Kyoto University,
Graduate School of Economics
Discussion Paper Series

Environmental disclosure and innovation activity: Evidence from EU corporations

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Discussion Paper No. E-16-012

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December, 2016

Abstract:

Innovation is expected to become an essential element in overcoming climate change issue. To examine the factors that might induce such innovation, this study focuses on environmental disclosure and scrutinises how it influences innovation activity. Utilising firm-level panel datasets from EU corporations (fiscal years 2000-08) that were constructed based on the Carbon Disclosure Project data and the EU Industrial R&D Investment Scoreboard, I estimate dynamic panel models using the system GMM estimator. The potential endogeneity issue is addressed in the models. Innovation activity is measured by R&D investment. The results show that corporations that implement a specific environmental disclosure action, namely, disclosing Scope 3 GHG emissions, are more likely to invest in R&D. This study suggests that supply chain management is crucial for corporations to enhance their innovation activity. In addition, this study reveals that a policy that stimulates corporate incentives to disclose Scope 3 GHG emissions may be a key to enhancing innovation activity. Since communication between corporations and other stakeholders, which may be enhanced by environmental disclosure, is a significant factor in encouraging corporate innovation activity, it is important to construct a system wherein environmental disclosure is evaluated objectively and corporations with strong environmental performance are adequately rewarded.

Keywords: Innovation; Environmental disclosure; Voluntary action; Endogeneity; Climate change

*This research was supported by the Japan Society for the Promotion of Science (JSPS KAKENHI Grant Number: 11J05836).

1. Introduction

Climate change is a serious problem we are currently confronting. Although various simulations, including the IPCC Fifth Assessment Report (2013) and the Stern Review (2006), suggest that substantial emissions reductions are inevitable, such reductions will not be easy and may occasionally be impractical without sacrificing economic growth in both developed and less developed countries. Innovation is expected to play a key role in overcoming this difficult situation.

Innovation has frequently been scrutinised in relation to environmental policy to determine which policies and/or factors may induce innovations, because environmental regulations and/or public funding of R&D have often provided fruitful opportunities to foster and enhance innovation activity (Popp et al., 2010). In addition to examining the influence of environmental policy, it is also important to focus on corporate actions because corporations are the most significant actors in the global economy, and many innovations are generated by corporate R&D. Innovation is vital for corporations to survive in the market (Eisdorfer and Hsu, 2011) and to acquire competitive advantage (Porter, 1985). In addition, innovation is considered to be positively connected with corporate market value (Hall et al., 2005) and stock returns (Rossi, 2006). It is therefore interesting to focus on corporations to scrutinise the mechanism of innovation and examine which factors are effective at inducing innovation.

This study focuses on voluntary environmental actions with respect to

environmental disclosure that are undertaken by corporations to address climate change and examines the influence of environmental disclosure on innovation activity that derives from R&D investment. While various disclosure programmes exist at national and international levels, some of which mandatory and imposed by government via regulation, in this study I focus on the voluntary environmental disclosure associated with climate change in the Carbon Disclosure Project (CDP) implemented by corporations themselves without any direct regulatory involvement. Although previous studies, including Inoue et al. (2013) and Rennings et al. (2006), focus on the relationship between environmental management systems (EMS) and innovation activity, little research has examined voluntary environmental actions that do not directly result from exogenously imposed regulations. As climate change is a serious global problem that must be addressed, corporate attitudes regarding voluntary environmental disclosure are an indicator of how corporations view climate change and how they are addressing it.

In this research, dynamic panel models are estimated using a system generalised method of moments (GMM) estimator by addressing the potential endogeneity problem. Using R&D investment to measure innovation, the models in this analysis are assumed to address the influence of past R&D investments. I also include financial status and other characteristics of corporations and sectors that are potential factors impacting innovation activity.

This research focuses on EU corporations. Because EU corporations must confront various types of environmental policies, from carbon taxes to emission trading systems, it is also worthwhile to examine how those corporations react to environmental policies. In particular, I examine the influence of the EU emissions trading system (EU ETS) on innovation activity. Launched in 2005, the EU ETS has played an important role in climate change policy in the EU. By including a dummy variable for the EU ETS and interaction terms for environmental disclosure and the EU ETS dummy variables, I seek to examine the relationship between corporate innovation activities and the EU ETS.

The results of this study show that one type of environmental disclosure positively influences R&D investment, namely, corporations that disclose Scope 3[1] GHG emissions are more likely to invest in R&D. This may suggest that supply chain management is important for corporations in terms of enhancing their innovation activity. Whether the EU ETS positively influences R&D investment is ambiguous; however, the results show that there are some indirect impacts.

