

Article

Voluntary Disclosure of Carbon Emissions Information, Managerial Ability, and Credit Ratings

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Abstract: This paper examines the relationship between the voluntary disclosure of carbon emissions information and credit ratings, and whether managerial ability affects this association. I examine a sample of 7996 non-financial companies with fiscal year-end in December listed in the Korea Stock Exchange Market (KSE) for the period of 2011–2019. Using CDP reports to measure the voluntary disclosure of carbon emissions information, this study reports that, on average, credit ratings can be increased through the proactive disclosure activities of environmental problems in South Korea. Moreover, in companies managed by competent managers, the positive association between the voluntary disclosure of carbon emissions information and credit ratings is pronounced, implying that competent managers encourage the disclosure of qualitative information to assess the intrinsic corporate value. These results are robust even after analyses with different empirical models.

Keywords: carbon emissions; managerial ability; credit ratings; South Korea

1. Introduction

The purpose of this study is to find out what impact voluntary disclosure of carbon emissions and managerial ability have on corporate credit ratings. If credit rating agencies impose a higher value on companies that voluntarily disclose carbon emission information than those that do not, companies with voluntary disclosure will be given a higher credit rating. This is because non-financial disclosure such as carbon emissions information may have positive effects on the firms regarding the enhancement of their financial performance, decrease in the degree of information asymmetry, improvement of the corporate reputation, as well as a reduction in the cost of capital [1–7]. Moreover, more capable managers will recognize the benefits of voluntary carbon emissions information disclosure, so companies with excellent managerial abilities are expected to receive higher credit ratings.

With the wave of the industrial revolution in the 18th century, as mankind entered the era of industrialization, greenhouse gas emissions increased exponentially, and as a result, global warming became a global issue in the 21st century. The concentration of greenhouse gases in the world's atmosphere in 2021 is approximately 413 ppm, which is 149% of the pre-industrial concentration and exceeds the average increase over the past decade. The concentration of carbon dioxide in the atmosphere has increased rapidly in the last 10 years at a rate of 2 ppm per year, and the concentrations of methane and nitrous oxide have also increased significantly. Energy use was a major factor in the surge in carbon dioxide concentration, with carbon dioxide accounting for 90% of the world's greenhouse gas emissions in the energy sector. According to the IPCC's 5th Climate Change Evaluation Report, food production will decrease, and grain prices will soar in 2030, especially in Asia, where water and food shortages due to drought, the destruction of infrastructure due to flooding, and heat waves will emerge as major social problems. As such, climate change is a serious risk factor that threatens the survival of mankind, and there is a consensus that a global response is urgently needed.

The risk of climate change was found to have a great deal of influence on investors' investment decisions. Nathan Fabian, CEO of the Investor Group on Climate Change (IGCC)



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in Australia and New Zealand, recently published an article in *Nature* that “investment in low-carbon is increasing”. According to the IGCC, commercial banks, insurers, pension funds, and capitalists are increasing their investment quotas for low-carbon companies. Some investors are forming a portfolio in the low-carbon and renewable energy sectors, judging that investing in renewable energy and green buildings can reduce the risk based on recent scientific research results and low-carbon policies around the world. In addition, the issuance of green bonds is rapidly increasing, centering on international organizations and private financial institutions, and some commercial banks and pension funds are freezing or reducing investment in fossil fuels. Korea’s National Pension Service also recently announced investment principles in accordance with the ESG principle, and among them, the environmental sector has decided to actively exercise shareholder rights by increasing or reducing the amount of investment according to carbon emissions.

In the field of business administration and accounting, attention has been paid to corporate social responsibility (CSR) activities, including environmental issues, and CSR research has been on the rise in recent years. In CSR studies so far, a great deal of attention has been paid to the question of whether a company’s CSR level affects the improvement of corporate performance, including financial performance and corporate value, and whether a company’s CSR disclosure activities reflect the actual CSR performance and are useful to capital market participants. Existing empirical studies on the relationship between a company’s CSR level and corporate performance account for a large number of cases reporting a positive relationship, but there are still limitations in reaching generalization as there are many contrary results. In addition, conflicting views and evidence are mixed in the relationship between corporate CSR disclosure activities and CSR levels, leaving much room for development in CSR research. Among CSR studies, environmental topics have been a continuous academic interest, but despite the rapid increase in investors’ interest in climate risks related to carbon emissions, studies that analyze information disclosure and capital market reactions related to carbon emissions are insignificant due to a lack of data.

