy.

Key words: Climate change; EU ETS; R&D investment

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1. Introduction

Climate change is one of the most serious problems the world is facing now. Although a large reduction in emissions is inevitable, as suggested by many simulations such as the IPCC Fourth Assessment Report (2007) and the Stern Review (2006), this is not an easy task and could be impracticable without sacrificing further economic growth in both developed and less developed countries.

Technological innovation is now expected to become an essential measure of overcoming this difficult situation. People have begun to recognise the limits of dealing with climate change based on existing framework such as technology and social systems. In order to tackle the problem, it is necessary to handle it from new dimensions or frameworks which may be realised through technological innovations and innovations of social systems.

Then, which policies and/or factors may induce these innovations? Previous studies examined the relationship between environmental regulations and innovation to find out the answers to this question. However, still few researches have examined the impact of the EU emissions trading system (henceforth EU ETS) on innovation based on econometric analysis. This study focuses on the EU ETS, an external environmental policy, and how it influences research and development (henceforth R&D) investment of EU corporations. EU corporations are interesting enough to focus on because they are facing a wide range of environmental regulations, carbon taxes and emission trading schemes. In particular, launched in 2005, the EU ETS has been playing an important role in the climate change policies.

In this study, a dynamic panel model is used to deal with the influence of past R&D investments. Variables regarding financial status, corporations' characteristics, years and sectors which are potential factors that have an impact on R&D investment are included in the models. In addition, endogeneity issues is addressed in the models.

The results show that the external pressure, the EU ETS, may positively influence corporations' R&D investments. Corporations which have a policy or a strategy to comply with the EU ETS or to react proactively before being regulated by the EU ETS are more likely to encourage R&D investments.

This study will contribute to the literatures in this field. Firstly, this is the first research which focuses on how the corporations' responses towards the EU ETS influence R&D investment by using data from the Carbon Disclosure Project (henceforth CDP). It is unique in terms of using CDP data, which has not been fully examined for academic purposes. Secondly, there are still few researches which have scrutinised the relationship between the EU ETS and R&D investment by focusing on corporations' actual internal reactions towards the EU ETS; therefore this paper may provide original insights regarding this relationship. Lastly, this research may provide interesting implications for environmental policy design in the aspect of encouraging R&D investment.

This paper is structured as follows: Section 2 gives the background literature, and Section 3 is an overview of the EU ETS and R&D investment. Section 4 presents the econometric models and methodology used for the analysis, and Section 5 provides the data description. The results are examined in Section 6, and finally a conclusion and an implication of the study are discussed in Section 7.

2. Background literature

The role of technological innovation has received a great attention in the field of environmental economics (Jaffe *et al.*, 2003). When facing long-term environmental problems, such as climate change, they remind us how technological innovation is vital for society. Since the benefits of innovations tend to diffuse into society, the market mechanism alone has had little power to stimulate R&D. On the other hand, environmental regulation or public funding of R&D has often provided opportunities of R&D activity (Popp *et al.*, 2010). Therefore, technological innovation has often been scrutinised in the context of environmental policy.

Beginning in the 1970s, interest was focused on which policy measurement may induce innovations (e.g. Magat, 1979; Milliman, and Prince, 1989). In the 1990s, the Porter

Hypothesis created a sensational argument in the relationship between environmental policy and technological innovation; because the argument was unlike the traditional view which economists had held. Many economists, at that time, believed that strengthened environmental regulation would impose additional costs on corporations in order to comply with. However, in this hypothesis, Porter mentioned that when corporations are faced with strengthened environmental regulations, they are inclined to look for potential technological innovation (Porter, 1991). Through the process of seeking unnoticed seeds of innovation, it can bring a positive effect on R&D activity, so that corporations can encourage innovations which may boost their competitiveness in the international market (Porter and Linde, 1995).

