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Does voluntary environmental information disclosure prevent stock price crash risk? – Comparative analysis of chaebol and non-chaebol in Korea

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ABSTRACT

This research sheds light upon the relationship between Korean firms' voluntary carbon disclosure tendency, as measured in Environmental Information Disclosure (EID), and their stock price crash. We pay attention to whether firms' affiliation to the *chaebols*, unique conglomerates in the nation, and environmentally sensitive industry, play as decisive role in mitigating stock price crash. For analysis, we divide samples into two different categories – namely, *chaebols* and non-*chaebols*, and environmentally sensitive and non-environmentally sensitive firms. Our findings are as following. First, we find the negative relation between EID for Korean firms and price crash risk in general. Second, we prove a negative relationship between EID and stock price crash for non-*chaebols*, which implies that their effort for voluntary environmental information disclosure reduces information asymmetries, thereby mitigating firm risk. Lastly, we find the negative relationship between EID and stock price crash for firms in non-environmentally sensitive industries, implying that their effort for voluntary carbon disclosure is more rewarded by investors and capital market.

1. Introduction

For last decades, the importance of environmental awareness has gained a wide popularity in business researches (Fan et al., 2020; Lee and Cho, 2021; Li et al., 2017; Kasim, 2017; Matsumura et al., 2014; Morales-Raya et al., 2019; Morrone et al., 2022; Sun et al., 2019; Wang et al., 2019; Zhang, 2017; Zhang et al., 2022). Under the pressures from a variety of international organizations, a growing number of firms have come to acknowledge the need to address the environmental information disclosure (EID hereafter) in an effort to commit to their goals in confronting climate change (Armstrong et al., 2010; Beyer et al., 2010; Chapple et al., 2013; Choi and Noh, 2016; Diamond and Verrecchia, 1991; Lambert et al., 2007; Matsumura et al., 2014).

In general, firms' environmental performance brings benefits to a variety of stakeholders. These benefits include profit growth (Tang and Zhang, 2020), an increase in firm value (Chapple et al., 2013; Heal, 2005; Matsumura et al., 2014; Saka and Oshika, 2014) and enhanced firm reputation (Cho et al., 2012; Cui et al., 2018; Godfrey et al., 2009; Morales-Raya et al., 2019). Moreover, growing pressures from a variety of external organizations and stakeholders has served as a strong momentum to influence firms' management level to acknowledge the need to collect and disclose carbon information. Under these circumstances, firms have come to voluntarily disclose carbon information while acknowledging that this could be rendered disadvantageous to the market, as doing so means additional cost of dealing with climate change (Bauer and Hann, 2010; Chava, 2014; Jung et al., 2018; Kleimeier and Viehs, 2018).

Recently, a number of scholars have addressed the effect of carbon emission disclosure on firm value (Chapple et al., 2013; Heal, 2005; Matsumura et al., 2014; Saka and Oshika, 2014; Nguyen et al., 2021; Tzouvanas et al., 2020). However, there are limited number of researches focusing on developing countries in which specific business environment and culture may influence the effect of firms' carbon disclosure choice. (Lee and Cho, 2021; Matsumura et al., 2014). In this research, we concentrate on the relationship between firms' carbon emission disclosure and firm value in Korean market. In particular, we focus on unique firm-specific and industry – namely, *chaebols*, a special type of Korean conglomerate, and environmentally sensitive industry. For analysis, we gather reports of CDP (Carbon Disclosure Project), a global charity that publishes the global carbon emission disclosure report, and create a dummy variable based on whether Korean firms disclosed carbon emission in the report. Our sample period is from 2009

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to 2021. As well, we employ a variety of firm-specific variables in our models to control effects for firm characteristics.

We focus on Korean market for several reasons. This market is interesting for analyzing the effect of firm heterogeneity in the relationship between carbon disclosure and stock price crash. In Korean market, there exists a unique set of family-owned business conglomerations—the *chaebols*, which historically have played a significant role in the nation's economic growth under the support of government. In particular, *chaebols* have maintained their "management rights" in the form of hereditary succession, which has been tolerated by the Korean government (Lee et al., 2010; Yoon and Lee, 2019).

Remarkably, the firm value of *chaebols* has been estimated based on profitability in last half-century. Since the 1997 Asian financial crisis, *chaebols* have become indistinguishably profitable firms, even with less over-investment under the long support from government. As a result, *chaebols* have wielded monopoly power along with higher profitability in volatile business environment, which led to high firm reputation and visibility, in contrast with their counterparts, non-*chaebols*. The relative discount of firm value for non-*chaebols* has been occasionally reported in recent researches (Ducret and Isakov, 2020; Lee, 2022). While a number of researches attribute the reasons to "less reputation and visibility" of non-*chaebols*, another branch of studies argue that firms could enhance its firm value, reputation and brand names through openly adhering to global standards (Choi et al., 2019; Pham and Tran, 2020). As market and investors pay attention to the "reputational" aspect of *chaebol*-affiliated firms, in contrast, non-*chaebols*' effort to comply with international investors would be value-strengthening (Lee and Cho, 2021; Matsumura et al., 2014). In turn, this firm tendency could favor the inclination of voluntary information disclosure to investors, although doing so could be detrimental to non-*chaebols* in short run.

In last decades, socially responsible management, including voluntary carbon disclosure, have become an important concern for Korean firms, including *chaebols* and non-*chaebols* (Lee et al., 2022; Lee and Cho, 2021; Lee and Lee, 2019; Lee et al., 2021; Oh et al., 2011; Yoon and Lee, 2019; Yoon et al., 2018). Still, however, it seems that the environmental demand is not yet fully reflected in the value of Korean firms, especially for *chaebols*. Previous researches present evidences on contrasting effects of *chaebols*' environmental performance from non-*chaebols*, such as firm value (Lee and Cho, 2021; Yoon and Lee, 2019; Yoon et al., 2018) and tax avoidance (Lee et al., 2021; Yoon et al., 2021).

In this context, we observe the role of EID in influencing the firm risk of Korean firms. The role of EID on price crash risk is relatively understudied in recent literature on developing market (Lee and Cho, 2021; Zhang et al., 2022). It is known that the disclosure of carbon information alleviates or aggravate price crash risk, they are expected to accordingly have a mitigating or causing effect on shareholder value (Kim et al., 2014; Lee et al., 2022). Following terminology in Chen et al. (2001), we use "negative coefficient of skewness" for the proxy of price crash risk, denoted as *NCSKEW*. We believe the affiliation to *chaebols*, unique types of conglomerates in the nation, and environmentally sensitive industry would lead to substantial heterogeneity in the effect between different types of firms in Korea.

Our study is theoretically based on agency-cost perspective, with a particular interest in (non)*chaebol*-affiliated firms' motivations in disclosing environmental information to the public (Abeysekera and Fernando, 2020; Beaudoin, 2008; Chih et al., 2008; Hemingway and Maclagan, 2004; Kothari et al., 2009). It is plausible that information asymmetries could be reduced by pressuring firms to voluntarily disclosing carbon emission (Bae et al., 2021; Kim et al., 2014; Lee and Cho, 2021). In this respect, the effort of firms in developing countries to disclose carbon emission could be interpreted as "transparency" in the perspectives of outside stakeholders, as it reduces information asymmetry, thereby resolving principal-agent problems (Chen et al., 2001; Kothari et al., 2009; Lee et al., 2022). In this way, firms' corporate value from the effort of EID could be enhanced. Perhaps surprisingly, the effect of EID on stock price crash for firms affiliated to *chaebols* and environmentally sensitive firms is far from uniform, which will be later discussed in detail.

In short, our paper adds to previous literature on EID and firm risk by providing new perspective on developing market. While previous literature focuses on the role of EID on firm risk in industrial aspects (Joshi et al., 2011; Lin and Wu, 2023; Luo et al., 2023; Ren et al., 2023; Sari and Adi, 2023; Zhang et al., 2022), we focus on heterogenous effect between *chaebols* and non-*chaebols* in the context of principal-agent problem. It is known that *chaebols* have advantages in leading investors to consider their affiliates "differently" from non-*chaebols*, due to their wide reputation and brand name (Ducret and Isakov, 2020). In this respect, we believe that potential firm risk which could arise from relatively "disadvantageous" position to their counterpart, could be reduced if non-*chaebols* sincerely conform to international standards such as (environmental) information disclosure. This aligns with previous literature on heterogeneity effect for (non)*chaebols* in resolving principal-agent problem (Lee et al., 2022; Lee and Cho, 2021; Yoon et al., 2018; Yoon et al., 2021; Yoon and Lee, 2019).

Further, we provide mechanisms on how EID affects stock price crash of Korean firms by conducting mediation analysis. In consideration of previous researches, we present three channels through which Korean firms' EID affects stock price crash. First, firms' tendency to voluntary EID could be "negative signal" to public and investors since it could imply cost-generative aspects of firm activities (Lee and Cho, 2021). Although the voluntary disclosure of environmental information could reduce firms' surplus, this, in turn, could reduce the principal-agent problem, which may strengthen firm-value in long run (Plumlee et al., 2015). Second, firms' disclosing environmental information via wide information transmission (e.g., internet technology) could greatly enhance the authenticity of firm information (Granados and Gupta, 2013). Public's increased chance of obtaining (non)financial information would prevent the formation of stock bubbles, which leads to low possibility of stock price crash. Third, media coverage on firms' voluntary disclosure of environmental information can be regarded as firm transparency to public and investors. Media coverage of firms' environmental information could pressure firms to consistently report and disclose the information to public (Fan et al., 2020;Ho et al., 2023; Krüger, 2015; Lee and Cho, 2021). In sum, our research asserts that Korean firm's EID mitigates stock price crash through channels including surplus management, audience exposure and media attention.

In our analysis, we further confirm this firm heterogeneity by adding one more dimension: Firms' affiliation to environmentally sensitive industry. Previous studies point out different firm characteristics due to firm's affiliation to environmentally sensitive industries (Iatridis, 2013; Miralles-Quirós et al., 2018; Yoon et al., 2018) Similar to non-*chaebols*, firms in less environmentally sensitive industry are in less regulative environment so that may have less incentive to voluntarily disclosing their environmental information. In turn, this effort would be regarded as meeting the "disclosure-performance gap" from outside stakeholders (Iatridis, 2013; Zhang et al., 2022), since it would eventually reduce information asymmetries to outside stakeholders (Pham and Tran, 2020; Zhang et al., 2022).

Our paper is closely related to the work of Zhang et al. (2022) in terms of terminology(EID), regression methodologies, theoretical framework, the adaptation of both (in)dependent variables, and implications in the context of principal-agent problems. The key difference is that while their analysis focuses on the relationship between EID and stock price crash for Chinese listed companies in heavily polluting industry between 2013 and 2019, we take consideration of (i) the firm characteristics of (non)*chaebols* which are unique to Korean market and (ii) firm affiliation to environmentally sensitive industry. As well, we expand the period into 2009–2021 and employ firms' environmental disclosure in CDP reports as main independent variables in order to better observe firm characteristics between firms' EID on stock price crash risk in Korean market. Moreover, we employ difference-in-difference (DID) test and a different set of mediating analysis in order

to find firm characteristics which are more unique to Korean market.

Our major findings are as follows. First, we find that the environmental disclosure information of Korean firms, as measured in EID, has a negative relationship with price crash risk, in consistence with previous researches (Bae et al., 2021; Dumitrescu and Zakriya, 2021; Kim et al., 2014; Lee et al., 2022). Second, we provide evidence on the heterogeneity effect between *chaebols* and non-*chaebols*. To be specific, while the relationship between EID and stock price crash is uncertain for *chaebols*, the negative role of EID and stock price crash is consistently demonstrated for non-*chaebols*. This result implies that the effort for voluntary information disclosure of non-*chaebols* could be regarded as conforming to international standards, whose "reputation and visibility aspect" is less concerned than *chaebols* (Ducret and Isakov, 2020). We further confirm this by conducting aforementioned mediating analysis. Third, the EID of firms, especially non-*chaebols*, in non-environmentally sensitive industry has negative relationship with price crash risk. This suggests that if firms with "less responsibility" in carbon disclosure voluntarily reveal carbon emission, this effort is rewarded by investors and capital market. We further confirm our results by considering mediating analysis with detailed analysis.

