1-1-2022

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Recommended Citation

Matsumura, E. M., Prakash, R., & Vera-Muñoz, S. C. (2022). Climate-risk materiality and firm risk. Review of Accounting Studies. https://doi.org/10.1007/s11142-022-09718-9

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https://doi.org/10.1007/s11142-022-09718-9

Climate-risk materiality and firm risk

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Accepted: 7 August 2022

Abstract

Managers are required to disclose material climate risk in Form 10-K, but their decision whether or not to disclose is confounded by the lack of consensus on whether climate risk is material to the firms, as well as uncertainty about enforcement of disclosure regulations. Using the SASB Materiality Map™ to proxy for market expectations of climate risk materiality, we test whether the association between disclosing climate risk in 10-Ks and firm risk (proxied by cost of equity (COE)) varies with market expectations of climate risk materiality. Using S&P 500 firms' decisions whether to disclose climate risk in Form 10-K for 2008 to 2016, we find that disclosing firms' COE is 27 bps lower than nondisclosing firms' COE. In industries where the market expects climate risk to be material, disclosing firms' COE is 50 bps lower than nondisclosing firms', while in industries where the market does not expect climate risk to be material, disclosing firms' COE is 23 bps lower than nondisclosing firms'. Our results indicate that markets use expectations of climate risk materiality to infer the *credibility* of managers' climate risk disclosure decisions. Our research contributes to policy-making on climate risk disclosures in regulatory filings and informs the debate around the costs and benefits of the SEC's current proposal to enhance climate risk disclosures.

Keywords Regulation S-K · Environmental risk · Climate change risk · Climate-related risk · SEC regulatory enforcement · Cost of equity capital

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Published online: 21 September 2022

JEL classification G32 · G38 · M41 · Q54

1 Introduction

Regulation S-K imposes an affirmative duty on managers to disclose all material risks, including climate risk, in Form 10-K. These disclosures are intended to align market expectations about risk materiality with managers' private risk materiality assessments. Prior research shows that capital markets infer firm risk from the risk disclosures in SEC filings (Campbell et al. 2014; Kravet and Muslu 2013). However, three key institutional features related to climate risk hinder investors' ability to discern whether managers who choose *not* to disclose climate risk in Form 10-K are deliberately trying to conceal material but adverse information, or are instead truthfully conveying that climate risk is not material. First, climate risk is multidimensional,[1] with little consensus on whether it is material to firms (Hulac 2016; Coburn and Cook 2014). Investors have difficulty assessing the broad impact of climate risk, including adaptation and mitigation costs (Ross 2021; Groom 2019). Second, even though Regulation S-K requires firms to disclose, in their SEC filings, "the most significant factors that make an investment in the registrant speculative or risky" (Securities and Exchange Commission (SEC) 2004), federal climate risk disclosure regulation has been inconsistently enforced across firms (Lubber 2019; (Government Accountability Office (GAO) 2018, 21). Third, stakeholder litigation pressing firms to disclose climate risk has had limited success (McCormick et al. 2018).

This complex institutional context creates an environment in which firms may view disclosing material climate risk as essentially voluntary. Consequently, the choice whether to disclose climate risk in 10-K filings—which is based on an unobservable analysis of the benefits versus the costs of disclosing material (and nonmaterial) climate risk—may not credibly reflect the materiality of climate risk to the firm. This context raises two fundamental empirical questions: (1) Is the association between disclosing climate risk in Form 10-K positively or negatively associated with firm risk? (2) Does this association vary depending on market expectations of climate risk materiality? To address the second question, we use capital market expectations of climate risk materiality as a cross-check on the *credibility* of firms' decision whether to disclose climate risk in Form 10-K.[2]

Our inquiry is important for several reasons. First, firms' failure to disclose material climate risk may leave investors, who are looking for credible information to assess and reduce risks in their portfolios, exposed to potentially significant losses. In his 2020 annual letter to CEOs, Larry Fink, the CEO and chairman of BlackRock (the world's

[1] Climate risk (also referred to as climate-change risk or climate-related risk) comprises transition risk and physical risk. *Transition* risk is defined as risks arising from transition to a low-carbon economy (McKinsey Global Institute 2020). It arises from policy, legal, technology, reputation, and market changes to address climate risk mitigation and adaptation. *Physical* risk arises from large-scale natural catastrophic events caused by extreme weather events as well as longer-term changes in climate patterns (Task Force on Climate-related Financial Disclosures (TCFD) 2017).

[2] In the interest of brevity, from this point onward, the choice whether or not to disclose climate risk in Form 10-K is generally implied whenever we refer to firms' "choice whether to disclose climate risk," and "users" refers to investors who use Form 10-K to make their decisions.

largest asset manager**),** declared that "climate risk is investment risk" (Fink 2020). Notably, three former treasury secretaries recommended that the SEC move to promote and enforce mandatory and meaningful industry-specific disclosures of the material effects of climate risk on issuers (Paulson et al. 2016). Likewise, shareholders are exerting pressure on companies, through proxy filings, to provide climate risk disclosures (Flammer et al. 2021).

Second, various other market participants are also interested in this information. Mainstream investment analysts' decisions to buy, sell, or hold a security are increasingly influenced by sustainability disclosures in general (Sustainability Accounting Standards Board (SASB) 2016) and climate risk disclosures in particular (Bradford 2019). Further, some of the world's largest insurance companies by revenue (e.g., Marsh and McLennan, Allianz SE) are creating products to help businesses better manage the impact of climate risk (Boynton 2019; Hope et al. 2018). Relatedly, in a recent letter to Congress, the Federal Reserve chairman, Jerome Powell, asserted that the "Federal Reserve stands ready to respond to climate-change related weather disruptions to the economy and is working to ensure banks' resilience from unexpected shocks tied to a warming global environment" (Derby 2019).

Finally, understanding the capital market effects of firms' decisions whether to disclose climate risk in SEC filings is important in light of recent global and domestic regulatory trends towards mandating such disclosures (Christensen et al. 2021). These trends include climate-risk assessment, management, and annual report disclosure recommendations developed by the Task Force on Climate-Related Financial Disclosures (Task Force on Climate-related Financial Disclosures (TCFD) 2017). The TCFD focuses on climate risk information needed by investors, lenders, and insurance underwriters, among others.[3] In November 2021, the International Financial Reporting Standards (IFRS) Foundation announced a new International Sustainability Standards Board "to develop … a comprehensive global baseline of high-quality sustainability disclosure standards to meet investors' information needs."[4]

In the U.S., the SEC recently issued a proposal to enhance climate risk disclosures in regulatory filings (Securities and Exchange Commission (SEC) 2022). Earlier, the SEC announced its plans to review public companies' climate risk disclosures, introduce new climate-related rules to step up ESG disclosures,[5] and modernize climate guidance that is now more than a decade old (Johnson 2021; Michaels 2021; Prentice and Chiacu 2021). In addition, the U.S. secretary of the treasury, Janet L. Yellen, recently announced the creation of the Financial Stability Oversight Council to assess the potential risk that climate change may impose on the financial stability of the U.S. (U.S. Department of the Treasury 2021).

[3] The TCFD is composed of a 32-member industry-led global task force selected by the G20's Financial Stability Board (FSB). The TCFD is supported by more than 1000 organizations with $12 trillion in capitalization (Task Force on Climate-related Financial Disclosures (TCFD) 2020b). For further information, see www.fsb.orga/org/.

[4] The November 3, 2021, announcement appears at https://www.valuereportingfoundation.org/news/ifrs-foundation-announcement/.

[5] In general, "sustainability" and "ESG" are used interchangeably. Consistent with the SASB standards, the concept of sustainability, as it relates to corporate activities, refers to ESG dimensions of a company's operations and performance (Sustainability Accounting Standards Board (SASB) 2020).

Prior research documents that managers are biased against disclosing bad news (Kothari et al. 2009a, b). Given this bias, we argue that markets use expectations of climate risk materiality to infer the credibility, and thus the informativeness, of firms' choice whether to disclose climate risk. We use the industry-level Materiality Map™ created by the Sustainability Accounting Standard Board (SASB) to construct an independent proxy for market expectations of climate risk materiality.[6,7] More specifically, we use the SASB map as a cross-check on whether managers' choices to disclose or not disclose climate risk in Form 10-K reflect their private materiality assessments of climate risk. Importantly, the Materiality Map™ adheres to the federal securities laws' materiality definition to classify the materiality of sustainability issues, allowing us to partition firms on whether the market expects climate risk to be material based on the industry in which the firm operates (Grewal et al. 2021; Khan et al. 2016; Grewal et al. 2016).

We hand-collect firms' decisions whether to disclose climate risk for about 4000 firm-year observations of S&P 500 firms for 2008 to 2016. We use the sample firms' 10-K filings in SEC EDGAR and a structured search rubric to manually code firms' choice whether to disclose climate risk. We use implied cost of equity (COE) to proxy for firm risk (Shevlin 2013).

Our propensity score matching (PSM) and doubly robust (DR) regression analyses yield two important results. First, after controlling for firms' decisions to voluntarily disclose climate risk,[8] we find a negative association between disclosing climate risk and COE. DR regression results indicate that the COE of disclosing firms is significantly lower, by 27 basis points (bps), than the COE of nondisclosing firms, or about 3.3% of the average COE of our sample firms.

Second, the penalty for nondisclosing firms versus the reward for disclosing firms varies with the market's climate risk materiality expectations. Specifically, in industries where the market expects climate risk to be material—and therefore expects firms to disclose climate risk—the COE of disclosing firms is 50 bps lower than the COE of nondisclosers, i.e., about 6.1% of the average COE of our sample firms. In contrast, in industries where the market does not expect climate risk to be material—and therefore expects firms to not disclose the risk—the COE for disclosers is only 23 bps lower than the COE of nondisclosers.

[6] SASB is an independent 501(c)(3) non-profit whose mission is to develop and disseminate sustainability accounting standards for reporting material sustainability issues in SEC filings and in compliance with SEC requirements (see https://www.sasb.org/about/). Chaired by an accounting academic, SASB's board of directors is composed of heads of sustainable/impact investing at large investment firms and former regulators and CEOs, among others. SASB (Sustainability Accounting Standards Board (SASB) 2017, 10) reported over 85% agreement, on average, between investors and registered issuers on the materiality of SASB's sustainability disclosure factors. Further details appear in Section 3 and Appendix 1.

[7] In his 2020 letter to BlackRock's shareholders, Larry Fink asserts, "While no framework is perfect, BlackRock believes that the SASB provides a clear set of standards for reporting sustainability information across a wide range of issues." (Fink 2020).

[8] A majority of the firms in our sample voluntarily report climate risk information through non-SEC channels, such as the CDP climate change survey. Therefore, we control for voluntary disclosures by including firms' decisions to participate in the survey. CDP (formerly the Carbon Disclosure Project) is an independent not-for-profit organization acting on behalf of 827 institutional investors representing over $100 trillion in assets under management. CDP surveys the world's largest companies by market capitalization on various sustainability topics, and is the world's largest repository of carbon emissions information. See https://www.cdp.net/en.

In summary, the market rewards (penalizes) firms for disclosing (not disclosing) climate risk in their 10-K filings. However, the *penalty for nondisclosure* is twice as large when the market expects climate risk to be *material* relative to when the market does not expect climate risk to be material. Overall, the results are economically and statistically significant and consistent with the theoretical argument that when the decision whether to disclose climate risk likely does not reflect firms' climate risk materiality assessments, the market ascribes lower credibility to the disclosure decisions. That is, market expectations about climate risk materiality serve as a cross-check on the credibility and thus informativeness of firms' decision whether to disclose climate risk.[9]

Our study extends research on risk disclosures in two ways. First, while extant capital markets research controls for investors' ex ante risk expectations associated with the firms' future cash flows (e.g., Campbell et al. 2014), prior studies do not incorporate market expectations of risk materiality for inferring the *credibility* of firms' choice whether to disclose this risk in regulatory filings. We document that the association between firms' choice whether to disclose climate risk and market assessment of firm risk varies depending on market expectations of climate risk materiality. Using market expectations of climate risk materiality allows us to provide empirical evidence of how investors interpret the omission of risk disclosures. Second, prior studies do not independently test the materiality of 10-K disclosures, either because (1) the disclosures are mandated in SEC filings regardless of their materiality (e.g., mine safety records disclosures (Christensen et al. 2017)), (2) the disclosures are unambiguously material (Kravet and Muslu 2013), or (3) the studies explore voluntary disclosures in non-SEC outlets and are therefore not bound by the federal securities laws' materiality definition (Matsumura et al. 2014; Dhaliwal et al. 2011).

