Do Market Valuations Incorporate Climate Risk?

Jonathan Jona
University of Melbourne

Khai Lim
Unaffiliated

Naomi Soderstrom*
University of Melbourne
198 Berkeley Street, Level 7
Parkville, VIC 3010
Australia
+61 3 9035 7702 phone
+61 3 9349 2397 fax
naomiss@unimelb.edu.au

University of Melbourne

Faculty of Business and Economics

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* Corresponding author

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Abstract:

Evidence supporting potential impacts of climate change is growing. While it is difficult to conclusively link any specific incident to climate change, there are an increasing number of natural events that are associated with extreme weather that have imposed huge costs on affected companies and industries. The nature of climate risk makes the probability, magnitude, and timing of impacts on firms diffuse and difficult to evaluate. We explore market valuation of different types of climate risks as revealed in company 10-K disclosures and find that climate risks related to physical effects of climate change on operations, enacted or pending regulations, renewable technologies, as well as other, non-specified risks, are negatively associated with market value. In addition, with the exception of physical risk, these forms of climate risk are associated with a higher implied cost of capital.

I. Introduction

Evidence supporting impacts of climate change has been growing. In this paper, we estimate the relation between climate risk and firms' equity financing costs. While it is difficult to conclusively link any specific incident to climate change, there are an increasing number of natural events that are associated with extreme weather, which have imposed large costs on affected companies and industries. For example, Honda reported $1.4 billion loss due to 2011 flooding of automobile assembly plants in Thailand (Haraguchi, and Lall 2014). During summer 2012, Dominion Resources was forced to stop energy production at one of its nuclear plants because the temperature of water drawn from Long Island Sound used for cooling was too warm. This was the first time the plant's 37-year history that this had occurred (Crawford, and Seidel 2013). In 2014, the California drought cost the agriculture industry an estimated $2.2 billion and an estimated 17,000 farmers lost their jobs (Schiavenza 2015). Thus, these events suggest considerable economic risk for firms related to the climate. In addition to these direct costs on firms' assets, firm climate risk also stems from policy changes in response to climate change, include "the uncertainty whether, when and how new regulations will be imposed, and what their impacts will be" (Hjort 2016, p. 5). The resulting costs usually involve levying of taxes, quotas, bans and other regulatory instruments and could be very costly to firms (e.g., Dowell, Hart, and Yeung 2000).

Although it is clear that these types of events pose significant financial risk for companies, historically there has been little disclosure in financial statements of climate risk.[1] In

[1] Doran, and Quinn (2009) examine SEC 10-K filings for the S&P 500 between 1995 and 2008. Although disclosures concerning climate change increased over their sample period, overall few companies discussed the climate-related risks and opportunities. In fact, in 2008, the last year of their sample period, 76.3% of these companies had no mention of climate change in their 10-Ks.

response to investor concerns about the lack of sufficient climate-related disclosures, the SEC provided explicit guidance on disclosures of risks and opportunities related to climate change in the SEC regulatory filings (SEC 2010). The SEC noted that while companies are increasing their voluntary climate risk-related disclosures outside of reports generated for the SEC, disclosure of material information is also required disclosure in company 10-Ks. The requirements cited by the SEC relate to the description of business (Item 101 of Regulation S-K), legal proceedings (Item 103 of Regulation S-K), risk factors (Item 503(c) of Regulation S-K), and management's discussion and analysis (Item 303 of Regulation S-K).

Given the SEC's increased scrutiny of disclosure of climate risk, companies that face material risks in this area are essentially mandated to discuss them in their 10-K's.[2] As a result, we view disclosure as evidence of existence of material risk for disclosing companies, rather than as a disclosure choice, and proxy the severity of climate risk by the relative mandatory disclosure. In this paper, we capitalize on a new data set that identifies and measures this mandatory climate risk disclosure to investigate the association between firm exposure to climate risk and market valuation of firm equity.