The contributions of our study are summarized as following. First, we find evidence supporting the traditional view of principal-agent and information asymmetry theory, which highlights the effect of firm managers' choice on firm risk. In consideration of the fact that environmental awareness in Korean market is still at development stage (Yoon and Lee, 2019; Yoon et al., 2018), firms' effort to conforming to global standards by voluntarily disclosing environmental information is highly rewarded by investors and capital market. Second, our finding supports evidence for firm heterogeneity on environmental policy determination in developing market (Zhang et al., 2022) Particularly, in Korea's unique market circumstances, the EID of non-*chaebols* who has less visibility and reputation than *chaebols*, prevents stock price crash by reducing information asymmetries between firm managers and stakeholders. Moreover, our results suggest that the affiliation to non-environmentally sensitive industry could "strengthen" the effect of EID on stock price crash, thereby reducing information asymmetries. This result further implies that the voluntary environmental disclosure of firms in non-regulatory environment are rewarded by investors and capital markets, especially for non-*chaebols*.

The remainder of this paper is organized as follows. Section 2 introduces previous literature on EID and stock price crash, followed by the development of hypothesis in Section 3. Section 4 illustrates the empirical results, followed by discussion in Section 5. Finally, Section 6 concludes the research.

2. Literature review

2.1. Voluntary carbon disclosure and stock price crash

Recent years have witnessed the increase of the public awareness of environmental transparency for firms at international and regional levels (Chapple et al., 2013; Choi and Noh, 2016; Cormier et al., 2011; Matsumura et al., 2014; Morales-Raya et al., 2019; Nguyen et al., 2021; Tzouvanas et al., 2020). Interestingly, previous researches reveal that carbon disclosure brings positive firm image to a variety of stakeholders (Morales-Raya et al., 2019; Cho et al., 2012; Tang and Zhang, 2020; Godfrey et al., 2009), increases firm value (Chapple et al., 2013; Matsumura et al., 2014; Nguyen et al., 2021; Tzouvanas et al., 2020) and reduces information asymmetries (Armstrong et al., 2010; Beyer et al., 2010; Cormier et al., 2011; Diamond and Verrecchia, 1991; Jung et al., 2018; Kasim, 2017; Lambert et al., 2007). However, there are limited evidence of whether the environmental disclosure affects stock price crash risk, especially for developing countries (Lee and Cho, 2021; Zhang et al., 2022).

There have been numerous studies on stock price crash, which is first introduced by Chen et al. (2001). In addressing stock price crash, researchers take agency theory and information asymmetry theory proposed by Jin and Myers (2006). Stock price crash takes place when firm managers do not disclose firm misbehavior deliberately, but instead, open up information favorable firm information with an intention to increase firm reputation or their own promotions. Previous researches find a variety of attributing factors to stock price crash in the perspective of principal-agent and information asymmetry theory, including earning manipulation (Chen et al., 2017; Lee et al., 2022), media coverage (), analyst coverage (Xu et al., 2013), economic policy uncertainty (Jin et al., 2019), investor sentiment (Firth et al., 2015) and corporate governance (Al Mamun et al., 2020; Liang et al., 2020; Park et al., 2023).

The existing literature provides a rational to believe that firms' environmental disclosure affects price crash risk. In fact, there exists a number of debates on the relationship between firms' "environmental performance" and "environmental disclosure", as firm managers may have incentive to exaggerate or underestimate their factual performance when disclosing their carbon emission level (Zhang et al., 2022). To describe further, Dawkins and Fraas (2011) argue that poor environmentally-performing firms may disclose carbon information to meet the "disclosure-performance gap" from outside stakeholders, while good environmentally-performing firms may not disclose further in order to avoid additional scrutiny from public. In this respect, firms, even with noticeable environmental performance, may not necessarily disclose their carbon emission (Meng et al., 2014). This "disclosure-performance gap" entails that the industry heterogeneity should be taken into account (Zhang et al., 2022; Iatridis, 2013).

In theory, it is believed that firms' EID influences stock price crash through a variety of channels. First, EID activity of firms may mitigate principal-agency problem in general. Firm managers' voluntary choice to disclose sensitive carbon emission would enhance insider information, thereby improve management transparency. Further, as noted by Zhang et al. (2022), voluntary EID means strong internal regulation and management ethics, so that it would weaken firm managers' opportunism to act on behalf of their own benefit and incentives (Ahn and Ko, 2017; Armstrong et al., 2010; Healy and Palepu, 2001). Acting on global norms of environmental disclosure under the pressure from a variety of agencies would enhance audit mechanism within firms in Korea, where environmental performance is still at development stage (Ahn and Ko, 2017; Kim and Kim, 2008; Park, 2013).

Second, firms' voluntary EID may help firms to improve their social reputation, as they retain trust and trustworthiness from a variety of stakeholders, leading to enhanced economic benefits (Tang and Zhang, 2020). In this way, capital market may less concern about their firm risk which could arise from intentionally not disclosing information. In Korean market, in which the environmental awareness of firms is still at development stage, firms' commitment to voluntary (environmental) information disclosure could be regarded as positive signal to outside investors and stakeholders (Lee and Cho, 2021; Yoon et al., 2018). To be specific, it is occasionally reported that firm managers in developing market may tempt to adjust (non)accounting performance to investors and stakeholders when disclosing the information which could be disadvantageous to firm reputation. For example, Nazir and Afza (2018) argue that the "intentional" alteration of accounting earnings of firm managers could harm the reliability and trustworthiness of firm information and could be corrected by effective corporate governance structure. As well, Dawkins and Fraas (2011) assert that firms with poor environmental records are likely to less disclose information in order to avoid negative exposure based on voluntary disclosure theory. In this respect, it is reasonable to assume that the aforementioned "disclosure and performance gap (for firm information)" could be reduced if firm managers in developing market, including Korea, endeavor to disclose their "factual performance" to public and investors.

Earning public credibility through revealing firm information is more convincing, considering that the assessment of firms' environmental performance is in early stage in Korea. For example, a number of

Fig. 1. Theoretical Framework for H-1.

ESG institutions, including KCGS (Korea Corporate Governance Service) and Sustinvest, have not yet placed important weight on carbon emission level in assessment (Oh, 2021), but have assigned positive weights on firms' carbon disclosure. Thus, firms which have strong environmental performance may have incentives to disclose carbon emission level to outside stakeholders in an effort to maintain reputations in market. (Lee and Cho, 2021; Matsumura et al., 2014) As well, firm managers' decision to voluntarily reveal environmental information which could not be favorable to firm reputation or their own promotions, could lead to the alleviation of stock price crash. Put it differently, if Korean firms voluntarily disclose their environmental information, this would reduce firm risk in the perspectives of investors and capital market. Thus, we present our first hypothesis as following.

H-1. Korean firms' voluntary disclosure of carbon emission mitigates stock price crash.

The theoretical framework of H-1 is graphically presented in following Fig. 1.

2.2. EID and Korean firms

Previous researches on Korean firms point out the unique characteristic of *chaebols* and non-*chaebols* which are distinguishable from each other (Lee et al., 2010; Lee et al., 2022; Lee and Cho, 2021; Lee et al., 2021; Yoon and Lee, 2019; Yoon et al., 2018). Ever since "socially responsible management practice" has become major agendas for both of firm groups, the value relevance of CSR, including environmental disclosure, has become key concerns (Choi et al., 2019; Lee and Cho, 2021; Lee et al., 2022; Seo and Choi, 2015). Under the support of government for last century, the growth of *chaebol*-affiliates in Korean market have generated a wide access to economic resources which led to the improvement of their firm reputation and brand names. Despite its large firm size and monopoly power, which cause substantial environmental pollution and other emissions, their rapid industrialization and global expansion of business have increased the level of monitoring and surveillance by investors and global agencies (Yoon and Lee, 2019; Lee et al., 2021; Yoon et al., 2021), which forced *chaebol*-affiliates to adhere to the global standard of transparency. In contrast, their counterpart, non-*chaebols*, are in relatively disadvantageous position due to their low reputation and invisibility (Ducret and Isakov, 2020). Simply speaking, it could be reasonable to assume that the marginal effort of non-*chaebols* to conform to global standards (e.g., voluntary disclosure of firm information) could be regarded as commitment to enhance their global reputation (Lee and Cho, 2021). Moreover, on average, they are smaller than their counterpart, *chaebols*, in sales and profit, so that their voluntary carbon disclosure would be regarded "positively" in the perspective of investors and capital market.[1] Their voluntary effort, in return, would lead to the reduction of "firm risk" in the eyes of stakeholders, leading to the decreased chance of stock price crash. Thus, it is reasonable to assume that the effect of non-*chaebols*' EID on firm risk, as measured in stock price crash, would differ markedly from *chaebols*. It is interesting to point out that this firm heterogeneity within "one nation" is seldomly found in previous researches (Lee et al., 2010; Lee and Cho, 2021; Lee et al., 2022). Therefore, our second hypothesis develops as the following.

H-2. There exists heterogeneity effect between *chaebols* and non-*chaebols* in the relationship between EID and price crash risk.

2.3. Korean firms and environmentally sensitive industry

Prior studies have paid attention to the potential role of environmentally sensitive industries in the relationship between EID and firm risk (Yoon et al., 2018; Zhang et al., 2022; Iatridis, 2013) Not surprisingly, the requirement for environmental disclosure is generally stricter for firms that belong to environmentally sensitive industries (Miralles-Quirós et al., 2018; Yoon et al., 2018). The firms under those industries would have to meet higher standards for eco-friendly manufacturing, non-toxic packing and lower polluting process. On the other hand, the requirement is less strict for firms in non-environmentally sensitive industries. Thus, there is less incentive for firm managers to voluntarily reveal related information, which could entail less information transparency.

To illustrate further, previous researches point out different firm characteristics in environmentally sensitive industries and non-environmentally sensitive industries (Iatridis, 2013; Miralles-Quirós et al., 2018; Yoon et al., 2018; Zhang et al., 2022). For example, it may seem natural that firms with higher environmental performance may be more likely to disclose their carbon emission in environmentally sensitive industries. In contrast, if firms with lower poor environmental performance choose to "voluntarily" disclose their carbon emission to outside stakeholders, this would be viewed as an effort to meet the "disclosure-performance gap" from outside stakeholders (Iatridis, 2013; Zhang et al., 2022). The benefit of voluntary carbon disclosure for non-*chaebols* in non-environmentally sensitive industry could outweigh "the potential cost" which may arise from voluntarily disclosing their information which could potentially put them into new regulation. On the other hand, this mechanism may not apply to *chaebol*-affiliated firms, to whom the monitoring and surveillance is consistently practiced for last decades.

Eventually, in consideration of previous researches, the voluntary environmental information disclosure of non-*chaebols* in non-environmentally sensitive industries could be regarded as effort to promote greater firm transparency by reducing information asymmetries. When firms in less regulatory environment disclose their information voluntarily, investors and public may gain greater understandings, which facilitate better investment decision-making. In consequence, this would greatly reduce information asymmetry for firms with less reputation and visibility to investors and public (Ducret and Isakov, 2020; Lee and Cho, 2021; Yoon et al., 2018).

Therefore, it is rationale to suggest that the (non) environmentally-sensitive industries may strengthen the firm-characteristic of non-*chaebols* in their relationship between EID and stock price crash. In this respect, our third hypothesis is presented as follows.

