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RESEARCH ARTICLE

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# The effect of carbon dissemination on cost of equity

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**Abstract**

This study examines whether firms can influence their cost of equity (COE) by broadly disseminating their carbon information over Twitter. We study firms' dissemination decisions of carbon information by developing a comprehensive measure of carbon information that a firm makes on Twitter, referred to as *iCarbon*. Using a sample of 1,737 firm-year observations for 584 nonfinancial firms with a Twitter account and listed on the U.S. NASDAQ stock exchange over the period 2009–2015, we find that *iCarbon* is significantly and negatively associated with COE. Our results are consistent after determining the effect of Bloomberg's environmental and environmental, social, and governance disclosure. The findings also hold when using alternative measures of COE and *iCarbon*.

KEYWORDS

carbon emissions, climate change, cost of equity, dissemination, legitimacy theory, twitter

## 1 | INTRODUCTION

Undoubtedly, climate change-related events that receive high media coverage and increased attention from environmental groups, governments, and investors motivate firms to make strategic investments to improve their environmental performance (El Ghoul, Guedhami, Kim, & Park, 2018) and to consider carbon impacts as part of their management strategy (Sprengel & Busch, 2011; Weinhofer & Hoffmann, 2010). Such interest has "created opportunities and challenges for firms in their risk-return relationships with shareholders and other stakeholders" (Ng & Rezaee, 2015, p. 128). This interest also puts growing pressure on managers to satisfy shareholders' carbon-related information demands to enable investors to assess potential risks, including regulatory, physical, and business risks, and evaluate their investment strategy (e.g., Dobler, Lajili, & Zéghal, 2014). Managers, therefore, have incentives to show their proactivity by strategically conveying messages about carbon-related information to reduce investors' uncertainty about future cash flows and to sustain a better competitive advantage and reputation (see Botosan, 1997; Diamond & Verrecchia, 1991). The value of carbon information, however, is expected to increase as more stakeholders become aware of it (Servaes & Tamayo, 2013). Although firms may disclose carbon information, it is difficult to ensure that this information reaches a larger set of investors by relying on traditional or third-party communication channels, which results in information asymmetry (see Blankespoor, Miller, & White, 2014; Easley & O'hara, 2004) and thus a higher cost of equity (COE; e.g., Dhaliwal, Li, Tsang, & Yang, 2011). Consequently, firms acknowledge the importance of improving the dissemination of their information apart from disclosure (Bushee, Core, Guay, & Hamm, 2010; Bushee & Miller, 2012). Thus, a broader spread of carbon information allows potential investors to be aware of a firm's information and enlarges the investor base, which in turn can improve firm value and reduce the COE (Byun & Oh, 2018; Heinkel, Kraus, & Zechner, 2001; Merton, 1987).

This study employs legitimacy theory to examine whether a firm's dissemination of carbon-related information (*iCarbon*) on Twitter's social media network can influence a firm's COE. Social media is an essential tool for connecting stakeholders with firms, for influencing corporate practice, and for controlling corporate pollution and irresponsible practices (Jia, Tong, Viswanath, & Zhang, 2016). The Twitter platform, which enables the isolation of the effect of dissemination from that of disclosure (Blankespoor et al., 2014; Jung, Naughton, Tahoun, & Wang, 2018), has "changed the disclosure landscape and the way firms communicate important information to stakeholders" (Lee, Hutton, & Shu, 2015, p. 368) and can provide positive signals to market participants about a firm's environmental responsibility to respond to the uncertainty of carbon risks and to improve the firm's reputation and image (Barnett & Salomon, 2012). Twitter's design of short messages (tweets) may allow many firms to gain legitimacy among stakeholders and avoid scrutiny by demonstrating that they are environmentally responsible organisations (see Stanny, 2013). Twitter also allows firms to know the size of their audience and the number of their followers, which may motivate their decision to disseminate to a broader audience, in a much more timely and efficient manner than a corporate website can achieve. Firms can share their news and discuss their performance through the use of a hashtag (#CarbonEmissions or #ClimateChange) to spread their messages to stakeholders who are concerned about global warming issues and threats and to attract the attention of these stakeholders. By retweeting, the recipients of carbon-related tweets can share this information with their followers to expand the information reach to a more diverse audience and to more potential investors. In essence, using Twitter allows firms to reach potential investors directly and prolongedly in a timely manner that can reduce the time, effort, and energy that investors need to spend on finding, searching for, and accessing information (Blankespoor, 2018; Miller & Skinner, 2015). Twitter also mitigates information asymmetry by meeting the demand for information and ensuring its availability to investors (Blankespoor et al., 2014; Hirshleifer, Lim, & Teoh, 2009; Hirshleifer & Teoh, 2003).

Our paper makes several contributions to the extant literature. First, although the extant research (e.g., Balvers, Du, & Zhao, 2017; Chen & Gao, 2011; Gupta, 2018; Jung, Herbohn, & Clarkson, 2018; Kim, An, & Kim, 2015; Lee, Park, & Klassen, 2015; Li, Liu, Tang, & Xiong, 2017; Peng, Sun, & Luo, 2015; Sharfman & Fernando, 2008; Zhou, Zhang, Wen, Zeng, & Chen, 2018) focused on temperature shocks, managing climate/environmental risks and responding to the Carbon Disclosure Project (CDP) survey to examine market responses to firms' voluntary climate change information disclosure or their associations with the cost of debt financing/equity capital, this paper examines the dissemination effect of carbon-related information via Twitter (*iCarbon*) on the COE. This broader effect is unlike that of disclosure and has its own capital market consequences (Bushee et al., 2010). Corporate disclosures also "often reach only a portion of investors, which results in information asymmetry among investors" (Blankespoor et al., 2014, p. 79). Second, the prior research (Bushee et al., 2010; Li, Ramesh, & Shen, 2011) has paid particular attention to press releases, as an information intermediary, to examine the effect of dissemination on information asymmetry. The press, however, is biased towards the coverage of highly visible firms and often modifies the information released by firms by adding a discussion, providing opinions, and/or summarising the news (Blankespoor et al., 2014). In contrast, tweets disseminated by firms are short and independent of media adjustments, which make them most likely to be used for disseminating purposes rather than for providing comprehensive information. Finally, although previous studies (Bartov, Faurel, & Mohanram, 2017; Chen, De, Hu, & Hwang, 2014; Jame, Johnston, Markov, & Wolfe, 2016) examine the effect of user-granted information over social media on capital market activity, we focus more on firm granted information. Prior work shows how firms' dissemination on Twitter improves market liquidity (Blankespoor et al., 2014; Prokofieva, 2015) and attenuates negative market reaction to product recalls (Lee, Hutton, & Shu, 2015) and acquisition announcements (Mazboudi & Khalil, 2017), to the best of our knowledge, no study has examined the effect of the Twitter dissemination of carbon-specific information on the COE.

We employ a sample of 1,737 observations, representing 584 nonfinancial firms with Twitter accounts, listed on the NASDAQ stock exchange for the period 2009–2015. We use the implied COE, which is based on the average of four estimates, as a proxy for the COE, and the number of tweets that relate to carbon information[1] as a proxy for *iCarbon*. Our findings show that the better dissemination of carbon information reduces a firm's equity financing costs. We also examine the effect of firms' environmental disclosure, using a scoring level, on the association between *iCarbon* and the COE. Our results report no effect of environmental reporting, whereas *iCarbon* is negatively related to the COE. Consistently, we find similar results by examining the effect of environmental, social, and governance (ESG) disclosure. Overall, our findings support the legitimacy theory and indicate that firms that voluntarily disseminate more carbon-related information have a lower COE. The results are robust for the alternative specifications of the model.

The organisation of the paper is as follows: The literature and hypothesis development are reviewed in Section 2. The data and methodology are presented in Section 3. Section 4 presents the results and discusses the key findings. Section 5 concludes.

## 2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Organisations operate in a social, political, and economic context (Buhr, 1998) and have obligations to society in general that go beyond their interests and legal responsibilities. As a part of the modern project of justice and progress, organisations establish their legitimacy based on society's perception of their contribution to the public good (Brunsson, 2006). The relationship between organisations and society, then, is viewed as a "social contract" in which their continuing existence relies upon adapting to the social norms, values, and expectations of organisations and their activities. Such a strategy is essential to obtain and preserve social approval or a licence to operate (Schepers, 2010), that is, legitimacy[2] by changing the societal perceptions of social constituencies (Buhr, 1998; Guthrie & Parker, 1989; Oliver, 1996; Patten, 1992;

[1]We focus on carbon information because U.S. firms that emit at least 25,000 metric tons of $CO_2$ are mandated to report their emissions, but not on Twitter, which allows us to differentiate the effect of dissemination from that of disclosure decisions.

[2]The legitimacy concept is "rooted in neo-institutional social theory…and has branched out from sociology and is commonly used within legal scholarship that examines the connections among legal frameworks, social norms and decision making" (Bowen, 2014, p. 59). Parsons (1960) viewed legitimacy in organisational institutionalism as the sharing of common values between the organisation and the social system in which it exists. Among other institutional theorists, Suchman (1995) provided an in-depth analysis of organisational legitimacy and referred to it as "a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (p. 574).

Scherer, Palazzo, & Seidl, 2013). As Dowling and Pfeffer (1975) state, "Organisations seek to establish congruence between the social values associated with or implied by their activities and the norms of acceptable behaviour in the larger social system of which they are a part" (p. 122). Undoubtedly, "organisations that … lack acceptable legitimated accounts of their activities … are more vulnerable to claims that they are negligent, irrational or unnecessary" (Meyer & Rowan, 2004, p. 50, cited in Suchman, 1995, p. 575).