We also extend the sustainability literature in several ways. Prior research examines whether the market prices ESG performance. Khan et al. (2016) find that firms with good ratings on material ESG issues significantly outperform firms with poor ratings on these issues. Eccles et al. (2014) match "high sustainability" firms—U.S. companies that adopted a large number of environmental and social policies from 1993 to 2010—with "low sustainability" firms. Their study finds that the high-sustainability firms outperform the low-sustainability firms on stock market performance, ROA, and ROE. Unlike these studies, our inquiry is at the intersection of firms' choice whether to *disclose* climate risk in Form 10-K and the market expectations of climate risk materiality.

Most studies focusing more specifically on GHG performance find that forward-looking investors seek compensation for higher GHG emissions risk. The research documents a positive association between GHG emissions and firms' stock returns (Bolton and Kacperczyk 2021), a negative association between GHG emissions and firm value (Matsumura et al. 2014), and higher stock returns for GHG-efficient firms relative to GHG-inefficient firms (In et al. 2019). Importantly, these studies do not

[9] We assess the robustness of our main results with several sensitivity tests: controlling for analysts' forecast bias, estimating COE following Easton et al. (2002), controlling for corporate governance, estimating the relationship between changes in COE and changes in managers' climate risk disclosure decisions, and using entropy balancing. Our inferences are unchanged.

address the fact that the costs of mitigating and adapting to climate risk will accrue not only to high GHG emitters but also to low GHG emitters (e.g., insurance, real estate, water utilities). This is because climate risk is multidimensional, comprising both physical risk and transition risk.

With the exception of Matsumura et al. (2014), most of the research on GHG emissions has focused primarily on GHG performance as opposed to GHG disclosures. In contrast, our study examines firms' decision whether to disclose climate risk in Form 10-K. While corporate GHG emission disclosures are voluntary in the U.S., federal securities laws and regulations require public registrants to disclose the financial impacts of material climate risk in their annual regulatory filings with the SEC. A related study uses an ESG composite index to proxy for sustainability disclosures after mandatory ESG reporting in China, Denmark, Malaysia, and South Africa (Ioannou and Serafeim 2019). The study finds an increase in Tobin's Q for firms that increased their ESG disclosures subsequent to the mandate relative to control firms. With the exception of South Africa, these disclosures can be provided outside of the annual financial filings (e.g., corporate social responsibility reports).

Performance and disclosure are not only conceptually different but also empirically distinct. Downar et al. (2021) examine the relationship between mandatory UK GHG disclosure and performance and find that subsequent emission levels decreased. Grewal et al. (2021) show that the correlation between ESG performance and disclosure is small. They document that Exxon Mobil consistently has high SASB-identified ESG disclosure scores (in the top decile, based on Bloomberg's database) and yet also has poor (bottom decile) ESG performance ratings in the same years. On the other hand, the cosmetics manufacturer Estee Lauder consistently has high ESG performance ratings and, at the same time, has low ESG disclosure scores (Grewal et al. 2021).

Our study also provides insights relevant to the SEC's call for public comment on whether certain Regulation S-K disclosure requirements need updating to better serve the needs of investors and registrants (Securities and Exchange Commission (SEC) 2016). The materiality definition is intended to balance investors' need for information to make informed decisions without being burdened with excessive information, against the cost to registrants of providing information. Our findings have implications for the risk effects of managers' choice whether to disclose other important types of material nonfinancial risks. For instance, in 2018, the SEC issued new interpretive guidance on cybersecurity risk disclosures in SEC filings in response to recent high profile data breaches (e.g., Sony, Home Depot, Target, and Yahoo) and other cybersecurity incidents (Securities and Exchange Commission (SEC) 2018).

The remainder of this paper is organized as follows. The next section discusses the institutional background on climate risk disclosures. Section 3 reviews the literature and develops our hypotheses. Sections 4 and 5 describe our research design and provide the results of empirical tests, respectively. The last section briefly summarizes the findings and discusses implications for research and practice.

2 Institutional background on climate risk disclosures

Climate risk is expected to have potential widespread financial impacts, either directly or indirectly, on most, if not all, entities (Task Force on Climate-related Financial

Disclosures (TCFD) 2017, Ross 2021). TCFD recommends that preparers disclose the material financial impacts of the transition risks and physical risks of climate change in their mainstream (i.e., public) annual financial filings (Task Force on Climate-related Financial Disclosures (TCFD) 2017). Notably, the U.S. treasury secretary, Janet L. Yellen, asserts:

> A threshold challenge … is imperfect information—understanding the risks and opportunities climate change presents. For example, the current financial reporting system is not producing reliable disclosures. Climate change also introduces new and increasing types of risk … physical risks … and transition risks. The emergence of these risks challenges one of the financial sector's most essential functions—ensuring that risk is borne by investors and institutions well placed to manage it. (U.S. Department of the Treasury 2021)

Transition risk refers to the risk introduced by the shift away from carbon polluting activities to achieve lower or net-zero emissions. This risk arises from policy, legal, technology, reputation, and market changes to address climate risk mitigation and adaptation. Transition risk consequences include, among others, adjustments to long-term price assumptions incorporating the potential impact of climate change, which could affect asset values, changes in useful life, and impairment estimates.

Physical risk arises from large-scale natural catastrophic events caused by extreme weather events (e.g., hurricanes, tornadoes, droughts, flooding) as well as longer-term changes in climate patterns (e.g., rising sea levels and sustained drought). The catastrophic events are associated with widespread direct damage to assets (e.g., roads, building, public transportation) and indirect financial losses from supply chain disruptions. For example, in 2017–2018, natural catastrophic losses caused by climate change amounted to $490 billion, where $275 billion (56%) were uninsured losses (Low 2019; Low 2018). Further, the value at risk from climate change is estimated to reach present value losses of up to $43 trillion—representing 30% of the entire stock of the world's manageable assets—by 2100 (The Economist Intelligence Unit 2015, 4).

Many companies argue that climate change affects their strategic decisions (Task Force on Climate-related Financial Disclosures (TCFD) 2020a), and several governments have started to mandate climate risk disclosures (Naik 2021). Despite the growing importance of climate change to investors' understanding of a company's climate risk exposure (Kent 2017; Cherney 2016; Deloitte 2016; Gelles 2016), a recent Moody's Investors Service report indicates that few companies disclose meaningful climate risk information (Groom 2019). Similarly, a study that examines climate risk disclosures in the10-Ks of the 20 largest publicly traded U.S. companies from 2012 through 2014 finds that most companies reported little or no useful information on climate risk (InfluenceMap 2015). BlackRock, the world's largest asset manager, has threatened to vote against companies that do not disclose climate risks, urging investors to make climate-proof portfolios a key consideration for all asset owners (BlackRock 2020). Eccles (2021) also exhorts investors to "use their votes to signal demand … for reliable financial reports to make climate impacts clear."

3 Literature review and hypotheses

In Section 3.1, we discuss competing predictions on whether disclosing climate risk may be positively or negatively associated with firm risk. Section 3.2 develops the second hypothesis about whether the association between firms' decisions whether to disclose climate risk and firm risk varies depending on market expectations of climate risk materiality.

3.1 Association between firms' choice whether to disclose climate risk and firm risk

3.1.1 Prediction of positive association

Federal securities laws state that materiality is "the cornerstone" of the corporate disclosure system and serves as a "standard for determining whether a communication (filed or otherwise) omits or misstates a fact of sufficient significance that legal consequences should result" (Sommer 1977, 320). Materiality, as defined by the Supreme Court in *TSC Industries, Inc. v. Northway, Inc.* (426 U.S. 4381976) and upheld in *Basic, Inc. v. Levinson* (485 U.S. 2241988), is "a substantial likelihood that disclosure of the omitted fact would have been viewed by the reasonable investor as having significantly altered the 'total mix' of information made available." Thus, materiality is premised on the importance of information available to a "reasonable investor" at the time the assessment is made (Hansen 2012). Firms are mandated to disclose information deemed relevant to the "reasonable investor" and must defend their omission of facts in court under this definition (Wasim 2019). However, what may be material to one registrant is not necessarily material to another. Consequently, lack of disclosure cannot be treated as a prima facie disregard for regulatory requirements or guidance (Hansen 2012).

Regulation S-K articulates nonfinancial statement disclosure requirements under both the Securities Act and the Exchange Act (Securities and Exchange Commission (SEC) 2016). Both of these acts require registrants to disclose information deemed necessary by the Commission, in the public interest, or for the protection of investors (Securities and Exchange Commission (SEC) 2016).[10] The 2010 SEC interpretive guidance clarifies Regulation S-K and specifies that companies are expected to disclose climate risk that can materially affect registrants' business operations and financial performance (Securities and Exchange Commission (SEC) 2010). Drawing on both federal securities regulation and case law, Heitzman et al. (2010) reiterate managers' affirmative duty to disclose material issues in the firm's SEC filings.

From a normative perspective, there are at least two mechanisms to compel managers to disclose material information. The first mechanism is the SEC's comment letter review process, which pressures companies to disclose material firm-specific risks in their SEC filings (Bozanic et al. 2017; Johnson 2010). Studies document lower bid-ask spreads and higher earnings response coefficients following SEC comment letter

[10] Although the initial materiality determination is management's, this assessment is subject to challenge or question by the Commission or in the courts (Sommer 1977, 332). To determine whether information is material, courts evaluate whether the "likelihood exists that the event is reasonably likely to occur" (Schwartz and Mussio 2007). If a firm determines that a trend, demand, commitments, event, or uncertainty is unlikely to occur, then the firm has no duty to disclose (Wallace 2008).

resolution (Johnston and Petacchi 2017). The second mechanism is litigation, as evidenced by the increasing number of companies facing investigations and lawsuits for failure to disclose material climate risk in their 10-Ks (Wasim 2019). Firms also face increasing pressure from shareholders, through resolutions and private engagement, to disclose material climate risk, indicating that the shareholders regard this information as material (Hasemyer 2019; Hasemyer 2016; EY 2021; Gelles 2016).

Based on the above discussion, if managers assess climate risk as material to the firm and anticipate that the regulation will be enforced (e.g., through the SEC's periodic review of registrants' filings or through litigation), then they will comply with mandatory disclosure under Regulation S-K. Disclosing (not disclosing) signals that managers assess climate risk as material (nonmaterial) to the firm, leading to the prediction of a positive association between disclosing climate risk and firm risk, consistent with compensating investors for the firms' exposure to material climate risk.

3.1.2 Prediction of negative association

Managers' choice whether to disclose climate risk is complicated by three key institutional factors. The first factor is that climate risk is multidimensional, with little consensus on whether it is material to the firms. When the SEC issued interpretive guidance on disclosing climate risk in 2010, disagreements regarding climate risk materiality surfaced in the SEC commissioners' 3–2 vote. One dissenting commissioner did not believe that the guidance "will result in greater availability of material, decision-useful information geared toward the needs of the broad majority of investors" (Casey 2010). Over a decade later, climate risk materiality and mandating climate risk disclosure in Form 10-K continue to be debated among the commissioners (Lee 2020; Maurer 2020; Tahmincioglu 2020).

Second, inconsistent enforcement of climate risk disclosures in regulatory filings can create perceptions of enforcement likely varying along a weak-to-strong continuum, where weak enforcement corresponds with essentially voluntary disclosure. Managers may perceive climate risk disclosure regulation as weakly enforced by the SEC for various reasons. The Commission's Investor Advisory Committee, which was charged with making recommendations regarding climate-related disclosures, was disbanded shortly after the 2010 guidance was issued. This led some public companies to view enforcement of climate risk disclosures as a lower priority for the Commission, a perception reinforced by the small number of climate-risk-related comment letters issued by the SEC. In 2010 and 2011 combined, the SEC issued only 49 comment letters specifically addressing these disclosures; this was followed by only three such letters in 2012 and none in 2013 (Coburn and Cook 2014). Of the 41,000 comment letters sent by the SEC between January 2014 and August 2017, only 14 addressed climate risk disclosures (Government Accountability Office (GAO) 2018). More recently, only one such letter was issued between January 2017 and July 2019 (Lubber 2019).

