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Environmental, Sustainable Behaviors and Innovation of Firms During the Financial Crisis

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ABSTRACT
In this paper, we analyze the relation between sustainable and environmental behaviors and performance and innovation. Altogether, 1032 observations are divided into specific groups according to the Carbon Disclosure Project (CDP) Global 500 report and the Dow Jones Sustainability Index (DJSI) for 2008 and 2009. Based on legitimation theory and stakeholder theory, we regard the voluntary activities of firms as having long-run effective characteristics that can be applied to industry in general. The environmental behavior of firms is represented by CDP activity, while the DJSI represents their sustainable activities. Based on the assumption that corporate environmentalism is a bilateral agreement between policymakers and firms, we answer four specific research questions. (i) What is the relation between voluntary activities and performance of firms? (ii) Do firms' voluntary activities in environmental and sustainable implementations induce innovation? (iii) How does the nature of innovation depend on voluntary type of the firms? (iv) What is the link between firm characteristics and innovation according to voluntary types? From the presented empirical analysis, we find positive relations between corporate environmentalism and innovative activities. We then classify environmental and sustainable issues and propose an empirical model of the links between environmental and sustainable behaviors and innovation activities. Copyright © 2013 John Wiley & Sons, Ltd and ERP Environment.

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Keywords: Carbon Disclosure Project; corporate environmentalism; corporate social responsibility; Dow Jones Sustainability Index; innovation; stakeholders

Introduction

THIS STUDY FOCUSES ON THE TYPICAL VOLUNTARY APPROACHES OF SO-CALLED 'CORPORATE ENVIRONMENTALISM' (Banerjee *et al.*, 2003; Carraro and Siniscalco, 1996; Eisner, 2004; Menon and Menon, 1997).[1] We premise that these approaches are a rather bilateral compromise between policymakers and firms. This paper thus addresses the environmental challenges faced by businesses, namely when corporate environmentalism is

*Correspondence to: Yunhee Kim, Directorate for Financial and Enterprise Affairs, Organisation for Economic Co-operation and Development (OECD), Paris, France. E-mail: yunhee.kim@oecd.org kimyunhe@gmail.com, The opinions expressed and arguments employed herein are those of the author and do not necessarily reflect the official views of the OECD or of the governments of its member countries.

[1]Please see Eisner (2004) for the benefits of self-regulation through corporate environmentalism. Banerjee *et al.* (2003) also explain the four antecedents and influences of industry type.

more related to environmental protection (Banerjee, 2001; Lyon and Maxwell, 1999; Menon and Menon, 1997). For instance, in the 1990s, the US Environmental Protection Agency started reducing regulatory intervention in order to promote environmental innovation; however, the results were unacceptable. On the contrary, changes in regulatory design that could promote improved environmental performance include combining elements of government regulation, government-supervised corporate self-regulation, mandatory information disclosure and green procurement (Eisner, 2004). Global environmental issues such as climate change that have a wider scope of sustainability have also had a growing impact on social demands over the past few decades, even influencing the international political agenda during the recent financial crisis.

Regulations for controlling greenhouse gas emissions have changed market mechanisms and thereby the activities of corporations in the marketplace. Moreover, the reactions of business leaders and recognition by consumers are becoming voluntary. For instance, the concepts of CSR (corporate social responsibility)[2] and SRI (socially responsible investment)[3] are becoming globalized concepts, and most multinational firms encourage sustainability practices in order to increase stakeholder satisfaction and thus provide a positive signal to the market (i.e. stakeholder theory; Freeman, 1983; Frooman, 1999). Consumers and investors are also showing confidence in a corporation's socially responsible activities in the market (i.e. legitimation theory; Campbell *et al.*, 2003; Lopez *et al.*, 2007).[4] Of course, there are trade-offs and conflicts in CSR and SRI because they are complex and complicated when discussing the nature of sustainability (Byggeth and Hochschorner, 2006; Goerner *et al.*, 2009, Hahn *et al.*, 2010). From this point of view, examining the advantages and disadvantages of corporate environmentalism for firm innovation and performance is necessary.

This study considers two major concepts of firms' environmental behaviors: the environmental behavior of firms, which can be represented by Carbon Disclosure Project (CDP) activity, and the Dow Jones Sustainability Index (DJSI), which shows firms' sustainable activities. We adopt both of these concepts simultaneously because many initiatives in the market can influence a firm's strategies. From this, we choose two major activities of firms' environmental strategies and aim to answer the following four research questions. (i) What is the relation between voluntary activities and performance? (ii) Do firms' voluntary activities in environmental and sustainable implementations induce innovation? (iii) How does the nature of innovation depend on the voluntary type of the firms? (iv) What is the link between firm characteristics and innovation according to the voluntary type of the firms?

Until recently, many studies described the impact of CSR and SRI on firm performance from the perspective of sustainable development (Akrich *et al.*, 2002; Heras-Saizarbitoria *et al.*, 2011; Martin Curran and Moran, 2007). However, there are still debates about the correlations between voluntary activities and performance, as their results have a number of statistical limitations. Furthermore, these studies only focus on the relation between financial performance and responsible activities and only estimate the short-term effects. This literature examines whether a firm's financial performance is affected by the public's endorsement of their environmental and social performance. The results show a trend towards positive and negative announcements having the expected effects on daily returns. However, these movements are not significant and the data do not suggest that a firm's presence on the index brings it a significant financial return (Hahn *et al.*, 2010). Lopez *et al.* (2007) examine whether businesses are affected by the adoption of CSR practices and show a short-term negative impact on firm performance. Consolandi *et al.* (2009) examine whether these incentives have been detectable with particular reference to the Dow Jones Sustainability Stoxx Index (DJSSI). They analyze the performance of this index over the period 2001–2006 by comparing it with that of the surrogate complementary index (SCI).[5] The result suggests that the evaluation of firm CSR performance is a significant criterion for asset allocation activities.