We use legitimacy theory (e.g., Adams, Hill, & Roberts, 1998; Campbell, 2000; Deegan & Gordon, 1996; Garriga & Melé, 2004; Guthrie & Parker, 1989; Suchman, 1995; Zhao, 2012) as a positive theory that embraces a system-oriented perspective, which is derived from political economy theory[3] (e.g., Deegan, 2014; Williams, 1999; Woodward, Edwards, & Birkin, 2001), to explain why firms disseminate carbon-related information via Twitter. Much of the prior research drawing on legitimacy theory to explain or predict particular managerial activities claims that environmental disclosures to communicate with society, on whom an organisation depends for its viability, are necessary to gain legitimacy among stakeholders (Deegan, 2014; Zeng, Xu, Yin, & Tam, 2012), improve stakeholders' perceptions of a firm's environmental efforts (Cho & Patten, 2007; Plumlee, Brown, Hayes, & Marshall, 2015), mitigate stock market risk (Bansal & Clelland, 2004; Orlitzky & Benjamin, 2001; Salama, Anderson, & Toms, 2011), reduce the COE capital (Dhaliwal et al., 2011; El Ghoul, Guedhami, Kwok, & Mishra, 2011), improve financial performance (Clarkson, Li, Richardson, & Vasvari, 2011; Margolis & Walsh, 2003; Orlitzky, Schmidt, & Rynes, 2003), and lessen exposures to political and public pressures (Cho, Freedman, & Patten, 2012).

Lindblom (1994) identifies four possible paths to legitimisation to respond to such public pressure. The first path is to inform the relevant public about actual changes in activities or intentions to improve performance. The second path is to attempt to alter stakeholders' perceptions of negative events without making any changes to those actions. The third path is to distract attention away from the threatening events by emphasising more positive actions that do not necessarily have to be related. The fourth path is to attempt to influence society's expectations with regard to performance.

It is also pertinent to note that legitimacy is "a multidimensional concept" (Álvarez-García, Maldonado-Erazo, & del Río, 2018, p. 72), which, according to Suchman (1995), is composed of three dimensions that co-exist in most real-world settings: pragmatic, moral, and cognitive legitimacy. Pragmatic legitimacy (Suchman, 1995) emphasises the self-interested calculations of the particular interests of an organisation's most immediate social actors, through exchange, influence, or disposition. Pragmatic legitimacy occurs when the legitimacy granter fulfils his/her interests, achieving a value contribution, while acquiring specific commitments with the legitimacy seeker (Díez-de-Castro, Peris-Ortiz, & Díez-Martín, 2018). The second dimension of legitimacy is moral (ethical) legitimacy, which "becomes the decisive source of societal acceptance for corporations in an increasing number of situations" (Palazzo & Scherer, 2006, p. 74). Stakeholder pressure reflects moral legitimacy (Salmi, 2008), which rests on judgements about whether a given activity is the right thing to do to promote the social welfare of the actors that surround the organisation, rather than on judgements about whether the evaluated objective benefits a particular set of constituents (Suchman, 1995). Therefore, "moral legitimacy should be achievable by claiming to be ethical and acting accordingly" (Treviño, den Nieuwenboer, Kreiner, & Bishop, 2014, p. 200). An organisation is evaluated as legitimate from a moral point of view when audiences perceive that it defends and pursues principles accepted and valued as socially positive, which are considered more important than private interests by such an organisation (Díez-de-Castro et al., 2018; Miranda, Cruz-Suarez, & Prado-Román, 2018). Maintaining this legitimacy notion leads to competitive advantages, such as enhanced reputation (Schepers, 2010), which emphasises the economic benefits to organisations of being different (Bowen, 2014). Moral legitimacy is usually analysed by evaluating the appropriateness or desirability of the outcomes (consequential legitimacy), procedures (procedural legitimacy), structures (structural legitimacy), and leaders (personal legitimacy) used to achieve the objectives. Unlike moral legitimacy, cognitive legitimacy is established when the techniques and procedures used to achieve an organisation's objectives are perceived to be adequate and accepted without question (Iglesias-Pérez, Blanco-González, & Navalón, 2018; Salmi, 2008). Cognitive legitimacy accentuates that an organisation is granted legitimacy when audiences see its activities as fitting into their beliefs and assumptions or when they cannot imagine that an organisation would not be corresponding to their interests (Treviño et al., 2014). Cognitive legitimacy, therefore, represents a state of "comprehensibility" or a "taken-for-granted" (inevitability or permanence; Palazzo & Scherer, 2006; Schepers, 2010) and operates at the subconscious level, making it difficult for the organisation to directly and strategically influence perceptions (Suchman, 1995).

Using legitimacy theory as an interpretive lens, Patten (1992) examined the change in the environmental disclosures of annual reports by 21 North American petroleum companies in response to the increased environmental concern resulting from the 1989 Alaskan Exxon Valdez oil spill incident. He argued that if the Alaskan oil spill resulted in a threat to the legitimacy of petroleum firms and not just to Exxon, then legitimacy theory would suggest that companies operating within the petroleum industry would respond by increasing environmental disclosures in their annual reports. Patten's results show that there was a significant increase in the environmental disclosures made by the companies across the petroleum industry for the post-1989 period, even though the incident itself was directly related to one petroleum company. Patten suggested that threats to a firm's legitimacy entice it to include environmental information in its annual report. Deegan and Rankin (1996) also utilised legitimacy theory to explore how organisations altered their environmental reporting practices in their annual reports around the time of environmental prosecutions. The sample consisted of 20 Australian companies, which

[3]According to Gray, Owen, and Dams (1996), stakeholder theory and legitimacy theory are both derived from a broader theory that has been called political economy theory. The political economy is "the social, political, and economic framework within which human life takes place" (Gray et al., 1996, p. 47). The viewpoint included is that society, politics, and economics are inseparable, and economic issues cannot be investigated without considerations of the political, social, and institutional framework in which the economic activity takes place.

were subject to successful prosecution by the New South Wales and Victorian Environmental Protection Authorities, during the period 1990–1993. Of those firms that had been prosecuted, 18 provided positive and qualitative environmental news in their annual reports. Only two of the companies within the sample made any reference to the prosecutions. They found that prosecuted firms disclosed more environmental information (of a positive nature) in the annual report in the year of prosecution than any other year in the sample period. The prosecuted firms also disclosed more environmental information relative to nonprosecuted firms. The results of the study supported the view that management considered that the prosecutions negatively impacted the community's perception of the organisation, and as a result, management made other affirmative environmental disclosures in the annual report to limit the likely damage to the company's reputation as a result of the prosecutions.

More recently, Cho et al. (2012) examined two competing theories (voluntary disclosure theory[4] and legitimacy theory) to explain why some firms choose to disclose their environmental capital spending, whereas others do not. They found that disclosure does not appear to signal better future environmental performance relative to nondisclosure and that firms with worse environmental performance are more likely to disclose the amount they spend. They concluded that firms use environmental disclosure more as a strategic legitimising resource for reducing their exposures to political and regulatory concerns than as a mechanism for signalling superior environmental performance. Stanny (2013) examined voluntary disclosures concerning greenhouse gas (GHG) emissions by U.S. S&P 500 firms to the CDP from 2006 to 2008 and found that many firms only answer the CDP questionnaire but do not disclose their emission amounts or how they account for them. Consistent with legitimacy theory's predictions, she concluded that firms disclose the minimum necessary to reduce adverse public opinion, avoid scrutiny, and deter the possibility of being targeted by a shareholder resolution.

This paper contributes to empirical tests of legitimacy by examining a particular class of voluntary environmental information (*iCarbon*) and its dissemination impact on the COE. Climate change and its consequences present one of the most persistent threats to global economic stability (Peng et al., 2015) and have the potential to affect firms' costs of equity capital, which is the required rate of return given the market's perception of a firm's riskiness (El Ghoul et al., 2011). The current emergence of investor interest in climate-related risks calls for a specific type of global data about such risks to support rational investment decisions (The Economist, 2017).

Managers have private information about firms' carbon profiles, including the carbon strategy, carbon emissions, and carbon reduction activities that is not directly accessible by outside stakeholders (Luo & Tang, 2014). Organisations seek to protect (or enhance) past legitimacy accomplishments that they have already acquired by developing "a defensive stockpile of supportive beliefs, attitudes and accounts" (Suchman, 1995, p. 595). Lee, Park and Klassen (2015) provided empirical evidence to support this theoretical supposition. They examined a sample of Korean firms from the CDP and concluded that firms could mitigate the adverse effects of carbon disclosure on shareholder value by communicating their carbon news periodically (i.e., carbon management efforts and performance through the media coverage of global warming in daily newspapers) in advance of its carbon disclosure. It can thus be implied that managers strategically release relevant information to maximise the value of the firm as perceived by capital providers (see Beyer, Cohen, Lys, & Walther, 2010).

Accordingly, *iCarbon* can be considered a legitimate social contribution made by firms to enhance organisational credibility and legitimacy (see S. Y. Lee et al., 2015) and can be among the various aspects of transparency in environmental reporting to change societal perceptions and to respond to climate change-related political and public pressures. *iCarbon* is also expected to reduce investors' incentive to acquire private information by improving the broadness of information to a wider reach of investors, reducing information asymmetry, increasing share demand, and thus reducing the COE (Blankespoor et al., 2014; Easley & O'hara, 2004). Correspondingly, using *iCarbon* enables a firm to transmit carbon-related information at lower acquisition costs, allowing potential investors to gain knowledge about a firm's environmental information and assess carbon-related risks. Such a strategy increases the willingness among those investors to take on a larger portion of a firm's shares, which improves risk diversification (risk sharing) and hence reduces the COE (Heinkel et al., 2001; Merton, 1987).