This study aims to investigate whether the disclosure of non-financial information is useful to creditors of the Korean capital market using recent data from domestic companies that voluntarily disclosed carbon emission information through the Carbon Disclosure Project (CDP). Specifically, the following two topics are empirically verified. First, it analyzes whether the carbon emission information voluntarily disclosed by a company is related to the credit rating, which is the comprehensive evaluation index of the bond market. Second, it investigates whether the better the manager’s ability when other conditions are the same, the stronger the relationship between the company’s voluntary disclosure of carbon emissions and credit ratings. Since managers are the main players in charge of strategic decision-making of the company, the competence of managers has a significant effect on the performance and value of the firm [8]. Excellent managerial ability means that managers can make decisions based on a high level of understanding of the corporate business environment and the overall flow of the industry [9], and the better the manager’s ability, the more accurately it will be possible to predict the impact of voluntary disclosure of carbon emissions on a corporate long-term valuation.

The results of this paper have several contributions, as follows. First, at a time when the interest in carbon-related climate change risks is rapidly increasing, this study conducted an empirical analysis on whether the voluntary disclosure of carbon emissions provides usefulness to investors in the bond market, not the stock market. In particular, it was intended to contribute to the accumulation of empirical evidence in Korea on the voluntary disclosure effect by analyzing whether the company’s policy to voluntarily disclose carbon emissions has an additional effect on credit ratings in the domestic capital market. In addition, it is expected to contribute to the development of international cooperative research related to climate change by comprehensively reviewing the evaluation results of Korean companies by CDP and reflecting them in academic research. Recently, studies have been actively conducted on the effect of carbon emissions on corporate value and financial performance in developed markets such as the United States, Europe, and Australia [10–13].

Most of these prior studies evaluated the information effect of corporate carbon emissions only from the perspective of stock market investors. On the other hand, this study is different from previous studies in that it has expanded the framework of analysis by evaluating the usefulness of carbon emission in terms of bond investors.

The composition of the study below is as follows. Section 2 examines the theoretical background and previous studies and establishes research hypotheses. Section 3 presents research designs including research models. Section 4 presents the results of empirical analysis and interprets their meaning. Section 5 summarizes the research results and concludes.

2. Backgrounds and Hypotheses

The Carbon Disclosure Project (CDP) was founded in December 2000 under the support of 35 European financial institutions (\$4 trillion). Since its foundation, the number of member institutions has gradually increased, and more than 5500 companies from around the world are providing their climate change information to investors through CDP. On behalf of financial institutions around the world, the CDP requires and collects accurate information on major greenhouse gas emissions, including carbon dioxide, a key cause of climate change, and companies' short- and long-term management strategies on associated topics. It also provides information for investors to avoid risks by identifying the level of climate change risk of a particular company in advance. Companies subject to the carbon emission survey voluntarily fill out responses to the CDP's questionnaire every year, and its contents are evaluated by the method jointly developed by the CDP and PwC. For domestic companies, the CDP Korea Committee will partially revise the method to suit the domestic situation to evaluate the response, and the evaluation results will be released through the CDP official website (<http://cdproject.net>, accessed on 1 April 2019) and the CDP final report. Corporate response data are analyzed and evaluated in two aspects: Performance and disclosure. Performance scores assess the level of climate change activities reported by companies, such as climate change mitigation, adaptation, and transparency, and disclosures assess whether the company responded appropriately according to the completeness, quality, and format of CDP questions.