In particular, environmental and sustainable implementations have been shown to exert a long-term impact on firm performance and innovation (Schaltegger and Wagner, 2011). The adoption of sustainable standards and

[2]CSR is 'a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis' (The European Commission's definition of CSR).
[3]SRI integrates – apart from financial criteria – social, environmental and/or ethical criteria into the processes of analysis, selection and choice of investment. For definitions, see Dahlsrud (2008).
[4]Other theories, such as utility maximization and institutional theory, also explain firms' sustainable and environmental behaviors (see Ervin *et al.*, 2012).
[5]According to Consolandi *et al.* (2009, p. 185), 'The Surrogate Complementary Index (SCI) is a new benchmark that includes only the components of the DJ Stoxx 600 that do not belong to the ethical index to evaluate more correctly the size of possible divergent performances'.

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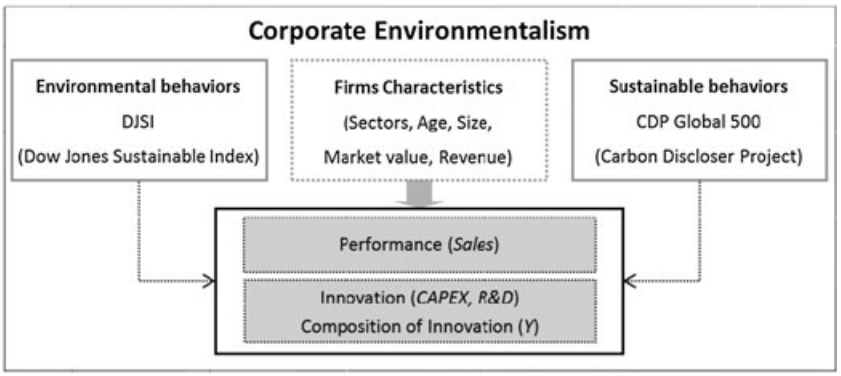

Figure 1. Schematic diagram of the research framework

environmental implementations has a latent effect and it is difficult to find causality between adoption and performance (Byggeth and Hochschorner, 2006). Nevertheless, most studies only consider the significant impact on performance. However, innovation is also a priority for firms because it sustains their growth and survival. Therefore, we examine how environmental and sustainable behaviors influence innovation activities and firm performance. Specifically, we divide 1032 sample firms into three groups according to the survey responses to the CDP Global 500 and the firm list of the DJSI between 2008 and 2009.

Following the research framework presented in Figure 1, this study investigates the differences in performance and innovation activities for the three investigated firm groups. The empirical analysis suggests answers to the above-mentioned research questions based on the results of a sample selection methodology. Another contribution of this study is to categorize environmental issues and to propose an empirical model of the links between them and firms' innovation activities. In particular, we consider the concept of environmental and sustainable implementations simultaneously and demonstrate their effect on the innovation and performance levels of firms and the market.

The remainder of this paper is organized as follows. In the following section, we briefly categorize the concepts of environmental and sustainable issues and innovations and then describe the relevant innovation-related studies. Based on this understanding, in the next section we explain the data, variables and methodology used in this study. The fourth section presents the results and analyzes the empirical models. Finally, we conclude and discuss policy implications in the fifth section.

Theoretical Background

Two major theories influence environmental and sustainable issues, namely legitimation theory and stakeholder theory. According to the first, legitimation theory, it is necessary to achieve society's confidence for the survival of firms (Deegan, 2002; Gifford *et al.*, 2010; Phillips, 2003). The second one, the stakeholder theory indicates that companies should only respond to shareholders' interests; in other words, their only social responsibility is the maximization of company value (Banerjee and Bonnefous, 2011; Sangle, 2011; Wilson *et al.*, 2010). From this perspective, any positive social act undertaken by the firm is associated with costs that would reduce profit and thereby prejudice shareholders (Friedman, 1970).

Environmental and Sustainable Firm Behaviors

There have been many debates about the concepts and definitions of CSR since the explosive growth in demand for social development (Dahlsrud, 2008). Based on historical perspectives and using philosophical analyses, Van Marrewijk (2003) reviews these debates over CSR concepts and suggests that for CSR we should 'accept various

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and more specific definitions matching the development, awareness and ambition levels of organizations'. Based on the corporate governance, sustainable development and stakeholder theory literature, Ricart *et al.* (2005) investigate how corporate governance systems integrate sustainable development with other factors. They analyze the governance systems of 18 DJSI corporations that are leading their market sectors in order to suggest a sustainable corporate governance model. Moreover, based on the theoretical analyses presented by previous studies, Konrad *et al.* (2006) empirically find that the adoption and implementation of sustainable development can be achieved through stakeholder relations management at the firm level. They explain the solutions of multinationals to 14 sustainable development issues as well as the roles of particular stakeholders, and conclude that stakeholder relations management boosts such development but cannot serve as a form of government regulation.