Third, shareholder litigation to pressure high-profile firms to disclose climate risk has had only mixed success over the last 25 years (McCormick et al. 2018). Notably, a class-action lawsuit filed by ExxonMobil's shareholders in 2016 was dismissed in 2019 by the New York State Supreme Court. The plaintiffs alleged that the firm had not disclosed that its oil reserves were significantly impaired. Exxon stated that none of its

assets were stranded, arguing that the impacts of climate change, if any, were uncertain and far in the future (Hasemyer 2016). In a separate case, the SEC also dropped its investigation of Exxon's accounting practices but indicated that this was not a change in how the SEC reviews companies' climate change statements (Michaels and Olson 2018).

In general, disclosures reduce information asymmetry between the firm and outsiders, contributing to efficient allocation of resources (Healy and Palepu 2001). However, managers are biased against providing unfavorable disclosures (Kothari et al. 2009a, b). Yet, investors may view nondisclosure as an adverse signal and penalize nondisclosing firms (Milgrom 1981; Giglio and Shue 2014; Zhou and Zhou 2020). Hence, if managers assess climate risk as material to the firm but perceive the regulation regarding these disclosures as weakly enforced, then they will view disclosing material climate risk as *essentially* voluntary. This will likely trigger an analysis of the benefits versus the costs of disclosing material climate risk.

The costs of disclosing climate risk include the deleterious effects of revealing proprietary information (Dye 1985; Verrecchia 1983) (e.g., on supply-chain risks from climate change), increased potential for climate-risk-related litigation (Wagner 2009), and unplanned expenditures on projects to mitigate or adapt to climate change. The possible benefits of disclosing climate risk include lower cost of capital for large firms that can attract increased demand from large investors due to increased liquidity of the firm's securities (Diamond and Verrecchia 1991), avoiding climate-risk-related lawsuits (Hasemyer 2016; McCann 2016; Olson and Viswanatha 2016), reducing future regulatory intervention (Blacconiere and Patten 1994), and achieving the positive effects of impression management (Merkl-Davies and Brennan 2007). If firms view disclosing material climate risk as *essentially* voluntary, then disclosing (not disclosing) signals that they assess the benefits of disclosing as greater (lower) than the costs of disclosing. Based on these arguments, we expect that firms that disclose material climate risk will have a *lower* COE than nondisclosing firms.

3.1.3 Hypothesis 1

In sum, firms' decisions whether to disclose climate risk are the observable outcomes of their unobservable assessments of both the materiality and SEC enforcement of climate risk disclosures, as well as of their evaluations of the costs and benefits of disclosing versus not disclosing climate risk.[11] If firms assess climate risk as material and expect mandatory disclosure of material climate risk to be enforced, firms that disclose climate risk in Form 10-K signal that the risk is significant. This would argue for a positive association between disclosing climate risk and firm risk. However, if managers assess climate risk as *nonmaterial* to the firm, or if they view disclosing *material* climate risk as essentially voluntary, firms will disclose climate risk only if it is beneficial to do so, leading to the prediction of a negative association between disclosing climate risk and firm risk. Given the arguments above for competing predictions regarding the

[11] When disclosure is mandatory, the costs of nondisclosure are assumed to be prohibitive; consequently, the cost-benefit tradeoff is usually not explicitly modeled in that situation.

association between disclosing climate risk and firm risk, we propose our first hypothesis in the null form, as follows:

> *H1: There is no association between disclosing climate risk in Form 10-K and firm risk.*

We may fail to reject the null hypothesis if firms' choice whether to disclose climate risk in Form 10-K provides no incremental information to the market about the materiality of climate risk. This may occur if the market views climate risk disclosures in SEC filings as boilerplate in nature (Hope et al. 2016; Kravet and Muslu 2013; Merkl-Davies and Brennan 2007). However, research indicates that managers' qualitative risk factor disclosures are not boilerplate but instead meaningfully reflect the specific risks the firm faces (Campbell et al. 2014). Alternatively, the market may consider firms' voluntary climate risk disclosures through non-SEC mechanisms as sufficiently informative to investors. In addition, if the market views climate risk disclosures in SEC filings as being untimely (Kothari et al. 2009a), or if climate risk is a diversifiable risk (Lintner 1965; Sharpe 1964), then there will be no association between disclosing climate risk and firm risk.

3.2 Market expectation of climate risk materiality

Our first hypothesis examines the association between investors' inferences regarding firms' climate risk materiality assessments (which are unobservable), their climate risk disclosure decisions (which are observable), and firm risk. Both the SEC and the FASB recognize that materiality is context specific, varying with the nature of business. Emphasizing these differences, the Sommer Report (Sommer 1977, 340) states that "disclosures material to one industry should not be required for other industries as to which they are not applicable." We draw on prior research examining the differences in materiality of information across different types of firms to probe deeper into the association between managers' decisions whether to disclose climate risk and firm risk.

Cheng et al. (2013) find that after a mandatory-to-voluntary SEC rule shift, smaller disclosing companies that chose to continue disclosing certain nonfinancial information (e.g., risk disclosures) in SEC filings experienced an increase in market illiquidity. However, the increase in illiquidity was even larger for firms that discontinued disclosing this information. The authors argue that the association between the choice to disclose and market illiquidity depends on the *materiality* of the potentially reduced information. The findings from Cheng et al. (2013) point to the important role of the materiality of nonfinancial disclosures for risks that companies were previously required to disclose, but they do not address the critical role of materiality assessment for emerging risks and the importance of market expectations of risk materiality.

Khan et al. (2016) hand-map industry-specific materiality guidance provided by SASB's Materiality Map™ to firm-level ratings from MSCI KLD to assess the firms' investments in material and immaterial sustainability issues. Their study reports that firms with strong ratings on material ESG issues have better future accounting performance than firms with inferior ratings on the same issues. In contrast, firms with strong ratings on immaterial ESG issues do not outperform firms with poor ratings on these same issues. Further, firms with strong ratings on material ESG issues and concurrently

poor ratings on immaterial ESG issues have the best future accounting performance. The authors conclude that the materiality guidance enhances the informativeness of ESG performance data for investors.

The discussion above leads us to predict that the association between managers' decisions whether to disclose climate risk in Form 10-K and firm risk will vary depending on market expectations of risk materiality. We propose our hypothesis in the null form, as follows:

H2: There is no differential effect of market expectation of climate risk materiality on the association between disclosing climate risk in Form 10-K and firm risk.

4 Research design

4.1 Sample

Our sample consists of S&P 500 firms over the nine-year period from 2008 to 2016. To maintain a consistent sample over this period we use firms that were included in the S&P 500 index on December 31, 2008. We select 2008 as our initial year because this year precedes the SEC's 2010 issuance of its interpretive guidance on climate risk disclosures, effective in fiscal year 2009 for most firms. The final year of 2016 is the last year for which CDP climate change reports were publicly available at the time of our data collection.

To control for voluntary disclosures of climate risk information through channels other than the SEC filings, we collect data on the sample firms' participation in the CDP climate survey, which is voluntary. The CDP survey elicits information on climate change risks and opportunities, among other information. Although firms may provide this information through other channels, such as their own corporate websites or corporate social responsibility (CSR) reports, CDP is widely considered the most comprehensive source of corporate climate-related data.

Table 1 shows the sample selection criteria. We begin with 4087 firm-year observations (485 unique S&P 500 firms) for which we are able to calculate COE. We are unable to calculate the COE measure when analysts' forecasts are not available for a firm, or when firms have a negative book value of equity or negative analysts' earnings forecasts for either year one or year two. We lose a total of 118 firm-year observations due to missing Compustat data (62), or insufficient data to calculate betas (19), or because we are unable to obtain CDP information (37). The final sample for hypotheses testing consists of 3,919 firm-year observations (481 unique firms).

4.2 Empirical models and variable definitions

As argued earlier, firms that disclose climate risk may be systematically different from firms that do not disclose climate risk. Therefore, using data from disclosing firms to draw inferences about nondisclosing firms without adjusting for the systematic differences between them could give rise to self-selection bias, potentially leading to biased coefficients, and thus, erroneous conclusions. We correct for self-selection using propensity score matching (PSM) and compare the implied COE of firms that disclose

Table 1 S&P 500 firms sample selection (2008 to 2016)[a]

	Firm-years	Unique Firms
Observation for which we could calculate cost of equity[b]	4,087	485
Less:		
Number of observations missing Compustat data	(62)	(0)
Number of observations missing information to calculate beta	(19)	(4)
Number of observations missing CDP information	(37)	(0)
Final sample for tests	3,919	481

[a] We have climate risk data and COE available through 2017 but do not have CDP data beyond 2016

[b] We exclude firms for which we are unable to calculate the COE measures because (1) they have a negative book value of equity, (2) they have negative analysts' earnings forecasts for years one and two, or (3) we are unable to obtain analysts' forecasts

climate risk with the COE of nondisclosing firms using doubly robust (DR) regressions. Further, we examine the COE differences between disclosing and nondisclosing firms after partitioning them into material versus nonmaterial groups based on market expectations of climate risk using SASB's Materiality Map™.

DR regressions provide additional robustness by removing the correlation between the omitted covariates and reducing the correlation between omitted and included variables (Imbens and Wooldridge 2009). As long as *either* the PSM model or the conditional expectation function is correctly specified, the estimates are consistent. Bias due to correlated omitted variables is also attenuated if the omitted variables are correlated with the variables included in one of the component models (Funk et al. 2011). Additionally, using the standard errors from the regression gives us robust standard errors clustered by firm.

4.3 Implied cost of equity calculations

The implied COE is the internal rate of return that equates the current stock price to the present value of all expected future cash flows to equity. This rate is an ex ante estimate of the COE, given market expectations about future growth. The value of the firm at time t is

$$P_t = \sum_{i=1}^{\infty} \frac{E_t[FCFE_{t+i}]}{(1+r_e)^i}$$

where P_t is the market value of common equity on the date of the earnings forecast at time t from the daily CRSP files, $FCFE_{t+i}$ is free cash flow to equity at time $t + i$, and r_e is the implied COE.

We rely on prior accounting and finance research (e.g., Hann et al. 2013; Hail and Leuz 2009) to estimate the implied COE. *COE*, the implied COE measure, is a composite COE constructed using the median of four measures: Easton's (2004) price earnings growth (PEG) model, Gebhardt et al. (2001) (GLS), Claus and Thomas (2001)

(CT), and the price-earnings ratio.[12] The four models differ in the assumptions made to forecast expected future cash flows. We follow Hann et al. (2013) in our operationalization of these models.

Following prior research, we use median analysts' forecasts as our proxy for *FCFE*. Analysts' forecasts for year 1 correspond to the fiscal year that ends *after* the forecast date. That is, if the first-year analysts' forecasts (year 1 in I/B/E/S) are for the previous year because the earnings for the previous year have not yet been announced, we use the second-year (current year) forecasts instead. For residual earnings models such as CT and GLS, which require an estimate of book value, we use the book value at the end of the prior year. Since the first forecast is only for part of the year, we discount for the proportionate number of days remaining through the year-end.

Prior studies retain only one analyst earnings forecast per year (e.g., Hann et al. 2013; Hail and Leuz 2009). Unlike these studies, we retain all analysts' forecasts made during the year for each firm to calculate the COE numbers used in our composite measure. Prior research shows that analysts' forecasts tend to exhibit an upward bias early in the fiscal year but are revised downwards over the year and finally exhibit a downward bias at earnings announcement (Richardson et al. 2004). These biases can lead to systematic biases in COE calculations (Easton and Sommers 2007). Using all available forecasts reduces this bias as well as any errors that may arise in the COE measure from errors in the retained forecast. We take the median of all the COE numbers for each measure for each firm-year. We then take the median across the four measures to calculate our composite *COE* measure for each fiscal year for each firm.

4.4 Proxy for market expectations of climate risk materiality

We examine the role of materiality on *COE* differences between disclosing and nondisclosing firms after partitioning them into material versus nonmaterial groups based on market expectations of climate risk. To construct our proxy for the market expectations of climate risk materiality, we use SASB's Materiality Map™ classifications to hand-map the SASB industry classification to SIC codes and to classify each firm as belonging to a material or nonmaterial group (see further details in Appendix 1). At the time of our data collection, the map classified 30 sustainability issues as material or nonmaterial by industry using an evidence-based approach based on input from a panel of 200 industry experts and SASB staff.[13] We identified the six sustainability issues from the map that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, we assigned each sample firm that belongs to that industry to the material group

[12] This is consistent with prior research that aggregates various measures to calculate a composite COE measure (see, e.g., Hail and Leuz 2009). Aggregating across measures reduces the idiosyncratic errors that may be present in any single measure.