Providing the disclosure of carbon emission information to the CDP is an option, not an obligation, but the company's carbon emission information disclosed through the CDP is evaluated as highly reliable on the following grounds [13]. The market can assess the reliability of the disclosed carbon emission information by comparing the carbon emission information of a company with other firms in the same industry. The CDP conducts a survey of major companies around the world, and in some countries, such as the EU, emissions are legally regulated. In this case, since the accuracy of carbon emission information is secured and these companies are subject to comparison with other companies, firms that voluntarily disclose information can secure reliability by using it as a reference standard. It also turns out that firms have the option to provide carbon emission information to the CDP and decide whether to disclose it, but once it has responded to the CDP's request and chosen to disclose it, it tends to continue disclosing it [14]. As the number of times firms respond to CDP requests increases, the cost of reporting less reliable or false information in the future will increase. As stakeholders' interest in climate change increases and the number of reporting companies in the same industry increases, the accuracy and reliability of information can be confirmed by the market. If the market finds out that the company has reported unreliable information, it may lose credibility. In this case, the risk that a company will bear, such as facing litigation probability, is very high. Therefore, it can be said that high reliability is secured despite the voluntary disclosure.

Research on whether disclosure of corporate environmental performance is useful for investors to evaluate corporate value has long received much attention in the field of environmental accounting [15–21]. Previous studies have mainly concentrated on the impact of environmental performance on corporate value [21–33]. Porter and van der Linder [29] argued that environmental performance has a positive influence on corporate value because environmental performance can be obtained by removing environmental

pollution and inefficiency. Heal [34] explained that CSR performance, including good environmental performance, improves long-term financial soundness by reducing risk due to conflict reduction, a decrease in pollution, improving conflict of interest with regulators, creating brands, increasing employee productivity, and reducing costs of capital. Chapple et al. [10] investigated the market response according to the level of carbon emissions in 58 Australian companies where carbon emission rights are publicly traded. As a result, whenever an event related to the introduction of an emission trading system (ETS) occurs, a significant market reaction is observed in a group with a high carbon emission level. Matsumura et al. [13] compared companies that disclose carbon emission information with those that do not and found that the market value of companies that voluntarily disclose carbon emission information was significantly higher than that of non-disclosed companies. Taken together, it can be said that the stock market positively reflects both carbon emission information and voluntary disclosure activities in stock prices.

Expanding the literature, this study aims to analyze whether corporate voluntary disclosure of carbon emission information provides useful information to investors in the bond market. Although the market is likely to underestimate companies with high carbon emission levels, the incentive for companies to voluntarily disclose carbon emission information can be explained as follows. Disclosure generally plays a role in promoting the efficient allocation of scarce resources by lowering the information asymmetry that occurs between managers and investors [35]. By voluntarily disclosing reliable carbon emissions information, companies communicate to the market about future possible costs of carbon emissions. This reduces uncertainty about future cash flows and costs of capital [36–39], which can contribute to higher corporate value and credit ratings. On the other hand, if a company does not disclose carbon emission information, the market can regard it as a reverse signal that the firm is emitting high levels of carbon. As a result, the market may lower its corporate value or credit rating for firms that avoid disclosure.

In addition, if an investor pays a high cost to obtain carbon emissions information from a non-disclosure firm, this could lead to an increase in the cost of capital [40]. Companies can attract interest from capital market participants by voluntarily disclosing information on carbon emission levels. This can have a positive effect on corporate liquidity by increasing investors' demand for securities issued by the firm [41]. As a result, it ultimately lowers the cost of capital, thereby improving its corporate value or credit rating. Furthermore, the disclosure itself may have beneficial results for companies and society as a whole. For example, one of the benefits of the U.S. TRI disclosure system was initially unintentional, resulting in a reduction in overall hazardous material emissions in the U.S. [42]. If a company is included in the "environmental blacklist" and gains a negative reputation, it will have a fatal impact on corporate value, so efforts have been made to reduce the emission of harmful substances on its own to avoid this. The disclosure of carbon emission information is at corporate discretion, but as the number of firms disclosing within the same industry increases and the demand for carbon emission information from stakeholders rises, there is a significant disclosure threat to individual companies. This can serve as an incentive to reduce carbon emissions, and the market can reward these companies with a high valuation [13]. Hence, this paper sets the following Hypothesis 1.