H-3. There exists heterogeneity effect between environmentally sensitive and non-environmentally sensitive firms in the relationship between EID and price crash risk.

The theoretical framework of H-2 and H-3 which are built upon conceptual framework of H-1 is presented in following Fig. 2 and Fig. 3 below.

[1] In our firm sample, which runs from 2009 to 2021, the sales and operating profit of *chaebols*, for average, are 9.94 times and 12.60 times those of non-*chaebols*, respectively. As well, the leverage ratio(debt-to-equity) of *chaebols*, for average, is 1.92, whereas the ratio of non-*chaebols* is 1.49, implying that *chaebol*-affiliated firms tend to rely more on leverages. The detailed results are available upon request.

Fig. 2. Theoretical Framework for H-2.

Fig. 3. Theoretical Framework for H-3.

2.4. Mediating analysis

Based on H-1, H-2 and H-3, this research introduces mediating channels through which EID mitigates the risk of stock price crash. First, previous literature pay attention to positive relationship between the disclosure of environmental information and firm surplus. Firm managers perceive earnings as proxy to which stakeholders evaluates firms' financial performance *and* survival prospects in near future (Graham et al., 2005; Song and Park, 2004). In the aspects of environmental disclosure, it is reported that markets penalize firms for carbon emissions, but penalty is further imposed on firms which do not choose to disclose environmental information (Matsumura et al., 2014). If firms are in disadvantageous position (e.g., non-*chaebols*) compared to other groups due to less reputation and visibility (Ducret and Isakov, 2020) and less regulatory environment (Yoon et al., 2018), the additional disclosure of environmental information can be regarded as effort to reduce information asymmetries which will decrease stock price crash. Based on our analysis, we present following hypothesis.

H-4a. Firms' surplus management mediates the relationship between environmental disclosure and stock price crash risk.

Granados and Gupta (2013) suggest that internet technologies bring markets close to the ultimate state of perfect information as it reduces information asymmetries. As information spreads through internet, public and investors are able to gather firms' information and gain insights from a variety of resources such as internet community and analyst reports. In turn, this would greatly enhance the transparency of firms' environmental information since public and investors can make to better judgement on whether to continue investment in firms (Ricky et al., 2022). As a result, firms' voluntary EID would greatly reduce information asymmetries, resolving principal-agent problems. In other words, firms' effort for EID to public could be regarded as complying with global standards; they are better able to build firm reputation and social images, which leads to reduction of so that it would greatly reduce chances of stock price crash. Based on aforementioned analysis, our hypothesis develops as following.

H-4b. Internet attention mediates the relationship between environmental disclosure and stock price crash risk.

Media plays an important role in disseminating firm information, forming public opinion, which leads to the formation of firms' social image to public and investors. They also are able to set social agendas which causes firms to change behaviors especially on social issues. Tavakolifar et al. (2021) argue that the agenda setting and issue framing functions of media can be used to facilitate firms' response to climate change issues. If firms choose not to disclose environmental information to public, media could choose to cover more negative news on the choice of firms which could lead to the intervention of regulatory authorities. In regard to this, argue that the informational roles of media coverage would lower tendency of firms to withhold bad news, which is proxied by stock price crash. Thus, media coverage would improve the chances of firms' EID, which then reduces principal-agent problems and associated firm risk. Therefore, we develop hypothesis as following.

H-4c. Media attention mediates the relationship between environmental disclosure and stock price crash risk.

The theoretical framework of our mediating analysis (H-4a, H-4b and H-4c) are presented in following Fig. 4 below.

Additionally, we believe that the benefit of voluntary EID is greater for non-*chaebols*, which are in non-environmentally sensitive industry. Less profitable than their counterpart(*chaebols*), non-*chaebols*' management of surplus could signal to investors and stakeholders that it has survival prospects so that generate stable cash flow in future. This effort of non-*chaebols* could outweigh "the potential cost" of voluntarily disclosing information, as their firm transparency strengthens thanks to the improvement of firm reputation and visibility which are due to increased internet and media attention. Further, voluntary EID of non-*chaebols* in less regulative environment would lead to greater understandings of investors and public, which facilitate their investment decision-making. Put it differently, we expect that the analysis for non-*chaebols* in non-environmentally sensitive industry support the aforementioned hypothesis.

3. Data and methodology

3.1. Data

Our data source is twofold – FnGuide and Bloomberg terminal. First, we obtain firm data from DataGuide, a financial database run by FnGuide, which is a private financial data provider in Korea. The firms are listed in KOSPI market. Our sample period is from 2009 to 2021. We divide the Korean firm samples into *chaebols* and non-*chaebols*, and environmentally sensitive firms and non-environmentally sensitive firms. Following Yoon et al. (2018), we define energy, material, and utility sectors as environmentally sensitive firms using the standard of

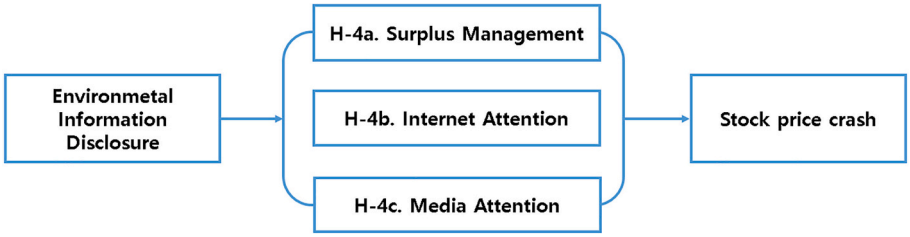

Fig. 4. Theoretical Framework for H-4a, H-4b, H-4c.

Table 1
Summary of Korean firms based on their voluntary environmental disclosure.

Firm Type		Disclosing CO_2	Not Disclosing CO_2	Total
All Firms		830	3628	4458
	environmentally sensitive	251	919	1170
	non-environmentally sensitive	579	2709	3288
Chaebol		458	798	1256
	environmentally sensitive	115	220	335
	non-environmentally sensitive	343	578	921
Non-chaebol		372	3830	3202
	environmentally sensitive	136	699	835
	non-environmentally sensitive	236	2131	2367

GICS (The Global Industry Classification Standard). The rest of sectors is defined as non-environmentally sensitive firms. Further, we exclude financial firms.

We choose those affiliated with *chaebols*, as defined by the KFTC, and assign them to a *chaebol* group, and rest of the sample to non-*chaebols* group. As a result, the observation number of firm samples is 4458 which is composed of 1256 *chaebol*-affiliates and 3202 non-*chaebol* affiliates. Accordingly, the observation number of our firm sample is 830, which is made up of 458 *chaebols* and 372 non-*chaebols*. Among all firms, the sample number of environmentally friendly firms and non-environmentally friendly firms are 1170 and 3288 which are divided into 335, 921 for *chaebols* and 835, 2367 for non-*chaebols* respectively. Again, the observation number of environmentally friendly and non-environmentally friendly firms are 251 and 579, which are divided into 115, 343 for *chaebols* and 136, 236 for non-*chaebols* respectively. The details for firm samples are presented in Table 1 below.

In our sample, around 18.6% (830/4458) of all firms voluntarily disclosed their carbon emission. 36.5% (458/1256) of *chaebol*-affiliated firms and 11.6% (372/3202) of non-*chaebol* affiliates disclosed carbon emission respectively, implying that substantially larger number of *chaebol*-affiliated firms chose to disclose their carbon emission.

3.2. Variables

3.2.1. Stock price crash risk

In employing a measure of price crash risk, we adopt the methodology of Chen et al. (2001). This is based on each firm's weekly returns estimated as market model residuals. Using firm-specific returns ensures that our price crash risk measures reflect firm-specific factors rather than broad market movements. We estimate the following expanded market model regression:

$$\gamma_{i,t} = \alpha_j + \beta_1\gamma_{m,t-2} + \beta_2\gamma_{m,t-1} + \beta_3\gamma_{m,t} + \beta_4\gamma_{m,t+1} + \beta_4\gamma_{m,t+2} + \varepsilon_{it} \quad (1)$$

Where $\gamma_{i,t}$ is the return on stock j in week t, and $\gamma_{m,t}$ refer to the return on the market index in week t. The firm-specific weekly return for firm j in week t ($W_{J,t}$) is calculated as natural logarithm of 1 plus the residual return from Eq. (1). Employing the methodology of Chen et al. (2001), we calculate our first baseline measure of skewness, denoted by *NCSKEW*, by taking the negative of the third moment of firm-specific weekly returns for each year and normalizing it by the standard deviation of firm-specific weekly returns which is raised to the third power. *NCSKEW* is calculated as follows for each firm j in year t as following:

$$NCSKEW_{i,t} = -\frac{n(n-1)^{3/2}\sum W_{i,s}^3}{(n-1)(n-2)\left(\sum W_{i,s}^2\right)^{3/2}} \quad (2)$$

Next, our second baseline measure of stock price crash is *DUVOL*. This measure refers to a down-to-up variance of firm-specific weekly returns (Chen et al., 2001). To be specific, *DUVOL* means the standard deviation of "down"-weekly firm-specific weekly returns, which is scaled by the number of "down"-weeks minus one. The extracted value is then divided by the standard deviation of "up"-weekly firm-specific weekly returns, which is also scaled by the number of "up"-weeks minus one over a year. The detailed expression for *DUVOL* is presented as following:

$$DUVOL_{i,t} = ln\left[\frac{(n_u-1)\sum_{DOWN}W_{i,s}^2}{(n_d-1)\sum_{UP}W_{i,s}^2}\right] \quad (3)$$

3.2.2. Environmental information disclosure

Previous researches employ a variety of EID scores which are, for example, collected from annual reports and social responsibility reports of firms (Clarkson et al., 2008; Meng et al., 2013; Zhang et al., 2022). Despite the methodology suggested by prior studies, we apart from these approaches due to the limitation of environmental data as the assessment of firms' environmental performance is at development stage. Instead, we choose CDP reports as main source of gathering data of Korean firms' which "voluntarily" disclose carbon emission. Upon request, firms submit their carbon emission amount to CDP. Once they decide to submit, they are more likely to decide to re-submit in the future (Stanny, 2013). Then, the repeated interaction between firms and CDP would increase the cost of reporting untruthfully; as more firms decide to report, the assurance of emissions is widespread (Matsumura et al., 2014). For our research, we manually check the CDP data in Bloomberg Terminal, which is originally published by CDP, to check whether Korean firms which are asked to disclose their carbon emission responded. We create a dummy variable which equals to 1 if firms responds to CDP by disclosing their carbon emission in year t and 0 for firms which do not disclose their carbon emission to CDP in year t.

The use of CDP data is becoming prevalent in growing number of international researches on carbon emissions and carbon disclosure (Alsaifi et al., 2020; He et al., 2013; Liu et al., 2023; Lee and Cho, 2021; Matisoff et al., 2012). The popularity of CDP data on previous research could be due to reliability, standard format, and most importantly, voluntary characteristics of firm's environmental disclosure (Depoers et al., 2016). Zhang and Liu (2020) report that over 7000 firms which account for >50% of the global stock market value, have disclosed their carbon information through CDP reports by 2018. which is known for its high objectivity and authority (Kim and Lyon, 2011).

3.2.3. Control variables

Following prior studies (Kim et al., 2014; Lee et al., 2021; Lee et al., 2022; Zhang et al., 2022), our control variables include *RETURN, SIGMA, DTURN, LogTA, BTD, TOP1, BIG4, FOREIGN, BOARD, REPORT* and *ROA*. The categories of these variables are twofold. First category of our control variables relates to our dependent variable, stock price crash risk. According to Chen et al. (2001), trading volume past returns are indicators of stock price crash. Thus, we control for return (*RETURN)* and a monthly averaged detrended stock turnover *(DTURN)*. We also control for stock volatility *SIGMA* as it volatile stocks are prone to price crash risk (Cao et al., 2022). As firm size is closely related with stock price (Cheung and Ng, 1992), we control for yearly changes in firm size (*LogTA)* and book-to-tax differences *(BTD)*. We further include return-to-asset ratio (*ROA*) as firms' financial performance relates to stock price crash (Liu and Ren, 2019).