[13] The 30 issues are grouped into five categories: environment, social capital, human capital, business model and innovation, and leadership and governance.

(*SASB_MTRL* = 1). Otherwise, we assigned the firm to the nonmaterial group (*SASB_MTRL* = 0).[14]

4.5 Propensity score matching and doubly robust regression

We use PSM (Rosenbaum 2005) and DR regressions to compare the *COE* of the firms that disclose climate risk with the *COE* of the nondisclosing firms. We use the probit model in Eq. (1) to calculate the propensity scores:

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

where *D10K* is an indicator variable that is coded 1 if the firm discloses climate risk information in Form10-K in year *t*, and 0 otherwise. To construct *D10K*, we use the sample firms' 10-K filings in SEC EDGAR and a structured search rubric to manually code firms' decisions whether to disclose climate risk. The search rubric consists of key words or phrases related to climate risk (e.g., "carbon," "climate change," "GHG," "hurricanes," "extreme weather"), and it is informed by the SEC 2010 interpretive guidance on climate change and our own review of hundreds of firms' 10-K filings. The interpretive guidance describes the following 10-K sections as the most pertinent in complying with climate risk disclosure: Item 1-Business, Item 1A-Risk factors, Item 3-Legal proceedings, and Item 7-Management's discussion and analysis of financial condition and results of operations. These sections correspond to items 101, 103, 503(c), and 303 of the Regulation S-K rules, respectively. We searched the full Form 10-Ks of the sample firms. Further details of the structured search rubric and coding appear in Appendix 2.

All the independent variables in the probit model are measured contemporaneously. We match the disclosers with the nondisclosers on the Fama-French three factors: market beta (*BETA*), book-to-market ratio (*BM*), and firm size (*SIZE*) (Fama and French 1993). *BETA* is the correlation between firm-specific returns and market returns. We use monthly returns for the firm and the CRSP value-weighted index for the market returns. We calculate betas using returns for the five years prior to and including fiscal year *t*, but require at least ten months of data. For firm-years with fewer than ten months of data, we substitute the mean beta for the firm as the beta for that fiscal year.[15] Following Francis et al. (2008), we predict a positive association between *BETA* and *D10K*. We control for firm growth by including the firms' book-to-market ratio (*BM*), measured as the book value of common equity divided by the market value of common equity at the end of the fiscal year. Because larger firms are more likely to provide more environmental disclosures (Matsumura et al. 2014; Stanny 2013), we include the log of firms' total assets as our proxy for *SIZE*.

[14] Eccles et al. (2012, 71) make a case for industry-level identification of material ESG issues because firms in an industry "tend to have similar business models; they operate within the same regulatory environment, have similar approaches to handling resources and externalities, and produce similar products and services."

[15] We make this substitution for 259 firm-year observations (or about 6.5% of our sample).

International product market interactions affect environmental disclosures (Matsumura et al. 2014; Stanny and Ely 2008; Khanna et al. 2004), and EU firms with higher proportions of international sales are more likely to provide climate risk disclosures. Therefore, we include annual pre-tax foreign income as a proportion of total pre-tax income (*FI/PI*) and expect a positive coefficient for this variable. Based on prior research that finds a positive association between firm performance and disclosures (e.g., Miller 2002), we expect a positive coefficient on the firm performance measure, *ROA*, measured as income before extraordinary items divided by total assets. Since firm leverage is positively associated with cost of equity (Fama and French 1993), we also include *LEV* in our model, measured as total long-term debt divided by total assets.

Firms choose the exchange on which to list their securities. This choice is a function of firm-level characteristics and the exchange's listing requirements, including disclosure requirements (Corwin and Harris 2001). Therefore, we also match firms on the stock exchange (*EXCH*) on which they trade. In general, larger and older firms are more likely to list on the NYSE, but since the vast majority of the sample firms (80%) are listed on the NYSE (the remaining firms trade on NASDAQ) and are likely to be among the largest global firms, we do not predict a sign on *EXCH*.

Empirical evidence indicates that more environmentally proactive firms are more likely to disclose environmental information (Matsumura et al. 2014). We use the MSCI ESG KLD database to construct the firms' environmental performance proxies. To proxy for environmentally proactive performance, denoted *STRNG*, we use "Climate Change – Carbon Emissions" (ENV-STR-D in the database), and to proxy for environmentally damaging actions, denoted *CNCRN*, we use "Energy and Climate Change" (ENV-CON-F in the database).[16] If the performance score is missing, we set it equal to zero. Consistent with prior research (Matsumura et al. 2014; Cho et al. 2012), we do not aggregate *STRNG* and *CNCRN* because the proactive dimensions are distinct from the damaging dimensions. Following Matsumura et al. (2014), we expect a positive coefficient for *STRNG*, and we do not predict a sign for *CNCRN*.

To address the possibility that firms may be providing climate risk information voluntarily through non-SEC channels, we include an indicator variable, *CDP*. If the firm participated in the CDP climate survey and the response is publicly available in that year (i.e., the CDP response status is AQ, AQ(L), or AQ(SA)), then we code the variable *CDP* as 1, and 0 otherwise.[17]

Nallareddy et al. (2020) find that current cash flows are a better predictor of future cash flows than are current earnings. Hence, we use the firms' cash flows from operations (*OCF*) as a proxy for markets' expectations of future cash flows. This controls for forecast errors or bias in analysts' forecasts that may be embedded in the COE estimate, potentially biasing our estimates.

[16] We are unable to use aggregate environmental strengths and aggregate environmental concerns (ENV-STR-NUM and ENV-CON-NUM in the database, respectively) because MSCI KLD discontinued providing the aggregate numbers in 2013. As MSCI ESG KLD changed the measures it provides during our sample period, we use the measure for which we are consistently able to obtain data for our entire sample period.

[17] CDP uses the following response status legend: AQ – Answered the survey; AQ(L) – Answered the survey late; AQ(SA) – Answered the survey but the company is a subsidiary or has merged; NP – Answered the survey but the response is not publicly available; IN – Information provided; DP – Declined to participate; NR – No response; and X – the company did not fall into the CDP sample that year.

5 Results

5.1 Descriptive statistics

Panel A of Fig. 1 shows descriptive statistics of firms that disclosed climate risk information in Form 10-K and their participation in the CDP climate survey from 2008 to 2016. In 2008, about one-third of the firms (31.3%) disclosed climate risk information. Notably, that percentage increased by over 13 percentage points from 2008 to 2009, and a further five percentage points in 2010. These increases make intuitive sense, as the years coincide with the issuance of the SEC's 2010 interpretive guidance on climate change disclosures, which became effective in February 2010. The percentage of firms disclosing climate risk remained steady around 50% through 2012, growing slightly to about 53% in 2016. Panel A also shows growth in the firms' participation in the CDP climate survey, from 57% in 2008 to 61% in 2016, with a peak of about 63% in 2009.

Panel B of Fig. 1 shows the percentages of firms that disclosed climate risk in Form 10-K, partitioned by market expectations of climate risk materiality. From 2008 to 2016, the number of climate risk disclosers for both the material and nonmaterial groups grew by about 30 percentage points, reaching 81% for firms in the material climate risk group and 49% for firms in the nonmaterial climate risk group. Over the same period, the percentages of climate risk disclosers are consistently higher, by an average of 30 percentage points, for the material climate risk group relative to the nonmaterial climate risk group.

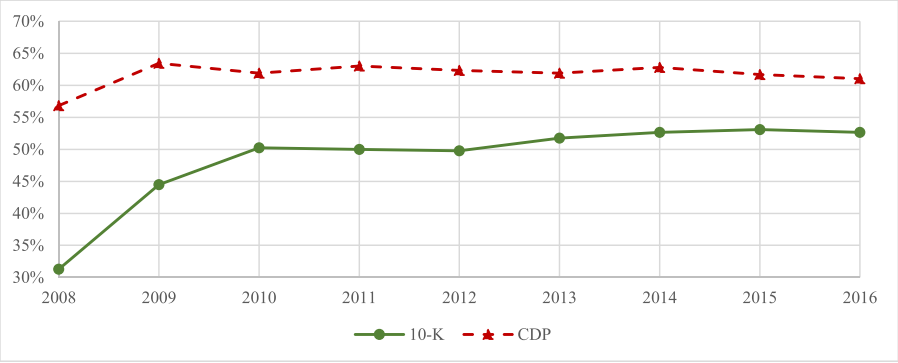
Panel A of Table 2 shows that, averaged over the nine-year period, about half of the sample firms (50.5%) disclosed climate risk, and about two-thirds (64.3%) participated voluntarily in the CDP climate survey. Further, while 36.4% both responded to the CDP climate survey and disclosed climate risk (cell 4), about 22% did neither (cell 1). Notably, almost 28% responded to the CDP climate survey but chose to not disclose climate risk (cell 3).[18] This is counterintuitive, since these firms voluntarily committed scarce resources to respond to the CDP survey yet chose not to disclose climate risk. Panel B of Table 2 shows firms' disclosure decisions in Form 10-K partitioned by market expectations of climate risk materiality (material versus nonmaterial). Averaged over the nine-year period, the majority of firms in our sample (66%) belong to industries where the market does not expect climate risk to be material.

Panel A of Table 3 shows that the majority of firms that participated in the CDP climate survey (Panel A) disclosed climate risk (56.6%), while Panel B shows that only 39.6% of the firms that did not participate in the CDP climate survey disclosed climate risk.

Table 4 provides summary statistics for the variables in Eq. (1). We winsorize all continuous variables at the 1% level on both tails of the distribution. Panel A of Table 4 shows that the mean (median) *COE* is 8.20% (7.80%), with an interquartile range of 6.4

[18] The null hypothesis of independence between disclosing climate risk information in Form 10-K and participation in the CDP climate survey is rejected (Chi-square = 104.02; p = 0.00).

Panel A: Percentages of S&P 500 firms that disclosed CR in Form 10-K and firms that participated in the CDP climate survey



Panel B: Percentages of S&P 500 firms that disclosed CR in Form 10-K, partitioned by the market expectations of CR materiality

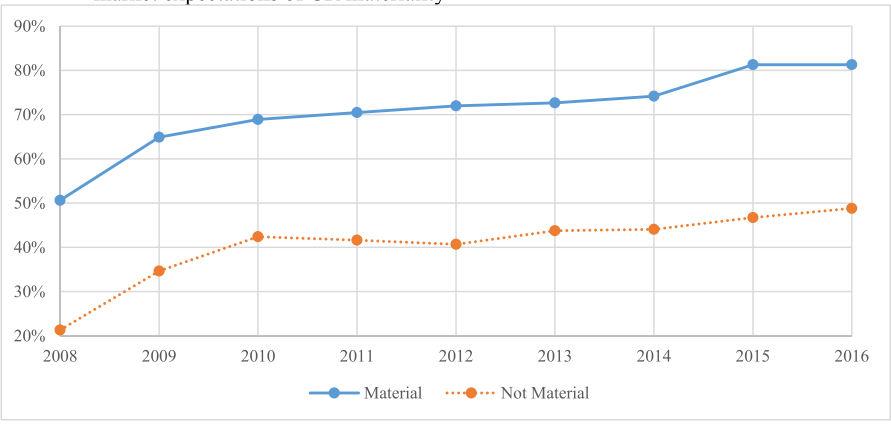


Fig. 1 Firms' climate risk disclosure decisions and CDP climate survey participation, 2008 to 2016. Panel A. Percentages of S&P 500 firms that disclosed climate risk in Form 10-K and firms that participated in the CDP climate survey (N = 3,919). Panel B. Percentages of S&P 500 firms that disclosed climate risk in Form 10-K, partitioned by the market expectations of climate risk materiality (SASB) (N = 3,919). This graph shows the percentage of firms that disclose climate risk in their 10-K filings, partitioned by market expectations of climate risk as material (N = 1,331) and nonmaterial (N = 2,588). See Appendix 1 for more details

to 9.2%.[19] The firms' mean (median) *BETA* is about 1.16 (1.08), which is consistent with the relatively low risk of S&P 500 firms in general. The firms' mean (median) *BM* is 0.512 (0.410), indicating that, on average, the firms are healthy and have growth opportunities. For a few firms, foreign income represents a large proportion of their total income (*FI/PI*). The mean *FI/PI* is 29.4%, although the median is only 10.7%. The *EXCH* variable reflects the composition of our sample: 3,174 firm-years (81%) trade on

[19] Damodaran (http://pages.stern.nyu.edu/~adamodar/) estimates an average risk premium of 2.58% over the 2008–2016 period for S&P 500 firms using the dividend discounting (DD) model, and 5.59% using the free cash-flows-to-equity (FCFE) approach. With an average risk-free rate of 2.55% over this period, this translates into COEs of 5.12% and 8.14% for the DD and FCFE approaches, respectively.

