Twitter Carbon Information and Cost of Equity: The Moderating Role of Environmental Performance

ABSTRACT

This study examines the moderating role of a firm's environmental performance, measured by its environmental strength and concern ratings, on the influences of Twitter dissemination of carbon-related information (Carbon_Tweets) on a firm's cost of equity (COE). Our key focus is to provide an insight as to whether different levels of environmental strength and concern would influence the effect of Carbon_Tweets on the COE. Employing the sample of non-financial NASDAQ firms covering the period between 2009 and 2015, we found that the negative association of Carbon_Tweets and COE is strengthened for firms with higher levels of environmental concerns; meanwhile, the results stay the same for different levels of environmental strength. These findings imply that although all firms can achieve lower COE by employing Twitter as a dissemination channel of Carbon information, firms with a concerning environmental status may benefit more by strategically disseminating via Twitter.

Keywords: Social Media; Twitter; Climate Change: Carbon Emission; Environmental Performance; Cost of Equity

1. Introduction

Over the past decades, the presence and impacts of climate change have attracted great interest from individuals, media, managers and regulators due to its impact on our life (Albarrak, Elnahass & Salama, 2019). With the rising interest, firms exhibit a strong motivation to enhance their environmental performance, transparency and dissemination levels (Sprengel & Busch, 2011; Weinhofer & Hoffmann, 2010; El Ghoul et al., 2018). Recently, social media has become an important channel for firms to disseminate their information by effectively expanding the reach of their carbon-related information to a broader investor circle and maximising the moral capital effects on corporate financial outcomes. Furthermore, social media platforms such as Twitter has been labelled a resourceful channel that helps firms address unfavourable activities/news by replying to users' concerns and comments (L. Lee, Hutton, & Shu, 2015; Mazboudi & Khalil, 2017; Cade, 2018; Albarrak, Elnahass, Papagiannidi & Salama, 2020). As such, this study extends this line of research by investigating whether a firm's current environmental values would moderate the negative effects of carbon-related messages over Twitter (Carbon_Tweets) on COE in terms of environmental concern and environmental strength.

Firms can create 'moral' capital and relational wealth if they are able to signal to the market their pro-environmental intentions and actions, which in turn alleviate the corporate risk and enhance firm values (Godfrey, Merrill & Hansen, 2009). Previous literature (see Plumlee et al., 2015) argues that managers may use different reporting strategies around "good and bad earnings". As such, managers may impose different reporting strategies depending on how positive or negative their environmental images. For instance, previous literature (Strike et al., 2006; Dunbar et al., 2020) argues that a firm's environmental concern causes a more negative impact than what environmental strength could generate. Therefore, we aim to provide further insights into whether the investors positively value and reward firms with a lower cost of equity for their use of Twitter in disseminating the carbon-related information in regard to firm's environmental images captured by environmental concern (negative aspects) and environmental strength (positive aspects).

Using the implied cost of equity (COE) based on the average of four COE estimates, 1) we find that firms that use Twitter to disseminate carbon-related information have a lower COE. This finding implies that investors positively value the firms' carbon transparency. Extending this finding, 2) we find that the negative effect of *Carbon_Tweets* on COE is negatively influenced by a firm's environmental concern but not environmental strength. This indicates that firms with concerning environmental situations should not constrain themselves but should be more encouraged in employing Twitter to disseminate their carbon-related information. Indeed, the rewards (i.e. lower COE) those firms can get through Twitter are greater than firms with only a high environmental strength can achieve. These results are consistent with the notion that interactive social media platforms such as Twitter help firms address the negative impact of their activities (L. Lee et al., 2015; Mazboudi & Khalil, 2017; Cade, 2018; She & Michelon, 2019). In addition, our findings are robust after controlling for endogeneity problems and many variables known to influence the COE.

Additionally, this research contributes to several areas in the literature by addressing a newsworthy question, such as whether firms are benefited by employing Twitter to voluntarily disseminate their carbon-related news amid their current levels of environmental concern and strength on the cost of equity. First, the research contributes to a firm's communication technology by showing the benefit of disseminating carbon-related information over Twitter on reducing the cost of equity, which means less costly financing (e.g. Blankespoor *et al.*, 2014; L. Lee *et al.*, 2015; Albarrak et al., 2020). Second, while prior research (Kim, An, & Kim, 2015; Balvers, R., Du, D.

& Zhao, 2017; Jung, Herbohn, & Clarkson, 2018; Lemma, Feedman, Mlilo, & Park, 2019; Bui, Moses, & Houqe, 2020) have examined the impact of carbon disclosure, emission intensity, temperature shock and carbon risk on the cost of equity; our research focus on the impact of firm's dissemination activity of carbon-related information over Twitter. Meanwhile, while Albarrak et al. (2019) have reported that the dissemination of carbon information over the social media platform Twitter reduces the firm cost of equity (COE), our study is distinguished by focusing on the use of Twitter as a dissemination channel for environment- and carbon-related information in relation to firm environmental performance on COE.

The remainder of the paper is structured as follows. Section 2 discusses literature and hypothesis development. Section 3 describes our sample, measurements and statistical methodology. Section 4 presents and discusses the main findings, including descriptive statistics and robustness checks. Section 5 presents the discussion. Conclusions are then drawn in Section 6.

2. Literature Review and Hypothesis Development

Corporate information impacts on cost of equity have been well documented and highlighted in the literature. Firstly, a greater provision of information can assist investors obtain more accurate and less uncertain risk parameter within their employed asset pricing formula (Barry and Brown, 1984, 1985; Lambert, Leuz, and Verrecchia, 2007), as well as decrease information asymmetry between principals and agents (García- Sánchez & Noguera-Gámez, 2017a; García- Sánchez & Noguera-Gámez, 2017b; Easley & O'hara, 2004; Diamond & Verrecchia, 1991). As a result, firms with greater transparency through disclosure expose to lower cost of equity due to more precise investors' forecasts, and less issues related to moral hazard and adverse selection (Vitolla, Salvi, Raimo, Petruzzella, & Rubino, 2020). Furthermore, investors tend to require lower returns for holding stocks with lower monitoring costs, which can be achieved through greater information disclosure (Lombardo and Pagano, 2002). Supporting these theoretical mechanisms, empirical studies of, for example, Salvi, Vitolla, Raimo, Rubino, & Petruzzella (2020), Vitolla et al. (2020), reported that integrated reporting quality and intellectual corporate disclosure can help to reduce firm's cost of equity. Nevertheless, Botosan, Plumlee, and Xie (2004) and Kothari, Shu, and Wysocki (2009) suggested that such negative association between information disclosure and cost of equity is dependent on a number of factors including disclosure type, method, and frequency. Overall, corporate information financially benefits and is demanded by investors of all firms within the markets. Hence, firms must put efforts into the voluntary dissemination of more information to the stakeholder.

Traditionally, firms that seek to disseminate their information rely on third-party intermediaries, such as the press (Bushee & Miller, 2012). However, this dependence can be problematic since not all firms can benefit from such intermediaries (see Blankespoor, Miller & White, 2014). As mentioned, a greater dissemination could play an influential role in enhancing the usefulness of reported information, leading to a lower information asymmetry (Bushee et al., 2010), higher share value (Li et al., 2011) and lower COE (Albarrak et al., 2020).