For the heterogeneity between practices and performance of sustainable behaviors, Gjolberg (2009) develops two indices to measure CSR practices and performance levels in 20 OECD countries and finds significant differences among them, indicating the need to address the impact of domestic structures on CSR. Sandberg *et al.* (2009) discuss the issue of the heterogeneity of SRI using four features: terminological, definitional, strategic and practical features. They suggest that accounting for this heterogeneity is necessary for SRI implementations, because there are cultural and ideological differences between regions as well as distinctions in the values, norms and ideologies of SRI stakeholders. Martin Curran and Moran (2007) also examine whether corporate performance is affected by the public endorsement of environmental and social performance. By using the FTSE4Good UK Index as a proxy for CSR, their results show a trend towards positive and negative announcements having the expected effects on daily returns.

Concerning firms' environmental behavior, Okereke (2007) explores the motivations, drivers and barriers to carbon management using a sample of FTSE 100 companies. Motivations towards implementing environmental management practices are shown to closely relate to generating profit and comparative advantage, while drivers are related to wider social pressures and environmental issues. In conclusion, this study presents five motivations and five drivers for corporations to tackle climate change. Luo *et al.* (2010) also investigate how Global 500 companies are formulating carbon disclosure strategies in order to prepare to meet the challenge of climate change. By considering the impact of economic, regulatory, social and financial market factors on the motivations of Global 500 firms, they find that financial factors are significantly related to voluntary environmental behaviors. In other words, a company that faces direct economic consequences is more likely to disclose carbon-associated information. The authors also explain why a large proportion of Global 500 firms refuse to disclose carbon information and show that the information demands of investors in terms of environmental management are not determined by the carbon disclosure decisions made by companies.

As verified by previous studies, firms' environmental and sustainable issues are affected by many internal and external factors (Ervin *et al.*, 2012; Hahn, 2012; Lee, 2012). Specifically, firm behavior depends on industry sector, corporate governance and social pressures. Hence, more studies of the sustainable and environmental behavior of firms and firm innovation are required in order to offer value-adding solutions for organizations.

Innovation, Environmental and Sustainability Issues

There are several dimensions of market environments and several types of investment activity, such as radical or incremental, and explorative or exploitative (Battaggion and Tedeschi, 2006; Ettlie *et al.*, 1984; Kessler and Chakrabarti, 1996). Thus, the consideration and detailed analysis of the innovative activities of firms are needed. Because of the heterogeneity of firms' investments, it is necessary to take into account the composition and level of competition in the market (Mansfield, 1981). In firms' managerial processes, the relation and balance between the exploration of new possibilities and the exploitation of old certainties are primary factors for survival and prosperity (March, 1991). Based on these ideas, we premise that explorative investment aims to induce and prompt firm innovation because it is more uncertain about the future and offers fewer guarantees of a return on investment. Therefore, explorative investment is rather more innovative than exploitative investment. Holmqvist (2004) also investigates the dynamics of exploitation and exploration in intra- and interorganizational learning processes as fundamental characteristics of modern organizations.

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Forsman (2013) empirically examines the links between environmental innovations and firm competitiveness based on a sample of 128 Finnish firms between 2002 and 2010. The result shows the types of competitive advantage as well as potential disadvantages of the innovation process. This emphasis on competitive advantage is enhanced in a successful innovation process. Halme and Laurila (2009) consider the relation between the potential impact of CSR integration and innovation. In their analysis, CSR integration is regarded as conducting existing business operations more responsibly, while CSR innovation involves developing new business models to solve social and environmental problems. Based on these concepts, the authors apply investments for new possibilities and for old certainties to a change in firms' strategies. This approach is related to decision making by entrepreneurs and CSR innovation (Gauthier and Wooldridge, 2012; Harmancioglu *et al.*, 2010; Kelley, 2010; Schaltegger and Wagner, 2011).

Assessing the relationships between environmental and sustainable behaviors and firms' investments is a well studied area and a key element for sustainable development. However, the exact meaning of innovation in a sustainable and environmental context has not yet been clearly explained (Blowfield *et al.*, 2007). On the relation between resource management and CSR, Zwetsloot (2003) points out the great potential for innovative business practices to influence 'people, planet, and profits' in a positive manner. By contrast, the literature has focused on regulated emission data and few studies have included climate change in this debate. However, Delmas and Nairn-Birch (2011) investigate empirically the profitability of environmental initiatives in the context of supply chain management using a sample of 1100 US firms between 2004 and 2008.

Most previous studies have examined how adopting sustainable innovation practices influences firm performance (Bönte and Dienes, 2013; Gauthier and Wooldridge, 2012; Ozaki, 2011). In early studies, Borger and Kruglianskas (2006) explore the adoption of CSR strategies and firm innovation by Brazilian enterprises. They analyze which CSR-related factors are associated with technological innovation and the environmental performances of firms, and find significant evidence of a strong relationship between the adoption of a CSR strategy by the firm and effective environmental and innovative performance. Frondel *et al.* (2008) hypothesize on whether the voluntary adoption of environmental management systems increases the environmental performances of firms. By using a choice model to assess the German manufacturing sector, they find evidence of a relation between the decision to support innovation activities and the decision to adopt environmental management systems. Hepburn (2010) also compares evidence on induced innovations and the implications for environmental policy with the conceptual basis and empirical findings on the effectiveness and efficiency of climate technology policies.

In the present study, we demonstrate how environmental and sustainable behaviors affect firm innovation and performance. This study therefore offers a more reflexive and structured approach compared with the literature in order to broadly consider innovation. Specifically, it uses a framework that distinguishes the factors behind exploration- and exploitation-related innovations from firms' environmental and sustainable behaviors.