Many studies on the Porter Hypothesis have been done since it was firstly published. Based on a dataset of Japan, U.S., and Germany, Lanjouw and Mody (1996) examined the relationship between patents and pollution abatement cost, which is a proxy for the stringency of environmental regulation. Their results showed that pollution abatement cost successfully affected the number of patents, but they did not control other factors which may influence technical innovation. Jaffe and Palmer (1997) analysed how the stringency of environmental regulations may affect both R&D expenditures and patents. They concluded that pollution abatement costs positively affected only R&D expenditures. Pollution abatement cost was also used as a proxy for the severity level of regulations in this study.

Brunnermeier and Cohen (2003) empirically analysed the relationship between regulation and the environmental related technological innovation. As a proxy for the stringency of regulation, they used pollution abatement costs and the number of inspections carried out by regulatory institutions. Although the pollution abatement costs increased the environmental related patents, inspections did not affect technological innovation.

Arimura *et al.* (2007) analysed what may induce environmental R&D, and tested the three variations of the Porter Hypothesis proposed by Jaffe and Palmer (1997). For this analysis, data of manufacturing facilities in seven OECD countries was used. The results showed that public policy could induce environmental R&D investment. The adoption of an environmental accounting system also induced environmental R&D investment, which was promoted by flexible policy instruments. The direct relationship between flexible policy instruments and environmental R&D investment was not proved. The “strong” version of the Porter Hypothesis was indirectly supported in their study. Lanoie *et al*. (2011) also tested the Porter Hypothesis by using same data as Arimura *et al*. (2007). In this study, four main elements: environmental policy, R&D, environmental performance, and commercial performance were examined. The “weak” version was strongly supported, the “narrow” version was conditionally observed, and the “strong” version was not supported in their study.

In terms of the EU ETS, some studies such as Anger & Oberndorfer (2007) focused on the influence of the EU ETS on social aspects such as employment and corporate performances. However, a few studies have investigated the impact of the EU ETS on innovation activity. Gagelmann and Frondel (2005) and Schleich and Betz (2005) focused on the first phase of the EU ETS and proved that innovation was not enhanced by the EU ETS because of free allocations of allowances in the first phase. Rogge and Hoffmann (2010) examined the influence of the EU ETS on the innovation regarding power plant technology in Germany based on case study method. Rogge and Hoffmann (2010) analysed from four aspects: “knowledge and technologies”, “actors and networks”, “institutions”, and “demand”, and concluded that the EU ETS gives some important impacts on innovation. Their study, however, could not detach the influences of other policies besides the EU ETS. Therefore, the exact impact of the EU ETS is not fully examined based on quantitative methods.

3. Overview of EU ETS and R&D investment

3.1 EU ETS

The EU ETS, the EU emission trading scheme, is one of the European Union's policies to deal with climate change which is designed to reduce industrial greenhouse gas emissions cost effectively. It launched in 2005, now it is in the third phase (2013-2020), covering more than 11,000 power stations and industrial plants in 31 countries (EC, 2014). In addition, from the beginning of year 2012, airlines were also included in the EU ETS. Therefore, the system now covers carbon dioxide (CO_2) emissions from power plants, a wide range of energy-intensive sectors and commercial aviation, nitrous oxide (N_2O) emissions from the production of certain acids, and emissions of perfluorocarbons from aluminum production (EC, 2015)[1]. It is mandatory for corporations operating in these sectors to participate in the EU ETS, but in some sectors only installations above a certain size are included. In terms of commercial aviation, CO_2 emissions from flights to and from the EU are covered.

The “cap and trade” principle is applied to the EU ETS. A cap is set on the total amount of greenhouse gases emissions by the power plants, facilities and other installations covered by this system. To reduce total emissions, the cap has been reduced over time. In 2020, emissions from sectors under the EU ETS may be 21% lower than that in 2005 (EC, 2014).

Once free allocation was a main method for allocating allowances, but now, auctioning is the default method for allocating allowances. The share and the scope of auctioning may gradually rise or widen each year. In 2013, more than 40% of allowances was auctioned (EC, 2014).