The fast-paced development of digital technology has caused the corporate communication landscape to change significantly, creating a much wider reach and more effective interactions with a broad spectrum of stakeholders. Adapting to this environment, corporations have increasingly employed social media to implement various content strategies, including marketing, brand awareness, lead acquisition, and strategic dissemination of information (e.g. Khobzi & Teimourpour, 2014). Among many social media platforms, Twitter has become a dominant tool for publicising investor-related information covering both financial and non-financial matters

(M.J. Jung, Naughton, Tahoun & Wang, 2018; Elliott, Grant & Hodge, 2018; Grant, Hodge & Sinha, 2018; Teti, Dallocchio & Aniasi, 2019; Albarrak et al., 2019). The design of short messages on Twitter makes it more likely to be used for bulletins rather than providing comprehensive information. However, firms have an incentive to gain legitimacy and avoid scrutiny by sending frequent short messages to stakeholders, demonstrating that they are socially responsible (Stanny, 2013; Castelló *et al.*, 2016). Furthermore, firms have more power through Twitter when deciding the timing, content, and frequency of disseminated information, and thus improve the effectiveness of their reports (Blankespoor et al., 2014). Twitter allows firms to know the size of their audience and the number of followers, which may motivate their decision to give update. Firms can share their views and discuss their performance through the hashtag key (#carbonemissions or #ClimateChange). This mechanism allows firms to spread their messages to users who are concerned about carbon emissions or climate change issues. It would also give labels or aims at the disseminated message (tweet) which may attract readers' attention. As firms post carbon-related information messages, these tweets could be shared by recipients through the "retweet" feature on Twitter. That is, the recipients of carbon-related tweets can share this information with their listed followers by clicking on the retweet button, which helps effectively to expand the outreach of Twitter messages. This allows a broader set of investors to incorporate more information on a timely basis, which helps them to evaluate this information.

Undoubtedly, climate change-related information is useful in enabling investors to assess the potential risks and evaluate their investment strategy. Accordingly, several risk categories are related to this, including regulatory, litigation, competition, production, physical, and reputation risks (Dobler, Lajili & Zéghal, 2014; Labatt & White, 2011; Kölbel, Heeb, Paetzold, & Busch, 2020). These categories include direct climate change risks related to extreme weather events such as droughts and floods (J. Jung, Herbohn, and Clarkson, 2018). Such temperature changes create a systematic risk factor that affects COE (Balvers et al., 2017). Market participants, therefore, become increasingly interested in carbon-related information, and firms recognise them as material issues (Weinhofer and Busch, 2013). That is, the reporting carbon-related information is expected to provide positive signals to market participants about a firm's environmental responsibility which will improve the firm's reputation, image and debt financing (Barnett & Salomon, 2012).

Usually, investors face higher information acquisition cost to process environmental concern than environmental strength (see Griffin et al., 2020). That is, environmental concerns supposedly need more effort to process than environmental strength. However, Twitter allows firms to push their information to investors who would receive the information directly rather than searching and gathering for the information. Such feature allow would help to reduce investor acquisition costs, which is the price that paid from accessing and retrieving the information (Blankespoor et al., 2014). In addition, a higher rating in environmental concern indicates the current environmental issues and problems that firms are facing. This environmental concern exhibits a negative environmental image due to its '*unpleasant*' carbon footprint or other environmental misconducts. Firms may use Twitter to share their views and demonstrate their uncertainty about an environmental issue that relates to carbon and climate change. This effective communication with investors may appease the anger of environmentally concerned groups and enhance their reputations. Previous literature (L. Lee et al., 2015; Mazboudi & Khalil, 2017; Miller & Skinner, 2015) finds that firms can benefit from Twitter by attenuating the adverse market reaction towards unfavourable news by replying to users' concerns and rebuilding damage to their reputation. Consequently, the association between Carbon_Tweets and COE may be influenced by the a firm's environmental concern rating. For this reason, this study aims to investigate how different aspects of corporate environmental performance (i.e. environmental concern and strength) would moderate the effect of carbon tweets on the COE.

According to Lundholm and Winkle (2006), the primary purpose of reports is to reduce information asymmetry and thus achieve a lower COE. That is, the lack of information between investors, in the case of information asymmetry, will generate high uncertainty among uninformed investors, which will drive them away from buying a firm's shares and hence reduce the firm's share liquidity and increase risk premium (Dhaliwal, Li, Tsang & Yang, 2011; Salvi, Vitolla, Giakoumelou, Raimo & Rubino, 2020). As a result, a broader spread of carbon information allows potential investors to be aware of a firm's information which in turn improves firm value and reduces COE (see Byun & Oh, 2018). Intriguingly, it has been found that investors perceive firms' information of corporate weaknesses "as a sign of management's honesty and integrity, and as a sign of management's willingness to improve internal control" (Ji, Lu & Qu, 2015, p.3). In other words, firms that are not constrained by their environmental weaknesses and flaws in disseminating their information through Twitter may indicate the presence of a firm's 'good mind' in improving their current 'bad act'. Spreading a positive, 'forward-looking' environmental image is likely to enhance investors' trust, and therefore lower firm risks and COE.

Consequently, once investors recognise the full worth of firms being transparent about their environmental values, they may be more appreciated on the dissemination efforts that firms make through Twitter when their environmental images are not amiable. In other words, taking into account the fact that firms may still be punished for their weak environmental practices (high environmental concerns) through a higher COE (Kim, An, & Kim, 2015; J. Jung et al., 2018; Lemma, Feedman, & Milo, 2019), the benefits of using Twitter for higher carbon transparency may be enhanced by the firm's environmental issues. Therefore, we expect that a firm's environmental concern strengthens the negative effects of *Carbon_Tweets* on COE. That is, firms highly rated in environmental problems may have a stronger motivation to use Twitter to disseminate carbon-related information. Consequently, the following hypothesis will be tested:

H1: A firm's environmental concern significantly negatively moderated the effect of its carbon-related tweet on the cost of equity.

On the other hand, whilst the environmental concern indicates the presence of a firm's 'bad act', the environmental strength captures the positive environmental images of firms as it determines a firm's initiatives in improving their environmental practices and awareness. Similarly, this environmentally 'good mind' acts as a positive 'green' signal to the market participants, which can enhance the firm's moral image. Consequently, we expect that firms with strong environmental record may gain more rewards from investors in terms of a lower COE for their use of Twitter to disseminate carbon-related information. In other words, the value of environmental activities should increase with stakeholder awareness (Servaes & Tamayo, 2013; Byun & Oh, 2018). Using Twitter allows a firm to transmit carbon-related information at lower acquisition costs, allowing many potential investors to know about a firm's environmental information. Hence, the negative association between Carbon_Tweets and COE is stronger if firms have a higher environmental strength rating. Accordingly, our second hypothesis is:

H2: A firm's environmental strength significantly negatively moderated the effect of its carbon-related tweet on the cost of equity.