Legitimacy, then, is a perception resource that organisations manipulate through various communication-related strategies (Aerts & Cormier, 2009; Deegan, 2014; Higgins & larrinaga, 2014) to engage in dialogues with stakeholders, to portray an image that these organisations are trying to convey to the relevant public (Stanny, 2013), and to enhance their reputation (Auger, Devinney, Dowling, Eckert, & Lin, 2013; Beyer et al., 2010; Busch & Hoffmann, 2011; De Villiers & Van Staden, 2006; Hasseldine, Salama, & Toms, 2005; Ullmann, 1985). As an innovative source of information, *iCarbon* serves as one of the communication channels between a firm and its stakeholders. Legitimacy theory suggests that the need to legitimise business actions will motivate managers to voluntarily disseminate carbon-related information on Twitter. The discussion above leads to the following hypothesis:

> **H1** *The dissemination of carbon-related information on Twitter (*iCarbon*) has a significant and negative association with the cost of equity (COE).*

## 3 | RESEARCH DESIGN

### 3.1 | Sample and data

Our sample comprises all nonfinancial firms with official Twitter accounts that are listed on the U.S. NASDAQ stock exchange for the period from 2009 to 2015. We focus on U.S. firms because foreign firms are exposed to different transparency levels, which influence

[4]Voluntary disclosure theory explains the disclosure of both general and financial environmental information (Bewley & Li, 2000). Such theory suggests that companies use the information "to signal an unobservable proactive strategy towards environmental concerns relative to poorer performing firms" (Cho et al., 2012, p. 487).

their COE. Additionally, the U.S. Securities and Exchange Commission permits firms to use social media, especially an interactive platform such as Twitter, for disclosing corporate announcements. Many U.S. firms also adopt Twitter and use it for multiple purposes, including corporate announcements (Blankespoor et al., 2014; Jung, Naughton, et al., 2018), which induces an expected coverage during the sample period. We also focus on a single stock exchange to avoid any effect from exchange listing (Bushee et al., 2010). Furthermore, our sample period allows us to mitigate any macroeconomic effects of the financial crisis.

Our data collection starts by identifying whether each firm in the sample has an official Twitter account. We first search firms' websites, including the Investor Relations pages, for any links or mentions of a firm's Twitter account. If a firm has not provided any Twitter account on its websites, we identify all profiles that match their names on Twitter by using the users' search engine. We ensure that only certified accounts, with a blue verified Twitter badge, are considered, assuring that the firms are the main source of carbon-related information. We also use Google's search engine to search for firms' adoption and presence on Twitter.

To measure the implied COE, we require all firms in our sample to have positive median earnings forecasts for 1 and 2 years ahead. These earnings forecasts are collected in June of each year to ensure that analysts have assimilated all the information from the fiscal year report in their forecasts. We also require firms to have available COE estimates. This procedure retains a full sample of 1,737 observations, representing 584 firms.

To download a firm's tweets, we use two main features that are usually used to aggregate Twitter data. We first use Twitter's application programming interface, which provides up to 3,200 tweets per user. If the number of tweets that the firm posts on Twitter exceeds 3,200, we then use keyword searches using Twitter's advanced search option. This procedure makes it easier to manually retrieve tweets. We refine our search criteria by using keywords that relate to carbon information (e.g., carbon, climate change, $CO_2$, emissions, GHG, global warming, GHG, and pollution). We then merge all firms' tweets from the Twitter application programming interface and advance search under one file.

We use two sources (*Bloomberg* and *DataStream*) to collect the data used to estimate the dependent and control variables. We also use *LexisNexis* to count the number of articles that are disseminated on other communication channels and that are related to carbon information. We allocate these articles by using company identifiers and keyword search features. We use our carbon keyword list, mentioned in Section 3.2.2, to retrieve carbon-related news articles. This procedure allows us to retrieve articles from many sources, such as *The Wall Street Journal*, *USA Today*, *The Washington Post*, and *The New York Times*. We also Winsorise the amount of carbon news coverage (CD_NEWS), financial leverage (LEV), long-term growth forecast (LTG), beta coefficient (BETA), book-to-market ratio (BTM), earnings surplus (SURP), and the dispersion of analysts' forecasts (DISP) at the 2.5th to 97.5th percentiles to control for outliers. This Winsorising level is also used for the COE to eliminate negative values because we are not expecting investors to require a negative rate of return.

## 3.2 | Variables

### 3.2.1 | Cost of equity

Our dependent variable (COE) is based on the implied COE (El Ghoul et al., 2011; Hail & Leuz, 2006), which is measured as the average of four COE estimates: (a) Claus and Thomas' model (Claus & Thomas, 2001), $R_{CT}$; (b) Gebhardt, Lee, and Swaminathan's model (Gebhardt, Lee, & Swaminathan, 2001), $R_{GLS}$; (c) Ohlson and Juettner-Nauroth's model (Ohlson & Juettner-Nauroth, 2005), $R_{OJ}$; and (iv) Easton's model (Easton, 2004), $R_{MPEG}$. We use the average of these estimates to reduce any estimation error of the COE (Hail & Leuz, 2006). We also use this measure because it enables us to differentiate between the influence of both cash flow and growth from the COE (Chen, Chen, & Wei, 2009). This estimate is useful for time-series variations in the COE (Pástor, Sinha, & Swaminathan, 2008).

### 3.2.2 | iCarbon

Our independent variable, *iCarbon*, reflects the number of carbon-related tweets that are disseminated to the public. We compute this measure by searching for keywords and phrases that relate to carbon-related information. In this regard, we use many keywords that were used in the prior literature and that align with carbon disclosure, reporting and information (e.g., Griffin & Sun, 2013; Hahn, Reimsbach, & Schiemann, 2015; Hsu & Wang, 2013; Lee, Park, & Klassen, 2015; Schmidt, Ivanova, & Schäfer, 2013). We also use the Twitter hashtag key (#), a feature that can be used to broaden climate information and trigger discussions among users about an event or specific topic. Thus, we include many hashtags that relate to carbon emissions, climate change, and global warnings. In general, we define several keyword lists based on combinations of words and single phrases to identify *iCarbon* tweets.

To allocate *iCarbon* tweets, we process all collected tweets through a matching scheme programme that we developed in Python. This programme follows many steps: We ask the programme to (a) read all firms' tweets, (b) divide these tweets into words, (c) remove the words that have no meanings ("stop words" such as "a" and "the"), and (d) align these tweets with our keyword lists, which we define as follows:

("carbon*", "emission*", "gas", "climate", "GHG", "pollution", "$CO_2$") AND ("disclos*", "report*", "statement*" "release*", "announce", "declare*").

("carbon* emission*", "gas emission*", "climate emission*", "GHG emission*", "pollution emission*", "$CO_2$ emission*").

("greenhouse gas", "carbon dioxide", "carbon neutral", "carbon footprint", "climate change", "greenhouse effect*", "carbon offset*", "carbon monoxide", "@CDP", "global warming*","fossil fuel*", "#globalwarming", "#global_warming", "#global-warming", "#climate-change", "#climatechange","#climate_change", "#climate", "#carbonemission").

After matching firms' tweets with our keyword lists, we count the annual number of tweets that match our keyword lists for each firm or zero otherwise. Appendix A provides some examples of *iCarbon* tweets.

### 3.2.3 | Control variables

Our control variables include many variables associated with firm characteristics such as firm size (*SIZE*), *BTM*, and *LEV* (Botosan, 1997; Fama & French, 1992; Hail & Leuz, 2006). Larger firms have a better information environment and thus a lower COE (Gebhardt et al., 2001). The COE increases for undervalued firms that have a greater *BTM* ratio. Additionally, firms that have high *LEV* in their capital structure expect to have a higher COE (Cao, Myers, Myers, & Omer, 2015). We also expect a positive association with the *DISP*, *BETA*, and *LTG*. Firms that have a more uncertain information environment, systematic risk or market mispricing would be expected to have a higher COE (Botosan, Plumlee, & Wen, 2011; Cao et al., 2015; El Ghoul et al., 2011; Gebhardt et al., 2001; Gode & Mohanram, 2003). We further control for the availability of information by other intermediaries by including the amount of *CD_NEWS* and the percentage of institutional holdings (*INSTOWN*; Cao et al., 2015; Zhou et al., 2018). We expect higher carbon coverage (*CD_NEWS*) and institutional ownership (*INSTOWN*) to improve a firm's information environment and thus be associated with a lower COE (Cao et al., 2015; Griffin & Sun, 2013; Li et al., 2017). We also consider the content of firm news by controlling for *SURP*. Due to the higher uncertainty of future earnings profitability, we expect that firms with negative earnings (*LOSS*) are difficult to analyse and thus have a higher COE (Orens, Aerts, & Cormier, 2010). Furthermore, we include many variables that determine climate change/carbon information. Additionally, we control for independent directors (*BOD_IND*), the environmental committee (ENV_COMMITTEE), CDP participation (CDP), firm age (AGE), and whether the firm is subject to the Environmental Protection Agency's (EPA) Mandatory Reporting Rule. Independent board directors play a monitoring role in managerial decisions and activities, which enhances disclosure policy and transparency. An environmental committee plays an advisory role in the better management of emissions and disclosure policy and a motivating role in reporting reliable information. We also include the CDP to control for firms' willingness to report carbon information. This measure represents the firm's ability to identify carbon-related issues and their potential consequences (Jung, Herbohn, & Clarkson, 2018). Aged firms "tend not to choose to operate environmental information disclosure" (Zeng et al., 2012, p. 317). Firms in industries that are more sensitive to carbon information are more inclined to choose greater transparency in the policy of disclosure to avoid the scrutiny of regulators (Deegan & Gordon, 1996). Therefore, we expect firms under EPA regulation to respond more to investor demand and to use *iCarbon* more. Technology firms are expected to be more inclined towards technology adoption, and thus, we expect them to be more active on Twitter (Blankespoor et al., 2014). The full definition and measurement of our dependent, independent, and control variables are presented in Appendixes B and C.