Within the cap, corporations can trade emission allowances with others. If a corporation reduces its emissions, it can keep remaining allowances to cover its future needs or it can sell those allowances to other corporations and gain money. The flexibility

[1] Greenhouse gases and sectors included in the EU ETS (EC, 2014): [I]Carbon dioxide from (i) power and heat generation, (ii) energy-intensive industry sectors such as oil refineries, steel, aluminum, metals cement, ceramics, pulp and paper etc., (iii) commercial aviation; [II] Nitrous oxide from nitric, adipic, glyoxal and glyoxlic acids; [III] Perfluorocarbons from aluminum production.

of this system is a key for reducing emissions cost effectively. If a corporation cannot comply with the conditions and rules of the EU ETS, heavy fines are imposed.

Now, around 45% of total EU greenhouse gas emissions are covered by the EU ETS (EC, 2015). By putting a price on carbon, the EU ETS has influenced the climate change policies of EU countries and corporations.

3.2 Impact of EU ETS on corporations' R&D investment

For the further survival in the market, what may become a key for corporations to reinforce their competitiveness? According to the argument by Porter and Linde (1995), competitiveness can be encouraged by innovation. Based on this context, R&D investment, an input for innovation, is the source of corporations' competitiveness. Therefore, corporations may strategically consider the optimal conditions for investment such as the amount and timing of investment, which are strongly affected not only by size, economic performance and human resources factors, but also their internal decision making process.

Corporations need to face with global issues in order to survive in the market. Climate change is a serious global issue that our society is experiencing. In the process of dealing with those issues, corporations also have to deal with external pressures such as regulations, shareholders, other stakeholders i.e., competitors and media in our global economy. It is important for corporations to improve the appropriateness of corporate actions within the regulations, its brand images, and market legitimacy.

The EU ETS is a policy for EU to combat climate change issue, which can be an example of external pressure. Under the EU ETS, corporations' policy against climate change may be affected. How to comply with or deal proactively with the EU ETS may become an important issue for continuous survival. Corporations under the EU ETS need to comply with the regulation to keep their appropriateness. Some of the corporations may be keen to react proactively to the EU ETS before its implementation, because through preparation towards the future regulation of the EU ETS, they might capture the accurate facts and circumstances that they face with. This process may help them to integrate a strategy for climate change into their business. This case shows that corporations may not only be stimulated by incentives to improve their values, but also to find the seeds for potential opportunities to further growth. Corporations may also gain important insights and information regarding R&D investment in the process of responding to the EU ETS.

Therefore, my hypothesis is that the corporations which actively or proactively react towards EU ETS are more likely to encourage R&D investment.

4. Model

In order to examine the impact of EUETS on R&D investment, I estimate the following dynamic model. I assume that a corporation's R&D investment is expressed as:

$$RD_{it} = \beta_1 RD_{i,t-1} + \beta_2 EUETSSTR_{it} + \beta_3 EMISSION_{it} + \beta_n X_{it}^n + \alpha_i + \mu_t + \varepsilon_{it}$$

$$i = 1, \dots, N; t = 1, \dots, T \qquad (1)$$

where i denotes corporations and t years. In this model, R&D investment divided by net sales is used as the dependent variable "RD".

Eq. (1) is a dynamic model which shows that R&D investment is determined by its own past realisations; therefore, lagged dependent variable $RD_{i,t-1}$ is adopted as one of the explanatory variables. This is based on the tendency that corporations which invest great on R&D activity are likely to encourage R&D in the future as well (Baumol, 2002). Many reasons for this tendency can be explained by corporate actions; for example, a corporation developed a new product in the process of R&D activity may invest in further R&D in order to improve the product or create a superior substitute.

$EUETSSTR_{it}$ and $EMISSION_{it}$ are dummy variables which show the corporate reactions towards EU ETS. X_{it}^n is a set of control variables. β_1, β_2, β_3 and β_n are parameters to be estimated. ε_{it} is the error term. Time specific effects μ_t are included to control for time-dependent determinants of R&D investments, such as some changes which affect a corporations overall R&D incentives. Corporation-specific effects α_i

capture the response of each corporation to external factors.

To estimate the dynamic model equation above, we need to deal with several econometric problems which may arise. First, "$EUETSSTR$" and "$EMISSION$" are assumed to be the endogenous variables which may correlate with the error term due to two-way causality between "RD" and these two dummy variables. If we do not take this relationship into account, a simultaneity bias may occur. The fact that the endogenous variables are included in this model means that strict exogeneity condition cannot be realised. If strict exogeneity (i.e., no correlation between the error term and explanatory variables across all time periods may occur (Wooldridge, 2010)) cannot be attained, the OLS estimator may be inconsistent.