Empirical Analysis

Data and Variables

To consider the environmental and sustainable behaviors of firms, this study uses two data sources collected between 2008 and 2009. First, the CDP Global 500 is referred to for firms' environmental behaviors. This is collected by the 500 largest corporations in the FTSE Global Equity Index Series (the market capitalization of these companies was $15.5 trillion in 2009).[6] The other data source is the DJSI, which shows the trends and connections between financial performance and investments by sustainable companies.[7] Since it is necessary to consider

[6]The CDP's Global 500 Climate Change Report in 2012 investigated whether companies strategically focus on climate change and assessed its long-term impact on business. On behalf of 655 institutional investors representing $78 trillion in assets, the report provided an annual update on greenhouse gas emissions data and climate change strategies for the world's largest public corporations.

[7]The DJSI comprises the companies with the best CSR practices in their respective industries. The evaluation is based on the cooperation of Dow Jones Indexes, STOXX Limited and SAM.

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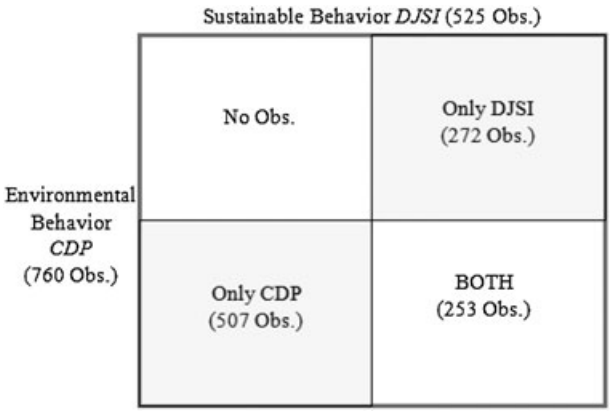

Figure 2. Distribution of observations according to the CDP and DJSI lists

both these concepts simultaneously for global companies, we choose a two-year period in our dataset. By using the DJSI and CDP lists, this study formulates a new list and matches it with the financial data provided by Thomson DataStream.[8] This dataset highlights how CSR and the recent financial crisis have affected firm innovation. Our analysis also shows the strengthened tendency to believe in necessary business change. This entails focusing on a broader concept of entrepreneurial profit from a long-term perspective and providing the proper signals to stakeholders during a financial crisis (Fernández-Feijóo Souto, 2009).

In order to answer our research questions through the presented empirical analysis, we obtain an unbalanced panel dataset based on 1346 observations of 806 firms that operate in 10 FTSE sectors.[9] We omit 314 firms that operate in the financial sector, leaving 1032 observations for analysis. Figure 2 presents the distribution of the observations according to the DJSI and CDP lists. As shown in the figure, 253 firms are identified in both the DJSI and the CDP lists. For CDP (DJSI) firms, there are 507 (272) observations. Table 1 presents the definitions, sources and descriptive statistics of the variables used in the analysis.

The firm-level data include three dependent variables including the log value of sales (lsales), log value of capital expenditure (lcapex) and log value of R&D expenditure (lrnd). Using logarithms allows us to interpret the results of the respective coefficients as elasticities. Firm characteristics such as assets per share (lassetpershare), revenue (lrevenue), market value (lmv), age (lage) and size (lemployee) are also considered as well as year dummies (d_2008 and d_2009) and dummies for the DJSI or CDP or both. Variables of the time period effect can capture macroeconomic shocks that affect all firms in the analysis. For instance, yearly dummies can account for the subprime mortgage crisis in 2008, which affected investments in all industries.

Next, we divide our industry sectors into 10 groups according to the FTSE industry categories (Table A in the appendix). To compare the environmental and sustainable indices, we omit the financial sector because most financial firms do not have capital or R&D expenditure. Afterwards, we create a polluting dummy variable in order to discriminate between polluting and non-polluting industries based on the evidence presented by Clarkson *et al.* (2011)[10] because considering firm-specific industry regulation prevents biasing the normalization for entire industry sectors. For the country distribution in our dataset, there are initially 39 countries (firm differences are shown in Table B in the appendix). Except for the developed country dummy (developed: income_level), we do not take into account country-specific dummies because most firms are listed on the US or EU stock markets and thus they tend to be affected by global shocks, standards and regulations.

[8]This database covers 51 900 active global companies and offers the broadest company coverage, representing 99% of the global market capitalization in 2010 (http://www.thomsonreuters.com).
[9]Utilities, telecommunication services, materials, information technology, industrials, health care, financials, energy, consumer discretionary, consumer staples.
[10]The study divides the sample data into four groups: pulp & paper (SIC 26), chemicals (SIC 28), oil & gas (SIC 29) and metals & mining (SIC 33). We focus on these four industries, given the evidence in the literature that they are the most polluting sectors in the US (Clarkson *et al.*, 2011).