## 3.3 | Model

To examine the impact of *iCarbon* on COE, we employ the following Model 1:

$$\begin{aligned} COE_{it} = {} & \beta_0 + \beta_1\, iCarbon_{it} + \beta_2\, SIZE_{it} + \beta_3 BTM_{it} + \beta_4 LEV + \beta_5 DISP_{it} \\ & + \beta_6\, BETA_{it} + \beta_7\, LTG_{it} + \beta_8\, Carbon\_NEWS_{it} + \beta_9\, INSTOWN_{it} \\ & + \beta_{10}\, SURP_{it} + \beta_{11}\, LOSS_{it} + \beta_{12}\, BOD\_IND_{it} \\ & + \beta_{13}\, ENV\_COMMITTEE_{it} + +\beta_{14}\, CDP_{it} + \beta_{15}\, AGE_{it} \\ & + \beta_{16}\, EPA_{it} + \beta_{17}\, TECH\_FIRM_{it} + \beta_{18} \textstyle\sum_{t=2015}^{2009} T_t + \varepsilon_{it} \end{aligned} \qquad (1)$$

Our estimation procedures employ pooled Ordinary Least Squares (OLS) regressions with robust standard error clustered at the firm level to control for serial correlation and heteroscedasticity (Cao et al., 2015; El Ghoul et al., 2011; Ferris, Javakhadze, & Rajkovic, 2017; Petersen, 2009).[5] We also utilise a two-stage least squares (2SLS) model as an alternative estimation, clustered at the firm level, to control for any potential endogeneity between *iCarbon* and the COE (Nikolaev & Van Lent, 2005). In this model, we use both the lagged value of *iCarbon* and the industry-year *iCarbon* mean as our instrumental variables. These instruments are more related to a firm's engagement in *iCarbon* but do not necessarily affect the firm's value or COE (Cheng, Ioannou, & Serafeim, 2014; Schreck, 2011). Firms' performance environmental and social issues are influenced by other firms' performance in the same year, country and industry, whereas *iCarbon* in the prior year is expected to reflect firms' persistence and the stability of using *iCarbon* over time. To capture the validity of these instruments, our tests show that both LAG_iCarbon and IND_iCarbon are significantly correlated with *iCarbon*. We perform two diagnostic tests to identify the validity of both the IVs and the specification of our system equations, the Sargan test (misspecification test with the null hypothesis of no misspecification) and the Breusch and Pagan LM test (to examine whether cross-equation disturbances are truly associated with each other and if the equations need to be tested simultaneously).[6] Both IVs theoretically and statistically satisfy the necessary conditions for validity and relevance, and hence, the 2SLS results tend to be consistent and more efficient than those obtained using the OLS method.

# 4 | RESULTS AND ANALYSIS

## 4.1 | Descriptive statistics

The descriptive statistics, provided in Appendix D, for all our variables in Model 1 show that the mean of COE is equal to 5.2%, which is consistent with the prior literature (El Ghoul et al., 2011; Ferris et al., 2017). The mean value of *iCarbon* is 0.51, which indicates that firms' use of *iCarbon* is not high. The natural logarithm of firm size (SIZE) has a mean equal to 21.147, which is equivalent to an unreported mean of firm value equal to 9,144.414 million dollars. The mean and median values of BTM are equal to 0.424 and 0.347, respectively. On average, firms in our sample have leverage equivalent to 15%.

[5] Our results show the existence of a heteroscedasticity problem; the Breusch–Pagan test is significant with $p$ value = 0.000.

[6] The partial $R^2$ is equal to 0.844, with an $F$ statistic higher than the critical value (Staiger & Stock, 1997). The Durbin Wu–Hausman test shows a $p$ value of 0.87, suggesting that endogeneity is not an issue. The Sargan test for overidentification is insignificant with a $p$ value equal to 0.4736.

The medians of DISP, BETA, and LTG are 0.081, 1.029, and 0.15, respectively.

Regarding news coverage of carbon information, on average, a natural logarithm of 0.77 news articles is issued regarding firms. Furthermore, the table shows that institutional investors own a high proportion in terms of the mean and median of the sample. It also appears that the mean of earnings surprise is negative (−0.334), whereas the median is positive (0.031). Accordingly, approximately 18% of our sample report negative earnings. Our sample also shows that 78% of firms' board directors are independent and that a small number of firms have an environmental committee and participate in the CDP, with a mean value of 0.014 and 0.22, respectively. The mean (median) of firm age (AGE) is 21.33 (18) years.

The Spearman and Pearson correlation matrix between the dependent, independent, and control variables at the 10% significance level are presented in Appendix E. The correlation matrix shows a negative correlation between the COE and *iCarbon*. This finding provides initial evidence that higher *iCarbon* use reduces the COE, which is consistent with our hypothesis. Larger firms tend to have a lower COE. The results also show that higher BTM, LEV, DISP, BETA, and LTG increase the COE, whereas INSTOWN, SURP, and BOD_IND reduce the COE. Additionally, our results show that loss-making firms have higher equity financing. In short, these results are consistent with the view that the COE is lower for firms with less uncertainty and a richer information environment. Consistently, participation in the CDP reduces the COE. However, the positive association between *iCarbon* and SIZE indicates that larger firms use *iCarbon* more, which is consistent with prior findings (Lee, 2012; Weinhofer & Hoffmann, 2010). Our results show that *iCarbon* is positively correlated with DISP and CD_NEWS. Firms that have negative earnings are less likely to use *iCarbon*.

Conversely, higher BOD_INDP leads to increased use of *iCarbon*. Consistently, firms that participate in the CDP disseminate more carbon-related information on Twitter. Overall, the correlation matrix and unreported variance inflation factor tests indicate that multicollinearity is not an issue across our empirical models.

## 4.2 | Empirical results

Table 1 reports the results of both the OLS and 2SLS estimation models for testing our hypothesis, identifying the possible negative significant impact of *iCarbon* on the COE. The results show significant negative coefficients between *iCarbon* and the COE for both models ($p < 0.05$) in Columns 1 and 2. These findings imply that a managerial decision to disseminate carbon-related information (*iCarbon*) on Twitter reduces the COE. Such an improvement in information dissemination allows many investors to receive information in a timely and efficient manner, resulting in lower uncertainty in evaluating a firm's future cash flows and a better assessment of a firm's risks. Therefore, firms' decision to disseminate and broaden carbon information provides benefits for both firm management and investors. First, this dissemination and broadening allows managers to mitigate information asymmetry and improve legitimacy and investor recognition. Second, this dissemination and broadening enables investors to acquire firm information at a lower acquisition cost and estimate firms' potential risks. Even though these tweets are short, providing less comprehensive information, the dissemination role of carbon information on Twitter, apart from disclosure, has a negative impact on the COE.

The findings also indicate a significant negative association for SIZE and positive associations for BTM, LEV, BETA, and LTG. These results suggest that the market perceives firms that are small in size or have a high growth rate, financial leverage, or systematic risk to be high-risk firms and thus should offer a higher required rate of return (COE). The negative coefficient of INSTOWN suggests that

**TABLE 1** The impact of *iCarbon* on cost of equity

| Independent variables | Dependent variables (1) COE (OLS) | (2) COE (2SLS) |
|---|---|---|
| *iCarbon* | −0.0003** (0.0001) | −0.0003** (0.0001) |
| SIZE | −0.0028*** (0.0011) | −0.0028*** (0.0011) |
| BTM | 0.0395*** (0.0047) | 0.0401*** (0.0052) |
| LEV | 0.0253*** (0.0064) | 0.0204*** (0.0065) |
| DISP | 0.014 (0.0107) | 0.0156 (0.0113) |
| BETA | 0.0062*** (0.002) | 0.0054*** (0.0021) |
| LTG | 0.0572*** (0.0175) | 0.05*** (0.0176) |
| CD_NEWS | 0.0024 (0.0015) | 0.003* (0.0016) |
| INSTOWN | −0.0115* (0.0059) | −0.0082 (0.0061) |
| SURP | −0.0003 (0.0002) | −0.0002 (0.0002) |
| LOSS | 0.0028 (0.0037) | 0.0025 (0.0039) |
| INDEPENT | 0.0132 (0.0115) | 0.0116 (0.0124) |
| ENV_COMMITEE | −0.0033 (0.0078) | −0.0049 (0.008) |
| CDP | 0.0044 (0.0028) | 0.0054* (0.0029) |
| AGE | 0.00001 (0.00006) | 0.00001 (0.00006) |
| EPA | 0.001 (0.0024) | 0.0009 (0.0025) |
| TECH_FIRM | −0.0127*** (0.0024) | −0.0111*** (0.0025) |
| Year effect | Yes | Yes |
| Firm effect | Yes | Yes |
| Constant | 0.0722*** (0.0244) | 0.0822*** (0.0250) |
| Observations | 936 | 839 |
| $R^2$ | 0.372 | 0.369 |

*Note*. COE: cost of equation; CD_NEWS: carbon news coverage; BTM: book-to-market ratio; LEV: financial leverage; ISTOWN: institutional ownership; DISP: dispersion of analysts' forecasts; BETA: beta coefficient; LTG: long-term growth forecast; ENV_COMMITEE: environmental committee; CDP: Carbon Disclosure Project; TECH_FIRM: technology firms; EPA: Environmental Protection Agency's. Table 1 presents the results of the impact of *iCarbon* on COE. The sample comprises of nonfinancial NASDAQ firms with Twitter accounts for a period from 2009 to 2015. See Appendixes B and C for variables descriptions and measurements. Column (1) presents the regression findings from pooled regression (OLS) clustered at the firm level. Column (2) presents the regression findings from the second stage of two stage least square (2SLS) model clustered at firm level. In parentheses, robust standard errors are presented.

*10%. **5%. ***1%.

greater institutional ownership enhances a firm's information environment, which reduces uncertainty and thus also reduces the COE. Furthermore, the nature of the industry may have a differing effect on the COE (Fama & French, 1997). Our results show that technology firms (TECH_FIRM) tend to have a lower COE. These firms face greater demand for information, which motivates them to provide more information through disclosure (Kothari, 2000). Previous studies have found that firms that belong to this industry and use Twitter to disseminate corporate information reduce information asymmetry and improve market liquidity (Blankespoor et al., 2014), which, in turn, reduces the COE. The regression models have $R^2$ equal to 0.37, indicating that our models explain 37% of the variance in the COE. This result is consistent with the previous literature (e.g., Breuer, Müller, Rosenbach, & Salzmann, 2018; Cao et al., 2015; El Ghoul et al., 2011), although smaller $R^2$ is not uncommon in the field of social sciences (Wooldridge, 2015). Overall, the results indicate that *iCarbon* helps to reduce equity financing. This finding may help managers to consider using *iCarbon* strategically as part of their voluntary disclosure policy to gain legitimacy among stakeholders. This evidence also provides insight into the importance of social media, particularly Twitter, as a communication channel to connect with various investors. This mechanism is expected to reduce information asymmetry, improve recognition, reduce acquisition costs, and enhance investors' estimation of risk.