3. Methodology

3.1 Sample Selection

Our sample consists of non-financial firms that were traded on the NASDAQ stock exchange from 2009 to 2015. We focus on NASDAQ because it is one of the major technology-focused stock exchanges. A large number of technology firms in the US are traded on the NASDAQ which induces a higher likelihood of adopting Twitter and, hence, ensuring a potentially greater coverage (Debreceny *et al.*, 2002; Blankespoor *et al.*, 2014; L. Lee *et al.*, 2015; Leuz & Wysocki, 2016). We require our selected firms to have positive future earnings forecasts for one and two years ahead ($FEPS_1$ and $FEPS_2$). That is, we require a firm to have a positive COE as investors expect to acquire a higher return rate given their risk that exceeds the risk-free. We use Bloomberg to obtain our financial data, Twitter's search engine and API to retrieve firms' tweets, and the MSCI Kinder, Lydenberg, and Domini (KLD) research and analytics dataset for environmental variables and LexisNexis for firms' carbon-related news. The final sample consists of 541 firm-year observations.

3.2 Variables

3.2.1 Cost of Equity (COE)

The dependent variable is estimated using the arithmetic mean of four implied COE models. These models are based on Claus' and Thomas' model (R_{CT}, 2001), Gebhardt's, Lee's, and Swaminathan's model (R_{GLS}, 2001), Ohlson's and Juettner-Nauroth's model (R_{OJ}, 2005) and a modification of Easton's model (R_{MPEG}, 2004). We use the athematic mean of these models to reduce any possible estimation error. This measure of COE is widely used in the literature (Chen et al., 2011; El Ghoul et al., 2011; El Ghoul et al., 2018; Dhaliwal Li, Tsang & Yang, 2011; Dhaliwal, Judd, Serfling & Shaikh, 2016; Ahmed, Eliwa & Power, 2019). The COE estimates are measured based on current stock prices and analysts' future earnings forecast. That is, cost of equity is discount rate that is used to determine the current stock value on future cash flows. However, each of COE estimation models has different implementations and assumptions. For instance, R_{CT} assumes that the market expects abnormal earnings to grow at a constant rate, which equals the inflation rate, beyond the forecast horizon. R_{GLS} assumes that the market expects share prices in terms of the future return on equity (FROE) "to linearly fade to an industry-based ROE 12 years hence, which GLS estimates based on historical industry ROE" (Botosan et al., 2011, p. 1098). Both models (R_{CT} and R_{GLS}) models assume clean surplus accounting. Whlist, R_{CT} allows the share price to be expressed in terms of book value, the perpetual abnormal earnings growth and the forecasted abnormal earnings growth. R_{GLS} expresses the share price in terms of book value, the forecasted return on equity (FROE) and forecasted book value. Furthermore, R_{OJ} is an extension of Gordon's constant growth model which expresses stock prices in terms of the forecasted earnings per share (FEPS) and perpetual growth rate. In addition, R_{MPEG} anticipates that the market expects abnormal earnings to grow at a zero rate beyond the forecast horizon. A further explanation of COE measurements is provided in Appendix A.1.

3.2.2 Carbon-related Tweets

Carbon-related tweets reflect the number of tweets that relate to carbon emissions and climate change. In collecting these tweets, we searched for keywords and key phrases. Our corpus is aligned with previous studies that used to identify carbon-related information (e.g., Griffin & Sun, 2013; Hahn, Reimsbach & Schiemann, 2015; Hsu & Wang, 2013; S. Lee, Park & Klassen, 2015;

Schmidt, Ivanova & Schäfer, 2013; Albarrak et al., 2019). We also use several Twitter features to identify carbon-related tweets such as carbon related hashtag (e.g., #ClimateChange). Our keywords list comprised the following terms:

> (“carbon* emission*”, “climate emission*”, “gas emission*”, “pollution emission*”, “GHG emission*”, “CO2 emission*”)
>
> (“carbon*”, “gas”, “emission*”, “GHG”, “climate”, “pollution”, “CO2”) AND (“report*”, “statement*”, “disclose*”, “release*”, “declare*”, “announce”).
>
> (“greenhouse gas”, “climate change”, “carbon neutral”, “carbon dioxide”, “carbon foot-print”, “carbon offset*”, “greenhouse effect*”, “global warming*”, “fossil fuel*”, “carbon monoxide”, “@CDP”, “#global_warming”, “#global-warming”, “#globalwarming”, “#carbonemission”, “#climate_change”, “#climate-change”, ”#climatechange”, “#climate”)

To compute carbon-related tweets, we use a matching scheme program in Python to align firms’ tweets with our listed keywords. We then count the total number of tweets that relate to carbon emissions for each firm in the year.

3.2.3 Environment strength (ENV_STR) and Concern (ENV_CON)

Our environmental variables are constructed from KLD data which has been widely used in the literature. In this study, we focus on the two categories of environmental strengths (ENV_STR) and concerns (ENV_CON). Previous studies (Walls et al., 2012; Glass et al., 2016) stated that ENV_STR and ENV_CON are theoretical and empirically different, and their effect should be examined separately. Whilst ENV_STR focus on the firm's plans and initiative to improve environmental response and awareness, ENV_CON assess violations, compliance and pollution levels. KLD data use variety of sources that include academic research, investor relation companies, media, government reports and company filing to collect their data. After gathering the data, each firm are evaluated and rated yearly based on their strength and concerns in several areas including: The environment, community, diversity, human rights, corporate governance, employee relation and product quality and safety. In this paper, we focus specifically on environmental concern and strength which include list of screens as follow (as stated in Bardos, Ertugrul & Gao, 2020, p. 6):

> *Environmental Strengths (ENV_STR): Beneficial products and services, pollution prevention, recycling, clean energy, communications, and other strength, management systems strength, water stress, biodiversity and land use, raw material sourcing, natural resource use, green buildings, renewable energy, waste management, energy efficiency, product carbon footprint, insuring climate change risk.*

> *Environmental Concerns (ENV_CON): Hazardous waste, regulatory problems, ozone depleting chemicals, substantial emissions, agricultural chemicals, climate change, and other concerns, negative impact of products and services, and use and biodiversity, non‐carbon releases, supply chain management.*

3.2.4 Control Variables

Our control variables include various factors that are related to firm characteristics, firm environment performances and corporate social media. We follow previous studies by controlling for several firm-level variables (El Ghoul et al., 2011; Dhaliwal et al., 2011; Cao et al., 2015; El

Ghoul et al., 2018; Albarrak et al., 2020). This includes for firm value (SIZE) because larger firms have a better information environment and thus have a lower risk and COE. Firms with high financial leverage (LEV) have a greater commitment to making payment to debt holders and therefore expect to have a higher default risk and COE. A greater dispersion in analysts' forecasts (DISP) is associated with a higher uncertainty surrounding the information environment, which puts upward pressure on the COE. Systematic risk (Beta) is an undiversified risk for which investors expect to be compensated with risk premium by requiring a higher COE. Furthermore, a high long-term growth forecasts rate (LTG) is associated with a greater COE. Carbon-related news (CD_NEWS) and the percentage of institutional ownership (INST_OWN) expect to improve firms' information environment, which consequently reduces their information asymmetry and COE.