This study contributes to the literature in several ways. First, it sheds light on the relationship between environmental disclosure and innovation activity, which is not

[1]Scope 3 GHG emissions are defined as other indirect emissions, such as those caused by the extraction and production of purchased materials and fuels, outsourced activities, and waste disposal, that are not covered in Scope 2. Emissions in the supply chain are also included in this scope. Scope 1 covers all direct GHG emissions of the entity, and Scope 2 covers indirect GHG emissions that are caused by the consumption of purchased electricity, heat or steam.

obvious. In particular, this study is unique in that it shows an interesting impact of Scope 3 GHG emissions disclosure, one of the environmental disclosure actions, on innovation activity. This is the first study to focus on how environmental disclosure influences corporate R&D investment using an original dataset constructed from the CDP that has not yet been fully examined for scholarly purposes. Several studies, such as Kim and Lyon (2011) and Misani and Pogutz (2015), use the CDP data to analyse the relationship between carbon performance and financial performance, but they do not focus on the relationship that this study investigates. Therefore, this study may provide original insight into the influence of environmental disclosure on innovation activity. Second, this study again reveals the importance of environmental disclosure for corporations. A number of studies show that environmental disclosure may bring advantages to corporations as explained in the next section, but in addition, this study reveals that Scope 3 disclosure is important for encouraging innovation activity. This result indicates that supply chain management is essential for corporations and possibly that findings in supply chain management may persuade corporations of the necessity for innovation. Finally, this research may have interesting implications for environmental policy to be effective in enhancing corporate innovation activities.

This paper is structured as follows. Section 2 discusses the background literature and provides an overview of environmental disclosure and its relationship with innovation activity. Section 3 presents econometric models and the methodology that

was used in the analysis, and Section 4 describes the data of this study. The results are examined in Section 5. Finally, the conclusion and implications are discussed in Section 6.

2. Background literature

2.1. Environmental disclosure and corporations

Environmental disclosure has been hypothesised to influence corporate actions in various respects. The most notable argument is that environmental disclosure may increase transparency, which may become important for investors and shareholders in terms of making investment decisions. Investors and shareholders may perceive corporations' environmental behaviour as an indicator of corporate attitude towards risk management and an indicator of financial liability (Hamilton, 1995; Khanna et al., 1998; Kim and Lyon, 2011; Konar and Cohen, 1997). In particular, disclosing improved environmental performance may help investors and shareholders to gauge risk level and to evaluate corporate ability to improve environmental performance. These factors may then connect to performance in the stock market. Several studies show that disclosure of poor environmental performance can have a negative impact on corporations' stock price (Hamilton, 1995; Khanna et al., 1998; Konar and Cohen,1997). In contrast, other studies mention that environmental disclosure may not always work effectively (Grant and Jones, 2004; O'Toole et al., 1997) and other factors may influence the improvement

in environmental performance.

Second, environmental disclosure may help consumers understand the environmental aspects of products and allow them to make choices based on environmental information (Delmas et al., 2010; Shimshack et al., 2007). For "green" consumers, environmental performance such as product energy efficiency may impact their purchase decision. Therefore, with regard to those green consumers who focus on environmental factors when they select products, it is crucial for corporations to gain a marketing advantage and improve their brand image by improving environmental performance. In this respect, environmental disclosure may become a means of improving the appropriateness, brand image, and legitimacy of corporate actions. Studies such as Brouhle and Khanna (2007) show that environmental disclosure can improve product quality as well. However, other studies (Miles and Covin, 2000; Prakash, 2002) argue that it is difficult to prove that those positive influences occur purely because of environmental disclosure and suggest that other factors such as green marketing should also be considered.

Third, another possible influence of environmental disclosure is that disclosure can affect employees and internal stakeholders and change their mind-set regarding environmental issues that corporations face. This change may lead corporations not only to improve environmental performance but also to pursue cost-effectiveness by caring for the environment (Cerin, 2002). The process of disclosure may allow corporations to

analyse their corporate activities and find where they can improve their efficiency and management techniques.

As seen from these arguments, environmental disclosure may produce various impacts on corporations. However, how much corporations can improve their performance depends on how often and how conveniently actors such as managers, investors and consumers can access the disclosed information in the decision-making process and analyse it further (Bae et al., 2010; Weil et al., 2005).

2.2. Innovation and R&D investment

Based on the argument by Porter and Linde (1995) that innovation is connected to competitiveness, it is clear that a key input for innovation, namely, R&D investment, constitutes a source of competitiveness. Because R&D investment is vital for corporations to succeed in the market, they strategically consider the optimal conditions for investment (e.g., the quantity of investment and investment timing), which are strongly affected by factors such as the size, economic performance and human resources of the corporations as well as by corporations' internal decision-making process.

R&D investment, not limited to environmental R&D investment, is used as a proxy for innovation in this study because environmental disclosure may impact various types of innovation not only environmental but also in the fields of logistics and supply

chain management. Environmental disclosure on GHG emissions not only in Scopes 1 and 2 but also in Scope 3 may encourage corporations to consider the whole process of their business activities including their supply chain.

For instance, when corporations realise that they must reduce emissions, they may consider, as one of the solutions, procuring smaller and lighter component parts from subcontractors, thus helping corporations to reduce GHG emissions during transportation. This decision may produce modifications in product design that first make it possible to integrate the improved component parts into the final products. Second, it may additionally induce innovations to make the final products smaller and lighter to facilitate transport. Third, it may induce innovations in the production and transportation process.

By monitoring GHG emissions produced by consumers' usage, corporations may be able to work on innovations to enhance energy efficiency or to use more eco-friendly components that can be easily recycled. Moreover, corporations may pursue ways to reduce industrial waste by considering product materials or redesigning the production process, among others. This is also connected not only to environmental innovations but also to other types of innovations.

As shown by these simple examples, environmental disclosure may be connected not only to environmental innovation but also to other types of innovation. Therefore, it is appropriate to use R&D investment in this study to consider the

comprehensive impacts of environmental disclosure.