The rest of control variables relate to characteristics of Korean firms. In consideration of the influence of large shareholders and foreign shareholders (Kim and Gong, 2014; Kim and Cho, 2019), we control for shares of largest shareholders (*TOP1)* and foreigners (*FOREIGN)*, both of which are divided by all shares. In order to control for audit quality, which is known to cause stock price crash (Chae and Hwang, 2017), we

Table 2
Variable definition.

Variables	Variable Definition	Source
NCSKEW	Negative coefficient of skewness	FnGuide
DUVOL	Down-to-up variance of firm-specific weekly returns	FnGuide
RETURN	Yearly returns	FnGuide
SIGMA	Standard deviation of firm's weekly returns	FnGuide
DTURN	Monthly averaged detrended stock turnover summed by year	FnGuide
LogTA	Changes in yearly firm size	FnGuide
LEV	Leverage ratio, calculated as total liability divided by book value of total assets	FnGuide
BTD	Book to tax differences	FnGuide
TOP1	Shares held by the largest shareholder	FnGuide
BIG4	A dummy variable which equals to 1 if the four largest audits employed for a firm i in year t, 0 otherwise	FnGuide
FOREIGN	Shares held by foreign investors	FnGuide
BOARD	Percentage of external directors	FnGuide
REPORT	Natural logarithm of one plus research reports for firm i in year t	FnGuide
ROA	Return on assets ratio, calculated as income before extraordinary items divided by total assets	FnGuide
DISC_CO_2	1 if Carbon Emission Disclosed, 0 otherwise	Bloomberg
SM (Surplus management)	Discretionary accruals after adjusting the total assets, following Yuzhu and Song (2022)	Google trends
IA (Internet attention)	Web search volume index, following Kim and Kwon (2017)	FnGuide
MA(Media attention)	Search volume index[a]	FnGuide

[a] The data for each company obtained through Google Trends and is calculated as ln(sum+1), following He et al. (2013).

set a dummy variable (*BIG4)* which equals to 1 if the four largest audit firms are employed for a firm i in year t, 0 otherwise. In order to control for ties between firm managers and outside directors, we control for the number of outside directors divided by the sum of the number of executive and external directors (*BOARD)*. Lastly, we control for analyst coverage (*REPORT)*, which is natural logarithm of one plus analyst reports. The Table 2 presents the detailed explanation of each (in)dependent variable in our empirical model.

Subsequently, Table 3 provides the summary statistics of firm-specific data along with EID data, which is denoted as *DISC_CO₂*. The table describes the mean, minimum values, standard deviation, first quartile, median, third quartile and maximum values. In the table, the mean value of *DISC_CO₂* is 0.186, meaning that relatively large number of firms chose not to reveal their carbon emission. The median and mean values of *RETURN* and *ROA* are 0.95, 11.3 and 2.8 and 2.27 respectively, implying that firms, in average, had positive returns in our sample period. On the other hand, the median and mean values of *LEV* are 1.04 and 1.61 respectively, suggesting that relatively large number of Korean firms has high leverage ratio.

Next, we present correlation for main variables. The Table 4 shows the correlation for our dependent and independent variables. The high correlation coefficients to *NCSKEW* are *ROA*, *DISC_CO₂* and *BOARD*, which are 0.071, 0.059, 0.093 at all significant level at 1%. As well, the high coefficient of 0.974 between *NCSKEW* and *DUVOL* is statistically significant at 1% level.

3.2.4. Model

Next, we describe our regression model. In order to test H-1, H-2 and H-3, we regress stock price crash on EID and other control variables using data from previous year. The equations are:

$$CrashRisk_{i,t+1} = \beta_0 + \beta_1 EID_{i,t} + \gamma \sum Controls_{i,t} + \varepsilon_{i,t+1} \quad (4)$$

$$CrashRisk_{i,t+1} = \beta_0 + \beta_1 EID_{i,t} + \gamma \sum Controls_{i,t} + Year_{i,t} + Firm_{i,t} + \varepsilon_{i,t+1} \quad (5)$$

$$CrashRisk_{i,t+1} = \beta_0 + \beta_1 EID_{i,t} + \beta_2 Chaebol_{i,t} + \gamma \sum Controls_{i,t} + Year_{i,t} + Firm_{i,t} + \varepsilon_{i,t+1} \quad (6)$$

where $CrashRisk_{i,t+1}$ is the stock price crash risk of firm i in year t measured by *NCSKEW* and *DUVOL* in Eqs. (4) and (5). The Eq. (4) is without year and firm effect, and the Eq. (5) is with both year and firm effect. $Control_{i,t}$ are the aforementioned control variables. $\varepsilon_{i,t}$ is the disturbance term. The Eq. (6) includes a dummy variable which indicates whether firm belongs to *chaebols*; the dummy variable equals to 1 if firm is affiliated to *chaebol*, 0 otherwise.

Further, to test H4a, H4b and H4c, we introduce following models which are based on Eqs. (4), (5) and (6).

$$Mediator_{i,t} = \beta EID_{i,t} + \gamma \sum Controls_{i,t} + Year_{i,t} + Firm_{i,t} + \varepsilon_{i,t+1} \quad (7)$$

$$CrashRisk_{i,t+1} = \beta EID_{i,t} + \eta Mediator_{i,t} + \gamma \sum Controls_{i,t} + \varepsilon_{i,t+1} \quad (8)$$

In above equations, $Mediator_{i,t}$ refers to a mediating variable for each firm i in year t which are measured in surplus management, internet attention and media attention. Based on the framework of Zhang et al. (2022), we construct mediation analysis in order to test the hypothesis on three channels in the relationship between voluntary environment disclosure and stock price crash.

4. Empirical results

4.1. EID analysis

Now we present the baseline results of the EID on stock price crash.

Table 3
Statistical summary.

	Mean	Std. Dev.	Min	Max	25%	50%	75%
NCSKEW	−0.316	0.751	−2.585	1.786	−0.699	−0.249	0.12
DUVOL	−0.198	0.344	−1.045	0.672	−0.428	−0.189	0.028
RETURN	11.299	45.439	−60.73	207.6	−16.947	0.95	27.105
SIGMA	5.82	2.694	1.857	15.705	3.949	5.208	6.965
DTURN	0	0.026	−0.129	0.126	−0.002	0	0.002
LogTA	13.014	1.794	9.751	17.292	11.538	12.859	14.301
LEV	1.61	2.085	0.089	14.894	0.541	1.04	1.865
BTD	0.12	0.233	−0.796	1.322	0	0.087	0.222
TOP1	43.115	16.663	7.87	81.4	30.818	42.7	54.705
BIG4	0.702	0.457	0	1	0	1	1
FOREIGN	12.178	13.82	0	60.374	1.789	6.67	18.45
BOARD	0.349	0.184	0	0.75	0.25	0.333	0.5
REPORT	1.149	1.267	0	3.367	0	0.693	2.485
ROA	2.274	7.977	−34.41	22.91	0.382	2.8	5.908
DISC_CO_2	0.186	0.389	0	1	0	0	0

Table 4
Correlation for All Firm.

	NCSKEW	RETURN	SIGMA	DTURN	LogTA	LEV	BTD	TOP1	BIG4	FOREGIN	BOARD	REPORT	ROA	DUVOL	DISC_CO$_2$
1.NCSKEW	1														
2.RETURN	−0.243***	1													
3.SIGMA	−0.257***	0.186***	1												
4.DTURN	−0.082***	0.229***	0.149***	1											
5.LogTA	0.212***	0.036**	−0.224***	−0.035**	1										
6.LEV	−0.01	−0.071***	0.147***	−0.022	0.084***	1									
7.BTD	0.03**	0.115***	−0.201***	−0.001	0.153***	−0.221***	1								
8.TOP1	−0.052***	0.028*	−0.139***	0.024	−0.08***	−0.128***	0.13***	1							
9.BIG4	0.123***	0.02	−0.208***	0.018	0.501***	0.11***	0.137***	0.039***	1						
10.FOREIGN	0.183***	0.074***	−0.271***	0.006	0.698***	−0.035**	0.198***	−0.195***	0.391***	1					
11.BOARD	0.093***	0.02	−0.044***	−0.038***	0.186***	0.069***	−0.005	−0.085***	0.16***	0.11***	1				
12.REPORT	0.232***	0.045***	−0.204***	−0.01	0.835***	0.11***	0.155***	−0.165***	0.452***	0.664***	0.196***	1			
13.ROA	0.071***	0.27***	−0.198***	−0.007	0.292***	−0.327***	0.426***	0.106***	0.171***	0.308***	0.069***	0.274***	1		
14.DUVOL	0.974***	−0.27***	−0.286***	−0.088***	0.193***	−0.022	0.032**	−0.043***	0.113***	0.176***	0.085***	0.214***	0.064***	1	
15.DISC_CO$_2$	0.059***	−0.007	−0.098***	−0.008	0.452***	0.051***	0.095***	−0.067***	0.227***	0.334***	−0.02	0.43***	0.055***	0.052***	1

Table 5
EID Analysis for all firms.

	(1)	(2)	(3)	(4)
	All Firm	All Firm	All Firm	All Firm
	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO$_2$	−0.1063***	−0.0529***	−0.0568**	−0.0308**
Control variables				
RETURN	−0.0025***	−0.0015***	−0.0026***	−0.0015***
SIGMA	−0.0594***	−0.0277***	−0.0582***	−0.027***
DTURN	−0.0833	0.0225	−0.1277	0
LogTA	0.0342***	0.0117**	0.0585***	0.0224***
LEV	−0.0033	−0.002	−0.0015	−0.0013
BTD	0.0135	0.0009	0.0268	0.0067
TOP1	−0.0026***	−0.001***	−0.0025***	−0.0009***
BIG4	−0.0107	−0.009	−0.0471*	−0.0251**
FOREIGN	−0.0016*	−0.0003	−0.0019**	−0.0005
BOARD	0.1417**	0.0589**	−0.0848	−0.044
REPORT	0.0842***	0.038***	0.0614***	0.0279***
ROA	−0.0035*	−0.001	−0.0041**	−0.0013
Constant	−0.3637**	−0.168**	52.1318***	23.4603***
Year effect	off	off	on	on
Firm effect	off	off	on	on
R-squared	0.1409	0.1572	0.153	0.1682
Adj. R-squared	0.1384	0.1547	0.1502	0.1654
Observations	4458	4458	4458	4458

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In Table 5 below, columns (1), (2), (3) and (4) present the results for all firms without year and firm effects and with both effects for our two proxies, *NCSKEW* and *DUVOL*, sequentially. The regression coefficients are −0.106, −0.053, −0.057 and −0.031 respectively, all of which are statistically significant at the 1% ∼ 5% level, implying that EID reduce the stock price crash of Korean firms in next year. In other words, Korean firms' voluntary environmental disclosure leads to a decreased chance of firm risk, as proxied in stock price crash risk. The results support H-1.

4.2. EID analysis for (non)chaebols and (non)environmental industry

Subsequently, Table 6 illustrate the results for *chaebols* and non-*chaebols* in same order. The regression results are quite similar to the results in Table 5 (All firms), but the statistical significance is strongly found for non-*chaebols*. When firm and year effects are not included, we find that the coefficients of EID for *chaebols* and non-*chaebols* are −0.064, −0.035 and −0.132, −0.064 respectively; for *chaebols*, only the coefficient for *DUVOL* is statistically significant at 10% level, while both coefficients for non-*chaebols* is for both proxies (*NCSKEW*, *DUVOL*) are statistically significant at 1% level. When firm and year effects are included, the coefficients of EID for *chaebols* and non-*chaebols* are 0.028, 0.015 and −0.096, −0.051 respectively, in which only the coefficients of latter are statistically significant.