## 4.3 | Additional analyses

### 4.3.1 | The effect of Bloomberg's environmental (ENV) and ESG disclosure

We further address whether a firm's level of environmental disclosure would affect the association between *iCarbon* and the COE. Firms that are more socially responsible have more incentives to disclose and engage in environmental activities and practices (Harjoto & Jo, 2015). These firms are motivated to maintain and improve their public images by generating positive media coverage, which, in turn, improves firm value and decreases the COE (Cahan, Chen, Chen, & Nguyen, 2015; Fatemi, Glaum, & Kaiser, 2018). That is, investor preference for environmentally friendly firms can lead to a lower investor base that is willing to buy and hold shares in polluting firms. This preference reduces risk sharing and thus increases firms' equity financing, creating environmental costs for firm managers (Chava, 2014; Heinkel et al., 2001; Merton, 1987). Accordingly, poor environmental performance induces lower demand by institutional investors and less "loan syndicate" participation by banks (Chava, 2014; Hsu & Wang, 2013). These studies show that firms should consider the benefits of environmental information to reduce their equity financing. Accordingly, firms with different levels of environmental performance induce different behaviours towards using communication channels to respond to environmental issues and concerns (de Villiers & Van Staden, 2011). As such, firms with better environmental performance promote more voluntary climate change disclosure (Dawkins & Fraas, 2011). We therefore expect firms with a higher environmental disclosure score to use *iCarbon*. Hence, we address whether a firm's disclosure score of environmental reporting would affect our main findings.

We use Bloomberg for firm environmental disclosure (ENV_SCORE). This variable incorporates data from many sources, including annual reports, the CDP, firms' websites, and CSR reports, generating a comprehensive score for firm disclosure. This score is estimated in terms of both industry relevance and data availability, starting from 0.1 for low-disclosing firms and continuing up to 100 for high-disclosing firms. The weighting system takes into account the importance of each category, making a category such as GHG emissions carry greater weight than other disclosure items. Weighting each data point in terms of its importance makes the disclosure score reflect both the quality and quantity of disclosure (Bernardi & Stark, 2018; Qiu, Shaukat, & Tharyan, 2016). We address this issue by including the environmental score (ENV_SCORE) and the interaction between *iCarbon* and the environmental score (*iCarbon* * ESG_SCORE) in Model 2 as follows:

$$
\begin{aligned}
COE_{it} = {} & \beta_0 + \beta_1 iCarbon_{it} + \beta_2\, ENV\text{¯}SCORE_{it} + \beta_3\, iCarbon_{it}{}^{*}ENV_{SCORE\,it} \\
& + \beta_4\, SIZE_{it} + \beta_5 BTM_{it} + \beta_6 LEV + \beta_7 DISP_{it} + \beta_8\, BETA_{it} \\
& + \beta_9\, LTG_{it} + \beta_{10}\, Carbon_{NEWS\,it} + \beta_{11}\, INSTOWN_{it} + \beta_{12}\, SURP_{it} \\
& + \beta_{13}\, LOSS_{it} + \beta_{14}\, BOD_{IND\,it} + \beta_{15}\, ENV_{COMMITTEE\,it} + \beta_{16}\, CDP_{it} \\
& + \beta_{17}\, AGE_{it} + \beta_{18}\, EPA_{it} + \beta_{19}\, TECH\text{¯}FIRM_{it} \\
& + \beta_{20} \textstyle\sum_{t=2015}^{2009} T_t + \varepsilon_{it}
\end{aligned}
\tag{2}
$$

We also examine a broader aspect of a firm's disclosure than simply environmental reporting by taking into account two components of sustainability reporting in addition to environmental disclosure: social and governance disclosures. In this section, we address whether a firm's disclosure score of ESG disclosure would also influence the association between *iCarbon* and the COE. The combination of all ESG dimensions enables many investors to evaluate a firm's risks, opportunities, and transparency, which in turn improves firm value and reduces the COE (Ng & Rezaee, 2015; Yu, Guo, & Luu, 2018). Such an effect is more pronounced for lower-ESG-disclosure-performing firms than for higher-ESG-disclosure-performing firms (Crifo, Forget, & Teyssier, 2015). However, firms with better ESG disclosure have better interaction and communication with stakeholders (Eccles, Ioannou, & Serafeim, 2014). These firms are likely to disclose their ESG activities and initiatives to signal and differentiate themselves in the capital market from those with lower ESG disclosure ratings (Crifo et al., 2015). We therefore expect firms with better ESG disclosure scores to strategically use *iCarbon* more than those with lower ESG disclosure scores.[7] Therefore, we investigate whether the ESG disclosure score (ESG_SCORE) would moderate the association between *iCarbon* and the COE. To examine this influence, we include ESG_SCORE and its interaction with *iCarbon* (*iCarbon* * ESG_SCORE) in Model 3:

[7]We use the Bloomberg database to obtain the ESG disclosure score, which reflects a firm's social, environmental, and governance data that are available to the public from corporate websites, press releases, annual reports, sustainability reports, and corporate governance reports. The score covers many topics such as board structure and independence, human capital, shareholders' rights, and GHG emissions. Such information is reflected in the ESG index score to reflect both the amount and importance of information. The score ranges from 0.1 to 100, where each data point is weighted in term of its importance and relevance to industry peers.

$$COE_{it} = \beta_0 + \beta_1 iCarbon_{it} + \beta_2\ ESG\text{-}SCORE_{it} + \beta_3\ iCarbon_{it}{}^{*}ESG_{SCORE} + \beta_4\ SIZE_{it} + \beta_5 BTM_{it} + \beta_6 LEV + \beta_7 DISP_{it} + \beta_8\ BETA_{it} + \beta_9\ LTG_{it} + \beta_{10}\ Carbon_{NEWSit} + \beta_{11}\ INSTOWN_{it} + \beta_{12}\ SURP_{it} + \beta_{13}\ LOSS_{it} + \beta_{14}\ BOD_{INDit} + \beta_{15}\ ENV_{COMMITTEEit} + \beta_{16}\ CDP_{it} + \beta_{17}\ AGE_{it} + \beta_{18}\ EPA_{it} + \beta_{19}\ TECH\text{-}FIRM_{it} + \beta_{20}\sum_{t=2015}^{2009} T_t + \varepsilon_{it} \quad (3)$$

We employ OLS regression with a robust standard error cluster at the firm level to estimate both Models 2 and 3 and present the results in Table 2. In these models, we have centralised our explanatory variables (i.e., *iCarbon*, ENV_SCORE, and ESG_SCORE) and their interactions (i.e., iCarbon*ENV_SCORE and iCarbon*ESG_SCORE). The finding from Model 2 shows that ENV_SCORE does not affect the association between *iCarbon* and the COE, as the interaction between *iCarbon* and ENV_SCORE has no significant coefficient with the COE. This result means that the number of *iCarbon* tweets has a direct association with the COE, which is not affected by the environmental disclosure score. The result from Model 3 shows a similar finding of a negative association for *iCarbon* on the COE, which is consistent with our main findings. The results also show no significant association for the interaction *iCarbon**ESG_SCORE.

Similarly, we found no significant association between ESG disclosure and the COE. Overall, the findings provide evidence that the association between *iCarbon* and the COE is not affected by either ENV_SCORE or ESG_SCORE. The results support our argument that investors appreciate carbon messages and dissemination, which is different from the reporting score.

### 4.3.2 | Robustness checks

As a robustness check, we use different measures for the COE and *iCarbon* and add different sets of control variables to our main Model 1. The results are reported in Table 3. We use $R_{PEG}$ (Easton, 2004) as an alternative measure of the COE. $R_{PEG}$ is considered a reliable measure for the COE and is widely used in the literature (Mangena, Li, & Tauringana, 2016). This measure assumes no dividend payout and is associated "with firm-specific risk characteristics in a theoretically predictable and stable manner" (Botosan et al., 2011, p. 1085). We employ the analysis in our main Model 1 by alternatively using $R_{PEG}$ instead of the COE in Column 1. The results show consistent evidence that *iCarbon* is negatively associated with the COE, as measured by $R_{PEG}$.

We also use two alternative measures of *iCarbon*. First, we use the number of *iCarbon* tweets that have a hyperlink. Including a hyperlink allows users to acquire more information by following the link (Blankespoor et al., 2014). Second, we use the number of *iCarbon* tweets that have been retweeted. This measure enhances the size of the audience as users share a firm's *iCarbon* tweets with their followers through the retweet button (Jung, Naughton, et al., 2018). Cade (2018) claim that retweeted messages are considered more valid by investors. We present the results in Columns 2 and 3 in Table 3. The results indicate that tweets with a hyperlink to the full information of a press release or news articles (*iCarbon_Hyperlink*) that are diffused to a larger number of users (*iCarbon_Retweet*) on Twitter are negatively associated with the COE. This finding is consistent with our main findings.