Table 2 Frequencies of firms partitioned by CDP climate survey participation, managers' climate risk disclosure decisions, and market expectations of climate risk materiality, 2008 to 2016[a]

Panel A: CDP climate survey participation and managers' climate risk disclosure decisions

Participated in CDP climate survey?[b]	Disclosed climate risk in Form 10-K? No	Yes	Total
No	1 846 (21.6)	2 554 (14.1)	1,400 (35.7)
Yes	3 1,094 (27.9)	4 1,425 (36.4)	1,953 (64.3)
Total	1,940 (49.5)	1,979 (50.5)	3,919 (100)

Panel B: Market expectations of climate risk materiality and managers' climate risk disclosure decisions

Market expectations of climate risk materiality (SASB)[c]	Disclosed climate risk in Form 10-K? No	Yes	Total
Nonmaterial	1 1,547 (39.5)	2 1041 (26.5)	2,588 (66.0)
Material	3 393 (10.0)	4 938 (24.0)	1,331 (34.0)
Total	1,940 (49.5)	1,979 (50.5)	3,919 (100)

[a] Cell frequencies are number of firm-year observations (% of total)

[b] Participation in the CDP climate survey is voluntary

[c] To construct our proxy for market expectations of climate risk materiality, we select the six sustainability issues from SASB's Materiality Map™ that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, then we assign each sample firm that belongs to that industry to the material group (coded *SASB_MTRL* = 1). Otherwise, we assign the firm to the nonmaterial group (coded *SASB_MTRL* = 0). See Appendix 1 for further details

the NYSE (coded = 1), and 19% trade on NASDAQ (coded = 3).[20] About 64% of the firms participated in the CDP climate survey and allowed their responses to be publicly available. Finally, a few sample firms have really large cash flows from operations (*OCF*). The mean *OCF* of $3.075 billion is larger than the third quartile, while the median is only $1.23 billion.

[20] About 55% of the firms listed on the NYSE disclose climate risk information in Form 10-K; in contrast, less than one-third, 32%, of the firms listed on NASDAQ disclose this information in Form 10-K.

Table 3 Frequencies of firms partitioned by CDP climate survey participation, market expectations of climate risk materiality, and managers' climate risk disclosure decisions, 2008 to 2016[a]

Panel A: Subsample of firms that participated in the CDP climate survey[b]

Market expectations of climate risk materiality (SASB)[c]	Disclosed climate risk in Form 10-K? No	Yes	Total
Nonmaterial	1 866 (34.4)	2 738 (29.3)	1,604 (63.7)
Material	3 228 (9.0)	4 687 (27.3)	915 (36.3)
Total	1,094 (43.4)	1,425 (56.6)	2,519 (100)

Panel B: Subsample of firms that did not participate in the CDP climate survey

Market expectations of climate risk materiality (SASB)[c]	Disclosed climate risk in Form 10-K? No	Yes	Total
Nonmaterial	1 681 (48.6)	2 303 (21.7)	984 (70.3)
Material	3 165 (11.8)	4 251 (17.9)	378 (29.7)
Total	846 (60.4)	554 (39.6)	1,400 (100)

[a] Cell frequencies are number of firm-year observations (% of total)

[b] Participation in the CDP climate survey is voluntary

[c] To construct our proxy for market expectations of climate risk materiality, we select the six sustainability issues from SASB's Materiality Map™ that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, then we assign each sample firm that belongs to that industry to the material group (coded *SASB_MTRL* = 1). Otherwise, we assign the firm to the nonmaterial group (coded *SASB_MTRL* = 0). See Appendix 1 for further details

Panel B of Table 4 shows summary statistics and univariate tests for the variables in Eq. (1), partitioned by whether the firms disclose or do not disclose climate risk (*D10K* = 1 and *D10K* = 0, respectively). The differences in *COE*, *BETA*, and *FI/PI* between disclosers and nondisclosers are not significant. For all the other variables, the disclosers are significantly different from the nondisclosers (p = 0.00). *BM* is higher for the disclosers than for the nondisclosers, indicating that disclosing firms may have more assets. Consistent with prior literature that large firms are more likely to disclose, the mean and median *SIZE* are significantly higher for the disclosers than for the nondisclosers. Contrary to intuition, the mean and median *ROA* are higher for the

Table 4 Descriptive statistics

Panel A: Full sample (N=3,919)

Variable	Mean	Q1	Median	Q3	Std Dev
COE	0.082	0.064	0.078	0.092	0.038
BETA	1.158	0.743	1.077	1.484	0.593
BM	0.512	0.240	0.410	0.678	0.414
SIZE	9.772	8.785	9.645	10.575	1.341
FI/PI	0.294	0.000	0.107	0.532	0.558
ROA	0.052	0.017	0.048	0.087	0.067
LEV	0.230	0.110	0.214	0.326	0.156
EXCH	1.380	1.000	1.000	1.000	0.785
STRNG	0.377	0.000	0.000	1.000	0.485
CNCRN	0.063	0.000	0.000	0.000	0.242
CDP	0.643	0.000	1.000	1.000	0.479
OCF	3.075	0.587	1.230	3.008	5.624

Panel B: Firms partitioned by Form 10-K climate risk disclosers and nondisclosers

	D10K=1 (Disclosers) (N=1,979)			*D10K*=0 (Nondisclosers) (N=1,940)			Difference	
							T-test	Wilcoxon
Variable	Mean	Median	Std Dev	Mean	Median	Std Dev	p value	p value
COE	0.082	0.077	0.037	0.082	0.079	0.038	0.62	0.69
BETA	1.150	1.103	0.589	1.167	1.053	0.596	0.35	0.95
BM	0.525	0.434	0.395	0.498	0.384	0.432	0.04	0.00
SIZE	10.028	9.887	1.296	9.510	9.308	1.336	0.00	0.00
FI/PI	0.295	0.132	0.546	0.292	0.092	0.571	0.89	0.39
ROA	0.046	0.044	0.063	0.057	0.053	0.071	0.00	0.00
LEV	0.242	0.234	0.146	0.218	0.191	0.165	0.00	0.00
EXCH	1.242	1.000	0.652	1.522	1.000	0.878	0.00	0.00
STRNG	0.463	0.000	0.499	0.289	0.000	0.453	0.00	0.00
CNCRN	0.105	0.000	0.306	0.020	0.000	0.139	0.00	0.00
CDP	0.720	1.000	0.449	0.564	1.000	0.496	0.00	0.00
OCF	3.763	1.654	6.161	2.373	0.971	4.920	0.00	0.00

Panel C: Firms partitioned by market expectations of climate risk materiality[a]

	(Material) (N=1,331)			(Nonmaterial) (N=2,588)			T-test	Wilcoxon
Variable	Mean	Median	Std Dev	Mean	Median	Std Dev	p value	p value
COE	0.075	0.072	0.033	0.086	0.081	0.039	0.00	0.00
BETA	1.032	1.004	0.598	1.223	1.121	0.579	0.00	0.00
BM	0.468	0.415	0.358	0.534	0.408	0.439	0.00	0.01
SIZE	9.633	9.644	1.111	9.843	9.645	1.440	0.00	0.02
FI/PI	0.258	0.060	0.518	0.312	0.132	0.577	0.00	0.00
ROA	0.050	0.044	0.069	0.052	0.050	0.067	0.23	0.13
LEV	0.286	0.280	0.150	0.202	0.174	0.151	0.00	0.00
EXCH	1.276	1.000	0.691	1.434	1.000	0.824	0.00	0.00
STRNG	0.437	0.000	0.496	0.346	0.000	0.476	0.00	0.00

Table 4 (continued)

CNCRN	0.128	0.000	0.334	0.029	0.000	0.168	0.00	0.00
CDP	0.687	1.000	0.464	0.620	1.000	0.486	0.00	0.00
OCF	2.838	1.297	5.003	3.197	1.218	5.915	0.05	0.12

[a] To construct our proxy for market expectations of climate risk materiality, we select the six sustainability issues from SASB's Materiality Map™ that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, then we assign each sample firm that belongs to that industry to the material group (coded *SASB_MTRL* = 1). Otherwise, we assign the firm to the nonmaterial group (coded *SASB_MTRL* = 0). See Appendix 1 for further details

For variable definitions see Appendix 3 Table 12

nondisclosers than for the disclosers. This may be because disclosing firms have more total assets, as indicated by their larger size. Disclosing firms also have higher *LEV* than nondisclosing firms. Taken together, our univariate results reinforce the importance of correcting for self-selection. That is, as discussed earlier, using data from the disclosing firms to draw inferences about the nondisclosing firms without first correcting for these differences will likely lead to biased coefficients and, thus, erroneous conclusions.

Panel C of Table 4 shows summary statistics and univariate tests for the variables in Eq. (1) with the sample firms partitioned by market expectations of climate risk materiality (material versus nonmaterial). Both the mean and median *COE* are significantly higher for firms in the nonmaterial climate risk group than for firms in the material climate risk group. Consistent with the higher *COE* for the nonmaterial climate risk firms, their *BETA* is also significantly higher. On average, material climate risk firms have significantly higher strengths (*STRNG*) and concerns (*CNCRN*) scores and are also significantly more likely to respond to the CDP survey.

Table 5 presents correlation coefficients for the variables in Eq. (1). The tables show Pearson and Spearman rank correlations above and below the diagonal, respectively. We discuss the Spearman correlations here. *COE* is not significantly correlated with either of the disclosure measures (*D10K* or *CDP*) ($p > 0.10$). *COE* is correlated with all the other variables in the regression model except *STRNG*. The signs for all the correlations are as expected, except for the positive correlation between *COE* and *SIZE* (Spearman rank = 0.17; $p < 0.01$). This result is consistent with Dhaliwal et al. (2011) and may be due to the sample firms (drawn from the S&P 500 index) being among the largest in the world.[21] *D10K* is significantly correlated with both *STRNG* and *CNCRN*, as well as with *CDP*, consistent with Panel B of Table 4.

5.2 Test of the association between disclosing versus not disclosing climate risk and COE

Table 6 presents the results of Eq. (1) matching the firms that disclose climate risk in Form 10 K (*D10K* = 1) with those that do not (*D10K* = 0) on various firm-level

[21] See also Easton (2007) for a discussion of assessing the validity of *COE* measures using associations or correlations with other known risk factors, such as *BETA* and *SIZE*.

Table 5 Correlation coefficients (N = 3,919)

	COE	*D10K*	*BETA*	*BM*	*SIZE*	*FI/PI*	*ROA*	*LEV*	*EXCH*	*STRNG*	*CNCRN*	*CDP*	*OCF*
COE	1	0.01	0.26	0.33	0.12	-0.02	-0.23	*0.04*	*-0.04*	*-0.05*	0.08	-0.07	*0.04*
D10K	-0.01	1	-0.01	*0.03*	0.19	0.00	-0.08	0.08	-0.18	0.18	0.18	0.16	0.12
BETA	0.28	0.00	1	0.28	-0.07	0.04	-0.28	*-0.03*	*-0.03*	-0.17	0.01	-0.14	-0.11
BM	0.48	0.07	0.23	1	0.33	-0.12	-0.43	-0.21	-0.11	-0.07	0.10	-0.11	0.04
SIZE	0.17	0.20	-0.11	0.33	1	-0.04	-0.19	-0.12	-0.16	0.24	0.11	0.26	0.63
FI/PI	*-0.03*	0.01	0.07	-0.23	-0.09	1	0.12	-0.06	0.07	0.08	*0.03*	0.12	0.06
ROA	-0.25	-0.08	-0.27	-0.56	-0.29	0.35	1	-0.14	0.15	0.07	-0.08	0.09	0.08
LEV	-0.10	0.11	-0.09	-0.22	-0.08	-0.12	-0.12	1	-0.17	-0.02	0.01	-0.09	-0.10
EXCH	-0.13	-0.18	-0.01	-0.15	-0.15	0.10	0.16	-0.21	1	-0.09	-0.11	*-0.04*	*-0.03*
STRNG	-0.02	0.18	-0.16	-0.06	0.23	0.11	0.08	0.01	-0.09	1	0.10	0.39	0.23
CNCRN	0.15	0.18	0.02	0.14	0.12	0.03	-0.08	*0.03*	-0.11	0.10	1	0.01	0.12
CDP	-0.02	0.16	-0.12	-0.08	0.25	0.19	0.12	-0.07	*-0.04*	0.39	0.01	1	0.22
OCF	*0.03*	0.22	-0.26	0.01	0.77	0.07	0.11	-0.05	-0.09	0.29	0.12	0.33	1

Pearson (Spearman rank) correlation coefficients are above (below) the diagonal.
Coefficients in regular font are significant at $p < 0.01$.
Coefficients in italics are significant at $p < 0.10$.
Coefficients in grey are not significant ($p > 0.10$).
For variable definitions see Appendix 3 Table 12

characteristics (Panel A), and of our tests to examine the COE effect of disclosing versus not disclosing climate risk after PSM (Panel B).[22] Panel A shows that, of the total 3,919 firm-year observations, we are able to match 3,874 observations: 1,934 disclosers are matched with 1,940 nondisclosers. We are unable to match 45 disclosers. Before matching, the two groups of firms are significantly different on most of the firm characteristics, as shown in Table 4, Panel B. After matching, only three firm-level variables are significantly different between the two groups: *BM*, *CNCRN* ($p < 0.01$), and *OCF* ($p < 0.05$) (Table 6, Panel A, covariate balance). Panel B of Table 6 shows the t-tests of differences in the *COE* of matched disclosers versus nondisclosers. The difference in *COE* is negative but not significant at conventional levels.