2.3. Relationship between environmental disclosure and innovation

The relationship between environmental disclosure and innovation is not obvious, but it is interesting to examine because there is still little research scrutinising this relationship. As far as I know, this paper is the first to analyse the relationship using CDP data.

Because corporations are influenced by external pressures (i.e., global environmental issues, investors, shareholders, other corporations' actions, consumers and the media) in today's global economy, once they disclose their environmental performance, they must face those external pressures and respond to external reactions by re-examining and further improving environmental performance.

As seen in section 2.1, by disclosing their environmental information, corporations may be able to produce various impacts. First, in the process of collecting information to disclose, corporations are able to capture their current environmental performance accurately and objectively. Corporations are able not only to understand the strengths and weaknesses they have to address and improve but also to discover important aspects they have not focused on previously. This may help corporations gain important insights and information regarding R&D investment and the relationship to economic performance, whose improvement may further enhance innovation activity.

In addition, environmental disclosure may enhance communication between corporations and external actors such as investors and shareholders. Environmental disclosure may enhance transparency regarding corporations' risk management and financial liability, which directly affect investors' investment decisions. Today, evaluating not only company performance but also the entire production process including supply chain management has become important in investment decisions. Corporations' performance in the stock market occasionally may even influence consumers' purchase decisions. It is thus important for corporations to succeed in the financial market.

Environmental disclosure may also help corporations to communicate with consumers. As consumers' behaviour may be influenced to some degree by such environmental disclosure, these behaviours may represent reactions to corporate disclosure. Based on consumers' responses, corporations may be able to discover consumer demand for certain products and/or services, which would be useful to corporations' innovation activity and help corporations decide in which area to invest.

For internal stakeholders such as employees, sharing the company's environmental information and observing reactions of external actors may provide the opportunity to examine and find the best strategy for R&D investment and management and help them integrate climate change solutions into their business strategy.

These interactions among actors are important for innovation activity. In

particular, close communication between corporations and consumers is significant for corporate innovation activity (Bekar and Lipsey, 2002; Hippel, 1998; Roelandt et al., 2000; Viederyte, 2016). As it is difficult to ensure the success of innovation each time corporations invest, communication can help them to avoid superfluous investment in an unpromising area and to facilitate their experimentation process with the lowest cost possible. To make a decision regarding appropriate investment, a close link between corporations and other actors may be significant. Therefore, environmental disclosure, which enables corporations to engage in close communication with relevant actors, will be an important factor to enhance innovation. Based on previous literatures and the arguments cited in 2.1 and 2.2, my hypothesis is that corporations that positively implement environmental disclosure are more likely to encourage innovation activity.

2.4. Other drivers of innovation

Previous studies have also focused on other drivers of innovation. For instance, the influences of environmental policy instruments, the role of managerial practices, such as EMS, and the corporations' characteristics have been examined.

Since the 1970s, the relationship between policy instruments and innovation has been a topic of interest to scholars (e.g., Magat, 1979; Milliman and Prince, 1989). In the 1990s, the so-called Porter Hypothesis provided a sensational argument for the relationship between environmental policy and technological innovation. The argument

behind the Porter Hypothesis contradicted the traditional view that was held by most economists at that time that stronger environmental regulations would simply impose additional compliance costs on corporations. However, in proposing his hypothesis, Porter noted that when corporations encounter appropriate environmental regulations, they are inclined to comply by means of technological innovation (Porter, 1991). Through the process of positively engaging in R&D activity and seeking unnoticed seeds of innovation, corporations can encourage innovations that may boost their competitiveness in the international market and may offset the costs of compliance (Porter and Linde, 1995). Although the degree of this effect may differ from case to case, many studies of the Porter Hypothesis (e.g., Arimura et al., 2007; Brunnermeier and Cohen, 2003; Hamamoto, 2006; Jaffe and Palmer, 1997; Lanjouw and Mody, 1996; Lanoie et al., 2011) have shown that the hypothesis can be validated in practice. Accordingly, if the EU ETS functions appropriately, it may lead to enhanced innovation activities.

Regarding the characteristics of corporations, the size of corporations defined in previous studies as number of employees or an organisation's resources may also impact corporate innovation activities. While larger corporations have sufficient capacity and resources to invest in R&D, smaller corporations have fewer resources, which can make it difficult for them to invest in R&D (Schumpeter, 1934). However, several studies find that smaller corporations can be more innovative because they have

greater flexibility and capacity to adapt to the surrounding environment and are more eager to invest in R&D (De Jong and Marsili, 2006).

3. Model

To examine the relationship between environmental disclosure and innovation activity, I estimate four types of models. In Models 1 and 2, R&D investment is used as the dependent variable. In Models 3 and 4, the dependent variable is R&D investment divided by net sales. Models 3 and 4 are estimated to check the robustness of Models 1 and 2.

I assume that a corporation's environmental R&D investment is expressed as:

$$RD_{it} = \beta_1 RD_{i,t-1} + \beta_2 EnvD_{it} + \beta_n X_{it}^n + \alpha_i + \mu_t + \varepsilon_{it} \qquad i = 1, \dots, N;\ t = 1, \dots, T \quad (1)$$

where i denotes corporations, and t denotes years. The lagged dependent variable $RD_{i,t-1}$ is adopted as an explanatory variable. Eq. (1) is a dynamic model that shows that R&D investment is determined by its own past realisations. According to Baumol (2002), corporations that invest heavily in R&D activity are likely to encourage R&D in the future as well. This tendency can be explained by corporate actions; for example, if a corporation develops a new product based on its R&D activity, the corporation may further invest in R&D to improve the product or to create the next superior substitute.