Second, a dynamic panel bias may occur due to the fact that the lagged dependent variable is endogenous to the individual effects α_i. In particular, when "small T, large N" panels (few time periods and many individuals) are used for estimation, this bias may become significant (Roodman, 2006). The OLS estimator may be inconsistent, because the lagged dependent variable would be correlated with the error term.

Based on these econometric problems, it is inevitable to focus on estimation methods that can be used for explanatory variables or instruments which are not strictly exogenous. This study uses the generalized method of moments (henceforth GMM) which adopt lags of the dependent variables as covariates, and include unobserved individual effects. The difference GMM is a consistent GMM estimator of dynamic panel models, which was developed by Arellano and Bond (1991). In order to eliminate the individual effects, the difference GMM uses Eq. (2) which can be derived by first-differencing Eq. (1), and adopts instruments i.e., previous observations of the endogenous variables and the lagged dependent variable. This is based on the assumption that the error term is not serially correlated and the explanatory variables are not correlated with future realisations of the error term (Roodman, 2006).

$$\Delta RD_{it} = \beta_1 \Delta RD_{i,t-1} + \beta_2 \Delta EUETSSTR_{it} + \beta_3 \Delta EMISSION_{it} + \beta_n \Delta X_{it}^n + \Delta\mu_t + \Delta\varepsilon_{it}$$

$$i = 1, \dots, N; t = 1, \dots, T \qquad (2)$$

The difference GMM, however, has limitations, too. For instance, when the explanatory variables are persistent over time like this model, the lagged levels may become weak instruments for the first-differences, and this may lead to a large finite sample bias (Blundell and Bond, 1998). There is some possibility that it may lead to a bias and imprecision because some explanatory variables are persistent over time in my study.

To overcome this problem and to generate consistent and efficient estimates, I chose the system GMM estimator, proposed by Blundell and Bond (1998) as an extended version of the difference GMM estimator. Blundell and Bond (1998) insists that it is possible to overcome the bias and poor precision by using two equations. One is the difference Eq. (2) which adopts suitably lagged levels as instruments, and second is the Eq. (1), the equation in levels, which uses suitably lagged differences of the explanatory variables as instruments. A one-step estimate was implemented to obtain the results.

In this study, I perform the misspecification test for second-order serial correlation in the first-differenced error term. If null hypothesis that there is no second-order serial correlation in the differenced residual cannot be rejected, the error term ε_{it} (in levels) is not serially correlated at order 1, and the estimated model will be supported. The Hansen J-statistic test which tests the null hypothesis of correct model specification and validity of the instruments used in the model is also performed. If we cannot reject this null hypothesis, it proves that the model has valid instruments.

5. Data description

5.1. CDP survey data and R&D investment data

To scrutinise the relationship between corporate actions regarding EU ETS and R&D investment, the firm level dataset (fiscal year 2000-08) of EU corporations (301 corporations) is constructed by matching data of CDP and EU industrial R&D Investment. The missing data were supplemented by CSR reports for each corporation. I focused on the data of fiscal year 2000-08 and did not include years after 2008 in order to exclude the macro-economic impact of the Lehman Brothers bankruptcy.

The Carbon Disclosure Project is an independent non-profit organisation working on how to actualise greenhouse gas emissions reduction and sustainable water use. With the world's largest investors, businesses and governments, CDP involves in the actions to realise a more sustainable economy, and provides measurement and disclose information for thousands of corporations and cities to improve their management towards environmental risk. As said in an old management adage "You can't manage what you don't measure", it is difficult to improve if we do not measure to see what is going on. CDP also thinks that evidence and insight are vital for real change, and gives an incentive to corporations and cities to measure and disclose their greenhouse gas emissions, potential risks and opportunities, and strategies for managing them (CDP, 2012).