The analysis above suggests that the effect of EID on stock price crash is more pronounced for non-*chaebols*. Put it differently, the voluntary environmental disclosure of non-*chaebols* decreases a chance of firm risk. In contrast, the mitigating effect of the EID of *chaebols* is weakly in found. Thus, our results support H-2.

Our analysis is further supported by following coefficient test. The coefficient test is to evaluate for statistically significant differences between *chaebols* and non-*chaebols*. The previous analysis for *chaebols* and non-*chaebols* indicates that the coefficients for latter are statistically significant. To support this finding, the effect (p-value) of interaction term for *chaebols* should be insignificant. The equation for the coefficient test is as the following:

$$CrashRisk_{i,t+1} = \beta_0 + \beta_1 EID_{i,t} + \beta_2 Chaebol_{i,t} + \beta_3 (EID \times Chaebol) + \gamma \sum Controls_{i,t} + Year_{i,t} + Firm_{i,t} + \varepsilon_{i,t+1} \quad (9)$$

For analysis, we set *chaebols* as 1 and 0 otherwise. The following Table 7 presents the results. The results for *NCSKEW* show that the

Table 6
EID Analysis for chaebols and non-chaebols.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Chaebol NCSKEW	Chaebol DUVOL	Chaebol NCSKEW	Chaebol DUVOL	Non-chaebol NCSKEW	Non-chaebol DUVOL	Non-chaebol NCSKEW	Non-chaebol DUVOL
DISC_CO_2	−0.0636	−0.0346*	0.028	0.0149	−0.1321***	−0.0644***	−0.0958**	−0.0511***
Control variables								
RETURN	−0.0025***	−0.0014***	−0.0027***	−0.0015***	−0.0025***	−0.0015***	−0.0026***	−0.0015***
SIGMA	−0.059***	−0.0294***	−0.0516***	−0.0251***	−0.0621***	−0.0284***	−0.0613***	−0.028***
DTURN	0.3632	0.2028	0.3152	0.1637	−0.0897	0.0205	−0.1188	0.0103
LogTA	0.01	0.0051	0.0139	0.0069	0.0512***	0.0172***	0.0782***	0.0273***
LEV	−0.012	−0.0044	−0.0071	−0.0018	0.0043	0.0006	0.0062	0.0013
BTD	0.0002	−0.0156	0.0288	−0.0001	0.0121	0.0035	0.0251	0.0084
TOP1	0	0.0002	0.001	0.0007	−0.0033***	−0.0013***	−0.0034***	−0.0013***
BIG4	−0.0738	−0.0281	−0.106	−0.046	−0.0033	−0.0043	−0.0397	−0.0179
FOREIGN	0.0003	0.0007	0.0012	0.0012	−0.0024**	−0.0008*	−0.0024**	−0.0008
BOARD	0.0663	0.0335	−0.3829***	−0.2127***	0.1935***	0.0767**	0.0164	0.0112
REPORT	0.1147***	0.0478***	0.097***	0.0382***	0.0918***	0.0427***	0.0659***	0.033***
ROA	0.0006	0.0012	0.0001	0.001	−0.0044**	−0.0015	−0.0047**	−0.0016*
Constant	−0.1857	−0.1516	94.7264***	51.6077***	−0.5341***	−0.2225***	42.6487***	15.7989***
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1332	0.1345	0.1747	0.1835	0.1378	0.1604	0.1484	0.1681
Adj. R-squared	0.1241	0.1254	0.1647	0.1736	0.1343	0.1569	0.1444	0.1642
Observations	1256	1256	1256	1256	3202	3202	3202	3202

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 7
Coefficient test (interaction).

	(1)	(2)
	Chaebol NCSKEW	Chaebol DUVOL
DISC_CO_2	−0.0718*	−0.0364*
Chaebol	−0.1096***	−0.0449***
Interaction	0.0463	0.021
Control variables		
RETURN	−0.0022***	−0.0013***
SIGMA	−0.0521***	−0.0244***
DTURN	0.0229	0.0397
LogTA	0.0621***	0.0233***
LEV	−0.0004	−0.0003
BTD	−0.005**	−0.0027***
TOP1	−0.0031***	−0.0011***
BIG4	−0.0428	−0.0253*
FOREIGN	−0.0026***	−0.0008*
BOARD	−0.0428	−0.0337
REPORT	0.0721***	−0.0331***
ROA	−0.0002	0.0001
Constant	48.2847***	22.6701***
Year effect	−0.0243***	−0.0114***
Firm effect	0.0002***	0.0001**
R-squared	0.1294	0.1495
Adj. R-squared	0.1261	0.1463
Observations	4458	4458

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

coefficients for EID and interaction term are −0.072 and 0.0463, in which the sum of each coefficient is <0, indicating that the EID for *chaebols* may "potentially" cause negative effect on stock price crash, like non-*chaebols*.

However, it is important to note that the coefficient for the interaction term is not statistically significant, so that we further conduct the Wald test in order to confirm a set of variables (EID and interaction term) are 'collectively statistically significant' for our model. Our separate analysis for β_1 and β_3 show that the Wald stat. is 3.229, but the p-value is 0.199(4.089 and 0.129 for *DUVOL*). This result implies that the 'collective' statistical significance for *chaebols* is not found, which is in align with our previous analysis for non-*chaebols*, supporting H-2.

Next, we test the relationship of EID and stock price crash for firms in environmentally sensitive and non-environmentally sensitive industry. Below, Table 8 presents regression coefficients for all firms under environmentally sensitive firms and non-environmentally sensitive firms without year and firm effects and with both effects sequentially. Subsequently, in Table 9 and Table 10, the results for the same analysis are presented for *chaebols* and non-*chaebols* separately.

In Table 8, the EID of Korean firms in (non)environmentally sensitive industry has negative relationship with stock price crash, suggesting that EID of Korean firms have mitigating effect on firm risk in Korea, especially for non-environmentally sensitive industry. For example, the regression coefficients of both *NCSKEW* and *DUVOL* in environmentally sensitive industry and non-environmentally sensitive industry indicate that only the coefficients for the latter are statistically significant at 1% and 10% level.

This result implies that in general, the EID of Korean firms under non-environmentally sensitive industry mitigates stock price crash. In summary, it is reasonable to claim that the voluntary disclosure of environmental information of Korean firms reduce principal-agent problem. Thus, our analysis supports H-3.

Now, we discuss the results for *chaebols* and non-*chaebols* under environmentally sensitive and non-environmentally sensitive industry in following Table 9 and Table 10. In Table 9, it is evident that the regression coefficients of *chaebols* in environmentally sensitive industry without year and with both effects, are negative values, all of which are not statistically significant. In contrast, the regression coefficients for non-*chaebols* for non-environmentally sensitive industry are at statistically significant level, without year and firm effects and with both effects. The results do not significantly change for the other proxy, *DUVOL*. However, the coefficients of non-*chaebols* in environmentally sensitive industry are only statistically significant without year and firm effect.

In summary, our results well align with the results in Table 6 in that the voluntary environmental disclosure of non-*chaebols* is found to be more pronounced when firms belong to non-environmentally sensitive industry. This suggests that the voluntary disclosure of (non)financial information not only increase firm reputation and visibility (non-*chaebols*), but also, to "voluntarily" increase transparency even in less regulatory environment (non-environmentally sensitive industry). Thus, it is reasonable to suggest that the analysis for *chaebols* and non-*chaebols* under (non)environmentally sensitive industry support H-2 and H-3.

Table 8
EID Analysis for firms in (non)environmentally sensitive industry.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Env. sens.	Env. sens.	Env. sens.	Env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.121**	−0.0676***	−0.0523	−0.035	−0.1023***	−0.0483***	−0.061*	−0.0305*
Control variables								
RETURN	−0.0026***	−0.0016***	−0.0026***	−0.0016***	−0.0025***	−0.0015***	−0.0026***	−0.0015***
SIGMA	−0.066***	−0.0298***	−0.0608***	−0.0275***	−0.0561***	−0.0264***	−0.0558***	−0.0262***
DTURN	−0.1595	−0.106	−0.2746	−0.1587	−0.0826	0.0567	−0.1065	0.043
LogTA	0.0153	0.0001	0.0503**	0.015	0.0375***	0.0142**	0.0578***	0.023***
LEV	0.008	0.0046	0.0098	0.0054	−0.0056	−0.0034	−0.0042	−0.0028
BTD	−0.0118	−0.008	0.0258	0.0092	0.0264	0.0055	0.0333	0.0083
TOP1	0	0.0003	0.0002	0.0004	−0.0033***	−0.0013***	−0.0032***	−0.0013***
BIG4	0.0123	0.0017	−0.0371	−0.0194	−0.0193	−0.012	−0.0507	−0.0258*
FOREIGN	−0.0034*	−0.0015*	−0.0023	−0.0011	−0.0009	0.0001	−0.0015	−0.0002
BOARD	0.0479	−0.015	−0.2237*	−0.139**	0.1583**	0.0756**	−0.0382	−0.013
REPORT	0.1378***	0.068***	0.0909***	0.0482***	0.0723***	0.0311***	0.0559***	0.0239***
ROA	−0.007*	−0.0022	−0.0081*	−0.0027	−0.0025	−0.0007	−0.0029	−0.0009
Constant	−0.2172	−0.0638	70.9847***	31.9112***	−0.3919**	−0.1944**	44.0532***	19.6462***
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1649	0.1797	0.1871	0.1994	01351	0.1536	0.1434	0.1612
Adj. R-squared	0.1555	0.1704	0.1765	0.189	0.1317	0.1502	0.1395	0.1573
Observations	1170	1170	1170	1170	3288	3288	3288	3288

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 9
EID Analysis for chaebols in (non) environmental-friendly industry.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Env. sens.	Env. sens.	Env. sens.	Env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.1074	−0.0556	0.0004	0.0004	−0.0564	−0.0313	0.0289	0.0151
Control variables								
RETURN	−0.0026***	−0.0013***	−0.0026***	−0.0014***	−0.0025***	−0.0014***	−0.0028***	−0.0016***
SIGMA	−0.0811***	−0.0411***	−0.0656***	−0.0329***	−0.0482***	−0.0232***	−0.0438***	−0.0206***
DTURN	−5.4897	−2.7854	−7.9859	−4.1595	0.529	0.2874	0.5751	0.3048
LogTA	0.0231	0.0133	0.0103	0.0049	0.0044	0.0017	0.014	0.0068
LEV	0.0226	0.0068	0.0426	0.0166	−0.0136	−0.0051	−0.0101	−0.0031
BTD	0.0648	−0.005	0.1457	0.0379	0.0023	−0.0051	0.0086	−0.0017
TOP1	0.005**	0.0026**	0.0069***	0.0035***	−0.0023	−0.001	−0.0013	−0.0004
BIG4	−0.03	−0.0005	−0.0975	−0.0328	−0.1218	−0.0612	−0.1309	−0.067
FOREIGN	0.0008	0.0004	0.0055	0.0027	0.0008	0.001	0.0011	0.0011
BOARD	0.0704	0.0109	−0.3923*	−0.2403**	0.039	0.0273	−0.3962***	−0.2121***
REPORT	0.1276***	0.0523**	0.114***	0.0469**	0.1269***	0.0582***	0.0967***	0.0415**
ROA	0.0049	0.0025	0.0023	0.0011	−0.0001	0.0011	0.0003	0.013
Constant	−0.6121	−0.3488	106.3325***	55.8185***	−0.0556	−0.0847	90.0161***	49.3378***
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.205	0.1866	0.2511	0.2358	0.1184	0.1268	0.1566	0.1732
Adj. R-squared	0.1728	0.1536	0.2159	0.1999	0.1058	0.1143	0.1427	0.1595
Observations	335	335	335	335	921	921	921	921

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

4.3. Mediation analysis

The following Table 11, Table 12 and Table 13 present the results in analyzing mediating roles of surplus management (*SM*), internet attention (*IA*) and media attention (*MA*) respectively. Each table is composed of analysis for all firms (Panel A), *chaebols* (Panel B) and non-*chaebols* (Panel C). The firm and year factor are all controlled in analysis. For each table, column (1) shows the mediation analysis of the variables between EID and mediating variable, which are in accordance with Eq. (7). The column (2) and (3) present the mediation analysis of the variables between EID and stock price crash proxies, *NCSKEW* and *DUVOL*, as shown in Eq. (8). The column (4) through (6), and (7) through (9) represent same analysis for firms in environmentally sensitive industry, and non-environmentally sensitive industry respectively.