Even after PSM, the matched sample is different on a few dimensions. Further, the standard errors from the PSM may not be unbiased. Therefore, to remove any residual misspecification that may remain after matching, we estimate a DR regression (Imbens and Wooldridge 2009), clustering the standard errors by firm (Permno). Panel C of Table 6 shows that the difference in *COE* between the disclosing firms (*D10K* = 1) and nondisclosing firms (*D10K* = 0) is negative and significant ($p = 0.017$): the *COE* of disclosers is approximately 27 bps lower than the *COE* of nondisclosers. This result translates to about 3.3% of the average *COE* of the sample firms, supporting H1b: the *COE* of firms that disclose climate risk in Form 10-K is *lower* than the *COE* of nondisclosing firms.

5.3 Tests of the association between disclosing climate risk and COE: Market expectations of climate risk materiality

We next examine whether the association between disclosing climate risk and *COE* varies with the market expectations of climate risk materiality. The PSM results in Table 7, Panel A show that, for the matched sample of 1,209 material climate risk firms (*SASB_MTRL* = 1), disclosing and nondisclosing firms differ significantly on these firm-level variables: *BETA*, *ROA*, and *EXCH* ($p < 0.01$); *LEV* and *CNCRN* ($p < 0.05$); and (*OCF*) ($p < 0.10$). We are able to match 840 disclosers to 369 nondisclosers. We are unable to match 98 disclosers.

For the matched sample of 2,546 climate risk firms in the nonmaterial group (*SASB_MTRL* = 0), we find no significant differences in firm-level characteristics between the disclosing and nondisclosing firms. We are able to match 999 disclosers to 1,547 nondisclosers but are unable to find matches for 42 disclosing firms.

Panel B of Table 7 shows the tests of differences in *COE* between matched disclosers and nondisclosers, partitioned by market expectations of climate risk materiality. For the matched sample of material climate risk firms (*SASB_MTRL* = 1), the *COE* of disclosing firms (*D10K* = 1) is significantly lower than the *COE* of nondisclosing firms. For the matched sample of nonmaterial climate risk firms, the *COE* of disclosers is not significantly different from the *COE* of nondisclosers.

The DR robust regression results in Panel C of Table 7 show that, for firms in the material climate risk group, the *COE* of disclosers is 50 bps lower ($p = 0.014$) than the *COE* of nondisclosers. This result translates to about 6.1% of the average *COE* of our sample firms. For firms in the nonmaterial climate risk group, the *COE* of disclosers is

[22] We use nearest-neighbor matching with replacement.

Table 6 COE effects of managers' decisions whether to disclose climate risk in Form 10-K

Panel A: Probit regression model for propensity score matching[a]

D10K	Estimates		Covariate Balance		
Variable	Coeff	*Z*-stat	Disclosers *D10K* = 1	Nondisclosers *D10K* = 0	t-stat
BETA	0.130***	2.87	1.150	1.177	-1.37
BM	-0.045	-0.64	0.524	0.496	2.20**
SIZE	0.268***	9.69	9.992	10.011	-0.44
FI/PI	-0.084**	-2.02	0.292	0.275	0.97
ROA	-0.337	-0.85	0.047	0.050	-1.52
LEV	0.468***	2.93	0.244	0.241	0.68
EXCH	-0.066**	-2.13	1.247	1.227	1.00
STRNG	0.148***	2.93	0.459	0.470	-0.71
CNCRN	0.014	0.12	0.090	0.114	-2.39**
CDP	0.319***	6.05	0.714	0.734	-1.44
OCF	-0.004	-0.78	3.460	3.947	-2.46*
N (Total)	3,919				
N (*D10K* = 1)	1,934				
N (*D10K* = 0)	1,940				
N (Matched)	3,874				
Pseudo-R^2	0.185				

23 bps lower (p = 0.079) than the *COE* of nondisclosers. Taken together, our results show that investors penalize nondisclosing firms, but the penalty is twice as large where the market expects climate risk to be material.

In summary, our results are consistent with a lower *COE* for firms that disclose climate risk in Form 10-K than for firms that do not disclose climate risk. However, the penalty for nondisclosure is much larger for firms where the market expects climate risk to be material. Overall, our results indicate that when managers' climate risk disclosure decisions might not reflect their private climate risk materiality assessments, the market ascribes lower credibility to those decisions. That is, market expectations about climate risk materiality serve as a cross-check on the credibility, and thus informativeness, of managers' climate risk disclosure decisions.

5.4 Sensitivity analyses

We conduct several sensitivity analyses to assess the robustness of the main results.[23] First, following Hail and Leuz (2009), we add analysts' forecast errors to control for systematic differences in *COE* estimates between the disclosing and nondisclosing

Table 6 (continued)

Panel B: Difference in *COE* of propensity-score-matched firms[b]

	Disclosers *D10K* = 1	Nondisclosers *D10K* = 0	Diff.	*t*-stat
Pre-matching	0.0825	0.0819	0.0006	0.50
Post-matching	0.0824	0.0827	-0.0003	-1.19
Matched N	1,934	1,940		

Panel C: Doubly robust regression estimates of *COE*[c]

	Coefficient	*Z*-stat[d]
D10K	-0.0027**	-2.40
Matched N	3,874	

*, **, and *** denote significance at p < 0.10, < 0.05, and < 0.01, respectively, two-tailed

We include industry fixed effects using Fama-French 12-industry classification

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk in Form10-K (*D10K* = 1) with firms that do not (*D10K* = 0), using the probit model below. We use nearest neighbor matching with replacement

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

We report covariate balance means and Z-stats to test how equal (balanced) the disclosing and nondisclosing firms are for each covariate after matching

[b] After matching the disclosing (*D10K* = 1) and the nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the composite cost of equity constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress COE for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regression also allows us to obtain robust standard errors.

[d] We report the Z-statistic based on standard errors clustered by firm identifier (Permno).

firms arising from systematic differences in analysts' forecast errors that may bias in favor of our results. We measure analysts' forecast errors as the difference in one-year-ahead actual EPS and forecast EPS per I/B/E/S (Daske et al. 2013; Hail and Leuz 2009). Table 8 presents robustness test results for the full sample. The results are inferentially similar to the main results reported in Panel C of Table 6. Panel B of Table 8 shows that the *COE* of disclosing firms (*D10K* = 1) is 23 bps lower than the *COE* of nondisclosing firms (p = 0.033).

Table 9 presents robustness test results with the firms partitioned by market expectations of climate risk materiality. Panel B of Table 9 shows that, for firms in the material climate risk group, the *COE* of disclosers is 43 bps lower than the *COE* of nondisclosers (p = 0.024). For the firms in the nonmaterial climate risk group, the *COE* of disclosers is 20 bps lower than the *COE* of nondisclosers, but the difference is not statistically significant (p = 0.120). Taken together, these results are consistent with the main results reported in panel C of Table 7.

Table 7 COE effects of managers' decisions whether to disclose climate risk in Form 10-K: sample partitioned by market expectations of climate risk materiality

Panel A: Probit regression model for propensity score matching[a]

D10K	Material (*SASB_MTRL* = 1)					Nonmaterial (*SASB_MTRL* = 0)				
	Estimates		Covariate Balance			Estimates		Covariate Balance		
Variable	Coeff	*Z*-stat	(1) *D10K*=1	(2) *D10K*=0	t-stat	Coeff	*Z*-stat	(3) *D10K*=1	(4) *D10K*=0	t-stat
BETA	0.097	1.10	0.996	1.088	-2.99***	0.161***	2.91	1.277	1.250	1.03
BM	-0.207	-1.29	0.484	0.515	-1.63	0.108	1.29	0.553	0.549	0.24
SIZE	0.439***	6.17	9.738	9.707	0.58	0.284***	8.60	10.195	10.161	0.50
FI/PI	-0.061	-0.70	0.241	0.206	1.36	-0.059	-1.19	0.335	0.306	1.14
ROA	-1.589**	-1.96	0.046	0.033	3.97***	0.238	0.49	0.051	0.050	0.39
LEV	-0.057	-0.17	0.288	0.302	-1.99**	0.197	0.96	0.203	0.196	1.24
EXCH	-0.063	-0.76	1.212	1.138	2.68***	-0.074**	-2.09	1.300	1.332	-0.98
STRNG	0.101	1.07	0.494	0.502	-0.34	0.151**	2.44	0.448	0.445	0.13
CNCRN	-0.330*	-1.80	0.111	0.145	-2.12**	0.208	1.20	0.054	0.043	1.14
CDP	0.212**	2.11	0.723	0.730	-0.33	0.346***	5.32	0.726	0.723	0.15
OCF	0.000	-0.01	2.653	3.077	-1.67*	-0.009	-1.46	4.100	4.231	-0.43
N (Total)	1,307					2,588				
N (*D10K*=1)	840					999				
N (*D10K*=0)	369					1,547				
N (Matched)	1,209					2,546				
Pseudo-R^2	0.199					0.152				

Panel B: Difference in *COE* of propensity-score-matched firms[b]

	Material (*SASB_MTRL* = 1)				Nonmaterial (*SASB_MTRL* = 0)			
	D10K = 1	*D10K* = 0	Diff.	*t*-stat	*D10K* = 1	*D10K* = 0	Diff.	*t*-stat
Pre-matching	0.0776	0.0688	0.0087***	4.35	0.0869	0.0853	0.0016	1.02
Post-matching	0.0763	0.0828	-0.0065*	-1.97	0.0878	0.0869	0.0009	0.41
Matched N	840	369			999	1,547		

Panel C: Doubly robust regression estimates of *COE*

	Material (*SASB_MTRL* = 1)		Nonmaterial (*SASB_MTRL* = 0)	
	Coefficient	*Z*-stat[d]	Coefficient	*Z*-stat[d]
D10K	-0.0050**	-2.47	-0.0023*	-1.76
Matched N	1,209		2,546	

*, **, and *** denote significance at p < 0.10, < 0.05, and < 0.01, respectively, two-tailed

We include industry fixed effects using Fama-French 12-industry classification

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk (*D10K* = 1) with firms that do not (*D10K* = 0), using nearest neighbor matching with replacement. We estimate the probit model below separately based on market expectations of climate risk materiality as material (*SASB_MTRL* = 1) or nonmaterial (*SASB_MTRL* = 0)

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

[b] After matching the disclosing (*D10K* = 1) and nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the composite cost of equity constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress COE for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regression also allows us to obtain robust standard errors.

[d] We report Z-statistics based on standard errors clustered by firm (Permno).