Hypothesis 1: *Voluntary disclosure of carbon emission information is positively associated with credit ratings.*

Meanwhile, according to Demerjian et al. [9], managerial ability is the ability to efficiently utilize a given resource to generate high returns, including the ability to understand industry trends, predict demand for products, identify investment plans to increase value, and effectively manage relationships with suppliers, customers, and employees. Therefore, competent managers will have a better understanding of the corporate business and prospects and can be predicted to produce more accurate and reliable information.

In addition, highly capable managers are expected to perform less opportunistic private profit-seeking behavior than those who do not. For example, Francis et al. [43] argued that managers with a high reputation maintain a high level of quality in financial reporting and disclosure because they themselves have a high value as a human resource and have much to lose due to poor financial reporting or disclosure. In addition, given that reputation reflects competence, highly reputed managers will also consider increasing financing costs due to poor financial reporting or disclosure. Consistently, previous studies have reported that companies with poor financial reporting quality try to hire more capable managers for improvement, and the better the manager's ability, the higher the financial reporting quality [44,45].

Regarding disclosure quality, the research results of Baik et al. [46] empirically emphasize that the better the manager's ability, the higher the probability of profit prediction, and the more accurate the manager is, the higher the understanding of the business outlook. Therefore, expanding this will allow competent managers to produce more accurate and reliable carbon emissions information based on their understanding of the company, which will provide more useful information to investors in the bond market.

Hypothesis 2: *Managerial ability affects the relationship between voluntary disclosure of carbon emission information and credit ratings.*

3. Research Design and Sample Description

3.1. Research Model

Based on prior studies [47], the following regression model was employed to explore the relationship between the voluntary disclosure of carbon emission information and future credit ratings.

$$CR_{t+1} = \alpha_0 + \beta_1 VD_t + \beta_2 MAO_t + \beta_3 FOR_t + \beta_4 ICR_t + \beta_5 MTB_t + \beta_6 LEV_t + \beta_7 ROE_1 + \beta_8 EQ_t + \beta_9 BETA_1 + IND_DUMMY + YR_DUMMY + \varepsilon_t \quad (1)$$

where CR = the natural logarithm of credit rating (1–20); VD = 1 if firms report carbon emission information voluntarily, and 0 otherwise; MAO = majority shareholders' ownership; FOR = foreign investors' ownership; ICR = interest coverage ratio (EBIT/interest); MTB = market value of equity/book value of equity; LEV = total debt/total asset; ROE = net income/total equity; EQ = earnings quality; $BETA$ = estimated value of beta, with the number of months for five years before the relevant year as a variable corresponding to the systematic risk.

This study used the conservative bond rating information based on three different credit rating agencies. This paper adopted this method in order to decrease biases in the proxies. Credit rating agencies in South Korea are Korea Ratings, Nice Investors Service Ratings, and Korea Investors Service Ratings. CR was measured by offering one point for the lowest C grade, and two points for the subsequent CC grade. In this way, for the highest grade (AAA), twenty points were provided, and the next highest grade (AA+) was given nineteen points, meaning that identical interval points by grade were received to evaluate the credit ratings. To reduce the endogeneity issues, the following year's term credit rating variables were employed as a dependent variable. Finally, the research model included the year-fixed dummies and industry fixed-effect dummies to allow for variations across firms in the identical industry–year observations. As far as each voluntary disclosure of carbon emission information has an influence on improving credit ratings, each coefficient will show a significantly positive number.

Second, this study adopted the following model to examine Hypothesis 2.

$$CR_{t+1} = \alpha_0 + \beta_1 VD_t + \beta_2 MA_t + \beta_3 VD \times MA_t + \beta_4 MAO_t + \beta_5 FOR_t + \beta_6 ICR_t + \beta_7 MTB_1 + \beta_8 LEV_t + \beta_9 ROE_1 + \beta_{10} EQ_1 + \beta_{11} BETA_1 + IND_DUMMY + YR_DUMMY + \varepsilon_t \quad (2)$$

where MA = managerial ability measured by the DEA method.

Demerjian et al. [9] proposed that managerial ability is measured as the level of efficiency when converting corporate resources into revenue, compared to its peer firms in the same industry. Highly competent managers excel at expecting future product demand, controlling their employees more efficiently, and yielding higher revenue from their existing resources. Hence, it is more attractive to evaluate managers' efficiency when it comes to generating revenue instead of their pay or media mentions, which is in accordance with the overall objective of profitable firms [9].