The dependent variable in this study may also be influenced by its past realisations; thus, it is essential to include its lagged variable in the set of explanatory variables.

$EnvD_{it}$ is a dummy variable for corporations' voluntary actions regarding environmental disclosure. X_{it}^{n} is a set of control variables. β_1, β_2 and β_n are parameters to be estimated, α_i is an individual corporation-specific effect, μ_t is a time specific effect, and ε_{it} is the error term. Corporation specific effects (α_i) capture the response of each corporation to external factors, such as regulatory shocks. To control for time-dependent determinants of R&D investments, such as changes in environmental policies that affect corporations' overall R&D incentives, time specific effects (μ_t) are included.

Several econometric problems may arise from estimating the dynamic model equation above. First, $EnvD_{it}$ is assumed to consist of endogenous variables that may correlate with the error term because of the two-way causality between variables $EnvD$ and RD. This study hypothesises that corporations that are keen to disclose environmental performance are more likely to engage in innovation activity. However, one could also argue that more innovative corporations are more likely to be willing to disclose environmental performance. In this respect, there is a possibility that two-way causality between $EnvD$ and RD exists. If we fail to take this relationship into account, a simultaneity bias may occur. The fact that endogenous variables are included in this model makes it difficult to comply with the "strict exogeneity" condition. "Strict

exogeneity" means that no correlation between the error term and explanatory variables may occur in any time period (Wooldridge, 2010). If variables that are not strictly exogenous are included, the OLS estimator may be inconsistent.

Second, the lagged dependent variable is endogenous to the individual effects, α_i, which may lead to a dynamic panel bias. When "small T, large N" panels (i.e., few time periods and many individuals) are used for estimation, this bias may become significant (Roodman, 2006). Because the lagged dependent variable is correlated with the error term, the OLS estimator is inconsistent.

Based on these econometric problems, I therefore focus on estimation methods that can be used for explanatory variables or instruments that are not strictly exogenous. In this study, the GMM estimator is used for the dynamic panel models. These models adopt lags of the dependent variables as covariates and include unobserved individual effects.

Arellano and Bond (1991) developed the difference GMM, which is a consistent GMM estimator of dynamic panel models. To eliminate individual effects, the difference GMM uses Eq. (2) by first-differencing Eq. (1) and adopts previous observations of the endogenous variables and a lagged dependent variable as instruments. This GMM estimator is based on the assumption that the error term is not serially correlated and that the explanatory variables are not correlated with future realisations of the error term (Roodman, 2006).

$$\Delta RD_{it} = \beta_1 \Delta RD_{i,t-1} + \beta_2 \Delta EnvD_{it} + \beta_n \Delta X_{it}^n + \Delta\mu_t + \Delta\varepsilon_{it} \quad i = 1, \ldots, N; \; t = 2, \ldots, T \quad (2)$$

However, this difference GMM also has limitations; for example, the lagged levels may become weak instruments for the first-differences when the explanatory variables are persistent over time, which may lead to a large finite sample bias (Blundell and Bond, 1998). In this study, certain explanatory variables are persistent over time, and there is thus a possibility that this may lead to bias and imprecision.

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

A misspecification test for second-order serial correlation in the first-differenced error term is also performed. If we cannot reject the null hypothesis that there is no second-order serial correlation in the differenced residual, the error term ε_{it} (in levels) is not serially correlated at order 1. In this case, the estimated model is supported. I also perform a Hansen test of overidentifying restrictions, which tests the

validity of the instruments that are used in the model. The null hypothesis is that overidentifying restrictions are valid. If this null hypothesis is not rejected, the instruments can be considered to be valid.

4. Data description

4.1. CDP survey data and R&D investment data

To scrutinise the relationship between environmental disclosure and R&D investment, the firm level dataset (unbalanced panel; fiscal years 2000-08) of 301 EU corporations is structured based on the CDP data and the EU Industrial R&D Investment Scoreboard. The missing data were supplemented by each corporation's "corporate social responsibility" (henceforth CSR) report. To remove the macro-influence of the financial crisis, I use the data through fiscal year 2008.

The CDP is an independent non-profit organisation that is focused on developing ways to actualise greenhouse gas emissions reductions and sustainable water use. Working with the world's largest investors, businesses and governments, the CDP engages in actions to realise a more sustainable economy and provides measurements and information to thousands of companies and cities to improve their management of environmental risk. An old management adage states "you cannot manage what you do not measure"; thus, it is difficult to manage improvement if you do not measure what is occurring. Because the CDP also believes that evidence and insight is vital for real

change, it provides incentives to corporations and cities to measure and disclose their greenhouse gas emissions, potential risks and opportunities related to climate change, and strategies for managing those risks and opportunities by leveraging market forces that are defined to include shareholders, governments and rival corporations (CDP, 2012).

On behalf of institutional investors, the CDP requests information on greenhouse gas emissions, energy use and the risks and opportunities from climate change from thousands of the world's largest corporations. This programme began in 2003, and the questionnaire has been sent to corporations each year since. Both the quantity and quality of the data that are disclosed by corporations have improved significantly, and the number of responding corporations has grown since the first CDP report in 2003.