Our investigation differs from extant research concerning voluntary sustainability disclosures. This research has primarily focused on voluntary disclosures outside of 10-Ks. For example, Clarkson et al. (2013), Plumlee et al. (2015), Dhaliwal et al. (2011), and Dhaliwal et al. (2014) examine disclosure via voluntary standalone sustainability reports. In this literature, voluntary disclosure is typically found to be positively associated with market value and negatively associated with the cost of equity capital. Focusing on voluntary disclosure of carbon

[2] In the two years after their guidance, the SEC issued 49 comment letters to companies addressing the adequacy of their climate change disclosures, although this number dropped off in later years (Gelles 2016).

emissions, through the Carbon Disclosure Project, Matsumura, Prakash, and Vera-Munoz (2014) find that while the market valuation of firms is negatively associated with the amount of disclosed carbon emissions, firms that choose not to disclose are relatively more penalized than firms that voluntarily disclose their emissions. Griffin, Lont, and Sun (2012) find that valuations are consistent with the market imputing a level of carbon emission for non-disclosers and valuing the firms accordingly. These studies focus on off-balance sheet liabilities that are not already reflected in the market's assessments of company value (Clarkson, Jones, and Ratnatunga 2012; Griffin et al. 2012). Our study focuses on the broader concept of climate risk, which relates to many aspects of company operations, including potential physical damage to facilities, increased operating costs, new regulatory costs, supply chain disruptions, and shifts in the markets for products or services. These impacts are not limited to firms (and industries) that emit large amounts of carbon and go far beyond off-balance sheet liabilities. Further, many climate risk-related impacts pertain to future, uncertain events, which are generally not required to be recognized in financial statements. The difficulty in quantifying these risks makes using disclosures to generate estimates of impacts problematic. Finally, the literature on voluntary disclosure indicates that disclosing firms generally have higher performance than non-disclosing firms (Verrecchia 1983; Dye 1985; Clarkson et al. 2008). In our setting, SEC disclosure requirements focus on material risks and opportunities. Better-performing firms will be unable to self-select whether or not to disclose, although the nature of what they disclose may differ from poor-performing firms.[3]

[3] We view any discussion of climate risk as an indication of material risk. If firms disclose that they have put measures into place to address climate risks (i.e., the firm has opportunities related to climate impacts), this still indicates an underlying exposure to risk. While our disclosure measure does not differentiate between disclosure of climate risks versus opportunities, our results are unchanged when we control for environmental performance.

Although disclosing companies have material climate-related risk, it is unclear how the market is likely to value this type of risk. Arguably, climate risk is diffuse and the timing and magnitude of any resulting impact is unclear. In addition, climate risk can take different forms, ranging from increased regulation to physical risks for both the firm itself and members of its supply chain. Climate risk may also be insurable and/or diversifiable, and thus, not priced. However, in our exploration of market valuation of different types of climate risks, we find that several dimensions of climate risk (physical risk, regulatory risk, renewable technology/fuels risk, and non-specific risk) are all negatively associated with market value.

In parallel with development of the voluntary sustainability disclosure literature (e.g., Dhaliwal et al. 2011; Dhaliwal et al. 2014; Plumlee et al. 2015), we extend the analysis to the implied cost of capital (ICC). We proxy for ex-ante expected stock returns by computing the ICC using analysts' earnings estimates in accordance with Gebhardt, Lee, and Swaminathan (2001). This measure is argued to be among the best expected return models (Chava 2014; Tang, Wu, and Zhang 2014). We document a statistically and economically positive relationship between climate risk and expected returns on firms stocks. With the exception of physical risk, all forms of climate risk are associated with a higher ICC, suggesting that the market perceives climate risks to be material and undiversifiable. These results are in contrast to the findings of Dhaliwal et al. (2011), Dhaliwal et al. (2014), and Plumlee et al. (2015), who find a negative association between *voluntary* sustainability disclosure and the cost of equity capital.

Our examination of market implications of climate risk thus extends the environmental accounting literature, which has focused on market perceptions of more narrow environmental aspects, such as Superfund liabilities[4] (Barth, and McNichols 1994) and emissions of Sulfur Dioxide (e.g., Hughes 2000; Johnston, Sefcik, and Soderstrom 2008) and carbon (Matsumura et al. 2014; Griffin et al. 2012).[5] It is important to note that climate risk differs from the environmental aspects previously studied in the literature. Climate risk is due to natural factors outside of the direct influence of any one firm and can impact firms throughout their value chain, whereas emissions-based costs and liabilities are more directly associated with specific firm behaviors and can be directly managed by reducing emission levels (Krueger 2015). Contingent liabilities associated with Superfund are narrowly related to clean-up of existing sites and do not depend on current or future company operations. The nature of climate risk makes the probability, magnitude, and timing of impacts on firms diffuse and difficult to evaluate. Nonetheless, we find evidence that the market recognizes climate risks as undiversifiable and penalizes those firms for whom these risks are material.