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Variable	Definition	Sources	Obs.	Mean	St.D	Min	Max
adoption	dummy value = 0 if firms are involved in only CDP group, dummy value = 1 if firms are involved in only DJSI group, dummy value = 2 if firms are involved in both CDP and DJSI group	computed	1032	0.75	0.82	0	2
cdp	dummy value = 1 if the firm is involved in CDP lists, otherwise = 0	CDP	1032	0.74	0.44	0	1
djsi	dummy value = 1 if the firm is involved in DJSI lists, otherwise = 0	DJSI	1032	0.51	0.50	0	1
both	dummy value = 1 if the firm is involved in DJSI and CDP lists, otherwise = 0	DJSI & CDP	1032	0.25	0.43	0	1
lcapex	log value of capital expenditures (US$)	Thomson DB	713	13.85	1.51	6.70	17.31
lrnd	log value of research and development expenditure (US$)	Thomson DB	529	12.64	2.03	4.03	16.99
lrevenue	log value of revenues (US$)	Thomson DB	687	16.58	1.77	2.21	20.03
lemployee	log value of employees (both full and part time employees: size)	Thomson DB	865	10.49	1.38	1.10	14.56
lage	log value of (2010 − established year)	Thomson DB	1032	4.20	0.77	1.39	7.61
lassetpershare	log value of assets per share	Thomson DB	698	2.63	1.97	−3.51	18.50
lmv	log value of market value (US$)	Thomson DB	713	9.91	1.22	2.52	14.72
developed	dummy value = 1 if the country is involved in OECD countries (income_level)	OECD	1032	0.90	0.30	0	1
d_2008	year dummy of 2008	computed	1032	0.50	0.50	0	1
d_2009	year dummy of 2009	computed	1032	0.50	0.50	0	1
polluting	dummy value = 1 if the firm is involved in utilities, materials, industrials, energy sectors, otherwise = 0*	FTSE	1032	0.52	0.50	0	1
health	dummy value = 1 if the firm is involved in health care sector, otherwise = 0	FTSE	1032	0.09	0.28	0	1
ITcom	dummy value = 1 if the firm is involved in IT and telecom sectors, otherwise = 0	FTSE	1032	0.15	0.36	0	1
service	dummy value = 1 if the firm is involved in CD and CS sectors, otherwise = 0	FTSE	1032	0.24	0.43	0	1

Table 1. Definitions and descriptive statistics of variables
*This polluting industry sectors refer to the polluting industry division of Clarkson *et al.* (2011).

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Model

In order to control for the limitations of the dataset, this study employs an integrated model, which incorporates two equations, namely an adoption equation of environmental or sustainable behaviors and an output equation measured by sales, R&D investment and CAPEX. There are some issues about the causation of selection effect. For example, forward causation has been shown to affect environmental proactivity and changes in performance (Dick *et al.*, 2008). In social responsibility studies, this means whether it pays to be good (i.e. treatment effects) or whether firms can afford to be good (i.e. selection effects) (Heras-Saizarbitoria *et al.*, 2011). Hence, we address this issue using adoption and performance models.

First, we estimate a multinomial logit model by examining the drivers for the adoption of the CDP or DJSI. In this study, firms have three alternatives for their adoption of environmental and sustainable behaviors: only the CDP, only the DJSI or the joint adoption of both the CDP and the DJSI. The adoption probabilities that firm n selects alternative i among these three options are derived as follows (Train, 2003):

$$Prob(Adoption_{ni}) = Prob\left(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}, \forall i \neq j\right) = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \quad (1)$$
$$where\ i,j \in \{CDP, DJSI, BOTH\}$$

A firm's preference for adoption choice i is usually specified to be a linear parameter, $V_{ni} = \beta' x_{ni}$, where x_{ni} is a vector of observed variables related to adoption i and firms' activities, strategies and characteristics, and ε_{ni} is a disturbance term following a type I extreme value distribution, which results in a simple and elegant form of choice probability (this is a closed form although it exhibits restrictive substitution patterns due to the 'independence from irrelevant alternatives' assumption). This analysis is concerned with the factors that affect the adoption of environmental and sustainable activities, especially understanding which industry sectors or firms are likely to take part in DJSI or CDP behavior. Next, we formulate the output equation in order to analyze the effects of DJSI or CDP adoption and of other factors on the firm's output (i.e. performance and innovation):

$$\begin{aligned} lsales_{nt} = {} & \beta_1 (Size)_{nt} + \beta_2 (Age)_{nt} + \beta_3 (lrevenue)_{nt} + \beta_4 (lmv)_{nt} + \beta_5 (income\_level)_{nt} \\ & + \beta_6 D.2009 + \beta_7 D.Industry + \beta_8 D.(CDP, DJSI, Both)_{nt} + \beta_9 sc_{nt}^{CDPorDJSI} \end{aligned} \quad (2)$$

where $(x)_{nt}$ is a vector of firm n's characteristics and the control dummies that affect performance such as age, size, revenue and market value, as well as the dummies for industry, year and adoption. sc_{nt}^{CDP} or sc_{nt}^{BOTH} are the estimated coefficients of the dummy variables, which might be biased due to the existence of selectivity bias (Heckman, 1979). That is, unobserved firm characteristics may affect the adoption of environmental or sustainable behaviors and thereby influence firm output, which might create correlations between the error terms of adoption and the output equation. If there is no control term in the correlations, a simple OLS regression leads to the specification error of an omitted variable. Therefore, the variable should be controlled through a methodology that corrects selectivity bias (Greene, 2003). The parameter dummy (CDP, DJSI, Both) represents how firms' adoptions affect performance, while η_{it} denotes a distribution following the normal distribution. In particular, we also include performance terms (sales) in Equations (2) and (3) as a dependent variable by taking into account that innovation is a part of CSR:

$$\begin{aligned} lCAPEX_{nt} = {} & \beta_0 (lSales)_{nt} + \beta_1 (Size)_{nt} + \beta_2 (Age)_{nt} + \beta_3 (lrevenue)_{nt} + \beta_4 (lmv)_{nt} \\ & + \beta_5 (income\_level)_{nt} + \beta_6 D.2009 + \beta_7 D.Industry + \beta_8 D.(CDP, DJSI, Both)_{nt} + \beta_9 sc_{nt}^{CDPorDJSI} \end{aligned} \quad (3)$$

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$$lRnD_{nt} = \beta_0(lSales)_{nt} + \beta_1(Size)_{nt} + \beta_2(Age)_{nt} + \beta_3(lrevenue)_{nt} + \beta_4(lmv)_{nt} + \beta_5(income\_level)_{nt} + \beta_6 D.2009 + \beta_7 D.Industry + \beta_8 D.(CDP, DJSI, Both)_{nt} + \beta_9 sc_{nt}^{CDPorDJSI} \quad (4)$$

Results and Analysis

The estimations are divided into two parts according to firms' choices of environmental and sustainable activities (CDP, DJSI, Both). First, we present the results of the sustainable (DJSI) and environmental (CDP) adoptions and output models with the basement estimation of adoption of both in Table 2. This means that each coefficient represents the distance from the frontier behavior, because we premise adoption of both to be the firm's most sustainable and environmental behavior.