Table 8 COE effects of managers' decisions whether to disclose climate risk in Form 10-K: including analysts' forecast errors

Panel A: Difference in *COE* of propensity-score-matched firms[b]

	D10K = 1	*D10K* = 0	Diff.	*t*-stat
Pre-matching	0.0825	0.0819	0.000	0.49
Post-matching	0.0824	0.0839	-0.0015	-0.73
Matched N	1,925	1,929		
Total N	1,969	1,929		

Panel B: Doubly robust regression estimates of *COE*[c]

	Coefficient	*Z*-stat[d]
D10K	-0.0023**	-2.13
Matched N	3,854	

*, **, and *** denote significance at p < 0.10, < 0.05, and < 0.01, respectively, two-tailed

We include industry fixed effects using Fama-French 12-industry classification

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk in Form10-K (*D10K* = 1) with firms that do not (*D10K* = 0), using the probit model below. We use the nearest neighbor matching with replacement

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

We report covariate balance means and Z-stats to test how equal (balanced) the disclosing and nondisclosing firms are for each covariate after matching

[b] After matching the disclosing (*D10K* = 1) and nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the composite cost of equity constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress *COE* for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regression also allows us to obtain robust standard errors.

[d] We report the Z-statistic based on standard errors clustered by firm identifier (Permno).

Our next sensitivity analysis computes *COE* following Easton et al. (2002). We retain *all* analyst forecasts made during the year for the firm; therefore, we compute *COE* on a firm-year basis using all available forecasts for the year for the firm. We obtain inferentially similar, but stronger, results relative to our main results. Panel B of Table 10 shows that for the full sample, the *COE* for the disclosing firms is 113 bps lower than the *COE* for the nondisclosing firms (p < 0.00). Panel B of Table 11 shows that the difference in *COE* between disclosing and nondisclosing firms is about 1.5 times greater where the market expects climate risk to be material, compared to where the market does not expect climate risk to be material.

We next run our main analyses using entropy balancing instead of PSM. Our results (untabulated) using entropy balancing are stronger than our main results. Specifically, for the full sample, the *COE* for the disclosers is 30 bps lower than the *COE* for the nondisclosers, (p = 0.05, N = 3,887)). Similarly, for firms where the market expects climate risk to be material, the *COE* for the disclosers is 60 bps lower than the *COE* for

the nondisclosers (p = 0.05, N = 1,327). Finally, for firms where the market does not expect climate risk to be material, the difference in *COE* between disclosers and nondisclosers is not significant at conventional levels (N = 2,560).

We have data from the firms' Form 10-K until 2017 but do not have CDP survey data beyond 2016. Therefore, for our next sensitivity analysis, we extrapolate the data regarding the firms' voluntary participation in the CDP survey for 2017 using CDP data from 2016. Firms' CDP survey participation is sticky; that is, once a firm participates, it is likely to continue to do so in subsequent years.[24] After extrapolating the CDP survey participation data for 2017, the sample increases by 381 observations to 4,300 firm-year observations, of which we are able to match 4,221 observations (2,137 disclosers to 2,084 nondisclosers). The DR regression results (untabulated) for the full sample are stronger than the main results. The *COE* of disclosers is 30 bps lower than the *COE* of nondisclosers (p = 0.004).

We next partition the firms based on market expectations of climate risk materiality. For firms in the material climate risk group, the DR regression results (untabulated) indicate that the difference in *COE* for the disclosers and nondisclosers is 47 bps (p = 0.016). For firms in the nonmaterial climate risk group, the difference in *COE* between disclosers and nondisclosers is 22 bps (p = 0.065).

Prior research finds that firms with better corporate governance have higher firm value and stock returns (Gompers et al. 2003). Thus, our next sensitivity analysis controls for the effects of corporate governance on *COE*. We construct a variable, *CGOV*, to proxy for firms' climate-related governance measures. We obtain corporate governance data from Bloomberg for fiscal years 2008 to 2014 on three separate dimensions: Does the firm have (1) a climate change policy, (2) a climate change committee, and (3) incentives tied to climate change management? We code each dimension as equal to one if the firm answers "yes," and zero otherwise. We add the scores on the three questions to construct the *CGOV* variable.[25] The DR regression results are consistent with the main results, and the coefficients are similar to the main results.

Next, we examine the association between changes in *COE* and changes in managers' climate risk disclosure decisions. The results (untabulated) should be interpreted with caution since less than 5% of the sample firms (i.e., 171 observations) change their disclosure decisions. Restricting the sample to firms that either begin or stop disclosing climate risk in their 10-Ks, we find that the *COE* is lower for firms that begin disclosing climate risk than for firms that stop disclosing it. The *COE* coefficient on changes in disclosure decisions is negative and is similar in magnitude to the coefficients in the main results for the full sample (p = 0.056) and for firms in the climate risk material group (p = 0.014). The *COE* coefficient is not significant for the firms in the climate risk nonmaterial group (p = 0.133).

Our next sensitivity analysis recognizes that some of the variables in our matching model—particularly those related to environmental performance—may be endogenous to the choice to disclose climate risk. Therefore, we run the model excluding the two environmental performance variables, *STRNG* and *CNCRN*. Our results are unchanged for the full sample and for *SASB_MTRL* = 0, but they are much stronger for the

[24] In the sample period, less than 10% of the firms change their reporting status from one year to the next. In addition, we find a positive and significant correlation of 0.84 for the firms' CDP reporting status in 2015 and 2016 (p < 0.01).

[25] The breakdown of corporate governance score, *CGOV* (untabulated) is: 0 (44%), one (16%), two (22%) and three (18%).

Table 9 COE effects of managers' decisions whether to disclose climate risk in Form 10-K: including analysts' forecast errors—sample partitioned by market expectations of climate risk materiality[a]

Panel A: Difference in *COE* of propensity-score-matched firms[b]

	Material (*SASB_MTRL* = 1)				Nonmaterial (*SASB_MTRL* = 0)			
	D10K = 1	*D10K* = 0	Diff.	*t*-stat	*D10K* = 1	*D10K* = 0	Diff.	*t*-stat
Pre-matching	0.0776	0.0687	0.0089***	4.40	0.0870	0.0854	0.0016	0.99
Post-matching	0.0761	0.0755	0.0006	0.19	0.0878	0.0865	0.0013	0.64
Matched N	814	366			992	1,539		
Total N	932	366			1,037	1,539		

Panel B: Doubly robust regression estimates of *COE*

	Material (*SASB_MTRL* = 1)		Nonmaterial (*SASB_MTRL* = 0)	
	Coefficient	*Z*-stat[d]	Coefficient	*Z*-stat[d]
D10K	-0.0043**	-2.26	-0.0020	-1.56
Matched N	1,180		2,531	

*, **, and *** denote significance at $p < 0.10$, < 0.05, and < 0.01, respectively, two-tailed

We include industry fixed effects using Fama-French 12-industry classification

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk (*D10K* = 1) with firms that do not (*D10K* = 0), using nearest neighbor matching with replacement. We estimate the probit model below separately based on the market climate risk materiality expectations as material (*SASB_MTRL* = 1) or nonmaterial (*SASB_MTRL* = 0):

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

[b] After matching the disclosing (*D10K* = 1) and nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the composite cost of equity constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress *COE* for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regressions also allow us to obtain robust standard errors.

[d] We report Z-statistics based on standard errors clustered by firm (Permno).

SASB_MTRL = 1 group (untabulated). The matching, however, is poorer for the sample split on materiality.

For the last set of sensitivity tests, instead of matching on firm performance using *ROA*, we match on whether the firm suffered a loss during the year. We include an indicator variable coded as 1 if the firm reported negative income before extraordinary items during the year, and 0 otherwise. The results (untabulated) are inferentially similar to the main results. We also check the sensitivity of the results to industry classification. We use the Fama-French 12-industry classification for industry fixed effects in our main analyses. The results are inferentially similar if we use the Fama-French 30-industry classification instead. Finally, instead of winsorizing the data at 1% at each tail, we winsorize the data at half of 1% at each tail and obtain inferentially similar results.

6 Conclusion

Managers' risk disclosures in regulatory filings are intended to bring market expectations about risk materiality in line with managers' private risk materiality assessments.

Table 10 COE effects of managers' decisions whether to disclose climate risk in Form 10-K: COE calculated following Easton et al. (2002)

Panel A: Difference in *COE* of propensity-score-matched firms[a,b]

	Disclosers *D10K* = 1	Nondisclosers *D10K* = 0	Diff.	*t*-stat
Pre-matching	0.1258	0.1471	-0.0213***	-6.79
Post-matching	0.1264	0.1422	-0.0158***	-2.77
Matched N	1,709	1,623		
Total N	1,736	1,623		

Panel B: Doubly robust regression estimates of *COE*[c]

	Coefficient	*Z*-stat[d]
D10K	-0.0113***	-3.53
Matched N	3,332	

*, **, and *** denote significance at p < 0.10, < 0.05, and < 0.01, respectively, two-tailed

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk in Form10-K (*D10K* = 1) with firms that do not (*D10K* = 0), using the probit model below (covariate balance untabulated). We use the nearest neighbor matching with replacement. We include industry fixed effects using Fama-French 12-industry classification

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

[b] After matching the disclosing (*D10K* = 1) and nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the implied cost of equity measured using the approach laid out in Easton et al. (2002).

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress COE for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regression also allows us to obtain robust standard errors.

[d] We report the Z-statistic based on standard errors clustered by firm identifier (Permno).

Because federal securities laws and related disciplinary forces encourage truthful disclosure of whether a risk is material, researchers have assumed that managers' decisions whether to disclose a risk in regulatory filings truthfully reveal their private risk materiality assessments. However, given research findings that managers are biased against disclosing bad news (Kothari et al. 2009a, b), managers likely evaluate the cost-benefit tradeoffs between disclosing and not disclosing a risk in Form 10-K. Consequently, when managers decide not to disclose a risk, the market cannot perfectly discern whether the managers assess the risk as nonmaterial or assess it as material but believe that the benefits of not disclosing exceed the costs.

This study examines whether managers' choices whether to disclose climate risk credibly reflect their private risk materiality assessments. Three factors in the climate risk context exacerbate the market's difficulty in assessing whether managers are truthfully revealing their private risk materiality assessments: (1) the lack of consensus on whether climate risk is material to the firms, (2) the SEC's past inconsistent enforcement of climate risk disclosures in regulatory filings, and (3) the limited success

Table 11 COE effects of managers' decisions whether to disclose climate risk in Form 10-K: sample partitioned by market expectations of climate risk materiality; COE calculated following Easton et al. (2002)

Panel A: Difference in *COE* of propensity-score-matched firms[a,b]

	Material (*SASB_MTRL* = 1)				Nonmaterial (*SASB_MTRL* = 0)			
	D10K = 1	*D10K* = 0	Diff.	*t*-stat	*D10K* = 1	*D10K* = 0	Diff.	*t*-stat
Pre-matching	0.1137	0.1445	-0.0307***	-4.66	0.1359	0.1478	-0.0118***	-3.10
Post-matching	0.1154	0.1204	-0.0050	-0.33	0.1373	0.1370	0.0003	0.06
Matched N	705	261			904	1,338		
Total N	793	261			943	1,338		

Panel B: Doubly robust regression estimates of *COE*

	Material (*SASB_MTRL* = 1)		Nonmaterial (*SASB_MTRL* = 0)	
	Coefficient	*Z*-stat[d]	Coefficient	*Z*-stat[d]
D10K	-0.0164***	-3.03	-0.0105***	-2.82
Matched N	966		2,242	

*, **, and *** denote significance at p < 0.10, < 0.05, and < 0.01, respectively, two-tailed

For variable definitions see Appendix 3 Table 12

[a] We match firms that disclose climate risk in Form10-K (*D10K* = 1) with firms that do not (*D10K* = 0), using the probit model below (covariate balance untabulated). We use the nearest neighbor matching with replacement. We include industry fixed effects using Fama-French 12-industry classification

$$D10K = \beta_0 + \beta_1 BETA + \beta_2 BM + \beta_3 SIZE + \beta_4 FI/PI + \beta_5 ROA + \beta_6 LEV + \beta_7 EXCH + \beta_8 STRNG + \beta_9 CNCRN + \beta_{10} CDP + \beta_{11} OCF + \varepsilon \quad (1)$$

[b] After matching the disclosing (*D10K* = 1) and nondisclosing (*D10K* = 0) firms using the propensity scores calculated in Panel A, we examine the difference in the *COE* between these two groups of firms. *COE* is the composite cost of equity constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.

[c] We run doubly robust (DR) regressions to control for any remaining bias after propensity score matching. Using the propensity scores calculated above, we regress COE for the matched sample of disclosing and nondisclosing firms on the variables in Eq. 1 and *D10K*. DR regression also allows us to obtain robust standard errors.