II. Background and Literature Review

Climate change has been a growing concern over the last few decades, argued to cause severe economic damage, negatively affect trade and even lead to political instability. These effects place firms' assets at risk not only in the long run but also contemporarily (Hjort 2016). To our knowledge, environmental accounting research has generally investigated how the

[4] The Superfund program was developed to clean up contaminated sites in the U.S. for which identification of individual responsible parties was not possible. Under this program, potentially responsible parties included individuals, partnerships, corporations, and governmental entities who owned or operated contaminated sites, as well as those who generated, transported to, or disposed of hazardous substances at the site. Estimates of clean-up costs were as high as $1 trillion (Campbell, Sefcik, and Soderstrom 1998).

[5] We note that in their analysis of stock market response to 8-K disclosures related to carbon emissions during the time period 2005-2010, (Griffin et al. 2012) include 8-K disclosures including the terms "carbon and emission," "carbon and climate," "greenhouse," and "climate change". Other than the last term, their search focuses on carbon emissions. These terms are included in the 5,000 keyword phrases used to develop our risk proxy and thus represent a small subset of the types of climate risk that we examine.

character and extent of disclosure impact the views of market participants and less attention has been given to the various types of risks that stem from climate change. Specifically, much of this research has focused on disclosures related to potential liabilities stemming from environmentally-related regulatory costs.

In an early study, Blacconiere, and Patten (1994) investigate the impact of disclosure in 10-K reports on the market reaction to a large chemical spill in Bhopal, India. This unanticipated event was generally viewed as leading to increased regulatory costs for chemical companies. While there were no specific environmental disclosure requirements at the time, companies were required to report material effects of complying with environmental laws. Blacconiere et al. (1994) find that while all chemical companies had a negative stock market reaction to the event, the reaction was less negative for companies with higher levels of disclosure.

Regulatory costs were also the focus of a series of studies examining the impact of liabilities related to the U.S. Superfund program. Barth et al. (1994) find that the market imputes a value for the contingent liability associated with cleanup of sites where the company is a potentially responsible party, and therefore, potentially liable for site cleanup costs. Campbell et al. (1998) find evidence of differential valuation of the associated contingent liabilities based upon disclosure characteristics.

D'Souza, Jacob, and Soderstrom (2000) investigate implications of deregulation for liabilities associated with nuclear plant decommissioning. Deregulation of the utility industry in the 1990's lead to an increase in liability because utilities could no longer be guaranteed to have decommissioning costs recovered through rate recoveries. D'Souza et al. (2000) find that the market impounds estimates of decommissioning liabilities not only for the portion of nuclear plants owned by the utilities, but also based upon the plant co-owners' share of unfunded decommissioning liability.

Research has also investigated market implications of other forms of environmental risk. In a precursor to the European Union's emission trading scheme, the U.S. developed a sulfur emissions trading market as a means of reducing emissions by large electric utilities, whose sulfur emissions were contributing to acid rain. This form of regulation allowed the market to set the price for emissions and determine where it was most economically efficient to reduce them. Hughes (2000) finds the value relevance of allowances was highest at the time of the change in environmental regulation. Arguably, this was at a point in time when the market understood that there was additional risk, but may not have had precise estimates of resulting costs to the affected utilities. Johnston et al. (2008) find that the market positively values the risk reduction strategy of building allowance banks that are a means of hedging future cash flows related to sulfur emissions.

Additional research has examined market implications of voluntary carbon disclosures. Matsumura et al. (2014) find that while the market penalizes firms for their carbon emissions, firms that choose not to disclose emissions information are penalized further. Griffin et al. (2012) also find negative valuation for voluntary disclosures of carbon emission volumes. In addition, they find that the market imputes an off-balance sheet liability related to carbon for non-disclosers. Unlike Matsumura et al. (2014), however, they do not find that non-disclosers are relatively penalized by the market. In addition, using an event study, Griffin et al. (2012) find that the negative stock market reaction to disclosure of carbon emissions is associated with the emission intensity. In sum, results in this literature indicate that voluntary carbon disclosures are value-relevant. Evidence that companies choosing not to provide voluntary disclosure are penalized by the market is mixed.