CDP requests information on greenhouse gas emissions, energy use and the risks and opportunities of climate change issue from thousands of the world's largest corporations on behalf of institutional investors. Started in 2003, the quantity and quality of response data have grown significantly. The number of responding corporations has been increasing since the first CDP report was presented in 2003. In 2009, CDP, backed by 475 institutional investors with $55 trillion in assets, sent the questionnaire to more than 3,700 of world's largest corporations (CDP, 2012). About 60% of corporations responded, and if you focus on the Global 500 corporations (the 500 largest corporations in the FTSE Global Equity Index Series), the overall response rate for CDP 2009 was 82% (CDP, 2012).

CDP has been gaining influence in the business arena and financial markets. These globally-collected climate change data are disclosed to the public and utilised as evidence for decision making by institutional investors. CDP data have been integrated into financial analysis, and indices such as the Carbon Disclosure Leadership Index (CDLI)[2] and the Carbon Performance Leadership Index (CPLI)[3].

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[2] The CDLI index is an index which indicates the quality of a company's degree of disclosure. CPLI index is qualified to corporations which are taking positive measures on climate change mitigation.
[3] The CPLI index is qualified to corporations which are taking positive measures on climate change mitigation.

CDP data are very valuable for this study because they enable us to examine the corporations' first-hand responses. Considering the fact that there are few academic papers using these CDP data, and the data have not been fully scrutinised, this study is original in terms of using a new dataset constructed mainly based on the CDP data.

For the data of R&D investment, I used "EU Industrial R&D Investment Scoreboard" data and corporation CSR reports. The EU Industrial R&D Investment Scoreboard was first issued in 2004 and has been providing firm-level data of R&D investment since then. These data enable us to monitor the R&D situation in the EU. To supplement missing data from CDP and EU Industrial R&D Investment Scoreboard, CSR reports of each company are also used in this research.

Considering the probability that corporations with environmentally conscious managers are more likely to respond to the CDP questionnaire, issue of potential response bias cannot be ignored. Corporations with higher commitments to the actions to deal with EU ETS and/or higher R&D investments/sales ratios may be more willing to respond to the questionnaire than those with lower commitments to the actions towards EU ETS and/or lower R&D investments/sales ratios.

5.2. Variables

A set of variables is summarised in Table 1. In order to consider the impact of EU ETS on R&D investment, the variable "*EUETSSTR*" and "*EMISSION*" are added as corporate responses towards EU ETS in the models. "*EUETSSTR*" is a dummy variable which takes the value 1 if the corporation has its own strategy to comply with the conditions of EU ETS or to respond proactively before being covered by EU ETS. Corporations may invest in R&D as an internal strategy toward EU ETS. This is because it is necessary for them to control GHG emissions in order to comply with EU ETS, and changing and innovating processes and/or products may be one of ways to achieve their emission abatement goals. Therefore, this variable may encourage R&D investment. "*EUETSSTR*" is assumed to be potentially endogenous variable, because corporation-specific factors, such as a corporation's internal decision-making system and the attitude of managers toward climate change, are likely to be correlated with "*EUETSSTR*". "*EMISSION*" is also included in Model 2. "*EMISSION*" is a dummy variable which takes the value 1 if the corporation discloses the amounts of GHG emissions. This corporate action is strongly connected with its strategy towards EU ETS. Corporations which disclose GHG emissions may be more likely to understand their status quo of their emission level and to know how important to enhance their R&D activity to reduce their emissions. This is also assumed to be potentially endogenous. Based on the arguments above, the coefficients for these two variables may be positive.

"*EUETS*", a dummy variable which takes the value "1" if the corporations are covered by the EU ETS, is also included. The coefficient for "*EUETS*" is difficult to predict; because both cases that corporations may or may not encourage R&D investment by becoming under the EU ETS can be assumed. This variable is treated as strictly exogenous. In order to examine the relationship between "*EUETS*" and variables: "*EUETSSTR*" and "*EMISSION*", the interaction term of "*EUETS*" and "*EUETSSTR*" is included in both models, and the interaction term of "*EUETS*" and "*EMISSION*" is included in the model 2.