We also control for factors that are associated with environmental performance and corporate use of social media (Blankespoor et al., 2014; L. Lee et al., 2015; Albarrak et al., 2019). Firms that have a higher percentage of independent directors (BOD_IND) and an environmental committee (CSR_COMMITEE) tend to exhibit better information monitoring and policies toward the environment (De Villiers et al., 2011; Jaggi et al., 2018). Previous research (e.g. Ng & Rezaee, 2015; Gupta et al., 2018) found that better governance mechanisms may be associated with a lower COE. Firms with a higher growth in sales (Sales_Growth) expect to use Twitter and are more inclined to report environmental information (Servaes & Tamayo, 2013; L. Lee et al., 2015). Furthermore, Sales_Growth is expected to negatively associate with COE. Financial analysts undergo more difficulties to analyse firms that record negative earnings (LOSS), leading to an increased COE (Albarrak et al., 2019). Firms investment in research and development (R&D) expect to generate values (Servaes & Tamayo, 2013). We also control for price momentum (MMT) to mitigate analysts' forecast noise (El Ghoul et al., 2011). Appendix A.2 provides further explanations on the measurements of variables.

3.3. Model Specifications

To examine our hypotheses, we employ the following models:

We use model (1) to examine the moderate role of environmental strength on the relationship between carbon-related tweets on firm cost of equity.

$$COE_{it} = \beta_0 + \beta_1\ Carbon\_Tweets_{it} + \beta_2\ ENV\_STR_{it} + \beta_3\ Carbon\_Tweets_{it} * ENV\_STR_{it} + \beta_4\ SIZE_{it} + \beta_5\ LEV_{it} + \beta_6\ DISP_{it} + \beta_7\ BETA_{it} + \beta_8\ LTG_{it} + \beta_9\ CD\_NEWS_{it} + \beta_{10}\ INST\_OWN_{it} + \beta_{11}\ BOD\_IND_{it} + \beta_{12}\ CSR\_COMMITTEE_{it} + \beta_{13}\ Sales\_Growth_{it} + \beta_{14}\ LOSS_{it} + \beta_{15}\ R\&D_{it} + \beta_{16}\ MMT_{it} + Industry\_Effect + Year\_Effect + \varepsilon_{it} \quad (1)e$$

Model (2) is used to examine the moderate role of environmental concern on the relationship between carbon-related tweets on firm cost of equity.

$$COE_{it} = \beta_0 + \beta_1\ Carbon\_Tweets_{it} + \beta_2\ ENV\_CON_{it} + \beta_3\ Carbon\_Tweets_{it} * ENV\_CON_{it} + \beta_4\ SIZE_{it} + \beta_5\ LEV_{it} + \beta_6\ DISP_{it} + \beta_7\ BETA_{it} + \beta_8\ LTG_{it} + \beta_9\ CD\_NEWS_{it} + \beta_{10}\ INST\_OWN_{it} + \beta_{11}\ BOD\_IND_{it} + \beta_{12}\ CSR\_COMMITTEE_{it} + \beta_{13}\ Sales\_Growth_{it} + \beta_{14}\ LOSS_{it} + \beta_{15}\ R\&D_{it} + \beta_{16}\ MMT_{it} + Industry\_Effect + Year\_Effect + \varepsilon_{it} \quad (2)$$

To have a comprehensive picture of the research questions, we use model (3) to examine the moderate role of environmental strength and concern on the relationship between carbon-related tweets on firm cost of equity.

$$COE_{it} = \beta_0 + \beta_1\ Carbon\_Tweets_{it} + \beta_2\ ENV\_STR_{it} + \beta_3\ Carbon\_Tweets_{it} * ENV\_STR_{it} + \beta_4\ ENV\_CON_{it} + \beta_5\ Carbon\_Tweets_{it} * ENV\_CON_{it} + \beta_6\ SIZE_{it} + \beta_7\ LEV_{it} + \beta_8\ DISP_{it} + \beta_9\ BETA_{it} + \beta_{10}\ LTG_{it} + \beta_{11}\ CD\_NEWS_{it} + \beta_{12}\ INST\_OWN_{it} + \beta_{13}\ BOD\_IND_{it} + \beta_{14}\ CSR\_COMMITTEE_{it} + \beta_{15}\ Sales\_Growth_{it} + \beta_{16}\ LOSS_{it} + \beta_{17}\ R\&D_{it} + \beta_{18}\ MMT_{it} + Industry\_Effect + Year\_Effect + \varepsilon_{it} \quad (3)$$

We use ordinary least squares (OLS), with robust standard errors, to control for serial correlation and heteroscedasticity as our estimation model. To ensure the reliability of the findings, we further employ the propensity score matching (PSM) technique to address potential endogeneity problems, i.e. the selection bias in particular. Furthermore, additional analyses with an alternative measure of the main explanatory variable (Carbon_Tweet) and different added control variables are also performed.

4. Results and Discussion

4.1 Descriptive statistics

The descriptive statistics in Table 1 show all our variables in models 1, 2 and 3. The table shows that the mean value for COE is 6%, which is consistent with previous studies (El Ghoul et al., 2011; Albarrak et al., 2019, 2020). The mean value of the natural logarithm of *Carbon_Tweets* is 0.12, which is equivalent to a mean of carbon tweets number equal to 0.43. The mean value of the firm size (SIZE) is equal to 20.64. The firms in our sample have low financial leverage (LEV) with a mean of 19%. The mean values of DISP, BETA and LTG are 0.13, 1.06 and 0.19, respectively. The firms' carbon-related news (CD_NEWS) has an average of 0.72. The firms in our sample have a high institutional investors ownership, with a mean (median) equal to 0.86 (0.92). It appears that the mean of BOD_IND is 0.78, while the median is 0.71. A small number of firms have

CSR_COMMITEE, with a mean of 0.02. The sampled firms have a mean growth in sales (Sales_Growth) equal to 9.9%. Accordingly, about a fifth (19%) of the firms report a LOSS. The data show that R&D and MMT have a mean value of 0.05 and 0.11, respectively.

[INSERT TABLE 1 ABOUT HERE]

The Spearman correlation matrix is presented in Table 2. The table shows that the Carbon_Tweets variable has a significant negative correlation with COE, indicating that firms disseminating their carbon-related information through Twitter may have a lower COE. This is consistent with our expectation. Furthermore, it shows that ENV_STR is negatively correlated with COE, whereas ENV_CON is positively correlated with COE. These results indicate that environmental strength signifies the firm's environmental 'good mind and intention', while environmental concern indicates the firm's 'bad act' in their environmental-related matters. The pairwise correlation test indicates that multicollinearity is not a concern the correlation coefficient between the independent variables are all far lower than the 0.8 thresholds. This is confirmed by the variance inflation factors (VIFs) which are lower than the value of 10.