It is possible that the positive benefits of disclosure are driven by superior environmental performance of companies that choose to disclose more (Clarkson et al. 2008).[6] Several research studies have addressed this issue. Freedman, and Patten (2004) examine the stock market reaction to mandatory Toxic Release (TRI) reporting.[7] They find that companies with worse pollution performance (higher levels of size-adjusted toxic releases) had more negative market reactions than companies with better performance, but companies with less extensive disclosures in 10-K's had more negative reactions than companies with more extensive disclosure. Although in the 10-K, financial disclosures were largely voluntary—they included operating costs for pollution control, capital expenditures, and statement of environmental policy and/or concern for the environment. Al-Tuwaijri, Christensen, and Hughes (2004) address this issue by using a simultaneous equations to study the relations among environmental disclosure, environmental performance, and financial performance. They find that controlling for environmental performance, disclosures had no impact on stock market returns. In more recent studies, however, there is evidence that disclosure provides incremental information to the market. Controlling for TRI releases as a measure of performance, Clarkson et al. (2012) find that voluntary disclosures are value relevant, although they fail to find a relation between disclosure and cost of equity capital. In contrast, following decomposition of voluntary disclosures into positive, neutral, or negative aspects of environmental performance and into hard or soft

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[6] See Clarkson et al. (2012) for a more complete review of this literature.
[7] The Toxic Release Inventory (TRI) is another mandated disclosure outside of financial statements required of US companies. TRI data include information about release of approximately 650 chemicals to air, water, or land and must be reported to the Environmental Protection Agency annually. Operations outside of the US are excluded from the reporting requirement.

disclosures, Plumlee et al. (2015) find a significant association between different disclosure characteristics and both cash flows and cost of equity capital.

Our study examines climate risk's association with market valuation and the cost of equity capital. This issue reflects a different dimension of the interaction between the environment and market perceptions of the firm than has been discussed in the literature. Studies related to Superfund (e.g., Barth et al. 1994), and nuclear decommissioning (e.g., D'Souza et al. 2000) focus on specific contingent liabilities and provisions that are inadequately represented in financial statements. The literature on carbon-related disclosures essentially uses carbon emissions as a proxy for future carbon liability (Clarkson et al. 2012). Studies of voluntary disclosure through dissemination of sustainability reports generally view disclosure as a means signaling superior performance and of gaining legitimacy (Clarkson et al. 2008), thus preserving firm reputation and long-term sales (Dhaliwal et al. 2011). These studies have used both mandatory and voluntary disclosures to address their research questions, although most have focused on voluntary disclosures.

How is climate risk different? Implications of climate risk are quite broad, as they relate to many aspects of company operations, including potential physical damage to facilities, increased operating costs, new regulatory costs, supply chain disruptions, and shifts in the markets for products or services. As climate change accelerates, these risks should become more material. Nike has acknowledged that "changing and less predictable weather patterns potentially could affect consumer buying patterns, production locations, product shipping and even the cost of insurance coverage to facilities" (Nike 2005). Thus, climate risk is likely to be reflected in many areas reported in financial statements rather than through specific types of liabilities. In addition, many impacts of climate risk pertain to future, uncertain events, which are generally not required to be recognized in financial statements. The difficulty in quantifying these risks makes using disclosures to generate (relatively) precise estimates of impacts infeasible.

Unlike most of the prior literature, we focus on a broader notion of risk rather than solely on estimates of unrecognized or disclosed liabilities. Few papers in the literature specifically examine risk associated with environmental issues. Exceptions include Al-Tuwaijri et al. (2004), who view TRI disclosures as allowing investors to revise their view of the likelihood that worse performing companies will have to incur future cash flows related to improving pollution technologies or pay penalties for non-compliance.[8] Due to the broad nature of climate risk impacts, we also look beyond regulatory risk and include examination of physical, renewable technology, and other climate risks.

The SEC has required firms to make (qualitative) disclosure of material exposure to climate change risk. We interpret disclosure as indication that the firm faces a material risk, rather than as a measure of the quality of disclosure. The use of the term 'material' suggests that these disclosures should have implications for valuation, but the manner in which they might influence valuation is unclear. Exposure to the effects of climate change may entail greater risk for future cash flows. However, a considerable portion of such risks may be diversifiable, and therefore, not be priced. Specific expected costs related to climate events may represent contingent liabilities, but their probability and estimability may not meet disclosure thresholds.