For all firms (Panel A) in Table 11 (*SM*), the coefficients of environmental disclosure (*DISC_CO₂*) on stock price crash are negative (−) at statistically significant level, which supports H4a. However, the statistical significance of the rest of the coefficients of environmental disclosure (*DISC_CO₂*) are found only for firms under environmentally sensitive industry. The Panel B further indicates that all of the coefficients for *chaebols* are statistically insignificant, implying that surplus management for *chaebols* have no mediating role in their EID and stock price crash.

The results for non-*chaebols* (Panel C) are quite contrasting. When compared with environmentally sensitive industry (column 5– 6), the coefficients of environmental disclosure for non-*chaebols* under non-environmentally sensitive industry are statistically significant, as shown in column (8) and (9). To summarize, for non-*chaebols*, EID reduces surplus management, which in turn, play a mediating role in their environmental disclosure and stock price crash risk.

Table 10
EID Analysis for non-chaebols in (non) environmental-friendly industry.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Env. sens.	Env. sens.	Env. sens.	Env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.	Non-env. sens.
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.1345*	−0.0808**	−0.0791	−0.0587	−0.1331***	−0.0605**	−0.0962*	−0.0472**
Control variables								
RETURN	−0.0024***	−0.0016***	−0.0025**	−0.0016***	−0.0025***	−0.0015***	−0.0026**	−0.0015***
SIGMA	−0.0662***	−0.0287***	−0.0623**	−0.0272***	−0.06***	−0.0278***	−0.0599**	−0.0278***
DTURN	−0.1102	−0.0645	−0.1658	−0.0858	−0.0833	0.0521	−0.091	0.0514
LogTA	0.0173	−0.0039	0.0624*	0.0137	0.0569***	0.0214***	0.0782***	0.0289***
LEV	0.0075	0.0053	0.008	0.0055	0.0032	−0.0008	0.0052	0
BTD	−0.043	−0.0105	−0.0131	0.0013	0.0289	0.0068	0.0375	0.01
TOP1	−0.0018	−0.0005	−0.0019	−0.0005	−0.0036***	−0.0014***	−0.0036***	−0.0014***
BIG4	0.0304	0.0101	−0.0156	−0.0078	−0.0127	−0.0068	−0.0433	−0.0175
FOREIGN	−0.0042**	−0.0019**	−0.0031	−0.0015	−0.0017	−0.0004	−0.002	−0.0005
BOARD	−0.0007	−0.0431	−0.2449	−0.1386**	0.2465***	0.1089***	0.1134	0.0643
REPORT	0.1585***	0.0867***	0.0915**	0.0608***	0.0768***	0.0329***	0.0605***	0.0272***
ROA	−0.0084*	−0.0026	−0.0089*	−0.0028	−0.0033	−0.0012	−0.0036	−0.0013
Constant	−0.1358	0.0227	63.2844***	24.8055***	−0.6138***	−0.2772***	33.3456***	11.3483**
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1523	0.1818	0.1719	0.1965	0.1349	0.1575	0.1424	0.1625
Adj. R-squared	0.1389	0.1688	0.1567	0.1817	0.1302	0.1528	0.1369	0.1572
Observations	835	835	835	835	2367	2367	2367	2367

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The following Table 12 presents the mediating analysis for internet attention. Similar to Table 11, the coefficients of environmental disclosure (*DISC_CO₂*) on stock price crash for all firms (Panel A) show negative sign (−) at statistically significant level, but the coefficients on the mediating variable are positive sign (+) at statistically significant level for all firm and non-environmentally sensitive industry, as in column (1) and (7). The following Panel B demonstrate that all of the coefficients for *chaebols* are statistically insignificant, implying that internet attention for *chaebols* have no mediating role in their EID and stock price crash.

In contrast, the analysis for non-*chaebols* in column (1) through (3) in Panel C show that the coefficient of the EID on the mediating variable (*IA*) is positive (+) at statistically significant level. Here, the coefficients of the EID on both stock price crash proxies are negative (−) at statistically significant level. In contrast with environmentally sensitive industry (column (4), (5), (6)), the coefficients of the EID on the mediating variable (*IA*) and stock price crash proxy (*NCSKEW*) are statistically significant, as shown in column (7) and (8) respectively. To summarize, the effect of voluntary environmental disclosure on internet attention for non-*chaebols* is positive (+) as firms' effort for voluntary disclosure leads to the increase of public opinion on internet; this, in turn, reduces information asymmetries, decreasing firm risk proxied in stock price crash.

Lastly, the Table 13 illustrates the mediating analysis for media attention (*MA*). The results in this table are not largely different from Table 11 (*SM*) and Table 12 (*IA*). In Panel A, the coefficients of EID on the mediating variable (*MA*) are statistically significant for all firms (column (1)) and all firms in non-environmentally sensitive industry (column (7)). The coefficients of EID on stock price crash are statistically significant for a proxy of *DUVOL* for all firms only. The coefficients for firms under both environmentally sensitive and non-environmentally sensitive industry are not statistically significant, indicating that the increase of media attention for all firms does not lead to the reduction of stock price crash, regardless of their affiliation to environmentally sensitive industry.

For *chaebols* in Panel B, only one coefficient of EID on the mediating variable (*MA*) is statically significant, but the rest of coefficients of EID on both mediating variable and both stock price crash proxies are not statically significant. The results for non-*chaebols* in Panel C are quite interesting. The coefficients of EID on the mediating variable (*MA*) and both stock price crash proxies are statistically significant for non-*chaebols*. The coefficient of EID on the mediating variable for non-environmentally sensitive industry are also partially robust to this analysis, as present in column (7) and (8). This result illustrates that in Korean market, the increase of media coverage mediates the relationship between EID and stock price crash for non-*chaebols*. We interpret that firms' voluntary disclosure of environmental information is regarded as firm transparency to public and investors. This, in turn, would reduce information asymmetries and further lower firm risk proxied in stock price crash.

4.4. Endogeneity test

We employ Sys-GMM model in order to address endogeneity. In line with previous research (Zhang et al., 2022), our idea is that the EID of firms could be affected by the past values of dependent variables. To be specific, firms who experienced stock price crash in past would be willing to disclose their carbon emission in effort to build trust with investors and capital market. As markets penalize firms with less transparency, it is rational to believe that firms with less reputation and visibility are more likely to disclose their environmental information (Ducret and Isakov, 2020; Matsumura et al., 2014).

The Table 14 reports the results of Sys-GMM model for firms based on (1) their affiliation to *chaebols* and (2) environmentally sensitive industry. The Arellano-Bond test for AR (1) and AR (2) in the table show the first and second order serial autocorrelation tests, in which the value is estimated from the values at times $t-1$ and $t-2$. The results in the table generally support our previous findings that the EID and stock price crash have negative relationship for all firms and non-*chaebols* in non-environmentally sensitive industry.

5. Robustness test

5.1. DID analysis for ETS in Korea

Now we conduct additional analysis in order to test robustness. First, employing Difference-in-Difference (DID) methodology, we analyze the impact of Emission Trading Scheme (ETS) in Korea on stock price crash risk. ETS is a mechanism under Kyoto Protocol, which let the markets to put cost on carbon emissions, forming incentives for firms to voluntarily reduce their level of carbon emission.

South Korea has implemented their version of ETS. The first stage

Table 11
Mediation analysis (surplus management).

Panel A: all firms									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firm	All Firm	All Firm	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL
DISC_CO$_2$	0.0003	−0.0602*	−0.0322**	−0.0025	−0.0947*	−0.0578**	0.0009	−0.0516	−0.0254
SM		0.0862	0.0335		0.6093*	0.2789**		−0.0822	−0.0443
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	0.0716	51.7229***	23.4029***	−1.4027	67.0349***	29.7803***	0.5781	44.8846***	20.3179***
R-squared	0.0396	0.154	0.168	0.0388	0.1945	0.2056	0.0438	0.1439	0.1611
Adj. R-squared	0.0364	0.1509	0.165	0.0261	0.1831	0.1943	0.0393	0.1397	0.1569
Observations	4394	4394	4394	1146	1146	1146	3248	3248	3248
Panel B: chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Chaebol	Chaebol	Chaebol	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL
DISC_CO$_2$	0.0009	0.0257	0.0132	0.0028	−0.0455	−0.0226	0.0011	0.0379	0.0194
SM		0.6689*	0.3458*		0.3951	0.1514		0.7348*	0.4069*
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	−1.4795	95.9106***	52.589***	−1.739	103.8627***	54.1245***	−1.1882	91.7762***	50.9835***
R-squared	0.078	0.1754	0.1815	0.1151	0.2614	0.2394	0.0822	0.1565	0.1723
Adj. R-squared	0.0666	0.1645	0.1707	0.0723	0.2232	0.2	0.0666	0.1412	0.1573
Observations	1229	1229	1229	326	326	326	903	903	903
Panel C: non-chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Non-chaebol	Non-chaebol	Non-chaebol	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL	SM	NCSKEW	DUVOL
DISC_CO$_2$	0.0002	−0.1004**	−0.053***	−0.0056	−0.1166	−0.0789**	0.0011	−0.0876*	−0.0423*
SM		0.011	−0.0061		0.608*	0.2844*		−0.1671	−0.0914
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	0.6254	42.3366***	15.749***	−1.0662	59.8318***	23.2084***	1.1729	34.4569***	12.041***
R-squared	0.0386	0.1482	0.1672	0.0314	0.1769	0.2	0.0457	0.1423	0.1627
Adj. R-squared	0.034	0.1439	0.163	0.0133	0.1605	0.184	0.0396	0.1364	0.157
Observations	3165	3165	3165	820	820	820	2345	2345	2345

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

runs between 2015 and 2017, as a start-up period to allow firms to have experience in emission trading. From the Phase I, several changes in the design of the ETS were adopted in the following Phase II which are between 2018 and 2020. For DID analysis, our sample period is from 2013 to 2020, which include two consecutive years (2013– 2014) prior to the initiation of ETS. For each phase, 603 and 659 institutions, including firms and local government, are under ETS.

In our sample, 127 and 176 firms are subject to caps under the K-ETS under Phase I and Phase II respectively. These firms are composed of 58 *chaebols* (Phase I), 78 *chaebols* (Phase 2), and 69 non-*chaebols* (Phase I), 98 non-*chaebols* (Phase II) respectively. Lastly, the observation numbers between 2013 and 2021, are 3343 which are composed of 958 *chaebols* and 2385 non-*chaebols*. The equation for DID is presented as following.

$$CrashRisk_{i,t+1} = \beta_0 + \beta_1 EID_{i,t} + \beta_2 Chaebol_{i,t} + \gamma \sum Controls_{i,t} + \beta_3 Firm_{i,t} + \beta_4 Time_{i,t} + \beta_5 (FirmXTime) + \varepsilon_{i,t+1} \quad (10)$$

The analysis for all firm, *chaebol* and non-*chaebol* is presented in following Table 15. In the table, the results confirm the robustness in Tables 5 and 6. The regression coefficient of all firms −0.068 for *NCSKEW*, which is statistically significant level at 5%. The respective coefficients of *chaebols* and non-*chaebols* are 0.016 and − 0.124, in which only latter is statistically significant at 1% level. The change of our stock price crash proxy to *DUVOL* does not change our results.