In 2009, backed by 475 institutional investors with $55 trillion in assets (Figure 2), the questionnaires were sent to more than 3,700 of the world's largest corporations, and approximately 60% of the corporations responded (CDP, 2015). The overall response rate of the Global 500 corporations (the 500 largest corporations in the FTSE Global Equity Index Series) for CDP2009 (data for fiscal year 2008) was 82% (409 corporations) (CDP, 2012).

The CDP has been gaining influence in the business arena and financial markets, and the globally collected climate change data are now utilised as evidence for

investment and policy decision making. CDP data are increasingly becoming more integrated into financial analyses, and indices such as the Carbon Disclosure Leadership Index (CDLI) and the Carbon Performance Leadership Index (CPLI) are being utilised. The CDLI is an index that measures the disclosure quality of corporations' responses, and the CPLI index focuses on corporations that are engaging in positive measures for climate change mitigation (CDP, 2016). The responses and indices are disclosed to the public.

The CDP data are unique and valuable because they enable us to examine the first-hand responses from corporations, which is not always possible in other surveys. This study is meaningful because it uses a new original dataset that was derived mainly from these CDP data, which have not been fully scrutinised in academia.

Regarding R&D investment, the EU Industrial R&D Investment Scoreboard data and data from corporations' CSR reports are used. The EU Industrial R&D Investment Scoreboard was first issued in 2004 and provides firm-level data on R&D investment. These data have been practically used to monitor R&D in the EU but not fully examined in academia. The CSR reports from each company are also used in this study to supplement the data when information was not available in the CDP and R&D investment data.

The issue of potential response bias, which is the notion that corporations with environmentally conscious managers are more likely to respond to the CDP

questionnaire, must be clarified. One possible scenario is that corporations with a higher commitment to environmental disclosure and/or higher R&D investments/R&D ratios may be more willing to respond to the questionnaire than those with a lower commitment to environmental disclosure and/or lower R&D investments/R&D ratios. Possibly, the corporations that respond to the CDP are those that are already active in addressing climate change issues, which could inflate the environmental disclosure-R&D relationship in this study.

4.2. Variables

In addition to the lagged dependent variable, the set of variables is summarised in Table 1.

Regarding corporate environmental disclosure actions, the following three variables ("*ENERGYCOST*", "*EMISSION3*", and "*INFO_VERIF*") are focused upon. The variables have values of 1 if the corporation has implemented or engaged in the following actions: whether the corporation discloses the total cost of its energy consumption from fossil fuels and electric power (*ENERGYCOST*); whether the corporation discloses Scope 3 GHG emissions (*EMISSION3*); and whether any of the disclosed information has been externally verified/assured in whole or in part (*INFO_VERIF*).

Table 1: Summary statistics

Variables		Number of observations	Mean	Std. Dev.	Min	Max
lnRD	R&D investment (log)	1571	4.394	1.798	0.148	8.822
RDSALES	R&D investment/net sales	1568	0.046	0.186	0.000	5.149
lnPROFIT	Operating profit (log)	772	6.852	1.784	0.675	15.156
lnMRKTCPTL	Market Capitalisation (log)	1040	8.923	1.594	3.584	12.169
lnEMPLO	Number of employees (log)	1107	10.108	1.532	5.142	13.171
ENERGYCOST	Discloses the total cost of its energy consumption e.g. from fossil fuels and electric power	684	0.482	0.500	0	1
EMISSION3	Discloses GHG emissions in Scope 3	634	0.491	0.500	0	1
INFO_VERIF	Any of the disclosed information has been externally verified/assured in whole or in part	533	0.775	0.418	0	1
EUETS	Covered by the EU ETS (EUETS dummy variable)	1690	0.206	0.404	0	1
*EUETS*ENERGYCOST*	Interaction term of EUETS dummy and *ENERGYCO* ST	684	0.250	0.433	0	1
*EUETS*EMISSION3*	Interaction term of EUETS dummy and *EMISSION3*	634	0.230	0.421	0	1
*EUETS*INFO_VERIF*	Interaction term of EUETS dummy and *INFO_VERIF*	533	0.371	0.484	0	1
DS1	Electric Utlities, Gas and Water supply	1690	0.092	0.289	0	1
DS2	Oil, Metals, Mining	1690	0.087	0.282	0	1
DS3	Paper and Forest products	1690	0.016	0.125	0	1
DS4	Chemicals and Pharmaceuticals	1690	0.125	0.331	0	1
DS5	Food, Beverage, Tobacco	1690	0.047	0.212	0	1
DS6	Industrial machinery, High-tech	1690	0.206	0.404	0	1
DS7	Automobiles and auto parts, Other manufacturing goods	1690	0.156	0.363	0	1
DS8	Bank and diversified financials, Other services	1690	0.270	0.444	0	1
DY2000	Dummy variable for year 2000	1690	0.041	0.198	0	1
DY2001	Dummy variable for year 2001	1690	0.043	0.202	0	1
DY2002	Dummy variable for year 2002	1690	0.066	0.248	0	1
DY2003	Dummy variable for year 2003	1690	0.117	0.321	0	1
DY2004	Dummy variable for year 2004	1690	0.148	0.355	0	1
DY2005	Dummy variable for year 2005	1690	0.166	0.372	0	1
DY2006	Dummy variable for year 2006	1690	0.161	0.368	0	1
DY2007	Dummy variable for year 2007	1690	0.147	0.355	0	1
DY2008	Dummy variable for year 2008	1690	0.112	0.315	0	1

Environmental disclosure is an important action that encourages corporations to precisely understand a particular situation. Therefore, disclosure regarding the total cost of its energy consumption and its Scope 3 GHG emissions may be an indicator of how seriously a corporation addresses climate change. In particular, managing Scope 3 GHG emissions means that corporations are concerned about emissions not only in their

business sphere but also in their supply chain. Recently, not only because of external pressures, corporations have been actively focusing on supply chain management because there is a potential for them to uncover elements of their business activity that they can improve. "*INFO_VERIF*" is essential for both environmental management and for success in the financial markets, as seen in the example of CDLI and CPLI scores, which are important for evaluation in the financial market. To receive high CDLI and CPLI scores, the external verification of reported information is a vital factor.