Management ability was measured by the DEA method based on a two-step analysis. First, DEA was employed to yield an efficient frontier that covers the number of resources that individual firms in the same industry use to generate revenue. The corporate efficiency score on the efficient frontier will be given a score of one, and a score becomes lower as the firm moves away from the frontier. In contrast, there is a limit to the efficiency measurement value that is simultaneously affected by firm-specific factors and management characteristics, such as the measurement values used in the literature including the rate of return on stocks and *ROA*.

Incompetent or ordinary managers in a large firm are less capable of negotiating with the manufacturer under preferred conditions than the managers of small and medium-sized companies with high ability. Hence, corporate unique factors that are predicted to be useful or hindered by the ability of the management were removed from the total efficiency measurement by employing Tobit regression. Put differently, after eliminating the effect of the factors that help or hinder management from the corporate total efficiency, the residual not explained by the efficiency is defined as managerial efficiency. The corporate relative efficiency in each industry was measured as follows.

$$Max_v = \frac{Sales}{v_1 COGS + v_1 SGA + v_1 PPE + v_1 INTANG_t} \quad (3)$$

where *Sales* = revenue; *COGS* = cost of goods sold; *SGA* = selling, general, and administrative expenses; *PPE* = tangible asset—land—CIP (Construction in progress); *INTANG* = intangible asset.

The regression model in the paper incorporated proper control variables that can affect credit ratings. The model included majority shareholders' ownership, foreign ownership, the interest coverage ratio, the market-to-book ratio, the debt ratio, return on equity (*ROE*), earnings quality (*EQ*), measured by Kothari et al. [48], and systematic risk (*BETA*) [47]. *EQ* is calculated based on the following Equation (4).

$$\frac{TA_t}{A_{t-1}} = \alpha_0 + \beta_1 \frac{1}{A_{t-1}} + \beta_2 \frac{\Delta S_t \Delta AR_t}{A_{t-1}} + \beta_3 \frac{PPE_t}{A_{t-1}} + \beta_3 ROA_t + \varepsilon_t \quad (4)$$

where *TA* = net income-cash flow from operations; *S* = sales revenue; *AR* = accounts receivables; *PPE* = plant, property, and equipment; *ROA* = net income/total assets; *A* = total assets.

The equation to calculate discretionary accruals was estimated based on all industries based on their two-digit industry codes. The sample incorporated companies that have at least 15 firm-year observations to guarantee an abundant sample for the estimation. The residuals calculated by Equation (4) were employed to measure the discretionary accruals. They were employed after multiplying the negative case for easier understanding. Other control variables are explained below the equation.

3.2. Data Selection

Table 1 displays the data description. The sample incorporated all the companies listed on the Korea Stock Exchange with a December year-end from 2011 to 2019. The data of the paper satisfied the following criteria: (1) Companies excluding financial institutions; (2) companies on the KIS database, which is sustained by Korea Investors Service, Inc.; and (3) companies with carbon emission data obtained from the CDP. Companies with an

incomplete sample were removed from the analyses. I winsorized the top and bottom 1% of the main and the control variables to diminish the outlier influence. Finally, I acquired 7996 firm-year observations.

Table 1. Data description.

Panel A: The Data Selection Process	
Firm year observations from 2011 to 2018 with December closing fiscal year	9210
Less:	
No data for control variables	562
Missing data of credit ratings	652
Final observation	7996
Panel B: Industry Distribution	
Industry	Number (%) of Firms
Foods/Tobacco	291
Textiles/Shoes/Bags	203
Woods/Pulp/Paper/Prints	165
Chemicals/Plastics/Rubber	1363
Nonmetals	160
Primary Metals/Metalworking Processes	585
Machinery/Computer/Vehicle	2735
Construction	211
Wholesale/Retail	665
Services	1618
Total	7996

4. Empirical Results

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics on the independent variables employed in the study. The mean value of credit ratings (*CR*) is 0.2580, and its median is 0.2500. The average value of *VD* is 0.0336 and its median is 0.0000. Finally, the mean value of *MA* is 0.0003, which was lower than its median value of 0.0035.