[d] We report Z-statistics based on standard errors clustered by firm (Permno).

of shareholder litigation to pressure climate risk disclosure. Using market expectations of industry-level risk materiality, we test whether the association between disclosing climate risk in Form 10-K and firm risk (proxied by a composite COE) varies with market expectations. We use SASB's Materiality Map™ to construct an independent proxy for market expectations.

Using a hand-collected sample of 3,919 firm-year observations of S&P 500 firms' choices of whether to disclose climate risk in Form 10-K for years 2008 to 2016, and controlling for firms' decisions to voluntarily disclose climate risk outside of Form 10-K, we find that disclosing firms' COE is 27 bps lower than nondisclosers', or about 3.3% of the average COE of our sample firms. In industries where the market expects climate risk to be material, disclosing firms' COE is 50 bps (about 6.1% of the average COE of the sample firms) lower than nondisclosers', while in industries where the market does not expect climate risk to be material—and therefore expects firms to not disclose the risk—the COE for disclosers is only 23 bps lower than the COE for nondisclosers. Thus, the market rewards (penalizes) firms for disclosing (not disclosing) climate risk in their 10-K filings. However, the *penalty for nondisclosure* is twice as large when the market expects climate risk to be *material*, compared to when the market does not expect climate risk to be material. These results indicate that market

expectations about climate risk materiality serve as a cross-check on the credibility, and thus the informativeness, of managers' risk disclosure decisions.

Our study contributes to accounting research and practice in the following ways. First, we extend prior research on risk disclosures by incorporating market expectations of risk materiality. Second, while most previous ESG research in the accounting literature examines whether the market prices ESG performance, our study is at the intersection of firms' choice whether to disclose climate risk and market expectations of climate risk materiality. Our research also contributes to policy-making on climate risk disclosures in regulatory filings. Importantly, our study informs the debate around the costs and benefits of the SEC's current proposal to enhance climate risk disclosures (Securities and Exchange Commission (SEC) 2022). Finally, the capital-markets effects of managers' ESG (including climate risk) disclosure decisions for SEC filings is important in light of recent global trends towards increasingly mandating such disclosures.

Appendix 1: Proxy for market expectations of climate risk materiality (*SASB_MTRL*): SASB's Materiality Map™

We used SASB's Materiality Map™ to construct a proxy for market expectations of climate risk (CR) materiality. At the time of our data collection, the map identified the materiality of 30 sustainability issues on an industry-by-industry basis and was designed to prioritize issues on behalf of reasonable investors. To determine materiality, SASB uses an evidence-based approach based on input from a panel of over 200 industry experts and SASB staff to score each issue based on three components: evidence of investor interest, evidence of financial impact, and forward-looking impact. Details appear in SASB's Conceptual Framework (Sustainability Accounting Standards Board (SASB) 2013).

The map consists of several sectors, and each sector comprises several industries.[26] At the sector level, the map classifies a sustainability issue as material if the issue is judged to be material for more than 50% of industries in the sector. At the industry level within each sector, the map indicates whether an issue is likely to be material for companies in the industry by scoring the issues based on the three components mentioned above. Specifically, evidence of investor interest uses two scores. The first, the heat map (HM) score, is out of 100 points, and indicates the relative importance of the issue among SASB's list of more than two dozen sustainability issues. The score is based on the frequency of relevant keywords in documents (i.e., SEC filings, shareholder resolutions, legal news, key newswires, and CSR reports) that are available in the Bloomberg terminal for the industry's publicly listed companies. The second score, the industry working group score (IWGS), represents the percentage of IWG participants that found the issue to be material. In some cases a third score, forward-looking impact, is used to raise the

[26] The sectors (number of industries within each sector) at the time of our data collection were: health care (5), financials (7), technology and communications (6), non-renewable resources (8), transportation (8), services (10), resource transformation (5), consumption (15), renewable resources and alternative energy (6), and infrastructure (6). Information on the Materiality Map™ is available at https://www.sasb.org/standards/materiality-map/.

importance of an issue if its management or mismanagement could potentially create positive or negative externalities that other stakeholders, industries, or future generations will deal with. SASB reports over 85% agreement, on average, between investors and registered issuers on the materiality of SASB's sustainability disclosure factors (Sustainability Accounting Standards Board (SASB) 2017).

We selected six issues from the Materiality Map™ that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, then we assigned each firm in the sample that belongs to that industry to the material group (*SASB_MTRL* = 1). Otherwise, we assigned the firm to the nonmaterial group (*SASB_MTRL* = 0).

The industry categories in the Materiality Map™ correspond to SASB's Sustainable Industry Classification System (SICS), which classifies industries "in accordance with their resource intensity and sustainability impact as well as their sustainability innovation potential" (Sustainability Accounting Standards Board (SASB) 2013, 10). Using the four-digit SIC codes (SICDESC) and, if needed, additional information obtained from web resources, we identified the industry to which each firm belongs. Finally, for each firm we matched the SIC industry description to a SASB industry classification.

Appendix 2: Structured search rubric and coding of managers' decisions whether to disclose climate risk in Form 10-K (*D10K*)

The 2010 SEC interpretive guidance regarding disclosure related to climate change clarifies Regulation S-K and specifies that companies are expected to disclose climate risk that can materially affect registrants' business operations and financial performance (Securities and Exchange Commission (SEC) 2010). The interpretive guidance describes the following sections of 10-Ks as the most pertinent in complying with climate risk disclosure: Item 1-Business, Item 1A-Risk factors, Item 3-Legal proceedings, and Item 7-Management's discussion and analysis of financial condition and results of operations. These sections correspond to items 101, 103, 503(c), and 303 of the Regulation S-K rules, respectively. We searched the full Form 10-Ks for the sample firms.

Informed by the 2010 SEC interpretative guidance, our structured search rubric consisted of searching for the following words or phrases in the 10-Ks: "carbon," "climate change," "emissions," "greenhouse," "GHG," "hurricanes," "renewable energy," and "extreme weather." We used the SEC Analytics Suite in WRDS for years 2008 through 2014, the last year for which data were available in WRDS. For subsequent years, we used Python to search EDGAR directly for the words or phrases in the firms' 10-Ks.[27] The programs extracted the lines with the words or phrases in our structured search rubric. If necessary, we referred to the firm's full 10-K to examine the

[27] We checked about one-third of firm-year observations for year 2014 to ensure that information extraction was consistent using WRDS Analytics Suite vs. using EDGAR and Python.

words or phrases more closely and to exclude false positives, such as firms referring to carbon monoxide.

Finally, after reading the extractions, we coded the firm as 1 if it disclosed climate risk information in Form 10-K in year *t*, or as 0 if it did not. The authors coded the data independently and had 99% inter-coder agreement; we reconciled the remaining differences.

Disclosure of risk due to physical impact of climate change

The Allstate Corporation Form 10-K for the fiscal year ended December 31, 2010, states (in Item 1A-Risk factors, page 23): [insurance]

> Climate change, to the extent it produces rising temperatures and changes in weather patterns, could impact the frequency or severity of weather events and wildfires, the affordability and availability of homeowners insurance, and the results for our Allstate Protection segment.

The Alcoa Inc. Form 10-K for the fiscal year ended December 31, 2008, states (in Item 1A-Risk factors, page 24): [aluminum production]

> The potential physical impacts of climate change on the company's operations … may include changes in rainfall patterns, water shortages, changing sea levels, …

Disclosure of regulatory risk related to climate change

The Abercrombie & Fitch Co. Form 10-K for the fiscal year ended January 28, 2012, states (in Item 1A—Risk factors, page 23): [specialty retailer; clothing, personal care]

> Our operations may be affected by regulatory changes related to climate change and greenhouse gas emissions.

The Hewlett-Packard Company Form 10-K for the fiscal year ended October 31, 2012, states (in Item 1—Business, page 12): [personal computing and enterprise info technology]

> Our operations and ultimately our products are expected to become increasingly subject to federal, state, local and foreign laws and regulations and international treaties relating to climate change.

False positives: Mention of carbon unrelated to climate risk, coded as nondisclosure of climate risk

The Boeing Company Form 10-K for the fiscal year ended December 31, 2012, states (in Item 1—Business, page 5):

> The most important raw materials required for our aerospace products are aluminum (sheet, plate, forgings and extrusions), titanium (sheet, plate, forgings and extrusions) and composites (including carbon and boron).

Reynolds American, Inc. Form 10-K for the fiscal year ended December 31, 2008, states (in Item 7—MD&A, page 52):

> SURGEON GENERAL'S WARNING: Cigarette Smoke Contains Carbon Monoxide.

Appendix 3

Table 12 Variable definitions

Variable	Definition
D10K	an indicator variable coded as 1 if the firm discloses climate risk in Form 10-K, and 0 otherwise (see Appendix 2 for further details).
COE	the composite implied cost of equity capital constructed using the median of four measures: Easton's PEG model (Easton 2004), Gebhardt et al. (2001) (GLS), Claus and Thomas (2001) (CT), and the price-earnings ratio.
BETA	the correlation of firm returns to market returns calculated using monthly returns and the value-weighted market index for the past five years;
BM	book value of equity / market value of equity.
SIZE	the log of the firm's total assets at the end of the fiscal year.
FI/PI	pre-tax foreign income / pre-tax total income.
ROA	income before extraordinary items / total assets.
LEV	total long-term debt / total assets.
EXCH	stock exchange membership, namely NYSE/AMEX (coded=1), NASDAQ (coded=3).
STRNG	an indicator variable coded as 1 if MSCI ESG KLD has identified the firm as proactively managing climate change risk from GHG emissions, and 0 otherwise [MSCI ESG KLD data code: ENV_STR_D].
CNCRN	an indicator variable coded as 1 if MSCI ESG KLD has identified the firm as having concerns related to climate change, and 0 otherwise [MSCI ESG KLD data code: ENV_CON_F].
CDP	an indicator variable coded as 1 if the firm participates in the CDP climate-change survey and the response is publicly available, and 0 otherwise.
SASB_MTRL	our proxy for market expectations of climate risk materiality. To construct our proxy, we select the six sustainability issues from the SASB Materiality Map™ that are most directly relevant to climate risk: (1) GHG emissions, (2) air quality, (3) energy management, (4) fuel management, (5) water and wastewater management, and (6) environmental and social impacts on assets and operations. If at least three of these six issues are classified in the map as material for a given industry, then we assign each sample firm that belongs to that industry to the material group (coded *SASB_MTRL*=1). Otherwise, we assign the firm to the nonmaterial group (coded *SASB_MTRL*=0). See Appendix 1 for further details.
OCF	cash flows from operations ($ billion).
FE	the median of all forecast errors for each firm-fiscal year. We measure forecast errors as the difference in one-year-ahead actual EPS and forecast EPS per I/B/E/S.

Acknowledgements An earlier version of this paper was titled "To disclose or not to disclose climate-change risk in form 10-K: Does materiality lie in the eyes of the beholder?" We gratefully acknowledge the helpful comments and suggestions of Peter Easton (editor), two anonymous reviewers, Mfon Jacob Akpan (discussant, Midwest Region Meeting), Brett Cantrell, Jeremy Douthit (discussant, AAA Annual Meeting), Shuping Chen, Lisa Gaynor, Brian Goodson, Jody Grewal (discussant, Telfer Conference), Eric Hirst, Steve Kachelmeier, Bill Kinney, Bob Lipe, Rick Mergenthaler (discussant, CFMA conference), Melanie Millar, Jeff Miller, Uday Murthy, Mark Nelson, Jaime Schmidt, Marcy Shepardson, Holly Skaife, Deb Wenger, and workshop participants at the Telfer conference, CFMA conference, Journal of International Accounting Research Conference, AAA Annual Meeting, Midwest Region Meeting, University of Texas–Austin Fall Research Conference, Fogelman College of Business and Economics at the University of Memphis, Lynn Pippenger School of Accountancy at the University of South Florida, and University of Cincinnati. We are especially grateful to Stephannie Larocque for generously sharing her cost-of-equity program with us. We also gratefully acknowledge the invaluable research assistance of Justin Gallagher and Emily Reckmeyer. Professor Vera-Muñoz gratefully acknowledges financial support by the Notre Dame/Deloitte Center for Ethical Leadership; KPMG and the Deloitte Foundation through the Department of Accountancy; and the Business Information Center at the University of Notre Dame.

Data availability Publicly available from the sources identified in the text.

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