Thus, our study addresses a broader scope of the role of accounting in understanding the impact of climate change on the economic environment. This is suggested by Linnenluecke, Birt, and Griffiths (2015) to have three functions: (i) a risk assessment function; (ii) a valuation

[8] In their study of environmental performance and executive compensation, Campbell et al. (2007) find evidence that TRI better serves as an environmental risk measure than as an environmental performance measure.

function; and (iii) a disclosure function. While most studies focus on the disclosure effects of firm valuation, our study provides empirical evidence for the risk assessment and subsequent valuation role of different types of climate risk using mandatory disclosure as a proxy for four types of climate risk. This type of evidence is lacking in existing literature (Linnenluecke et al. 2015).

III. Model Development

Consistent with much of the extant literature, we begin our study of market implications of climate risk by examining associations between valuation and risk in line with Ohlson (1995). Empirical studies in the environmental accounting literature that base their analyses on the Ohlson model typically augment the basic model with independent variables based upon some quantitative measure of the environmental construct examined. For example, Matsumura et al. (2014) include disclosed quantity of carbon emissions as an independent variable. In our setting, disclosure of climate risk is qualitative and forward-looking, rather than disclosed through traditional accounting or non-financial measures. This makes it difficult to model a precise functional relation between the disclosures of exposure to climate change and fundamental accounting measures. Instead, our approach is at a higher level, where we investigate how the market views climate risk and how the market impounds different forms of climate risk.

We follow established convention in the empirical literature by estimating association between observed market value of equity (*MVE*) and contemporaneous reported accounting book value of equity (*BVE*) and earnings (*EARNS*), using the model in Equation (1).[9]

[9] Variable definitions are in Appendix A.

$$MVE_t = \beta_0 + \beta_1 BVE_t + \beta_2 EARNS_t + \varepsilon_t \tag{1}$$

We expect firms' disclosed exposures to climate risk proxy for differences between the market's estimated "true" levels of book values or earnings and their disclosed values (Dechow, Hutton, and Sloan 1999; Lo, and Lys 2000). To model this, we augment the basic (restricted) model from Equation (1) with a proxy for contemporaneous firm-specific climate risk (*CR*), as in Equation (1a).

$$MVE_t = \beta_0 + \beta_1 BVE_t + \beta_2 EARNS_t + \gamma CR_t + \varepsilon_t \tag{1a}$$

We expect that exposure to climate risks should on average be associated with lower market values. This stems from our expectation that climate risks primarily result in additional cost and risk, rather than in future opportunities, that would be reflected in higher market valuation.

We supplement our analysis by investigating the implications of climate risk for the ICC. The basic valuation model has been applied empirically to estimate firms' ICC, using not only reported accounting measures, but also analysts' forecasts of future earnings and growth rates (Gebhardt et al. 2001). Consequently, for those firms followed by analysts, we can estimate their ICC and then test for an association between ICC and exposure to climate risks. If a significant portion of the exposure to these risks is non-diversifiable, we expect to find a positive association between firms' reported exposure to such risk and their implied cost of capital.

The Gebhardt et al. (2001) measure of ICC is not free from potential limitations and some studies have suggested other measures for ICC (E.g., Hou, van Dijk, and Zhang 2012). Criticisms of the measure include potential optimism bias and the misrepresentation of small firms in I/B/E/S (especially for earlier years). However, these concerns are not relevant to our study, as the time period contains only a small number of very recent years. In addition, the climate risk data are mostly available for firms that are of a notable size and thus are very likely to have analysts following for the sample time period. More importantly, this measure contributes to understanding the mechanisms through which market participants view climate risks. It provides evidence about whether analysts are incorporating climate risks when forecasting GAAP earnings.

Prior capital market studies have documented variables that are likely associated with firms' ICC. Consistent with the literature, we control for size (log of market value), book to market ratio, leverage, firm beta, and include year and industry fixed effects, when estimating the association between our indicators of a firm's exposure to climate risk and ICC. [10,11] Equation (2) includes the variable *CR,* but similar to our valuation model, we estimate a restricted version that omits it.

$$ICC_t = \beta_0 + \beta_1 LogMV_t + \beta_2 BtoM_t + \beta_3 LEV_t + \beta_4 Beta + \gamma CR_t + \sum YEAR + \sum IND + \varepsilon_t \quad (2)$$

IV. Methods

Our sample is drawn from Russell 3000 firms reported in the Ceres-CookESG SEC Climate Disclosure Search Tool[12] for the period 2011-2014.[13] These data include results of a

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[10] We use two way clustering for firm and industry in Equations (1) and (1a). We use year and industry dummies for Equation (2), since analyst following could be correlated with industry. This is motivated by the small number of years in the panel and efficiency concerns. However, following the concerns raised by Amir et al. (2015) with respect to inclusion of fixed effects in panel datasets, all results robust to the inclusion of firm and year fixed effects and annual regressions (untabled).