Table 2. Descriptive statistics.

Variables	Mean	STD	Q1	Median	Q3
<i>CR</i>	0.2580	0.0959	0.2000	0.2500	0.3000
<i>VD</i>	0.0336	0.1803	0.0000	0.0000	0.0000
<i>MA</i>	0.0003	0.0764	−0.0036	0.0000	0.0035

Notes: Variable definition: *CR* = the natural logarithm of credit rating score; *VD* = 1 if firms report carbon emission information voluntarily, and 0 otherwise; *MA* = managerial ability measured by DEA method.

Table 3 displays the Pearson Correlation for the main variables. It indicates that the voluntary disclosure of carbon emission information is positively associated with credit ratings (*CR*). Additionally, a positive relationship is shown for the relationship between *MA* and *CR*, but it is not significant. In spite of the significant relationship between the variables, this correlation test is a univariate analysis, which does not reflect the other influences of control variables.

4.2. Regression Results and Discussion

Table 4 describes the multivariate test results on the credit rating tendency of voluntary disclosure firms, testing the first hypothesis. The coefficient of the *VD* is 0.0137, and it is significant at the 1% level, which provides support for H1. This significant coefficient supports the evidence that credit ratings include voluntary disclosure activities on carbon emission information in their assessments. To be more precise, it was found that disclosing carbon emission information is positively associated with firm value [13]. Moreover,

when companies voluntarily disclose carbon emission information, stakeholders, including debtholders, react positively to the disclosure of environmental information, and the cost of debt financing decreases [49]. Clarkson et al. [12] show that investors are more likely to react positively to corporate environmental disclosure because of the lack of public information available to the public. Furthermore, companies that disclose environmental information at a higher level may benefit from lower costs of capital [49]. Since companies with lower costs of capital are related to higher corporate value, the act of voluntary disclosure of carbon emission information may increase the market value of the firm. Moreover, voluntary disclosure supports diminishing the corporate negative externalities, especially when they have a bad environmental reputation. Blacconiere and Northcutt [50] also document that the companies with better environmental disclosure recover promptly from the negative yields after substantial chemical leaks. Voluntary disclosure of carbon emission information is perceived as a corporate concern for environmental issues and builds a reliable reputation. Significant associations are also shown between credit ratings and the control variables. Some of the control variables (*MAO*, *FOR*, *ICR*, *MTB*, *LEV*, *ROE*) show a significant positive relationship with credit ratings, and the others (*EQ*, *BETA*, *SIZE*) present a significant negative relationship.

Table 3. Pearson correlation.

	(1)	(2)	(3)
(1) <i>CR</i>	1.0000	0.0354 (<0.0001)	0.0196 (0.5084)
(2) <i>VD</i>		1.000	−0.0222 (0.4544)
(3) <i>MA</i>			1.000

Table 4. The regression result of Hypothesis 1.

Variables	Coeff.	t-stat.
<i>Intercept</i>	−0.2101	−10.79 ***
<i>VD</i>	0.0137	2.87 ***
<i>MAO</i>	0.0803	16.35 ***
<i>FOR</i>	0.1519	16.55 ***
<i>ICR</i>	0.0000	15.82 ***
<i>MTB</i>	0.0008	1.66 *
<i>LEV</i>	−0.0410	−46.97 ***
<i>ROE</i>	0.0754	24.80 ***
<i>EQ</i>	−0.1323	−13.72 ***
<i>BETA</i>	−0.0087	−4.51 ***
<i>SIZE</i>	−0.0016	−2.09 **
<i>IND Dummy</i>		Included
<i>YEAR Dummy</i>		Included
F-value		452.41 ***
Adj. R ²		0.517
Observations		7996

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. *VD* = 1 if firms report carbon emission information voluntarily, and 0 otherwise; *MAO* = majority shareholders' ownership; *FOR* = foreign investors' ownership; *ICR* = interest coverage ratio (EBIT/interest); *MTB* = market value of equity/book value of equity; *LEV* = total debt/total asset; *ROE* = net income/total equity; *EQ* = earnings quality; *BETA* = Estimated value of beta, the number of months for five years before the relevant year as a variable corresponding to the systematic risk.