[INSERT TABLE 2 ABOUT HERE]

4.2 Empirical results

The OLS results in Table 3 show that Carbon_Tweets have significant negative associations with firm COE across all three models at a critical level of 10 % or below (β_{Carbon_Tweets} = -0.006, -0.003,

-0.006; columns 1-3). The results show that at an increase of Carbon_Tweets by 100% cause the COE to decrease by approximately 0.6%. These findings are consistent with those of previous studies that a firm's carbon-related information dissemination over Twitter helps to reduce the information asymmetry between firms and market participants, improve investor recognition on the firm's environmental values that adhere with investors' ethical values, and reduce the uncertainty surrounding firm carbon information. All of these in combination lead to a lower COE.

[INSERT TABLE 3 ABOUT HERE]

Extending this finding, the results also show that the interaction between environmental strength (ENV_STR) and Carbon_Tweets is not statistically significant ($\beta_{Carbon\_Tweets*ENV\_STR}$ = 0.0024, nonsignificant, column 3), whilst a significant negative coefficient is obtained for the interaction term of environmental concern (ENV_CON) and Carbon_Tweets ($\beta_{Carbon\_Tweets*ENV\_CON}$ = -0.0141, $p \leq 0.1$, column 3). Results are consistent whether ENV_STR and ENV_CON are tested separately or together in the same model. This is to say, our first hypothesis is supported. Particularly, the evidences provide supports for firms with negative environmental values to use Twitter to achieve a wider dissemination of their carbon-related information to the market since their rewards through a lower COE.

The findings also point to significant positive effects of LEV, Beta, LTG, and CSR_COMMITEE on COE. These indicate that COE has a positive association with firm risk factors (i.e. LEV and Beta). It also reveals that firms with a high growth forecast rate (LTG) should offer a higher COE. These results are consistent with our expectations and the previous literature (Cao et al., 2015; El Ghoul et al., 2018). The results also see CSR_COMMITEE increasing the investors' required rate of return. Nevertheless, the results show that price momentum (MMT) has a statistically negative association with COE. MMT is associated with analysts' sluggishness, which creates noise concern over analysts' forecasts and hence increase the COE (El Ghoul et al., 2011; Albarrak et al., 2020).

4.3 Robustness checks

To test the robustness of our main findings, we employ a propensity score matching (PSM) procedure to mitigate the endogeneity and sample selection bias issues. In particular, we use a nearest neighbor technique to match our sample with nearest neighbor, requiring no substitute and mainly one match pair between each other. We estimate the probability to adopt social media based on our previously used control variables and further additional variables to calculate the propensity score. We use additional variables that are related to the corporate adoption of Twitter: whether a firm is a technology firms (Tech_Firm)[1]; whether the headquarter in Silicon Valley (Silicon); whether firm's CEO is younger-than-average CEOs' age (CEO_AGE); and whether the firm is subjected to the environmental Protection Agency plan (EPA). The matching procedure has resulted in a sample of 802 observations that are equally distributed. After the matching procedure, we have run an OLS regression based on the 802 matched pairs in Table 4. The results of the matched sample are consistent with our main findings that Carbon_Tweets are statistically negatively significant for COE in columns 1, 2 and 3 with the coefficient (β= -0.006, $p < 0.1$; β= -0.004, $p < 0.05$; β= -0.0055, $p < 0.05$ respectively). The results also show that the interaction between Carbon_Tweets and ENV_CON is negatively significant (coefficient -0.02, $p < 0.1$) in

[1] Firms are considered technological if SIC equals to 3570-3579, 3610-3699, 7370-7379, 3810-3849, 4800-4899, 4931, 4941, which take a value of 1 or 0 otherwise.

columns 2 and 3. This supports our main findings that Twitter is a useful channel for firms in addressing negative activities and announcements.

[INSERT TABLE 4 ABOUT HERE]

Furthermore, we include several control variables that relate to a firm's risk, social media adoption and environmental performance in Column 1, Table 5. We include the market to book ratio (MTB) as a risk proxy of firm risk and growth opportunity which likely influence a firm's COE (Aghazadeh et al., 2018). Accordingly, we expect firms with a higher market to book ratio (MTB) to be negatively associated with COE. We also control the size of the boards of directors (BOARD_SIZE). Firms that have a larger number of board members expect to have better corporate governance which may contribute to a lower COE (Ng & Rezaee, 2015; Gupta et al., 2018; Jaggi et al., 2018). We also control for capital expenditure (CAPX). Firms that have a higher capital expenditure expect to have an improved environmental performance (de Villiers et al., 2011). Furthermore, more mature, higher aged firms (Firm_AGE) tend not to have a good environmental performance (Zeng et al., 2012). In addition, firms that miss the earnings forecast (Surp) may experience greater uncertainty and expect higher compensations to investors with a higher COE (Albarrak et al., 2020). The results in Column 1 show consistent results as our main findings, even after adding further variables. However, the findings show that MTB and CAPX are negatively associated with COE, whereas firms' AGE have a positive association with COE.

[INSERT TABLE 5 ABOUT HERE]

As an alternative measure of Carbon_Tweets, we use the number of carbon-related tweets that have been retweeted (Carbon_Retweets). The retweet feature allows Twitter users to share messages of other users with their own followers. This feature expects to enhance the spread of the Twitter messages to advance the general outreach (Albarrak et al., 2019). Cade (2018) suggests that retweeted messages are perceived more valid to investors and thus have a stronger impact. Column 2 presents the results of Carbon_Retweets. The results indicate that Carbon_Retweets is significantly and negatively associated with COE at around 5% (β= 0.0052, $p < 0.05$). The results show a noticeable and negative association between Carbon_Retweets * ENV_CON and a firm's COE. These findings are similar to our main findings in Table 3 which robust our main findings.

5. Discussion

One might think that firms with a negative environmental image and considerable issues in their environmental practices should not use social media platform such as Twitter to spread their information as it may impose negative impression on investors mindset. Consequently, the benefits of Twitter may diminish or even reverse. Nevertheless, reporting information and disseminating actions of a company can provide investors with more credible and updated information for a better evaluation of the firm's values. Therefore, such actions should be highly valued and rewarded by investors regardless of the news that firms report (Lundholm & Winkle, 2006). Furthermore, the courage of firms to widely spread their carbon-related information over Twitter, even with the acknowledgement of their possibly unpleasant character, may be viewed as an honest and virtuous corporate behavior. This may also signal a firm's 'good mind' in addressing and improving their current environmental practices and strategies including their carbon performances (Ji, Lu, & Qu, 2015). As a result, the rewards firms receive from investors through a lower COE by disseminating their carbon-related news through Twitter, are greater if firms have enough courage to do so with their environmental concerning reputations.

On the other hand, we do not obtain a significant negative moderating effect of a firm's environemental strength on the Carbon_Tweets-COE association as expected. Our results indicate that the benefits of the Twitter dissemination channel for firms with a high environmental strength in terms of lower COE are just similar to those for other firms with a weaker environmental strength. This may be because, when firms have a strong environmental reputation, market participants may think that they do not need to put too much effort into dissemination through Twitter compared to firms with concerning environmental records (Strike et al., 2006; Dunbar et al., 2020). Consequently, although the COE is still lowered through the use of Twitter, the environmental strength does not moderate such effects further. Overall, our findings paint the interesting picture that ceteris paribus , the use of Twitter for the dissemination of carbon-related information lowers the COE of environmentally concerning firms at a relatively greater rate than that of firms with strong environmental ethics.