These environmental disclosure actions may play positive roles in addressing climate change and may drive corporations to be "greener". Corporations may encourage their R&D investments to become more cost effective and improve their environmental performance by developing new technologies, products and production processes. In fact, according to the responses to the CDP survey, corporations that seriously consider climate change are inclined to encourage innovation activity (CDP, 2015). Some corporations may believe that the risk of climate change provides them with a potential business opportunity (MOE, 2016); thus, they may increase their R&D investment to reinforce their status as leading corporations and to become more competitive based on their innovations. Therefore, I assume that these variables influence R&D investment. Because corporation-specific factors, such as their internal decision-making systems and managers' attitudes towards climate change, are likely to be correlated with these variables, they are assumed to be potentially endogenous.

The following variables that are related to the characteristics of corporations are also included: "*lnPROFIT*", "*lnMRKTCPTL*" and "*lnEMPLO*". A corporation's economic performance is represented by the variable "*lnPROFIT*", which indicates operating profit. Because corporations with better economic performance are more likely to pursue environmental performance improvements (Nakamura et al., 2001), which may be realised through innovation, the coefficient for "*lnPROFIT"* is expected to be positive. Market capitalisation (*lnMRKTCPTL*) not only indicates the economic performance but also explains the overall valuation of a corporation in the market. Investors and other stakeholders' decisions are one of the most important external factors that influence corporate actions. It is plausible that larger corporations may experience more external pressure from those actors to be eco-friendly (Nishitani, 2009). Corporations with high market capitalisations tend to be affected by such external pressures, which may encourage them to increase R&D investment. Considering this possibility, I predict that the expected sign for this variable will be positive.

The number of employees (*lnEMPLO*) describes the size of the corporation. The sign of this coefficient is difficult to predict because the relationship between the corporate size and attitude towards innovation activity cannot be defined universally. Large corporations may be likely to engage in R&D investment as a strategy for the future, and small corporations may be eager to invest in R&D to acquire market advantages for future growth. Therefore, both signs are possible. In this study,

"*lnPROFIT*", "*lnMRKTCPTL*" and "*lnEMPLO*" are treated as predetermined variables.

Finally, to consider the impact of the EU ETS, a dummy variable "*EUETS*" and the interaction terms of "*EUETS*" and dummy variables of environmental disclosure actions are added in Models 2 and 4. "*EUETS*" has a value of 1 if the corporation is covered by the EU ETS. The sign of this variable may be positive because corporations under the EU ETS are more likely to consider their strategy towards climate change as part of their EU ETS compliance. Corporations must control GHG emissions to comply with the EU ETS, and changing and innovating processes and/or products may be a means of achieving emissions abatement. Alternatively, the sign of this variable may be negative because the free allocation of allowances may not enhance a corporation's innovation activity. Therefore, the sign of this exogenous variable is difficult to predict. Similarly to the previous discussion, the signs of interaction terms, which are treated as predetermined variables in this study, are difficult to define.

Sector dummy variables are created by referencing the NACE system and the Industry Classification Benchmark (ICB). The former is the European standard for industry classifications, and the latter is an industry classification that was developed by Dow Jones and the FTSE. In addition, year dummy variables are created. These are treated as exogenous variables in the models. For instruments, the models use suitably lagged levels and suitably lagged differences of the explanatory variables.

5. Results and discussion

Four types of models were estimated in this study; two models used the amount of R&D investment as the dependent variable (Model 1 & Model 2), and two models used the ratio of R&D investment to net sales as the dependent variable (Models 3 & 4). Models 3 and 4 are estimated to check the robustness of Models 1 and 2. The results are shown in Table 2.

The results of the Arellano-Bond test show that the null hypothesis was not rejected in any of the models. In other words, there is no evidence of serial correlation, which indicates that model misspecification should not be a problem. All of the models also pass the Hansen test of overidentifying restrictions, which confirms that the instruments can be considered to be valid.

In Model 1, the estimated coefficient of the lagged dependent variable (R&D investment) is positive and statistically significant at the 1% level. Notably, the variable "*EMISSIONS3*" is significantly positive at the 5% level, which indicates that corporations that disclosed Scope 3 GHG emissions are likely to encourage R&D investment. The variable "*EMISSIONS3*" is not directly connected with a corporation's own business activity but may help corporations enhance their awareness of Scope 3 GHG emissions. This action provides an opportunity to examine the influence of corporate actions beyond their business sphere and to investigate the relationships between business strategies, total GHG emissions, and climate change issues in more

detail. This finding implies that managing emissions outside of their business sphere, such as in the supply chain, is crucial for corporations that seek to enhance their innovation. The results show that "*EMISSIONS3*" may lead corporations to recognise the necessity of R&D investment, but the other two actions did not show significant influences on R&D investment.