As for characteristics of the corporations, the following variables were focused on: "*lnEMPLO*" "*lnPROFIT*" and "*lnMRKTCPTL*". Corporate size is explained by the variable "*lnEMPLO*", the number of employees the corporation has. Some larger corporations tend to invest in their R&D activity for their future competitiveness; on the other hand, some larger corporations may focus on other investment besides R&D for their survival. Therefore, the coefficient for "*lnEMPLO*" is difficult to predict. Corporate economic performance is explained by the variable "*lnPROFIT*" which indicates operating profit. Since corporations with better economic performance are more likely to pursue environmental goals (Nakamura *et al*., 2001), the coefficient for "*lnPROFIT*" is expected to be positive. Market capitalisation (*lnMRKTCPTL*) shows not only the economic performance, but also explains overall evaluations of corporations in the market.

Stakeholder decisions are one of the most important external factors which influence corporate actions. It is plausible that larger corporations may experience more pressure to be greener from stakeholders (Nishitani, 2009). Corporations with high value market capitalisation also tend to be affected by these pressures. External pressures may encourage corporations to be green and may increase R&D investment. Considering this possibility, I predict that the coefficient of this variable will become positive. These variables are treated as predetermined variables in the models.

Sector dummy variables are created by referring to the NACE code system and the Industry Classification Benchmark (ICB). The former is the European standard for industry classifications and the latter one is an industry classification developed by Dow Jones and FTSE. In addition, year dummy variables are created. Lastly, interaction terms of "*EUETS*" and sector dummy are included. These variables are treated as strictly exogenous in the models.

6. Results and Discussion

In this study, two models were estimated and the results are shown in Table 2. The results of the Arellano–Bond test show that in both models, the null hypothesis was accepted. In other words, there is no evidence of serial correlation and does not imply model misspecification. Two models also pass the Hansen test, which confirms that the instruments can be considered valid.

In Model 1, the estimated coefficient of the lagged dependent variables is positive and statistically significant at the 1% level. It is interesting to notice that the coefficient of the "*EUETSSTR*" is positive and statistically significant at the 5% level. This indicates that corporations which have a strategy for the EU ETS to comply with or have proactively reacted to the future regulation by the EU ETS are likely to encourage R&D investment, and to increase the ratio of R&D investment to net sales. It implies that in the process of implementing the strategy towards or reacting proactively towards the EU ETS may lead corporations to notice the necessity of R&D investment. In other words, R&D investment may become important for corporation when considering how to react towards the EU ETS. The coefficient of the "*lnEMPLO*" is also positive and statistically significant at the 10% level. This result shows that corporation which has larger number of employees is more likely to invest in their R&D activity. In Model 2, the coefficient of the lagged dependent variables is positive and statistically significant at the 1% level. Also the coefficient of the "*EUETSSTR*" is positive and statistically significant at the 5% level. "*EUETSSTR*" becomes positive and statistically significant in both models.

7. Conclusion

Using the dataset of EU corporations which was constructed based on CDP, EU Industrial R&D Investment data and CSR reports, the impacts of the EU ETS on R&D investment were scrutinised. In order to estimate dynamic panel models, system GMM was employed. Endogeneity issue was also addressed in the models. This research is unique in terms of using CDP data which have not been fully examined for academic purposes. CDP enables us to examine first-hand information from corporation responses regarding the climate change issue, which may allow us to extract intriguing factors. For instance, by using CDP data, we can examine the actual influence of the EU ETS, one of the important external regulations regarding climate change, towards EU corporations.

The findings of this study show that corporations which have a policy or a strategy to comply with the EU ETS or to react proactively before being regulated by the EU ETS are more likely to encourage R&D investment. The process of reacting towards the EU ETS may provide an opportunity to closely examine the relationship between corporate actions and the climate change issue. In this process, corporations may become aware of the importance of innovation activity for complying with and/or for increasing their competitiveness.

This is a unique study which shed light on the relationship between the corporate response towards the EU ETS and R&D investment, but estimation methods can be improved further. Increasing the number of years and/or corporate data would make this study more persuasive. In addition, it is interesting to examine how the stringency level of the EU ETS influences corporations' innovation activity by comparing the stringency level in first, second and third phases of the EU ETS.