In Column 4, we control for multiple variables used in the prior literature (El Ghoul et al., 2011; Harjoto & Jo, 2015; Jung, Naughton,

**TABLE 2** The effect of ENV and ESG score

| | Dependent variables | |
|---|---|---|
| Independent variables | Model (2) | Model (3) |
| | COE | COE |
| *iCarbon* | −0.0005* (0.0003) | −0.0013** (0.0006) |
| ENV_SCORE | 0.00006 (0.0002) | |
| *iCarbon* * ENV_SCORE | 0.00002 (0.00002) | |
| ESG_SCORE | | 0.0002 (0.0002) |
| *iCarbon* * ESG_SCORE | | 0.00003 (0.00002) |
| SIZE | 0.0003 (0.0021) | −0.0035*** (0.0011) |
| BTM | 0.0448*** (0.012) | 0.0385*** (0.0046) |
| LEV | 0.0161 (0.0176) | 0.0249*** (0.0064) |
| DISP | 0.0195 (0.0164) | 0.0145 (0.0107) |
| BETA | 0.0032 (0.0047) | 0.0065*** (0.002) |
| LTG | 0.0291 (0.0368) | 0.0594*** (0.0176) |
| CD_NEWS | −0.0033* (0.0018) | 0.0019 (0.0015) |
| INSTOWN | 0.0073 (0.0124) | −0.0096 (0.0059) |
| SURP | 0.0003 (0.0033) | −0.0003 (0.0002) |
| LOSS | −0.0052 (0.0077) | 0.0031 (0.0037) |
| INDEPENT | 0.0101 (0.0193) | 0.0107 (0.0123) |
| ENV_COMMITEE | | −0.0026 (0.0082) |
| CDP | 0.0005 (0.0057) | 0.0028 (0.0028) |
| AGE | 0.000006 (0.0001) | 0.00001 (0.00006) |
| EPA | 0.0009 (0.0045) | 0.0005 (0.0024) |
| TECH_FIRM | −0.0124*** (0.0044) | −0.0128*** (0.0024) |
| Year effect | Yes | Yes |
| Firm effect | Yes | Yes |
| Constant | 0.0229 (0.0568) | 0.0875*** (0.0261) |
| Observations | 212 | 927 |
| $R^2$ | 0.335 | 0.377 |

*Note*. ENV_COMMITEE: environmental committee; ESG: environmental, social, and governance; COE: cost of equation; CD_NEWS: carbon news coverage; BTM: book-to-market ratio; LEV: financial leverage; DISP: dispersion of analysts' forecasts; BETA: beta coefficient; LTG: long-term growth forecast; CDP: Carbon Disclosure Project; SURP: earnings surplus; ISTOWN: institutional ownership; TECH_FIRM: technology firms; EPA: Environmental Protection Agency's. Table 2 presents the effects of environmental and ESG reporting on the association between *iCarbon* and COE. The sample comprises of nonfinancial NASDAQ firms with Twitter accounts for a period for a period from 2009 to 2015.See Appendixes B and C for variables descriptions and measurements. Model (2) presents the results after adding environmental reporting (ENV) score and its interaction with *iCarbon*. Model (3) includes environmental, social, and governance (ESG) score and its interaction with *iCarbon*. The coefficient estimates are results from pooled regression (OLS) clustered at the firm level. In parentheses, robust standard errors are presented.

*10%. **5%. ***1%.

**TABLE 3** Robustness tests for other measurements and additional variables

| Independent variables | Dependent variables: Alternative measure of COE (1) $R_{PEG2-1}$ | Alternative measure of iCarbon (2) COE | Alternative measure of iCarbon (3) COE | Additional control variables (4) COE | GMM (5) COE |
|---|---|---|---|---|---|
| *iCarbon* | −0.0004** (0.0002) | | | −0.0003* (0.0002) | −0.0017* (0.001) |
| *iCarbon_Http* | | −0.0005** (0.0002) | | | |
| *iCarbon_Retweet* | | | −0.0004** (0.0002) | | |
| SIZE | −0.0135*** (0.0017) | −0.0034** (0.0014) | −0.0034** (0.0014) | −0.0015 (0.0013) | .004 (0.0061) |
| BTM | 0.008 (0.009) | 0.0407*** (0.0061) | 0.0406*** (0.0061) | 0.0501*** (0.0064) | 0.0501*** (0.019) |
| LEV | −0.0007 (0.011) | 0.0226** (0.0089) | 0.0225** (0.0089) | 0.0286*** (0.0087) | 0.0117 (0.0176) |
| DISP | 0.0736*** (0.0129) | 0.0214 (0.0132) | 0.0218 (0.0133) | −0.0004 (0.0136) | 0.0006 (0.0238) |
| BETA | 0.0166*** (0.0042) | 0.0059** (0.0026) | 0.0059** (0.0026) | 0.0048* (0.0025) | −0.0073 (0.0091) |
| LTG | −0.0876*** (0.0168) | 0.0495** (0.0207) | 0.0495** (0.0207) | 0.0684*** (0.0158) | 0.0720*** (0.0227) |
| CD_NEWS | 0.0052** (0.0024) | 0.0043** (0.0019) | 0.0041** (0.002) | −0.0002 (0.0016) | 0.0036 (0.0026) |
| INSTOWN | −0.0610*** (0.0128) | −0.0170** (0.0077) | −0.0170** (0.0078) | −0.0108 (0.0081) | −0.0085 (0.0113) |
| SURP | −0.0004 (0.0005) | −0.0002 (0.0003) | −0.0002 (0.0003) | −3.35e-06 (0.0003) | −0.0002 (0.0003) |
| LOSS | 0.0554*** (0.0061) | 0.0068 (0.0046) | 0.0068 (0.0046) | −0.0036 (0.0046) | 0.0007 (0.0058) |
| INDEPENT | 0.0232 (0.0185) | 0.0104 (0.0145) | 0.0100 (0.0145) | 0.0277* (0.0156) | 0.0010 (0.0152) |
| ENV_COMMITEE | −0.023** (0.0089) | −0.0031 (0.011) | −0.0031 (0.0108) | −0.0011 (0.0121) | 0.0105 (0.0098) |
| CDP | 0.0051 (0.0048) | 0.0038 (0.0036) | 0.0037 (0.0036) | 0.0038 (0.0038) | −0.0065 (0.0075) |
| AGE | −0.0003*** (0.00008) | −0.00004 (0.0001) | −0.00003 (0.0001) | 0.00005 (0.00006) | −0.0001 (0.0003) |
| EPA | 0.0062 (0.0047) | 0.0008 (0.0033) | 0.0008 (0.0033) | 0.0066* (0.0034) | 0.0008 (0.0032) |
| TECH_FIRM | −0.0053 (0.0044) | −0.0144*** (0.0031) | −0.0143*** (0.0031) | −0.0116*** (0.0036) | −0.0081 (0.0052) |
| DUM_CEO | | | | −0.0026 (0.0028) | |
| GROWTH_SALES | | | | −0.0042 (0.0082) | |
| R&D | | | | 0.0017 (0.0277) | |
| CAPX | | | | −0.0613* (0.0351) | |
| ADVERTISING | | | | −0.0054*** (0.0017) | |
| LITI | | | | 0.0032 (0.0031) | |
| $COE_{t-1}$ | | | | | 0.410*** (0.137) |
| Year effect | Yes | Yes | Yes | Yes | Yes |
| Firm effect | Yes | Yes | Yes | Yes | No |
| Constant | 0.409*** (0.0423) | 0.0915*** (0.0307) | 0.0916*** (0.0310) | 0.0218 (0.0318) | −0.0686 (0.127) |
| Observations | 1,873 | 561 | 561 | 480 | 461 |
| $R^2$ | 0.419 | 0.414 | 0.413 | 0.456 | |

*Note*. ENV_COMMITEE: environmental committee; ESG: environmental, social, and governance; COE: cost of equation; CD_NEWS: carbon news coverage; BTM: book-to-market ratio; LEV: financial leverage; DISP: dispersion of analysts' forecasts; BETA: beta coefficient; LTG: long-term growth forecast; CDP: Carbon Disclosure Project; SURP: earnings surplus; ISTOWN: institutional ownership; R&D: Research and development; TECH_FIRM: technology firms; EPA: Environmental Protection Agency's; GMM: generalised method of moments. Table 3 presents the regression findings from our main Model (1) using alternative measures of *COE*, *iCarbon*, including additional control variables and using alternative estimation model. The sample comprises of nonfinancial NASDAQ firms with Twitter accounts for a period from 2009 to 2015. See Appendixes B and C for variables descriptions and measurements. In Column (1) we use $R_{PEG}$ on Model (1) instead of COE. Alternative: we use *iCarbon* with hyperlink in Column (2) and *iCarbon* tweets that are retweeted in Column (3) instead of *iCarbon* in Model (1). Column (4) reports the regression after adding many control variables (*ADVERTISING*, *CEOAGE*, *SALES_GROWTH*, *LITI*, *R&D*, and *CAPX*). Column (5) estimate Model (1) by using GMM regression technique and including lagged value of COE ($COE_{t-1}$). The coefficient estimates are results from pooled regression (OLS) clustered at the firm level except for Column (5). In parentheses, robust standard errors are presented.

*10%. **5%. ***1%.

et al., 2018; Lee, Hutton, & Shu, 2015). We control for the ratio of advertising expenses to total assets (ADVERTISING) and a dummy variable for whether a firm's CEO is younger than the average (CEOAGE) and the percentage change in sales growth (SALES_GRWOTH). Firms that spend more on advertisements and have younger CEOs and high growth rates in sales are expected to adopt social media, have Twitter accounts, and disclose more announcements on communication channels (Jung, Naughton, et al., 2018; Lee, Hutton, & Shu, 2015). We also expect a firm's valuation to increase by generating high sales growth. Additionally, some industries are subject to different litigation risks and more potential lawsuits. Hence, we include dummy variables (LITI) for firms that operate in high-litigation industries (Dhaliwal et al., 2011). We also control for research and development (R&D) and capital expenditure (CAPX). Although R&D is an expense that a firm pays, this expense might generate value (Servaes & Tamayo, 2013). Furthermore, firms with high growth in sales (SALES_GROWTH, R&D and CAPX) are expected to disclose more environmental information (Dhaliwal et al., 2011; Harjoto & Jo, 2015). The results show negative associations for ADVERTISING and CAPX with the COE. In contrast, DUM_CEO, GROWTH_SALES, R&D, and LITI have no association with the COE. These findings mitigate any concern towards a firm's willingness to adopt Twitter and disclose carbon information.

Finally, we further reestimate our regression model by using the generalised method of moments (GMM).[8] We use the GMM model to address the endogeneity problem that may affect the interpretation of our association between *iCarbon* and the COE. Our results in Column 5 show that *iCarbon* is significant and negatively associated with the COE. This finding is consistent with our main finding. The results for the GMM estimation model show that first-order serial correlation (AR(1)) is significant ($p$ = 0.031), rejecting the null hypothesis of correlated differences in the residual, whereas the second-order serial correlation (AR(2)) is insignificant ($p$ = 0.391), indicating no correlation difference in the residual. The results also show that the result of the Hansen test ($p$ = 0.231) is insignificant, which validates our instruments to address the overidentification problem.