The number of employees, "*lnEMPLO*", is also significantly positive at the 1% level. This variable shows that corporations that have large numbers of employees (i.e., larger corporations) are more likely to enhance their R&D investment than smaller corporations.

The dummy variable for year 2005 is also positive and significant at the 5% level, which indicates that 2005, the year when the EU ETS began, may positively influence the corporations' R&D investments. The variables of sectors 4 (chemicals and pharmaceuticals), 6 (industrial machinery and high-tech) and 7 (automobiles, auto parts and other manufacturing goods) are significantly positive at the 1%, 5% and 5% levels, respectively. These results indicate that the corporations in these industries are more inclined to encourage R&D investment than those in other industries. The other sector and year dummy variables are not significant.

Table 2: Estimation results

Variables	Model 1	Model 2	Model 3	Model 4
	R&D investment (log)	R&D investment (log)	R&D investment/net sales	R&D investment/net sales
	Coefficient (Robust Std. Err.)	*Coefficient (Robust Std. Err.)*	*Coefficient (Robust Std. Err.)*	*Coefficient (Robust Std. Err.)*
L. lnRD	0.473*** (0.130)	0.726*** (0.089)	—	—
L. RDSALES	—	—	0.857*** (0.055)	0.879*** (0.050)
ENERGYCOST	-0.208 (0.165)	-0.459* (0.259)	-0.002 (0.003)	-0.005 (0.004)
EMISSIONS3	0.446** (0.184)	0.347** (0.170)	0.006** (0.003)	0.007* (0.004)
INFO_VERIF	0.079 (0.246)	-0.103 (0.201)	0.005 (0.004)	0.005 (0.006)
lnPROFIT	-0.294 (0.713)	-0.265 (0.490)	-0.000 (0.017)	-0.001 (0.014)
lnMRKTCPTL	-0.068 (0.089)	0.010 (0.059)	-0.001 (0.001)	-0.001 (0.001)
lnEMPLO	0.463*** (0.149)	0.157 (0.097)	0.001 (0.002)	0.000 (0.002)
DS1	-0.187 (0.172)	-0.239 (0.159)	-0.001 (0.002)	-0.000 (0.003)
DS2	0.212 (0.206)	-0.053 (0.148)	-0.000 (0.003)	0.001 (0.003)
DS3	-0.286 (0.205)	-0.462*** (0.176)	-0.004 (0.003)	-0.003 (0.003)
DS4	0.930*** (0.335)	0.244 (0.191)	0.008 (0.005)	0.006 (0.005)
DS5	-0.254 (0.235)	-0.316** (0.133)	-0.001 (0.002)	-0.001 (0.002)
DS6	0.573** (0.237)	0.189 (0.150)	0.004 (0.003)	0.002 (0.003)
DS7	0.423** (0.208)	0.079 (0.131)	0.000 (0.002)	0.000 (0.002)
DY2001	—	—	—	—
DY2002	—	—	—	—
DY2003	—	—	—	—
DY2004	—	—	—	—
DY2005	0.368** (0.169)	0.154 (0.129)	-0.007 (0.006)	-0.009 (0.006)
DY2006	0.195 (0.134)	0.046 (0.081)	0.003* (0.002)	0.001 (0.002)
DY2007	0.000 (0.080)	-0.032 (0.060)	0.001 (0.002)	0.001 (0.002)
DY2008	—	—	—	—
EUETS	—	-0.378 (0.264)	—	0.003 (0.007)
*EUETS*ENERGYCOST*	—	0.564* (0.287)	—	0.006 (0.004)
*EUETS*EMISSION3*	—	-0.168 (0.171)	—	-0.007 (0.004)
*EUETS*INFO_VERIF*	—	0.413 (0.338)	—	-0.003 (0.008)
Number of observations	421	421	421	421
Arellano-Bond test for AR(2) in first differences Pr > z	0.268	0.283	0.334	0.358
Hansen test	0.722	0.701	0.709	0.957

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

In Model 2, which incorporated "*EUETS*" and the interaction term of the "*EUETS*" and dummy variables of environmental disclosure actions into Model 1, the estimated coefficient of the lagged dependent variable is positive and statistically

significant at the 1% level. The "*EMISSIONS3*" is positive and statistically significant at the 5% level. This result implies that corporations that disclose Scope 3 GHG emissions are more likely to increase their R&D investment. However, in this model, "*ENERGYCOST*" is significantly negative at the 10% level, which indicates that corporations that disclose energy costs are less likely to encourage R&D investment. In contrast, the interaction term of "*EUETS*" and "*ENERGYCOST*" is significantly positive at the 10% level, which indicates that corporations that are covered by the EU ETS and disclose energy costs are more likely to invest in R&D. The direct influence of "*EUETS*" is not so clear in this model; however, a comparison of the coefficients of these two variables (i.e., "*ENERGYCOST*" and the interaction term of "*EUETS*" and "*ENERGYCOST*") shows that the influence of the EU ETS on the R&D investment of the corporations that disclose energy costs is higher by 0.105. This result suggests that "*EUETS*" may positively influence R&D investment.

The variables for sectors 3 (paper and forest products) and 5 (food, beverage and tobacco) are significantly negative at the 1% and 5% levels, respectively. These unexpected results indicate that the corporations in these sectors are less likely to encourage R&D investment. The other sector and year dummy variables are not significant.