Our findings contribute to the literature by providing further insights into which firms benefit more from using Twitter for their carbon-related information dissemination purposes. Within the issues of climate change and global warming, firms have received more pressure from different stakeholders, such as the media, environmentally concerned groups and regulators on their environmental impacts. As a result, working towards a ‘cleaner’ and ‘greener’ image would substantially enhance firms’ values and reputations. Based on our findings, firms that use Twitter to send messages about carbon emissions and climate change exhibit higher managers incentives by reducing COE by being perceived as ‘greener’ and more sustainable. Additionally, firms can directly promote the greener practices and information to address the concerns of pro-environmental exposure. This may enhance firms' recognition and market participants' views and attitudes towards environmental problems by exhibiting a lower COE. Whist, prior literature (Servaes & Tamayo, 2013; Byun & Oh, 2018) argue that stakeholders' awareness of firm environmental activity may enhance the benefit of such activities. Our findings show that the benefit of increasing investor awareness is higher toward firm's environmental concern.

6. Conclusion

Twitter has become an important communication channel for corporate information in general and carbon related information and climate change, in particular, allowing firms to engage with various stakeholders, including pro-environmental groups. Extending the study of Albarrak et al. (2019) on the negative association between Twitter as a dissemination channel of carbon-related information (Carbon_Tweets) and cost of equity (COE), our paper aims at investigating whether such association remains under the firms' different environmental conditions. In other words, by examining the moderating effects of a firm's environmental performance on the influences of Carbon_Tweets on the COE, this paper can detect the variations in the effectiveness of Carbon_Tweets on the COE across different levels of their environmental performance. Building on this objective, the findings can provide implications whether firms exhibit incentives to use Carbon_Tweets only if they have a good record of environmental performance. This would be advantageous for investors to better understand the motivation behind a firm's disclosure actions.

Based on a sample of non-financial firms that are traded in NASDAQ and that do have Twitter accounts over a period between 2009 and 2015, we obtained two main findings. First, we found that firms that use Twitter to share information about (their) carbon emissions and climate change have a lower COE. In extension, we found that the influences of Carbon_Tweets on COE are stronger for firms with concerning environmental records, whilst the effects are relatively stable for firms with strong environmental ethics, i.e. plans and initiatives for future environmental performances. In other words, statistically confirmed are only the moderating effects of environmental issues on the association between Carbon_Tweets and COE. This may be because investors perceive the greater efforts firms put into the process and the dissemination of their carbon-related information given their environmentally concerning backgrounds compared to firms with good environmental images (Strike et al., 2006; Dunbar et al., 2020).

Our findings provide important implications for firm managers and regulator. In this regard, the findings allow firms' managers to understand the potential benefit of using Twitter strategically to send messages about climate change and carbon emissions information. Such communication with various of audience in Twitter should help firms to reduce the negative impact of firm's environmental performance in a way to improve their equity financing. Whilst, regulators should take more actions to reduce the negative impact of climate change and carbon emissions by pushing firms to improve their environmental performance. They may push the firms to be more transparent about their environmental performance which as a result would generate economic benefits.

Our paper has some limitations which can be address in future studies. As our sample size, we use firms that are traded in NASDAQ. Prior studies (see El Ghoul et al., 2011) argue that country's religion and culture may influence investor perception of weak versus strong firms' environmental performance. Future studies may extend the research internationally by using a global sample. Furthermore, it would be worthy to extend the literature by examining the link between carbon tweets and debt pricing. Future studies may give more consideration to the sentiment of carbon tweets and its impact on the capital market.

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TABLES

Table 1: Descriptive statistics

The table presents the descriptive statistics of all variables included in the baseline estimation model (eq.3).

Variables	*N*	*Mean*	*P25*	*P50*	*P75*	*Min*	*Max*	*SD*
COE	2104	0.06	0.03	0.05	0.07	0.00	0.17	0.04
Carbon_Tweets	2104	0.12	0.00	0.00	0.00	0.00	4.72	0.44
ENV_STR	1752	0.52	0.00	0.00	1.00	0.00	5.00	0.88
ENV_CON	1752	0.02	0.00	0.00	0.00	0.00	2.00	0.16
SIZE	2104	20.64	19.57	20.53	21.53	15.27	26.17	1.59
BTM	2098	0.43	0.21	0.36	0.57	-0.18	1.75	0.32
LEV	2097	0.19	0.00	0.05	0.22	0.00	2.08	0.35
DISP	1940	0.13	0.05	0.08	0.14	0.00	1.48	0.14
Beta	1922	1.06	0.70	1.03	1.37	-2.08	11.65	0.62
LTG	2104	0.19	0.12	0.15	0.20	-1.16	0.85	0.16
CD_NEWS	2104	0.72	0.00	0.00	1.10	0.00	3.37	1.03
INST_OWN	1795	0.86	0.74	0.92	1.04	0.00	1.27	0.26
BOD_IND	1954	0.78	0.71	0.80	0.88	0.14	1.00	0.12
CSR_COMMITEE	1919	0.02	0.00	0.00	0.00	0.00	1.00	0.13
Sales_Growth	1931	0.099	0.02	0.09	0.17	-1.13	0.79	0.18
LOSS	2104	0.19	0.00	0.00	0.00	0.00	1.00	0.39
R&D	2044	0.05	0.00	0.02	0.09	0.00	0.74	0.07
MMT	1673	0.11	-0.13	0.12	0.32	-1.90	1.74	0.48

Table 2.
Correlation matrix.
*This table reports correlation matrix among independent variables used in our empirical models. * denotes significance level of 5%.*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1. COE	1																
2. Carbon_Tweets	-0.04*	1															
3. ENV_STR	-0.14*	0.14*	1														
4. ENV_CON	0.06*	0.07*	0.02	1													
5. SIZE	-0.13*	0.24*	0.24*	0.13*	1												
6. LEV	0.25*	0.003	-0.08*	0.03	0.2*	1											
7. DISP	0.12*	0.04	0.07*	0.09*	0.24*	0.02	1										
8. Beta	0.17*	0.02	-0.01	0.02	0.03	0.09*	0.1*	1									
9. LTG	0.34*	-0.07*	-0.03	-0.02	-0.29*	-0.06*	0.12*	0.05*	1								
10. CD_NEWS	-0.03	0.32*	0.23*	0.17*	0.5*	0.03	0.18*	0.07*	-0.11*	1							
11. INST_OWN	-0.17*	-0.001	0.08*	-0.01	0.22*	-0.03	-0.01	0.01	-0.16*	0.02	1						
12. BOD_IND	-0.07*	0.12*	0.07*	-0.005	0.04*	-0.1*	-0.01	-0.03	-0.04	0.04*	0.18*	1					
13. CSR_COMMITEE	0.02	0.2*	0.12*	0.11*	0.23*	0.04	0.03	-0.02	-0.08*	0.17*	-0.03	0.08*	1				
14. Sales_Growth	0.06*	-0.03	0.03	-0.02	0.08*	-0.06*	0.15*	0.021	0.21*	-0.02	-0.02	-0.03	-0.06*	1			
15. LOSS	0.2*	-0.07*	-0.04	-0.03	-0.21*	0.12*	0.02	0.08*	0.28*	-0.05*	-0.1*	-0.02	-0.06*	-0.08*	1		
16. R&D	-0.05*	-0.01	0.09*	-0.07*	-0.2*	-0.25*	0.09*	0.05*	0.25*	-0.03	-0.06*	0.1*	-0.03	0.1*	0.26*	1	
17. MMT	-0.23*	-0.03	-0.01	0.03	-0.02	-0.06*	-0.001	0.04	0.03	0.01	0.07*	-0.003	0.03	0.05*	-0.12*	-0.01	1