## 5 | CONCLUSION

This study examined whether a firm's voluntary dissemination of carbon-related information on Twitter influences the COE. Using a sample of nonfinancial firms with Twitter accounts that were listed on NASDAQ throughout the period 2009–2015, we developed a measure of carbon information reported via Twitter to reflect the number of firms that decide to disseminate carbon-related information in this way and broaden their reach to investors. The results show that firms disseminating carbon-related information tend to have a lower COE. This association holds consistently throughout alternative estimations and is not affected by either environmental or ESG disclosure. Overall, our results suggest that the increase in a firm's dissemination of carbon information improves investor recognition among many potential investors and environmentally concerned groups, reduces information asymmetry between market participants, and enables investors to evaluate firms' potential risk and acquire firm information at lower acquisition costs, which in turn reduces the COE.

This paper provides several implications for market participants, managers, and policymakers about integrating information technology into their strategic voluntary disclosure policy. Our results show the importance of firm managers considering the dissemination of carbon-related information seriously and the benefit to the COE. As Twitter allows market participants to receive firm information in a timely and efficient manner, *iCarbon* enables many market participants to assess a firm's potential risk and make better investment decisions. Additionally, firms should consider using *iCarbon* to address investors' concerns and information demands. Our findings suggest that market participants incorporate carbon information, in addition to disclosure, that is disseminated on Twitter. This evidence prepares regulators to take steps towards encouraging firms to disseminate carbon information and providing more guidance on carbon emissions. Although firms are mandated to report their emissions under EPA regulations, further regulations under the Clean Power Plan are under review, and they are expected to be dismantled by President Trump, who led the United States's exit from the Paris Agreement on climate change (Davenport & Rubin, 2018). The initial plan under Obama's administration aimed to reduce GHG emissions by 32% by 2030. The Trump administration proposes an easier plan that would cut emissions by approximately 0.7% to 1.5%. Our evidence suggests that market participants have an interest in climate change reporting, which should encourage regulators to implement a more solid plan for climate change. Furthermore, these results show the importance of using Twitter as a disclosure channel to communicate with market participants, to attract potential investors, and to improve information sharing. These benefits are expected to improve firms' information environment and transparency and to reduce the COE.

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# APPENDIX A
## EXAMPLES OF *iCarbon* TWEETS



# APPENDIX B
## VARIABLES DEFINITION AND MEASUREMENTS

| Variable | Definition | Measurement | Source |
|---|---|---|---|
| **Dependent variables** | | | |
| *COE* | Implied cost of equity | The average of four cost of equity estimates ($R_{OJ}$, $R_{MPEG}$, $R_{CT}$ and $R_{GLS}$) | Bloomberg |
| $R_{PEG2-1}$ | Easton (2004) Price Earnings Growth Model | $P_t^* = \frac{FEPS_2 - FEPS_1}{R_{PEG}^2}$ <br> $P_t$ = share price as of June next year <br> FEPS $_t$ = median forecast of earnings per share | Bloomberg |
| **Independent variables** | | | |
| *iCarbon* | Firm's carbon-related Tweets | The number of carbon-related tweets or zero otherwise | Twitter API and Manual collection |

(Continued)

| Variable | Definition | Measurement | Source |
|---|---|---|---|
| *iCarbon_Hyperlink* | Firm's carbon-related Tweets with hyperlink | The number of carbon-related tweets that contain hyperlink or zero otherwise | Twitter API and Manual collection |
| *iCarbon_Retweet* | Firm's carbon-related Tweets that are retweeted | The number of carbon-related tweets that are retweeted or zero otherwise | Twitter API and Manual collection |
| **Control variables** | | | |
| *SIZE* | Firm size | Natural logarithm of firm's equity market value | Bloomberg |
| *BTM* | Book value to market ratio | Book to market value ratio | Bloomberg |
| *LEV* | Financial leverage | Long-term debt to equity market value ratio | Bloomberg |
| *DISP* | Analysts' forecast dispersion | Standard deviation of one-year consensus EPS forecast | Bloomberg |
| *BETA* | Firm beta | Beta coefficient of market model using 60 with at least 24 months stock and market return | Bloomberg |
| *LTG* | The consensus long term growth forecast | The mean of long-term growth rate of earnings forecast or 2 minus 1 year ahead average EPS forecast scaled by 1 year ahead average EPS forecast | Bloomberg |
| *CD_NEWS* | News coverage | Natural logarithm of number of carbon-related news articles | LexisNexis |
| *INSTOWN* | Institutional ownership | The percentage of firm's shares owned by institutions | Bloomberg |
| *SURP* | Earning surprise | Consensus earnings forecast minus firm's earnings scaled by share price | Bloomberg |
| *LOSS* | Negative earnings | Indicator variable that takes a value of 1 if a firm reports negative earnings and 0 otherwise | Bloomberg |
| *BOD_IND* | Board Independence | The percentage of independent directors in the board | Bloomberg |
| *ENV_COMMITTEE* | Environmental Committee | Dummy variable that takes a value of 1 if a firm has an environmental committee and 0 otherwise | Bloomberg |
| *CDP* | CDP participation | Dummy variable that takes a value of 1 if a firm participate and report to CDP and 0 otherwise | Bloomberg |
| *AGE* | Firm age | The number of years since the firm is listed | CRSP |
| *EPA* | EPA industry rules | Dummy variable that take a value of 1 if the firm belong to industry under GHG Mandatory Reporting Regulation and 0 otherwise | Manually |
| *TECH_FIRM* | Technology firms | Indicator variable that takes a value of 1 if a firm belongs to technology industry (SIC 3570–3579, 3610–3699, 7370–7379, 3810–3849, 4800–4899, 4931, 4941) and 0 otherwise | Manually |
| *ENV_SCORE* | Environmental reporting score | Disclosure score of the amount of environmental reports that available to the public | Bloomberg |
| *ESG_SCORE* | Environmental, social and governance reporting score | Disclosure score of the amount of environmental, social and governance reports that available to the public | Bloomberg |
| *ADVERTISING* | Advertising intensity | Total advertising expenses divided by total revenue | Bloomberg |
| *CEOAGE* | CEO age | Dummy variable that takes 1 if CEO age is under the median value of other CEO age and 0 otherwise | DataStream |
| *SALES_GROWTH* | Sales growth | Sales change from previous year divided by total sales of previous year | Bloomberg |
| *LITI* | Litigation | Dummy variable that take 1 if the firm belong to high litigation industry (SIC 2833–2836, 3570–3577, 5200–5961, 3600–3674, 7370) and 0 otherwise | Manually |
| *CAPX* | Capital expenditure | Total capital expenditure divided by total revenue | Bloomberg |
| *R&D* | Research and development | Research and development expenditure divided by total assets | Bloomberg |

## APPENDIX C
## COST OF EQUITY MEASUREMENTS

| COE estimates | Formula |
|---|---|
| $R_{OJ}$<br>Ohlson and Juettner-Nauroth (2005) | $R_{OJN} = A + \sqrt{A^2 + \left(\frac{E_t(EPS_{t+1})}{P_t^*}\right)(g_2 - g_{lt})}$<br>$A = 0.5\left(g_{lt} + \frac{DPS_{t+1}}{P_t^*}\right)$<br>$EPS_{t+1}$ = The median forecast of EPS for June next year<br>$DPS_{t+1}$ = Dividend per share (DPS) for the next year or 6% of ROA<br>$g_2$ equals to the growth rate of short-term earnings ($EPS_{t+2}/EPS_{t+1}-1$) or long-term consensus analysts' earnings forecasted. This model requires both $EPS_{t+1}$ and $EPS_{t+2}$ to be positive. $g_{lt}$equals to 10-year treasury bonds yield minus 3% |
| $R_{MPEG}$<br>Modified Easton (2004) cost of equity model | $P_t = \frac{E_t(EPS_{t+1})}{R_{MPEG}} + \frac{E_t(EPS_{t+1})E_t[g_{st} - R_{MPEG} \times (1 + \mathrm{FDIV})]}{R^2_{MPEG}}$<br>$P_t$ = share price as of June<br>FEPS = the median value of future earnings per share (EPS)<br>FDIV = dividend pay-outs ratio $\left(\frac{\mathrm{DPS}}{\mathrm{EPS}}\right)$<br>DPS = dividend per share<br>EPS = earnings per share<br>The model assumes FEPS to be positive and if FEPS is negative, we measure FDIV as 6% of ROA. |
| $R_{CT}$<br>Claus and Thomas (2001) | $P_t^* = B_t + \sum_{i=1}^{5} \frac{[FEPS_{t+i} - R_{CT} \times B_{t+i-1}]}{(1 + R_{CT})^i} + \frac{[FEPS_{t+5} - R_{CT} \times B_{t+4}] \times (1 + g_{lt})}{(R_{CT} - g_{lt})(1 + R_{CT})^5}$<br>The model measures EPS for the first 3 years by using analyst earnings forecast. The fourth and fifth earnings forecasted years are measures by multiplying the previous year earnings forecast by long term earnings growth rate (LTG). If the LTG rate is missing, short-term growth rate of $FEPS_{t-2}$ and $FEPS_{t-2}$ is used. The model measure $g_{lt}$ as the difference between 10 years Treasury bonds and 3%. The model also assume clean surplus relation to measure future book value ($B_{t+i-1} = B_t + EPS_{t+1} - DPS_{t+1}$). Future dividend is measured by multiplying EPS by dividend pay-out ratio ($DPS_{t+1} = EPS_{t+1} \times FDIV$). |
| $R_{RGLS}$<br>Gebhardt et al. (2001) | $P_t^* = B_t + \sum_{i=1}^{T-1} \frac{[FROE_{t+i} - R_{GLS}] \times B_{t+i-1}}{(1 + R_{GLS})^i} + \frac{[FROE_{t+T} - R_{GLS}] \times B_{t+T-1}}{(1 + R_{GLS})^{T-1} R_{GLS}}$<br>The model use analyst forecast to measures future return on equity (FROE) of the first 3 years. Afterward, FROE is measured by using linter interpolation of 10 years historical industry specific ROE median. If industrial ROE is lower the risk-free rate, we use risk free rate to replace industry ROE (Liu, Nissim, & Thomas, 2002). Beyond the 12 year, the model assumes industry ROE to remain constant. Clean surplus is used to measure future book values. Where:<br>$B_{t+i-1} = B_t + EPS_{t+1} - DPS_{t+1}$<br>$DPS_{t+1} = EPS_{t+1} \times FDIV$ |
| *COE* | The average of four cost of equity estimates ($R_{OJ}$, $R_{MPEG}$, $R_{CT}$, and $R_{GLS}$) risk free |

*Note.* COE: cost of equity.