We find three results according to the industrial sectors in adoption Equation (1) including firm characteristics. The result consists of two parts, where the first six lines indicate the effect of the firm's characteristics on CDP adoption, while the second part shows their impact on DJSI adoption. The first part of result (1) considers all industry sectors, while parts (2a) and (2b) assess whether the firm is polluting or not. Because some industries have

Y = adoptions	All industries (1)		Polluting industries (2a)		Non-polluting industries (2b)	
	Coeff.	Std error	Coeff.	Std error	Coeff.	Std error
Y = CDP						
lrevenue	−0.262[c]	0.147	−0.243	0.212	−0.489[b]	0.222
lemployee	0.039	0.098	−0.056	0.161	0.181	0.126
lage	−0.565[a]	0.146	−0.210	0.221	−0.844[a]	0.210
lassetpershare	0.142[c]	0.080	−0.022	0.105	0.322[a]	0.118
lmv	−0.312[b]	0.145	−0.024	0.220	−0.586[a]	0.211
_cons	9.906[a]	1.788	6.538[a]	2.268	15.863[a]	3.031
Y = DJSI						
lrevenue	−0.502[a]	0.184	−0.626[b]	0.275	−0.483[c]	0.274
lemployee	0.266[c]	0.155	0.117	0.238	0.620[a]	0.235
lage	−0.327	0.208	−0.200	0.288	−0.325	0.336
lassetpershare	0.069	0.105	−0.321[b]	0.163	0.508[a]	0.158
lmv	−2.406[a]	0.246	−1.948[a]	0.337	−3.062[a]	0.395
_cons	29.741[a]	2.816	29.355[a]	3.800	31.080[a]	4.391
No of obs.	626		312		314	
LR chi^2(10)	322.98		152.88		197.08	
Prob. > chi^2	0		0		0	
Log likelihood	−488.800		−253.424		−220.504	
Pseudo R^2	0.248		0.232		0.309	

Table 2. The results for the adoption of CDP and DJSI groups
There are three choices for the sustainable and environmental behaviors: 0 is given in the case with adoption of both CDP and DJSI, 1 for the adoption of CDP, 2 for the adoption of DJSI. In the analysis, 1 and 2 were compared with 0, which is regarded as a base outcome.
[a] $p < 0.01$,
[b] $p < 0.05$,
[c] $p < 0.1$.

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Y	(1) lsales		(2) lcapex		(3) lrnd	
	Coeff.	Std error	Coeff.	Std error	Coeff.	Std error
lsales	—	—	0.951a	0.080	0.337	0.307
lemployee	0.440a	0.061	−0.061	0.055	0.751a	0.109
lage	0.093b	0.038	−0.113c	0.062	0.057	0.150
lrevenue	0.221b	0.100	−0.108a	0.026	−0.479	0.338
lmv	0.454a	0.072	0.212a	0.080	0.818a	0.168
developed	0.483a	0.129	−0.505a	0.147	2.157a	0.439
year = 2009	0.244a	0.057	0.148c	0.083	0.248	0.177
CDP group	2.930a	0.625	−0.608	0.732	−3.787b	1.664
DJSI group	3.197a	0.577	−0.975	0.676	−2.602c	1.523
Both group	−3.382a	0.574	1.311b	0.648	2.055	1.414
sc1	−0.133a	0.031	0.120a	0.037	−0.284a	0.082
sc2	0.073	0.071	−0.230b	0.109	0.622c	0.356
Obs.	486		485		373	
R^2	0.999		0.997		0.987	
Root MSE	0.574		0.797		1.468	

Table 3. The results of the output model for polluting industrial firms

mandatory environmental regulations, we estimate the adoption of sustainable and environmental behaviors by industry. As noted earlier, polluting industry sectors are based on the division of Clarkson *et al.* (2011), which shows the factors that affect firms' decisions to adopt a proactive environmental strategy and explains whether pursuing proactive environmental strategies results in an improved financial performance for the four most polluting industries in the US (pulp & paper, chemicals, oil & gas, and metals & mining).

Using the log likelihood test, we compare the log likelihoods of the two models and test whether this difference is statistically significant. If the difference is statistically significant, then the considered polluting industry can be said to fit the data significantly better than the non-polluting industry model. The test statistic is 65.84, with a very low associated *p*-value (less than 0.001). This result shows that dividing the polluting group has a statistically significant improvement in terms of model fit.[11]

This study next compares polluting and non-polluting industries. Compared with adoption of both DJSI and CDP as the top frontier, the results (generally, most coefficient values are negative) can be explained by how close they are to adoption of both DJSI and CDP (zero level). In non-polluting industries, the firms in the DJSI group have more revenue (lrevenue: $-0.483^{c} > -0.489^{b}$) and higher market value (lmv: $-3.062^{a} > -0.586^{a}$) than CDP group firms. Larger firms (lemployee: 0.620^{a}) are more likely to adopt DJSI, while those with fewer assets per share (lassetpershare: $0.322^{a} < 0.508^{a}$) are more likely to be in the CDP group. For polluting industries, the DJSI group is significantly more connected with financial status than the CDP group. When we compare the asset per share values of the polluting and non-polluting industries, lassetpershare shows the opposite effect on choice of DJSI.