Subsequently, the analysis in Table 16 presents the results for firms in environmentally sensitive industry and non-environmentally sensitive industry. This table confirms the results in Table 8. The regression coefficients of firms in environmentally sensitive industry are −0.017 and − 0.015 for *NCSKEW* and *DUVOL*, but are not statistically significant. On the other hand, the coefficients of non-environmentally sensitive firms are −0.082 and − 0.038 for respective proxies, both of which are statistically significant at 5%.

This result implies that even after the adoption of ETS, the voluntary environmental disclosure of firms in non-environmentally industry prevents price crash risk. The effect of voluntary environmental disclosure on stock price crash of non-*chaebols* (Table 15) and firms in non-environmentally industry (Table 16) further support H-2 and H-3. To be specific, the firm characteristics, such as affiliation to *chaebols* and environmentally industry, are further confirmed during the implementation of ETS.

5.2. Analysis for firm size

Lastly, we conduct additional robustness test based on different sizes of firms. In Korean market, *chaebol*-affiliated firms are relatively large in

Table 12
Mediation analysis (internet attention).

Panel A: all firms									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firm	All Firm	All Firm	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL
DISC_CO$_2$	2.106***	−0.0537	−0.0249	−1.0865	−0.0456	−0.0352	3.67***	−0.0598	−0.0237
IA		−0.0031***	−0.0014***		−0.0005	−0.0001		−0.0037***	−0.0017***
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	2703.1684***	64.4105***	29.545***	2771.5369***	85.9551***	34.4425***	2591.4832***	54.3918***	26.2434***
R-squared	0.2044	0.1678	0.1832	0.3091	0.2328	0.2468	0.1872	0.1529	0.1693
Adj. R-squared	0.2006	0.1635	0.179	0.2952	0.2163	0.2306	0.182	0.1471	0.1637
Observations	3132	3132	3132	761	761	761	2371	2371	2371
Panel B: chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Chaebol	Chaebol	Chaebol	Env. sens	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens	Non-env. Sens
	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL
DISC_CO$_2$	−0.3131	0.0221	0.0157	−1.7569	−0.0903	−0.0531	0.3173	0.0356	0.0241
IA		−0.004**	−0.0017**		−0.002	−0.001		−0.0045***	−0.002**
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	2684.6698***	115.7702***	61.2383***	3051.9949***	141.5407***	63.1668***	2438.0034***	105.6714***	58.2762***
R-squared	0.1788	0.1769	0.187	0.456	0.2607	0.2322	0.1574	0.1732	0.1933
Adj. R-squared	0.1651	0.1623	0.1725	0.4144	0.2	0.1692	0.139	0.1539	0.1744
Observations	914	914	914	212	212	212	702	702	702
Panel C: non-chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Non-chaebol	Non-chaebol	Non-chaebol	Env. sens	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens	Non-env. Sens
	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL	IA	NCSKEW	DUVOL
DISC_CO$_2$	4.4139***	−0.0833*	−0.0408*	1.0026	−0.0451	−0.0408	6.9288***	−0.1011*	−0.044
IA		−0.0025**	−0.0011**		−0.0005	0		−0.003**	−0.0014**
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	2779.348***	50.2408***	19.815***	2911.3944***	72.8917***	25.7801***	2676.5389***	37.4641***	14.8947***
R-squared	0.1948	0.1655	0.1864	0.2664	0.2282	0.2633	0.1829	0.1514	0.1698
Adj. R-squared	0.1893	0.1594	0.1805	0.2457	0.205	0.2412	0.1755	0.1432	0.1617
Observations	2218	2218	2218	549	549	549	1669	1669	1669

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

their asset size, plausibly due to business expansion under the support of government and large number of affiliates under same group (Lee et al., 2010; Yoon and Lee, 2019). For analysis, we use the median number of asset size for firms, *chaebols* and non-*chaebols*, and apply year-and-firm effect accordingly. Interestingly, for all *chaebol*-affiliates, 86.1% of samples (1082/1256) are found to be greater than median asset size. In contrast, only 35.9% of samples (1149/3202) for non-*chaebols* are found to be greater than median asset size, which is in accordance with previous researches.

Table 17 presents the analysis for all firms based on asset size without and with firm and year effects. The regression coefficients for all firms over median asset size −0.098 and − 0.049 for *NCSKEW* and *DUVOL*, both of which are statistically significant at 1% level. However, when firm and year effects are controlled, the coefficients are no longer statistically significant, as present in column (3) and (4). In contrast, the regression coefficients for all firms under median asset size are −0.132 and − 0.073 for *NCSKEW* and *DUVOL*, but only the latter is statistically significant at 5% level. If we control firm and year effects, the statistical significance of the latter (*DUVOL*) is further confirmed as in column (4), suggesting that the results are different, depending on the choice of stock price crash proxy. Our analysis implies that the voluntary environmental disclosure of firms with small asset size is more rewarded with the reduction of stock price crash. This could be due to the fact that the firms "under" median asset size are composed mainly of non-*chaebols*, which has less reputation and visibility than *chaebols*, so that the improvement in their environmental disclosure is reflected in the firm samples.

The following Table 18 presents analysis for *chaebols* and non-*chaebols*. This table further confirms our results in Table 6. In contrast with *chaebols* where statistical significance is not found, the statistical significance for non-*chaebols* is strongly found, regardless of their firm asset size. This result implies that the voluntary environmental disclosure of non-*chaebols* mitigates stock price crash more apparently in both large and smaller asset.

The following Table 19 confirms the results in Table 8. We use the median asset size as baseline analysis for firms in environmentally sensitive and non-environmentally sensitive industry. Here, the regression coefficients for firms in environmentally sensitive industry are statistically significant under median asset size, as evident in column (1)

Table 13
Mediation analysis (media attention).

Panel A: all firms									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firm	All Firm	All Firm	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL
DISC_CO$_2$	0.0907*	−0.0573	−0.0264*	−0.1724	−0.0441	−0.0349	0.2473***	−0.0615	−0.0243
MA		−0.0316***	−0.0151***		0.0058	0.0008		−0.0485***	−0.0221***
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	100.3533***	59.2605***	27.3838***	100.9016***	83.9275***	33.9619***	95.9193***	49.3783***	24.04***
R-squared	0.3224	0.1671	0.1829	0.3751	0.2328	0.2468	0.3115	0.1533	0.1699
Adj. R-squared	0.3191	0.1629	0.1787	0.3625	0.2163	0.2306	0.3071	0.1476	0.1643
Observations	3132	3132	3132	761	761	761	2371	2371	2371
Panel B: chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Chaebol	Chaebol	Chaebol	Env. sens	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens	Non-env. Sens
	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL
DISC_CO$_2$	−0.1633**	0.018	0.0137	−0.2766	−0.0787	−0.0479	−0.0733	0.0292	0.0211
MA		−0.033*	−0.0151		0.0293	0.0127		−0.0686***	−0.0325***
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	65.3692***	107.2685***	57.563***	2.4527	135.2996***	60.1239***	68.5129***	99.3092***	55.7346***
R-squared	0.2744	0.1727	0.1839	0.3852	0.2615	0.2326	0.3268	0.172	0.1936
Adj. R-squared	0.2623	0.1579	0.1694	0.3381	0.2009	0.1696	0.3121	0.1527	0.1748
Observations	914	914	914	212	212	212	702	702	702
Panel C: non-chaebols									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Non-chaebol	Non-chaebol	Non-chaebol	Env. sens	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens	Non-env. Sens
	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL	MA	NCSKEW	DUVOL
DISC_CO$_2$	0.2936***	−0.0859*	−0.0416*	0.0789	−0.0454	−0.0407	0.4922***	−0.1034*	−0.0449
MA		−0.0293**	−0.0141**		−0.0022	−0.0015		−0.038**	−0.0172**
Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year	on	on	on	on	on	on	on	on	on
Firm factor	on	on	on	on	on	on	on	on	on
Constant	118.9587***	46.679***	18.3999***	158.1307***	71.8329***	25.9705***	105.7917***	33.3758**	13.0859**
R-squared	0.2414	0.1657	0.187	0.3656	0.2282	0.2633	0.2065	0.1519	0.1704
Adj. R-squared	0.2362	0.1596	0.181	0.3477	0.205	0.2412	0.1993	0.1437	0.1623
Observations	2218	2218	2218	549	549	549	1669	1669	1669

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

to (4). The statistical significance of coefficients over median size are also reported in column (1), (2), (5) and (6), but when firm and year effects are controlled, statistical significance is lost. This result suggests that the EID of firms with small asset size under environmentally sensitive industry, have negative relationship with price crash risk in future.

6. Discussion

Our research takes agency-cost perspective in analyzing the relationship between firms' EID and stock price crash. In particular, we pay attention to heterogenous effect across firms based on their affiliation to *chaebols* and environmentally sensitive industry. Our results are consistent with the idea that the EID of firms with "less affiliation" to both *chaebols* and environmentally sensitive industry have mitigating effect on price crash risk. In other words, the voluntary environmental disclosure of firms in "less visibility and reputation" and "less regulatory environment" is rewarded with substantial risk of firm risk, proxied in stock price crash in our research.

In particular, the EID of non-*chaebols*, in which firm reputation and visibility are "less than" than their counterpart, *chaebols*, have mitigating effect on price crash risk, which is in consistence with previous researches (Doan and Sassen, 2020; Lee and Cho, 2021; Zhang et al., 2022). In consideration of the fact that the environmental awareness in Korean market is still at development stage, the EID of non-*chaebols* which have less reputation than *chaebols*, due to their low profitability and visibility, would be more favored in the eyes of investors and capital market. As investors and capital markets ask more firm transparency for Korean firms rather than growth option, voluntary disclosure of environmental information could be rewarded with less firm risk. In this way, our analysis on *chaebols* and non-*chaebols* suggests that the valuation mechanism across them, are different in the Korean market.

Also, previous researches suggest that if firms with lower expectation on environmental performance "voluntarily" choose to disclose their carbon emission, this would be regarded as their effort to meet global standard (Doan and Sassen, 2020; Iatridis, 2013; Zhang et al., 2022). This result is in line with the aforementioned finding that firms with

Table 14
Sys-GMM analysis of all firms, chaebols and non-chaebols based on their affiliation to environmentally sensitive industry.