Table 3: Baseline Estimation Model

The table presents the results for the moderating effects of firm environmental strength (ENV_STR) and environmental concern (ENV_CON) on the effects of Carbon_Tweets on firm cost of equity (COE)

Variables	(1) COE	(2) COE	(3) COE
Carbon_Tweets	-0.0056**	-0.0029*	-0.0055**
	(0.0024)	(0.0017)	(0.0023)
ENV_STR	-0.0022		-0.0023
	(0.0016)		(0.0015)
Carbon_Tweets * ENV_STR	0.0023		0.0024
	(0.0015)		(0.0015)
ENV_CON		0.008	0.0082
		(0.009)	(0.0093)
Carbon_Tweets * ENV_CON		-0.0137*	-0.0141*
		(0.0081)	(0.0082)
SIZE	0.0007	0.0003	0.0006
	(0.0009)	(0.0008)	(0.0008)
LEV	0.0154**	0.0159**	0.0157**
	(0.0062)	(0.0062)	(0.0062)
DISP	0.0086	0.0082	0.0082
	(0.0076)	(0.0073)	(0.0074)
Beta	0.0139***	0.0140***	0.0139***
	(0.0020)	(0.0020)	(0.0020)
LTG	0.0073**	0.0071**	0.0072**
	(0.0031)	(0.0031)	(0.0031)
CD_NEWS	0.0008	0.0006	0.0008
	(0.0012)	(0.0012)	(0.0012)
INST_OWN	-0.0044	-0.0040	-0.0044
	(0.0045)	(0.0045)	(0.0045)
BOD_IND	0.0102	0.0092	0.0098
	(0.0084)	(0.0084)	(0.0084)
CSR_COMMITEE	0.0133***	0.0126***	0.0135***
	(0.0046)	(0.0047)	(0.0046)
Sales_Growth	-0.0084	-0.0084	-0.0085
	(0.0098)	(0.0098)	(0.0099)
LOSS	0.002	0.0021	0.0019
	(0.0031)	(0.0031)	(0.0031)
R&D	-0.0147	-0.0153	-0.0129
	(0.0183)	(0.0179)	(0.0181)
MMT	-0.0257***	-0.0255***	-0.0257***
	(0.0030)	(0.0030)	(0.0030)
Year Effect	Yes	Yes	Yes
Industry Effect	Yes	Yes	Yes
Constant	0.0278	0.0343*	0.0293
	(0.0197)	(0.0193)	(0.0194)
Observations	963	963	963
R^2	0.325	0.324	0.327

Table 4: Robustness check - Endogeneity problem: Propensity Score Matching

The table presents results of the robustness check to confirm the main findings obtained in Table 3. The analyses are performed using the Propensity Score Matching to tackle potential issues of endogeneity.

Variables	**(1) COE**	**(2) COE**	**(3) COE**
Carbon_Tweets	-0.0058**	-0.0038**	-0.0055**
	(0.0024)	(0.0019)	(0.0024)
ENV_STR	-0.0009		-0.002
	(0.0022)		(0.0020)
Carbon_Tweets * ENV_STR	0.0018		0.0020
	(0.0017)		(0.0017)
ENV_CON		0.0239*	0.0252*
		(0.0125)	(0.0129)
Carbon_Tweets * ENV_CON		-0.0229**	-0.0241**
		(0.0106)	(0.0107)
SIZE	0.0011	0.0008	0.001
	(0.0009)	(0.0009)	(0.0009)
LEV	0.0123*	0.0130**	0.0128**
	(0.0065)	(0.0065)	(0.0065)
DISP	0.0068	0.0054	0.0052
	(0.0078)	(0.0073)	(0.0073)
Beta	0.0157***	0.0159***	0.0158***
	(0.0021)	(0.0021)	(0.0021)
LTG	0.0082***	0.0077**	0.0079**
	(0.0031)	(0.0031)	(0.0031)
CD_NEWS	-0.0001	-0.0004	-0.0003
	(0.0012)	(0.0012)	(0.0012)
INST_OWN	-0.0036	-0.0029	-0.00314
	(0.0048)	(0.0048)	(0.00483)
BOD_IND	0.007	0.0048	0.005
	(0.0091)	(0.0091)	(0.0091)
CSR_COMMITEE	0.0170***	0.0173***	0.0178***
	(0.0051)	(0.0052)	(0.0052)
Sales_Growth	-0.0154	-0.0159	-0.0161
	(0.0103)	(0.0104)	(0.0104)
LOSS	0.0018	0.0018	0.0016
	(0.0034)	(0.0034)	(0.0034)
R&D	-0.0202	-0.0175	-0.0159
	(0.0185)	(0.0180)	(0.0181)
MMT	-0.0234***	-0.0228***	-0.0229***
	(0.0033)	(0.0033)	(0.0033)
Year Effect	Yes	Yes	Yes
Industry Effect	Yes	Yes	Yes
Constant	0.0175	0.0245	0.0210
	(0.0210)	(0.0202)	(0.0206)
Observations	802	802	802
R^2	0.335	0.341	0.342

Table 5: Robustness Check – Alternatives measures of Carbon_Tweets and Additional Control Variables		
Variables	**(1)** **COE**	**(2)** **COE**
Carbon_Tweets	-0.0049**	
	(0.0024)	
Carbon_Retweets		-0.0052**
		(0.0026)
ENV_STR	-0.0023	-0.0015
	(0.0016)	(0.0018)
Carbon_Tweets * ENV_STR	0.0023	
	(0.0015)	
Carbon_Retweets * ENV_STR		0.0002
		(0.0004)
ENV_CON	0.0093	0.0073
	(0.0092)	(0.0081)
Carbon_Tweets * ENV_CON	-0.0137*	
	(0.008)	
Carbon_Retweets * ENV_CON		-0.0021**
		(0.0010)
SIZE	0.0002	-0.0009
	(0.001)	(0.0011)
LEV	0.0185***	0.0264***
	(0.0063)	(0.0085)
DISP	0.0074	0.0144
	(0.0073)	(0.0089)
Beta	0.0143***	0.0163***
	(0.0020)	(0.0027)
LTG	0.0080***	0.0084**
	(0.0031)	(0.0037)
CD_NEWS	0.0008	0.0034*
	(0.0012)	(0.0012)
INST_OWN	-0.0031	-0.0064
	(0.0045)	(0.0064)
BOD_IND	0.0055	0.0214*
	(0.0085)	(0.0128)
CSR_COMMITEE	0.0105**	0.0156***
	(0.0047)	(0.0053)
Sales_Growth	-0.0098	-0.0022
	(0.0099)	(0.0116)
LOSS	0.0023	0.0055
	(0.0030)	(0.0039)
R&D	-0.0064	0.0022
	(0.0177)	(0.0200)
MMT	-0.0260***	-0.0271***
	(0.0031)	(0.004)
MTB	-0.766*	
	(0.409)	
BOARD_SIZE	0.0023	
	(0.0050)	
CAPX	-0.0366*	
	(0.0191)	
AGE	0.0002**	
	(0.00008)	
Surp	0.0002	
	(0.0003)	
Year Effect	Yes	Yes
Industry Effect	Yes	Yes
Constant	0.0324	0.0451*
	(0.0204)	(0.0270)
Observations	962	581
R^2	0.338	0.390