Regarding the OLS results of output Equations (2)–(4) for polluting industries (Table 3), three robust results for each dependent variable (lsales, lcapex and lrnd) are presented. Note that non-polluting firms are excluded from this analysis. First, most of the selectivity correction variables (sc1, sc2) for DJSI and CDP adoption are significant, indicating that we need to overcome the sample selection problem in the estimation, which justifies the use of the Dubin–McFadden model. Therefore, the main interpretation and conclusions are made based on the results of this model.

Of the firms' characteristics, market value (lmv) is found to be positive and significant for all models. Market value also has a positive correlation with firms' performance and innovation activities, which implies in the case of firms' sustainable or environmental behaviors that their current market values can serve as a proxy for their

[11]The log likelihood LR test statistic is calculated like this, as follows: $LR = -2\ln(L(2a_{Polluting\ \ Industry})/L(2b_{Non-Polluting\ \ Industry}))$ with $\chi^2(2) = 65.84$, $(Prob > \chi^2 = 5.047e-15)$.

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adoption. Moreover, younger firms have more investment in CAPEX investments, whereas older firms have a higher effect on performance. Further, income level (for firms of developed countries) indicates that these firms concentrate more positively on R&D investment (2.157[a]) and financial performance (0.483[a]) than firms in undeveloped countries and are less concerned about CAPEX (exploitative) investments (−0.505[a]).

In addition, larger firms focus on R&D investment (0.751[a]), but there is no significant effect for CAPEX, which is more related to current financial status. For instance, younger firms (−0.113[c]) and those that have less revenue (−0.108[a]) have negative relations with capital expenditure. However, when a firm has higher sales (0.951[a]) and higher market value (0.212[a]), it focuses on CAPEX (in polluting industries). Further, the results on the individual impacts of sustainable and/or environmental behavior on firm output show that the individual effects of environmental and sustainable behavior have negative relations with firms' R&D (explorative) investment (−3.787[b], −2.602[c]), but adoption of both DJSI and CDP has a positive coefficient, although this is insignificant.

By contrast, these individual adoptions have positive effects (2.930[a], 3.197[a]), while adoption of both DJSI and CDP (−3.382[a]) shows negative effects, on sales. This finding implies that firms concerned about individual environmental or sustainable behaviors focus on financial performance more heavily than firms that consider both adoptions, which are more concerned about investment (see the effect of adoption of both DJSI and CDP for CAPEX: 1.311[b]) than financial performance.

Table 4 presents the results of the output model for non-polluting industries. The effects of specific industry sectors show that health firms pay more attention to explorative investment (2.007[a]) than to financial performance (−0.359[a]) or exploitative (−0.470[a]) investment. The telecoms sector also shows a significantly positive relation with R&D investment (0.959[a]). In addition, we identify that the influence of firms' characteristics on performance and innovation depends on each condition. Higher market value leads to more investment and higher financial performance. However, the effect of firm age and size on output is not significant.

The results of the individual adoptions show that the individual effects of environmental and sustainable behavior have a positive influence on performance (3.117[a], 3.167[a]) but adoption of both DJSI and CDP has a negative coefficient (−3.255[a]). In contrast, individual adoptions have positive effects on adoption of both DJSI and CDP (1.787[b]) but negative effects on CDP and DJSI adoptions (−1.397[c], −1.405[c]). This means that firms concerned about

Y	(1) lsales		(2) lcapex		(3) lrnd	
	Coeff.	Std error	Coeff.	Std error	Coeff.	Std error
lsales	—	—	1.012[a]	0.082	0.822[c]	0.425
lemployee	0.163[a]	0.063	−0.082	0.056	0.932[a]	0.110
lage	0.031	0.032	−0.049	0.067	−0.028	0.151
lrevenue	0.553[a]	0.142	−0.226[a]	0.029	−0.941[b]	0.469
lmv	0.225[b]	0.088	0.349[a]	0.074	0.290[b]	0.116
developed	0.339[a]	0.122	−0.445[b]	0.187	1.886[a]	0.530
year = 2009	0.192[a]	0.051	0.164[b]	0.083	−0.048	0.174
Health	−0.359[a]	0.125	−0.470[a]	0.119	2.007[a]	0.256
ITcom	−0.016	0.067	−0.232	0.171	0.959[a]	0.315
service	−0.104	0.087	−0.649[a]	0.121	−0.455	0.340
CDP group	3.117[a]	1.115	−1.397[c]	0.823	−0.064	1.352
DJSI group	3.167[a]	1.082	−1.405[c]	0.734	0.227	1.260
Both group	−3.255[a]	1.112	1.787[b]	0.741	−0.194	1.305
sc1	0.089	0.067	−0.175	0.108	0.181	0.298
sc2	0.130	0.155	−0.270	0.192	−0.109	0.347
Obs.	405		404		333	
R^2	0.999		0.997		0.989	
Root MSE	0.458		0.732		1.352	

Table 4. The results of the output model for non-polluting industrial firms

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individual environmental or sustainable behaviors focus on financial performance more than firms that consider both adoptions, which prefer investment (see the effect of adoption of both DJSI and CDP for CAPEX: 1.787[b]) to financial performance. For explorative investment, there is no significant relation between output and adoption. In other words, there is no link between decisions on investments and firm performance.