In Model 3, the estimated coefficient of the lagged dependent variable (the ratio of R&D investment to net sales) is positive and statistically significant at the 1% level.

The variable "*EMISSIONS3*" is also positive and statistically significant at the 5% level. The result implies that corporations that disclose Scope 3 GHG emissions are inclined to boost their R&D investment ratio to net sales. The dummy variable for year 2006 is positive, which is significant at the 10% level.

In Model 4, which incorporated "*EUETS*" and the interaction terms of the "*EUETS*" and dummy variables of environmental disclosure actions into Model 3, the estimated coefficient of the lagged dependent variable is positive and statistically significant at the 1% level. "*EMISSIONS3*" is also positive and statistically significant at the 10% level. This result implies that corporations that disclose Scope 3 GHG emissions are more likely to increase their R&D investment ratio than other corporations.

"*EMISSIONS3*" is clearly positive and statistically significant in all of the models. This robust result may indicate that corporations that disclose Scope 3 GHG emissions are more likely to invest in R&D. Measuring and disclosing the Scope 3 GHG emissions, which account for indirect emissions outside of their corporate business activities, may help corporations understand the importance of innovation activity.

6. Conclusion

Using datasets for EU corporations that were constructed based on the CDP data, the EU Industrial R&D Investment Scoreboard, and CSR reports, the effects of environmental disclosure on R&D investment are scrutinised. A system GMM was

employed to estimate dynamic panel models and to address the issue of endogeneity. This research is unique in terms of using CDP data, which are valuable for scrutinising corporations' attitudes towards climate change that have not yet been fully examined in scholarly research. The CDP data enable us to examine first-hand information about corporations' responses to climate change, which may provide intriguing information.

Findings in this study show that one type of environmental disclosure action positively influences R&D investment. All four models revealed that corporations that disclose Scope 3 GHG emissions are likely to invest in R&D. This result suggests that managing emissions not only in Scopes 1 and 2 but also in Scope 3 and addressing emissions in the supply chain are crucial to enhancing innovation activity. This robust result again recalls the adage "you cannot manage what you do not measure". To disclose indirect emissions from their business activities in Scope 3, corporations may attempt to accurately measure the overall environmental impacts of their GHG emissions and provide opportunities to closely examine the relationship between their corporate actions and climate change. It may enable corporations to engage in supply chain management, which has recently become crucial for corporations to succeed in the market. Corporations may become aware of the importance of innovation activity through this commitment, which may lead to enhanced R&D investment.

Although "*ENERGYCOST*" has a negative coefficient in Model 2, the interaction term of "*EUETS*" and "*ENERGYCOST*" has a positive coefficient in the same

model. The coefficient of the interaction term of "*EUETS*" and "*ENERGYCOST*" is 0.105 higher than that of "*ENERGYCOST*". Although other estimation methods or tests are necessary to prove the direct positive impact of "*EUETS*", this result suggests that "*EUETS*" may positively influence R&D investment.

The results show that "*INFO_VERIF*", a dummy variable which takes value 1 when any of the disclosed information has been externally verified/assured in whole or in part, is not significant in all models. Considering the characteristics of the CDP and the fact that when corporations disclose their environmental performance to the CDP, the information will be strictly examined by institutional investors, whether it is externally verified may not be particularly important for corporations. Instead, the decision regarding whether to disclose their information voluntarily to the CDP may become significant for corporations.

This study is unique in that it elucidates the relationship between environmental disclosure and innovation activity; however, the results must also be considered with caution because of the issue of potential response bias, which is the notion that corporations with environmentally conscious managers are more likely to respond to the CDP questionnaire than other corporations. The corporations that respond to the CDP are possibly those that are already active in addressing climate change, and there is a possibility that the environmental disclosure-R&D relationship may be slightly inflated. In addition, the estimation methods can be improved further. Because this study could

not prove the direct impact of the EU ETS on innovation, I would like to examine it by utilising different methods. Furthermore, increasing the number of corporations would increase the persuasiveness of this study.

Although certain limitations remain, this study nonetheless provides interesting findings. First, this study may provide original insights about the relationship between environmental disclosure and innovation activity. In particular, this study is unique in that it presents an interesting impact of disclosure of Scope 3 GHG emissions on innovation activity. Second, this study shows how environmental disclosure is important for corporations. Environmental disclosure may increase the transparency of corporate attitudes towards the management of risk with regard to environmental issues and of financial liability, which may enable investors to consider their investment strategy. In fact, large institutional investors refer to CDP data in making investment decisions. In addition, environmental disclosure may help corporations communicate with consumers and improve their brand image and/or legitimacy. Moreover, the reactions of investors, shareholders and consumers may help corporations to improve their environmental performance and innovation strategy. Based on the mutual influences among these actors, it is clear that environmental disclosure may enhance communication among actors and may ultimately encourage innovation activity.

The implication of this finding is that to enjoy the advantages of environmental disclosure, it is essential to construct a system wherein environmental disclosure is

evaluated objectively. In addition, it is important for corporations with strong environmental performance to be adequately rewarded by this system. It is also essential to provide incentives to corporations to sustainably engage in environmental disclosure. Moreover, to enhance communication among actors and to encourage innovation activity, it may be useful to implement a policy that stimulates actions to disclose environmental performance.

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