Table 5 presents the regression results on hypothesis 2 investigating the effect of managerial ability on the relationship between the voluntary disclosure of carbon emission information and credit ratings. The coefficient of the interaction term between voluntary disclosure of carbon emission information and credit ratings is 0.1864 and is significant at

the 5% level, which supports the second hypothesis. This result implies that competent managers are the key drivers in effectively applying social, environmental, and economic activities [51]. The role of managers is emphasized as the focus on the overall decision-making process [52]. They are expected to understand a customer base and macro-economic situation better when estimating possible risk, better appreciate the future benefits, and better recognize complex accounting standards. Amongst the numerous choices made by management, disclosing private information is directly associated with corporate transparency and helps reduce information asymmetry between the companies and outside investors. Managers should determine how and to what extent internal information should be documented to outside investors. The active disclosure of carbon emission information by competent managers provided to outside investors who have limited availability to the corporate internal information is useful to assess the ultimate risk and affects the corporate valuation in the bond market, thereby increasing the credit ratings. Significant associations are also shown between credit ratings and the control variables. Some of the control variables (*FOR*, *ICR*, *ROE*) have a significant positive relationship with credit ratings, and others (*LEV*, *EQ*, *BETA*, *SIZE*) show a negative association.

Table 5. The regression result of Hypothesis 2.

Variables	Coeff.	t-stat.
<i>Intercept</i>	−0.0225	−0.25 ***
<i>VD</i>	0.0073	1.10
<i>MA</i>	0.0756	1.89 *
<i>VD × MA</i>	0.1864	2.54 **
<i>MAO</i>	0.0209	1.14
<i>FOR</i>	0.1272	5.29 ***
<i>ICR</i>	0.0000	4.36 ***
<i>MTB</i>	−0.0010	−0.75
<i>LEV</i>	−0.0289	−10.83 ***
<i>ROE</i>	0.1084	6.70 ***
<i>EAQ</i>	−0.1756	−3.63 ***
<i>BETA</i>	−0.0258	−3.29 ***
<i>SIZE</i>	−0.0063	−1.95 *
<i>IND Dummy</i>		Included
<i>YEAR Dummy</i>		Included
F-value		28.28 ***
Adj. R ²		0.490
Observations		596

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. *MA* = managerial ability measured by DEA method. See Table 4 for definitions of other variables.

4.3. Robustness Regression

Robustness analyses are conducted on the regression models using fixed-effect model techniques to diminish the impact of outlier bias in all the specifications. Such regression models provide a contribution to managing the omitted variable problem due to unseen heterogeneity. This heterogeneity is known to be constant over time. It can be removed by subtracting the group-level mean over time.

As a result, the coefficient for *VD* is positively significant, which supports Hypothesis 1. Moreover, the coefficient for the interaction term of *VD × MA* is positive at the 5% significance level, which also supports Hypothesis 2. Overall, as can be seen in Table 6, the results of the paper remain consistent with the main regression results when run through the robustness test.

Table 6. Robustness regression.

Panel A. Hypothesis 1			
Variables	Coeff.		t-stat.
VD	0.0317		7.02 ***
Control Variables		Included	
F-value		6661.68 ***	
Adj. R ²		0.940	
Observations		7996	
Panel B. Hypothesis 2			
Variables	Coeff.		t-stat.
VD	0.0079		1.26
MA	0.0760		1.90 *
VD × MA	0.1871		2.55 **
Control Variables		Included	
F-value		395.92 ***	
Adj. R ²		0.935	
Observations		596	

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. See Tables 4 and 5 for definitions of other variables.