In sum, we show that individual groups (CDP or DJSI) concentrate more on firm performance than the group considering both adoptions for both polluting and non-polluting industries during financial crisis. These firms also prefer performance to investments. In addition, firms' investment strategies vary by industry. That is, the individual groups have negative effects on investment in new possibilities (R&D) in polluting industries and on CAPEX investment in non-polluting industries. On the other hand, the group adopting both DJSI and CDP in polluting industries focuses on explorative investment (R&D), while that in non-polluting industries prefers to invest in exploitative investment (CAPEX). Finally, it is necessary to consider specific industry sectors and firm characteristics because there is heterogeneity among them. Nevertheless, we overall find more explorative investment in the health and IT industries compared with the others.

Conclusions and Implications

Environmental and sustainable implementations have a long-term impact on firm performance and innovation, and thus it can be difficult to find significant causality between adoption and performance. Moreover, in addition to performance, innovation is another crucial factor that influences a firm's long-term growth and survival. Therefore, fostering innovation is the important element of sustainable development policies (Bönte and Dienes, 2013; Forsman, 2013; Nill and Kemp, 2009). In this study, we examine the relation between environmental and sustainable implementations and innovative activities during the financial crisis based on the results of an empirical analysis. In addition, this study assumes that investment is the preparation for tomorrow's profits; therefore, we consider not only investment in technology and R&D, but also sustainability of human, social, environmental, technical and economic investments. Categorizing the established environmental and sustainable issues and proposing an empirical model of the links between these issues and innovation activities are other contributions of this study. In particular, we consider the concept of environmental and sustainable implementations simultaneously, which helps explain the effect of environmental and sustainable issues on firm innovation and performance and on the market.

Based on the results of the empirical estimations, we suggest solutions to the presented research questions and present policy implications for sustainable development. First, an overall positive relation can be found between voluntary behavior and firm performance (i.e. sales). Second, we find that the synchronous adoption of both behaviors induces more investment than individual adoption. In detail, the group adopting both DJSI and CDP in polluting industries focuses more on explorative investment (R&D), while that in non-polluting industries prefers exploitative investment (CAPEX). Knoepfel (2001) also emphasizes that investors are attracted to new investment styles that promise to create long-term shareholder value by embracing opportunities and managing risks from ongoing economic, environmental and social developments. Therefore, considering environmental and sustainable implementations simultaneously is important for focusing on future challenges and for considering various factors including the quality of management, corporate governance structures, reputational risk, human capital management, stakeholder relations and CSR.

Third, polluting industries emphasize long-term investments over short-term ones. Because there are more considerations, negotiations and expectations of sustainable and environmental behaviors in polluting industries, long-term-oriented innovation strategies and activities are important to firms compared with the case in non-polluting industries. Chen *et al.* (2006) also explore whether the performance of green innovation brings about a positive effect on competitive advantage in some industries. These authors find that the performance of innovation and the innovation process are positively correlated to competitive advantage. Therefore, investment in innovation and the consideration of innovative activities are necessary for sustainable development. Last, the effect of firms' characteristics on performance and innovation varies according to their heterogeneity.

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Appendix

	FTSE industry sectors	Freq.	Percent	Cum.
1	Utilities	82	7.95	7.95
2	Telecommunication service	75	7.27	15.21
3	Materials	126	12.21	27.42
4	Information technology	84	8.14	35.56
5	Industrials	202	19.57	55.14
6	Health care	88	8.53	63.66
7	Financial			
8	Energy	125	12.11	75.78
9	CD (consumer discretionary)	117	11.34	87.11
10	CS (consumer staples)	133	12.89	100.00
	Total	1347	100	

Table A. The frequencies of firms according to the industry sectors

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	Country	Freq.	Percent	Cum.
1	Australia	20	1.94	1.94
2	Austria	1	0.10	2.03
3	Belgium	4	0.39	2.42
4	Bermuda	1	0.10	2.52
5	Brazil	13	1.26	3.78
6	Canada	44	4.26	8.04
7	Chile	1	0.10	8.14
8	China	19	1.84	9.98
9	Czech	2	0.19	10.17
10	Denmark	9	0.87	11.05
11	Finland	13	1.26	12.31
12	France	64	6.20	18.51
13	Germany	48	4.65	23.16
14	Greece	1	0.10	23.26
15	Hong Kong	9	0.87	24.13
16	India	19	1.84	25.97
17	Indonesia	1	0.10	26.07
18	Ireland	6	0.58	26.65
19	Israel	2	0.19	26.84
20	Italy	19	1.84	28.68
21	Japan	131	12.69	41.38
22	Korea	13	1.26	100.00
23	Luxembourg	2	0.19	41.57
24	Mexico	7	0.68	42.25
25	Morocco	1	0.10	42.34
26	Netherlands	25	2.42	44.77
27	Norway	7	0.68	45.45
28	Portugal	4	0.39	45.83
29	Russia	15	1.45	47.29
30	Singapore	2	0.19	47.48
31	South Africa	8	0.78	48.26
32	Spain	35	3.39	51.65
33	Sweden	15	1.45	53.10
34	Swiss	25	2.42	55.52
35	Taiwan	9	0.87	56.40
36	Thailand	4	0.39	56.78
37	Turkey	2	0.19	56.98
38	UK	97	9.40	66.38
39	US	334	32.36	98.74
Total		1032	100	100

Table B. The frequencies of firms according to the countries

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