## APPENDIX D

### DESCRIPTIVE STATISTICS FOR COE, *iCarbon*, AND CONTROL VARIABLES

| Variables | *N* | Mean | Med | Min | Max | *SD* |
|---|---|---|---|---|---|---|
| COE | 1,737 | 0.052 | 0.045 | 0.001 | 0.172 | 0.035 |
| *iCarbon* | 1,737 | 0.509 | 0 | 0 | 111.000 | 3.522 |
| SIZE | 1,732 | 21.147 | 20.968 | 17.009 | 27.163 | 1.715 |
| BTM | 1,732 | 0.424 | 0.347 | −0.006 | 1.755 | 0.314 |
| LEV | 1,736 | 0.146 | 0.082 | 0 | 0.770 | 0.172 |
| DISP | 1,588 | 0.131 | 0.081 | 0.017 | 0.926 | 0.157 |
| BETA | 1,600 | 1.055 | 1.029 | −2.075 | 3.879 | 0.563 |
| LTG | 1,737 | 0.181 | 0.153 | −1.162 | 0.847 | 0.134 |
| CD_NEWS | 1,737 | 0.770 | 0 | 0 | 3.367 | 1.061 |
| INSTOWN | 1,490 | 0.863 | 0.920 | 0.00 | 1.707 | 0.260 |
| SURP | 1,703 | −0.334 | 0.031 | −85.714 | 42.446 | 7.962 |
| LOSS | 1,737 | 0.176 | 0 | 0 | 1 | 0.381 |
| INDEPENT | 1,625 | 0.781 | 0.818 | 0.143 | 1 | 0.122 |
| ENV_COMMITEE | 1,400 | 0.014 | 0 | 0 | 1 | 0.119 |
| CDP | 1,737 | 0.223 | 0 | 0 | 1 | 0.417 |
| AGE | 1,737 | 21.33 | 18 | 0 | 78 | 16.66 |
| EPA | 1,737 | 0.324 | 0 | 0 | 1 | 0.468 |
| TECH_FIRMS | 1,737 | 0.482 | 0 | 0 | 1 | 0.500 |

*Note*. ENV_COMMITEE: environmental committee; COE: cost of equation; CD_NEWS: carbon news coverage; BTM: book-to-market ratio; LEV: financial leverage; DISP: dispersion of analysts' forecasts; BETA: beta coefficient; LTG: long-term growth forecast; CDP: Carbon Disclosure Project; SURP: earnings surplus; ISTOWN: institutional ownership; TECH_FIRM: technology firms; EPA: Environmental Protection Agency's. Appendix D presents summary statistics for *COE*, *iCarbon* and control variables for nonfinancial NASDAQ firms with Twitter accounts for a period from 2009 to 2015. See Appendixes B and C for variables descriptions and measurements. This table shows variables' observations number (*N*), values of mean (Mean), median (Med), minimum (Min) and maximum (Max) and standard deviation (*SD*). We use Winsorising percentiles level of 2.5th to 97.5th to control for outliers.

## APPENDIX E

### PEARSON AND SPEARMAN CORRELATIONS FOR THE COE, *iCarbon*, AND CONTROL VARIABLES

| | COE | *iCarbon* | SIZE | BTM | LEV | DISP | BETA | LTG | CD_NEWS | INSTOWN | SURP | LOSS | INDEPENT | ENV_ COMMITEE | CDP | AGE | EPA | TECH_ FIRMS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COE | 1 | −0.06** | −0.24*** | 0.37*** | 0.09*** | 0.06* | 0.11*** | −0.03 | 0.03 | −0.1*** | 0.02 | 0.06* | 0.00 | −0.004 | 0.013 | 0.03 | 0.026 | −0.2*** |
| *iCarbon* | −0.01 | 1 | 0.24*** | −0.02 | 0.05 | 0.05 | 0.01 | −0.07** | 0.28*** | −0.02 | −0.05 | −0.07** | 0.11*** | 0.02 | 0.16*** | 0.004 | 0.030 | 0.01 |
| SIZE | −0.29*** | 0.14*** | 1 | −0.38*** | 0.16*** | 0.16*** | −0.01 | −0.19*** | 0.47*** | 0.15*** | −0.15*** | −0.2*** | 0.08** | −0.1*** | 0.30*** | 0.24*** | −0.06** | 0.08*** |
| BTM | 0.38*** | −0.02 | −0.44*** | 1 | 0.00 | 0.07** | 0.13*** | −0.2*** | −0.01 | −0.06* | 0.15*** | 0.11*** | −0.06* | 0.08*** | 0.012 | 0.01 | 0.14*** | 0.05* |
| LEV | 0.09*** | 0.03 | 0.15*** | −0.06** | 1 | 0.11*** | −0.03 | −0.2*** | 0.10*** | 0.05 | −0.06** | 0.02 | 0.10*** | −0.08** | 0.11*** | 0.02 | −0.03 | −0.04 |
| DISP | 0.05** | 0.1*** | 0.29*** | −0.05* | 0.06** | 1 | 0.11*** | −0.03 | 0.21*** | 0.10*** | 0.01 | 0.02 | 0.02 | 0.006 | 0.046 | 0.04 | 0.18*** | −0.01 |
| BETA | 0.15*** | 0.02 | −0.03 | 0.09*** | −0.04 | 0.06** | 1 | 0.07** | 0.15*** | −0.02 | 0.08** | 0.08** | 0.01 | 0.00 | 0.00 | −0.04 | 0.08** | 0.18*** |
| LTG | 0.24*** | 0.002 | −0.18*** | −0.05** | −0.08*** | 0.09*** | 0.05** | 1 | −0.08** | −0.03 | 0.07** | 0.15*** | −0.04 | −0.04 | −0.19*** | −0.3*** | 0.03 | 0.03 |
| CD_NEWS | 0.01 | 0.22*** | 0.47*** | −0.04* | 0.06*** | 0.23*** | 0.08*** | −0.09*** | 1 | −0.06** | −0.05 | −0.01 | 0.11*** | −0.05* | 0.31*** | 0.1*** | 0.05 | 0.06** |
| INSTOWN | −0.17*** | −0.06** | 0.24*** | −0.1*** | 0.07*** | −0.00 | −0.03 | −0.13*** | 0.01 | 1 | −0.1*** | −0.06** | 0.18*** | −0.01 | 0.002 | −0.02 | 0.00 | 0.01 |
| SURP | −0.11*** | 0.000 | 0.09*** | −0.04* | −0.01 | −0.00 | −0.02 | −0.06** | −0.00 | 0.09*** | 1 | 0.08** | −0.05 | −0.01 | −0.07** | −0.1*** | −0.01 | 0.11*** |
| LOSS | 0.17*** | −0.04* | −0.27*** | 0.16*** | 0.01 | 0.01 | 0.08*** | 0.21*** | −0.03 | −0.1*** | −0.2*** | 1 | −0.01 | −0.00 | −0.02 | −0.2*** | 0.03 | 0.12*** |
| INDEPENT | −0.06** | 0.08*** | 0.09*** | −0.08*** | −0.07*** | 0.01 | −0.01 | −0.04* | 0.04* | 0.18*** | 0.03 | −0.03 | 1 | −0.03 | 0.11*** | 0.12*** | 0.03 | 0.00 |
| ENV_ COMMITEE | −0.01 | 0.00 | −0.04* | 0.05* | −0.06** | −0.03 | 0.02 | −0.03 | −0.03 | −0.01 | −0.01 | 0.01 | −0.04 | 1 | −0.01 | −0.02 | 0.09*** | 0.06** |
| CDP | −0.04* | 0.06*** | 0.38*** | −0.07*** | 0.02 | 0.06** | −0.01 | −0.13*** | 0.3*** | 0.07*** | 0.01 | −0.06*** | 0.1*** | 0.02 | 1 | 0.2*** | −0.02 | 0.08*** |
| AGE | −0.02 | 0.002 | 0.2*** | 0.05* | −0.03 | 0.02 | −0.1*** | −0.2*** | 0.1*** | −0.01 | −0.007 | −0.15*** | 0.1*** | −0.02 | 0.14*** | 1 | −0.06* | −0.1*** |
| EPA | −0.01 | −0.00 | 0.01 | 0.05** | −0.07*** | 0.15*** | 0.06** | 0.03 | 0.04* | 0.05* | 0.01 | 0.010 | 0.06** | 0.1*** | 0.00 | −0.04* | 1 | −0.01 |
| TECH_FIRMS | −0.15*** | −0.02 | 0.03 | 0.01 | −0.10*** | −0.05* | 0.14*** | 0.04* | 0.01 | −0.02 | 0.03 | 0.11*** | 0.07*** | 0.03 | 0.06** | −0.2*** | −0.05** | 1 |

*Note*. ENV_COMMITEE: environmental committee; COE: cost of equation; CD_NEWS: carbon news coverage; BTM: book-to-market ratio; LEV: financial leverage; DISP: dispersion of analysts' forecasts; BETA: beta coefficient; LTG: long-term growth forecast; CDP: Carbon Disclosure Project; SURP: earnings surplus; ISTOWN: institutional ownership; TECH_FIRM: technology firms; EPA: Environmental Protection Agency's. Appendix E shows the Pearson and Spearman correlation matrix between *COE*, *iCarbon*, and control variables for nonfinancial NASDAQ firms with Twitter accounts for a period from 2009 to 2015. See Appendixes B and C for variables descriptions and measurements.

*10%. **5%. ***1%.