4.4. The Effect of Information Asymmetry

Information asymmetry is an inefficient resource allocation that can lower firm value [47]. Based on the agency issues between management and external stakeholders, the effect of voluntary disclosure of carbon emission information may vary. Generally, managers retain more essential information on the intrinsic value of firms compared to external stakeholders. If there is a high degree of information asymmetry between management and external stakeholders, the managers, who possess a competitive advantage, can occupy superior positions, exploiting internal information for private interests. In these conditions, information on carbon emission is likely to be more value-relevant to external stakeholders. This study uses two variables to measure information asymmetry, which is stock return volatility and is equal to the standard deviation of market excess returns per day, and firm age measuring from the natural logarithm of corporate listing periods. As a result shown in Table 7, in the sub-sample with higher information asymmetry based on the two alternative measures, the voluntary disclosure of carbon emission variables (VD) had significant effects on higher credit ratings. However, in the sub-sample with lower information asymmetry, any VD was significant. These indicate that the higher the degree of information asymmetry, the more voluntary disclosure activities have a tendency to signal to external stakeholders, thereby improving credit ratings.

Table 7. The effect of information asymmetry.

Panel A. Volatility					
Variables	Coeff.	t-Stat.	Coeff.	t-Stat.	
VD	0.0313	2.22 **	0.0128	0.92	
Control Variables		Included		Included	
F-value		210.38 ***		209.62 ***	
Adj. R ²		0.496		0.497	
Observations		4033		3963	

Table 7. Cont.

Panel B. Firm Age				
Variables	Coeff.	t-stat.	Coeff.	t-stat.
VD	0.0179	2.17 **	0.0102	1.22
Control Variables	Included		Included	
F-value	213.41 ***		217.56 ***	
Adj. R ²	0.518		0.523	
Observations	3754		4242	

** and *** indicate significance at the 5% and 1% levels, respectively. See Table 4 for definitions of other variables.

5. Conclusions

In the past two decades, numerous companies have evaluated and reported environmental problems such as climate change, greenhouse gas emissions, water pollution and consumption, and waste formation. In the early 1990s, fewer than 20 companies had a tendency to disclose their internal environmental information, but in 2016, more than 9000 companies documented sustainability reports, suggesting investors' concern on environmental issues. In 2019, mutual funds that incorporated environmental content led to USD 20 billion in inflows, which surpassed the prior year's record by four times [53]. Regardless of the COVID-19 pandemic in 2020, the level of inflows on these funds increased, suggesting that firms' environment-related reports play the role of risk-adjusting functions [54].

This study enhances the credit rating literature by investigating the effect of corporate voluntary carbon emissions disclosure and explaining quantitative and qualitative aspects that affect credit ratings. Based on the stakeholder theory that asserts firms should pay attention to the interest of shareholders including outside stakeholders, the voluntary disclosure of carbon emission information may be useful to debtholders by decreasing information asymmetry between management and external stakeholders, thereby diminishing the litigation threat to companies [55]. Specifically, this paper investigates the association between the voluntary disclosure of carbon emission information and credit ratings. Furthermore, the study investigates whether the association between the voluntary disclosure of carbon emission information and credit ratings differs depending on managerial ability.

In a sample of 7996 firm-year observations for the period of 2011–2019, this study documented that the voluntary disclosure of carbon emission activities is useful to gain a higher credit rating, which supports the notion of the stakeholder theory. Moreover, the association between the voluntary disclosure of carbon emission information and credit ratings is more evident for companies maintained by competent managers. These results imply that credit rating agencies assess the creditworthiness of companies by incorporating the qualitative aspects of voluntary disclosure and the characteristics of managers.

Environmental issues such as climate change are risk factors that threaten all humankind. Greenhouse gas emissions or carbon emissions are one of the main offenders of climate change. Many countries around the world have a great deal of experience due to extreme weather triggered by climate change. This significantly affects corporate sustainability. Responding to the problem of climate change is beyond a choice, and is considered a corporate duty, reflecting investor needs. If a competent manager is aware of the risks of climate change and is proactive in responding to them, then their response to climate change is not a constraint but rather regarded as an opportunity to create value.

This paper possesses several caveats. First, despite the fact that a focus on South Korean firms can deliver a powerful analysis by isolating research data, it may be difficult to make generalizations of the empirical findings to other countries with diverse business situations. Second, since not all the companies disclose CDP reports, the data can be biased, thereby affecting the explanatory power of the current results and the validity of the paper.

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