Appendix

A.1: The measurements of Cost of Equity (COE)

COE estimates	Formula
R_{OJ} Ohlson and Juettner-Nauroth (2005)	$R_{OJN} = A + \sqrt{A^2 + \left(\frac{E_t(FEPS_{t+1})}{P_t^*}\right)(g_2 - g_{lt})}$ $A = 0.5\left(g_{lt} + \frac{FDPS_{t+1}}{P_t^*}\right)$ FEPS $_{t+1}$ = The median forecasted earnings per share for June next year FDPS $_{t+1}$ = Forecasted dividend per share for the next year or 6% of return on assets (ROA) g_2 = Growth rate from the long-term consensus analysts' earnings forecasted (LTG) or the growth rate of short-term earnings ($FEPS_{t+2}/FEPS_{t+1}$ -1). g_{lt}= 10-year treasury bonds yield minus 3%. The model demands positive $FEPS_{t+1}$ and $FEPS_{t+2}$.
R_{MPEG} Modified Easton (2004) cost of equity model	$P_t = \frac{E_t(FEPS_{t+1})}{R_{MPEG}} + \frac{E_t(FEPS_{t+1})E_t[g_{st} - R_{MPEG} \times (1 + \text{FDIV})]}{R_{MPEG}^2}$ P_t = Share price in June FEPS= The median value of forecasted future earnings per share FDIV= Future dividend pay-outs ratio which equal to $\left(\frac{\text{Dividend per share}}{\text{Earnings per share}}\right)$ The model assumes FEPS to be positive and if FEPS is negative, we measure FDIV as 6% of ROA.
R_{CT} Claus and Thomas (2001)	$P_t^* = B_t + \sum_{i=1}^{5}\frac{[FEPS_{t+i} - R_{CT} \times B_{t+i-1}]}{(1 + R_{CT})^i} + \frac{[FEPS_{t+5} - R_{CT} \times B_{t+4}] \times (1 + g_{lt})}{(R_{CT} - g_{lt})(1 + R_{CT})^5}$ The model uses forecasted earnings per share (FEPS) by analysts for the first three years to measure the COE. The 4th and 5th forecasted earnings per share years are measures by multiplying the previous year forecast earnings per share by long term earnings growth rate (LTG). In case the LTG rate is missing, the growth rate of $FEPS_2$ and $FEPS_3$ is used. The g_{lt} in the model is measured as 10 years Treasury bonds minus 3%. The model use clean surplus to measure future book value ($B_{t+i-1}=B_t + FEPS_{t+1} - DPS_{t+1}$). The future dividend ($DPS_{t+1}$) in the model is measured by multiplying FEPS by dividend pay-out ratio (FDIV)
R_{RGLS} Gebhardt, Lee, and Swaminathan (2001)	$P_t^* = B_t + \sum_{i=1}^{T-1}\frac{[FROE_{t+i} - R_{GLS}] \times B_{t+i-1}}{(1 + R_{GLS})^i} + \frac{[FROE_{t+T} - R_{GLS}] \times B_{t+T-1}}{(1 + R_{GLS})^{T-1}R_{GLS}}$ The model use analyst forecast of return on equity (FROE) of the first 3 years to measure COE. Afterward, FROE is measured by using linter interpolation technique of previous ten years of industry specific FROE. In case the industrial FROE is lower the risk-free (Rf) rate, we use Rf rate instead of industry FROE (Liu, Nissim, and Thomas, 2002). After the 12 year, the model assumes industry FROE to stay constant. The model also uses accounting clean surplus to measure future book values (($B_{t+i-1}=B_t$ + $FEPS_{t+1}$ - DPS_{t+1}) where $DPS_{t+1}=FEPS_{t+1}$ * FDIV
COE	The arithmetic mean of four implied cost of equity measures (R_{OJ}, R_{MPEG}, R_{CT} and R_{GLS})-risk-free

A.2: Variables definition and measurements

Variable	Definition	Measurement
COE	The implied cost of equity	The mean value of four implied cost of equity measures (R_{OJ}, R_{MPEG}, R_{CT} and R_{GLS})
Carbon_Tweets	Firm's carbon-related Tweets	The natural logarithm of the total number of carbon-related tweets
iCarbon_Retweet	Firm's carbon-related Tweets that are retweeted	The natural logarithm of the total number of carbon-related tweets that are retweeted
ENV_STR	Environmental strength	The number of firm's environmental strength rating at the year
ENV_CON	Environmental concern	The number of firm's environmental concern rating at the year
SIZE	Firm size	Natural logarithm of firm's total assets
LEV	Financial leverage	The ratio of debt to market equity value
DISP	Analysts' forecast dispersion	The standard deviation of one-year consensus earnings per share forecast ($FEPS_1$)
BETA	Firm beta coefficient	Firm's beta coefficient using market model of 60 with at least 24 months stock and market return
LTG	The long term consensus growth forecast	The natural logarithm of the mean of long-term growth rate of earnings forecast or $FEPS_2$ minus $FEPS_1$ divided by one year ahead average $FEPS_{1\&2}$
CD_NEWS	News coverage	Natural logarithm of total number of news articles that relate to carbon information
INST_OWN	Percentage of institutional ownership	The percentage of shares that owned by institutions investors
BOD_IND	The percentage of independent directors	The percentage of independent directors in the board of directors
CSR_COMMITTEE	Environmental Committee	Dummy variable of whether a firm has an environmental committee
SALES_GROWTH	Growth in Sales	The change in sales from previous year scaled by previous year total sales
LOSS	Losing firm	Dummy variable of a firm reports negative earnings during the year
R&D	Research and development	The ratio of research and development expenses to total assets
MMT	Price momentum	The compounded rate of return of the last 12 months
MTB	Market to book ratio	Market to book value ratio
BOARD_SIZE	Board size	The natural logarithm of the number of board of directors members
CAPX	Capital expenditure	Total capital expenditure divided by total revenue
AGE	Firm age	The number of years since firms are listed in CRSP
SURP	Earnings surprise	Firm's Consensus earnings forecast minus current earnings divided by share price