Although some limitations might exist, this study still presents an interesting implication that the external pressure such as the EU ETS may become an important factor to stimulate incentives for enhancing innovation activity. Decision making process related to R&D investment is important for corporations because it may strongly connect with the future competitiveness and it has to be done from a long-term perspective. The results of this study show that this important decision making process is significantly affected by the external regulations. In order to enhance corporations' R&D activity, this study indicates how to design the external pressures is one of the important issues to deal with. There are few studies which proved the positive relationship between the EU ETS and R&D investment; therefore, this study may give an important insight to this field of studies.

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Tables:

Table 1. Summary statistics

Variable	Number of observation	Mean	Std. Dev.	Min	Max
RD_SALES	1568	0.046	0.186	0	5.149
L.RD_SALES	1262	0.047	0.192	0	5.149
lnPROFIT	772	6.852	1.784	0.675	15.156
lnEMPLO	1107	10.108	1.532	5.142	13.171
lnMRKTCPTL	1040	8.923	1.594	3.584	12.169
EUETSSTR	431	0.826	0.380	0	1
EMISSION	735	0.875	0.331	0	1
EUETS	1690	0.206	0.404	0	1
*EUETS*EUETSSTR*	431	0.513	0.500	0	1
*EUETS*EMISSION*	735	0.359	0.480	0	1
DY2000	1690	0.041	0.198	0	1
DY2001	1690	0.043	0.202	0	1
DY2002	1690	0.066	0.248	0	1
DY2003	1690	0.117	0.321	0	1
DY2004	1690	0.148	0.355	0	1
DY2005	1690	0.166	0.372	0	1
DY2006	1690	0.161	0.368	0	1
DY2007	1690	0.147	0.355	0	1
DY2008	1690	0.112	0.315	0	1
DS1	1690	0.092	0.289	0	1
DS2	1690	0.087	0.282	0	1
DS3	1690	0.016	0.125	0	1
DS4	1690	0.125	0.331	0	1
DS5	1690	0.047	0.212	0	1
DS6	1690	0.206	0.404	0	1
DS7	1690	0.156	0.363	0	1
DS8	1690	0.270	0.444	0	1
*EUETS*DS1*	1690	0.045	0.207	0	1
*EUETS*DS2*	1690	0.031	0.174	0	1
*EUETS*DS3*	1690	0.008	0.091	0	1
*EUETS*DS4*	1690	0.037	0.188	0	1
*EUETS*DS5*	1690	0.021	0.142	0	1
*EUETS*DS6*	1690	0.023	0.150	0	1
*EUETS*DS7*	1690	0.032	0.176	0	1
*EUETS*DS8*	1690	0.009	0.094	0	1

Table 2. Estimation results

Variables	**Model 1** R&D investment/sales Coefficient (Robust Std. Err.)		**Model 2** R&D investment/sales Coefficient (Robust Std. Err.)	
L.RD_SALES	0.814 ***	(0.075)	0.829 ***	(0.077)
EUETSSTR	0.015 **	(0.007)	0.015 **	(0.008)
EUETS	0.008	(0.008)	0.008	(0.008)
EMISSION	-		-0.003	(0.007)
lnPROFIT	-0.002	(0.002)	0.000	(0.002)
lnEMPLO	0.006 *	(0.003)	0.004	(0.002)
lnMRKTCPTL	0.001	(0.003)	0.000	(0.002)
*EUETS*EUETSSTR*	-0.014	(0.010)	-0.015	(0.010)
*EUETS*EMISSION*	-		0.008	(0.008)
*EUETS*Sector dummy*	YES		YES	
Sector dummy	YES		YES	
Year dummy	YES		YES	
Number of Observation	378		374	
Arellano-Bond test for AR(2) in first differences Pr>z	0.190		0.180	
Hansen test	0.887		0.857	

Note: System GMM, Robust one-step. Standard errors are shown in parentheses. *, ** and *** indicate the significance at the 10%, 5% and 1% levels, respectively. Constant is included in the model, though its coefficient is not reported here.