Panel A: all firms						
	(1)	(2)	(3)	(4)	(5)	(6)
	All Firm	All Firm	Env. sens	Env. sens	Non-env. sens	Non-env. sens
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.453***	−0.238***	−0.454	−0.233	−0.500***	−0.261***
$NCSKEW_{t-1}$	−0.00104		−0.0881		0.0278	
$NCSKEW_{t-2}$	−0.0126		−0.0488		−0.0149	
$DUVOL_{t-1}$		0.0294		−0.0460		0.0443
$DUVOL_{t-2}$		−0.0111		−0.0837		−0.00674
Constant	−1.361	−0.890	0.820	0.147	−2.245	−1.246
Observations	2836	2836	744	744	2092	2092
AR(1) (p-value)	0	0	0	0	0	0
AR(2) (p-value)	0.494	0.968	0.713	0.545	0.73	0.856
Hansen test (p-value)	0.187	0.228	0.073	0.093	0.497	0.588
Diff. hansen test (p-value)	0.317	0.499	0.057	0.032	0.658	0.771
Panel B: chaebols						
	(7)	(8)	(9)	(10)	(11)	(12)
	Chaebol	Chaebol	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.150	−0.0638	−0.155	−0.0222	−0.0944	−0.0124
$NCSKEW_{t-1}$	0.0591		0.0483		0.0950	
$NCSKEW_{t-2}$	−0.0293		0.108		−0.0789	
$DUVOL_{t-1}$		0.0607		0.162		0.109*
$DUVOL_{t-2}$		−0.0526		0.213		−0.0766
Constant	−0.135	0.242	−2.554	0.364	−0.0236	0.0340
Observations	938	938	261	261	677	677
AR(1) (p-value)	0	0	0.011	0.061	0	0
AR(2) (p-value)	0.96	0.798	0.901	0.968	0.903	0.919
Hansen test (p-value)	0.398	0.23	0.996	0.994	0.566	0.566
Diff. hansen test (p-value)	0.139	0.041	0.97	0.0861	0.148	0.122
Panel C: non-chaebols						
	(13)	(14)	(15)	(16)	(17)	(18)
	Non-chaebol	Non-chaebol	Env. sens	Env. sens	Non-env. Sens	Non-env. Sens
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO_2	−0.392***	−0.200***	−0.412	−0.271	−0.397*	−0.215**
$NCSKEW_{t-1}$	−0.0436		−0.103		−0.0367	
$NCSKEW_{t-2}$	−0.0229		−0.0498		−0.0455	
$DUVOL_{t-1}$		−0.00658		−0.116		−0.0109
$DUVOL_{t-2}$		−0.0151		−0.103		−0.0261
Constant	−0.611	−0.414	1.015	0.229	−0.456	−0.702
Observations	1898	1898	483	483	1415	1415
AR(1) (p-value)	0	0	0.001	0.001	0	0
AR(2) (p-value)	0.414	0.48	0.59	0.825	0.932	0.882
Hansen test (p-value)	0.424	0.514	0.381	0.291	0.207	0.428
Diff. hansen test (p-value)	0.694	0.798	0.522	0.381	0.847	0.873

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

poor or lower-than-expected environmental performance may voluntarily disclose carbon information to meet the "disclosure-performance gap" from a variety of stakeholders (Meng et al., 2014). The disclosure requirement of carbon emission would be previously demanded for firms under environmentally sensitive industry mostly. Contrastingly, firms under non-environmentally sensitive industry would not have been demanded "same level" of carbon disclosure requirement, so that these firms' effort for EID could be regarded as their "voluntary effort" to reduce information asymmetry, thereby resolving principal-agent problem.

Our research also provides important policy implications. For instance, the South Korean government introduced a policy for mandatory environmental disclosure along with social and governance

Table 15
EID Analysis (DID) for all firms, chaebols and non-chaebols.

	(1)	(2)	(3)	(4)	(5)	(6)
	All Firm	All Firm	Chaebol	Chaebol	Non-chaebol	Non-chaebol
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO2	−0.0675**	−0.0335**	0.0161	0.0075	−0.1241***	−0.0611***
Year dummy	−0.1636***	−0.0818***	−0.2302***	−0.1355***	−0.1391**	−0.063**
Treatment	−0.1293**	−0.0609**	−0.1216	−0.0584	−0.0733	−0.0455
DID	0.0581	0.0332	0.1578*	0.0826*	−0.0326	0.0028
Control	yes	yes	yes	yes	yes	yes
Constant	−0.2801	−0.0992	0.0841	0.0185	−0.5243**	−0.1878*
R-squared	0.164	0.1783	0.1769	0.1817	0.1652	0.1837
Adj. R-squared	0.1599	0.1742	0.1626	0.1674	0.1594	0.178
Observations	3254	3254	937	937	2317	2317

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 16
EID Analysis (DID) for firms in (non) environmentally sensitive industry.

	(1)	(2)	(3)	(4)
	Env. sens.	Env. sens.	Non-env. sens	Non-env. sens
	NCSKEW	DUVOL	NCSKEW	DUVOL
DISC_CO2	−0.0169	−0.015	−0.082**	−0.0382**
Year dummy	−0.3494***	−0.1743***	−0.1197**	−0.0602**
Treatment	−0.2278	−0.1135*	−0.132*	−0.062*
DID	0.1806	0.0885	0.0474	0.0306
Control	yes	yes	yes	yes
Constant	0.3695	0.2371	−0.4509**	−0.1874*
R-squared	0.1963	0.2124	0.1559	0.1714
Adj. R-squared	0.1808	0.1972	0.1502	0.1658
Observations	846	846	2408	2408

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 17
Subgroup analysis based on asset size for all firms.

	(1)	(2)	(3)	(4)
	All Firm	All Firm	All Firm	All Firm
	NCSKEW	DUVOL	NCSKEW	DUVOL
Median Asset >50%				
DISC_CO2	−0.0984***	−0.0492***	−0.0232	−0.0098
Control	yes	yes	yes	yes
Constant	−0.3115	−0.2482**	69.4841***	36.3611***
Year effect	off	off	on	on
Firm effect	off	off	on	on
R-squared	0.1282	0.1394	0.1515	0.1651
Adj. R-squared	0.1231	0.1344	0.1458	0.1595
Observations	2231	2231	2231	2231
Median Asset <50%				
DISC_CO2	−0.1316	−0.0734**	−0.1136	−0.0679*
Control	yes	yes	yes	yes
Constant	−0.4925**	−0.1339	40.9281***	12.4338***
Year effect	off	off	on	on
Firm effect	off	off	on	on
R-squared	0.1343	0.1649	0.1433	0.1703
Adj. R-squared	0.1292	0.16	0.1375	0.1646
Observations	2227	2227	2227	2227

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

(ESG) disclosure by 2025, but decided to postpone the implementation, because a majority of firms, which are mostly non-*chaebols*, are found not to be prepared to meet ESG reporting standard.[2] While the "unpreparedness" for environmental disclosure is true for majority of Korean firms, our analysis suggests that the environmental disclosure of non-*chaebols* and firms in non-environmentally sensitive firms, may accelerate the time to meet the global ESG standard while reduce their firm risk *simultaneously*; the government's assistance could be necessary in firms disclosing their environmental information including carbon emission such as Scope 1 and 2.

7. Conclusion

Our major findings are as follows. First, we find that the environmental disclosure information of Korean firms, as measured in EID, has a negative relationship with price crash risk in general, which is in consistence with previous researches (Lee et al., 2022; Dumitrescu and Zakriya, 2021; Bae et al., 2021; Kim et al., 2014). Second, we provide evidence on the heterogeneity effect between *chaebols* and non-*chaebols*. To be specific, the EID of only non-*chaebols* has negative relationship with price crash risk, meaning that their disclosure of environmental information mitigates price crash risk. Specifically, the environmental information disclosure of non-*chaebols*, whose visibility and reputation are less than those of *chaebols*, is regarded as effort for decreasing firm risk by reducing information asymmetries. Lastly, the negative relationship of EID and stock price crash for non-environmentally sensitive industry is confirmed in our study. This suggests that the affiliation to this specific industry would decrease price crash risk for firms which endeavor to disclose their environmental performance, especially for non-*chaebols*. All of our major findings are further confirmed in our mediating analysis under three channels: Surplus management, internet attention and media attention.

The contributions of this research are as following. First, we verify empirical evidence supporting the traditional view on principal-agency problem in the case of Korean firms. Our analysis highlights the firms' tendency to disclose their environmental information which reduce information asymmetries by decreasing firm risk proxied in stock price crash. Second, our finding confirms firm heterogeneity on environmental policy determination in developing market (Lee and Cho, 2021; Zhang et al., 2022) Especially, the EID of non-*chaebols* with "less reputation and visibility" aspect, prevents stock price crash, which are evidenced in our three-channel mediating analysis. Third, our results also suggest that firms' affiliation to non-environmentally sensitive industry "strengthens" the effect of EID on stock price crash, since the efforts of firms in non-regulatory environment are regarded as reducing information asymmetries, especially for non-*chaebols*.

Our results could be temporary as the understanding and implementation of environmental policy in Korea are still at early stage. As the regulation on environmental disclosure becomes stricter, we expect that the firm risk, as measured in stock price crash, would reduce as firms are more willing to disclose their environmental information voluntarily, which are more rewarded by investors and capital market. The further analysis is left for future research.

[2] Previously, the Financial Services Commission (FSC) in Korea announced the implementation of ESG disclosure for KOSPI listed firms with >2 trillion won ($ 1.5 billion) in assets.Seon, H.G., 2023. Korea delays ESG reporting rules for firms to 2026 or later. The Korea Economic Daily Global Edition. https://www.kedglobal.com/esg/newsView/ked202310160022.

Table 18
Subgroup analysis based on asset size for chaebols and non-chaebols.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Chaebol	Chaebol	Chaebol	Chaebol	Non-chaebol	Non-chaebol	Non-chaebol	Non-chaebol
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
Median Asset >50%								
DISC_CO$_2$	−0.0559	−0.0264	0.044	0.0278	−0.1392***	−0.07***	−0.0891*	−0.0453**
Control	yes	yes	yes	yes	yes	yes	yes	yes
Constant	−0.3437	−0.2358	105.4148***	57.5639***	−0.4468	−0.338**	43.5882***	21.3256***
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1216	0.1296	0.1763	0.1914	0.1473	0.1599	0.1567	0.1695
Adj. R-squared	0.1109	0.119	0.1647	0.18	0.1376	0.1503	0.1456	0.1585
Observations	1082	1082	1082	1082	1149	1149	1149	1149
Median Asset <50%								
DISC_CO$_2$	0.1843	0.0486	0.197	0.0541	−0.2131**	−0.1054**	−0.2033**	−0.1031**
Control	yes	yes	yes	yes	yes	yes	yes	yes
Constant	1.1791	0.6419	31.1675	15.358	−0.6082**	−0.1885*	40.2273***	11.6668**
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.3027	0.2815	0.3063	0.2856	0.135	0.1679	0.1446	0.1736
Adj. R-squared	0.2398	0.2167	0.233	0.2102	0.1295	0.1626	0.1383	0.1675
Observations	158	158	158	158	2069	2069	2069	2069

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 19
Subgroup analysis based on asset size for (non)environmentally sensitive firms.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Env. sens	Env. sens	Env. sens	Env. sens	Non-env. sens	Non-env. sens	Non-env. sens	Non-env. sens
	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL	NCSKEW	DUVOL
Median Asset >50%								
DISC_CO$_2$	−0.1334**	−0.0619**	0.011	0.0148	−0.0879**	−0.045***	−0.0278	−0.014
Control	yes	yes	yes	yes	yes	yes	yes	yes
Constant	−0.2335	−0.2204	100.5924***	52.9185***	−0.3318	−0.2649**	60.9136***	31.6332***
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1585	0.1665	0.2075	0.219	0.1234	0.1362	0.1412	0.1558
Adj. R-squared	0.1364	0.1446	0.1834	0.1952	0.1167	0.1296	0.1336	0.1484
Observations	509	509	509	509	1722	1722	1722	1722
Median Asset <50%								
DISC_CO$_2$	−0.243*	−0.1357**	−0.2951**	−0.1536**	−0.1041	−0.0618	−0.0588	−0.0473
Control	yes	yes	yes	yes	yes	yes	yes	yes
Constant	−0.0716	0.1611	53.6652**	18.9393**	−0.571**	−0.1967*	33.5014***	8.2936
Year effect	off	off	on	on	off	off	on	on
Firm effect	off	off	on	on	off	off	on	on
R-squared	0.1453	0.1874	0.1618	0.1977	0.1348	0.1657	0.1408	0.1688
Adj. R-squared	0.1252	0.1683	0.1391	0.1759	0.128	0.1591	0.1329	0.1612
Observations	568	568	568	568	1659	1659	1659	1659

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

CRediT authorship contribution statement

Jinhyung Cho: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing. **Gunhee Lee:** Data curation, Formal analysis, Methodology. **Mincheol Bae:** Data curation, Formal analysis, Resources. **Joongchan Sohn:** Formal analysis, Methodology, Visualization. **Chanwoo Han:** Conceptualization.

Declaration of competing interest

We have no known conflict of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107394.

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