[11] The closest to our study is Chava (2014), who measures climate risk by evaluating the amount of revenue derived from the sale (or combustion) of coal or oil and its derivative fuel products. His measure is narrowly focused and essentially identifies affected industries, rather than company-identified materiality of climate risk. He also includes measures from the KLD database, which tracks environmental performance metrics rather than climate risk.

[12] The SEC Climate Disclosure Search Tool is developed by Ceres and CookESG Research and started in 2009. Ceres is a coalition of investors, firms and environmental organizations advocating for sustainability leadership. The climate risk data are available on the Ceres website (http://www.ceres.org/resources/tools/sec-climate-disclosure/sec-climate-disclosure). The data are coded based upon key words and natural language processing to identify combinations of words, e.g., "EU trading system". According to Jackie Cook of CookESG Research, who developed the tool, the Ceres data portal "helps investors make sense of textual climate disclosures, conduct

textual analysis of firm 10-K reports. Because it is mandatory for firms to disclose any material climate risks, we assume that any firm discussing climate risk in their 10-K faces material climate risks.[14]

In line with the Ceres-CookESG SEC Climate Disclosure dataset we use the following classification of climate risks discussed in firm 10-Ks:[15] (1) ***Regulatory Risk*** relates to any enacted or pending regulations (both domestic and international) that are likely to have material effects on the company's financial condition or operation. (2) ***Physical Risk*** refers to the physical effects of climate change on firm operations, such as increased incidence of severe weather, rising sea levels, reduced arability of farmland, and reduced water availability and quality. (3) ***Renewable Technology/Energy Efficiency*** is associated with the type of energy (i.e. renewable or non-renewable) that firms use in their operations, as well as the way they manage their energy consumption. For instance, firms may choose to rely on fossil fuels to supply their electricity. This signals lower energy efficiency, as fossil fuel is not clean energy and may require higher compliance costs in the future. Alternatively, firms may opt to invest in solar-power or geothermal energy to power their plants. (4) ***Non-specific*** relates to any climate related risks that firms are exposed to which do not fall into the other three categories.

We use the extracted discussion of climate risks to develop two basic types of measures. First, we set dummy variables equal to one for each type of risk that is discussed in a firm's 10-K

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company-to-company comparisons and identify best practice" (http://www.ceres.org/press/press-releases/new-web-tool-provides-easy-access-to-sec-climate-change-disclosure-from-3-000-public-companies).

[13] We focus on the time period following the SEC guidance for climate risk disclosures. Prior to this time period, fewer than 24% of companies discussed climate risk in their 10-Ks (Doran et al. 2009). In our sample, 56% of companies identify some type of climate risk as material enough to be disclosed.

[14] Our models do not differentiate between positive and negative aspects of climate risk. This is driven by our use of the Ceres-CookESG metrics. Regardless of the disclosure tone, however disclosure signals that the firm faces a material risk. Future research could develop a refined measure to explore valuation of risks versus disclosed means of addressing the risks.

[15] See Appendix B for specific example for each category.

(*Regulatory, Physical, Renewable,* and *NonSpecific*, for each category respectively) and 0 otherwise.

We also employ two variables that summarize the firm's overall climate risk. *All* is the sum of the dummy variables across all four categories of risk, thus indicating the existence of any discussion of climate risk. Finally, the variable *RawScore* reflects the overall amount of disclosure for each report/abstract. The score is a function of both the length/volume of relevant disclosure as well as the specificity of the language used. Language that is more directly relevant to climate risk is scored higher than language that is only indirectly relevant.[16]

All data related to accounting items, share prices and shares outstanding are retrieved from the Center for Research in Security Prices (CRSP), I/B/E/S and Compustat databases.[17] We exclude financial institutions and insurance companies by removing all companies with SIC codes of 6000-6999.

Our measure of the implied cost of capital (*ICC*) is computed according to the method in Gebhardt et al. (2001). This method solves Equation (1) for the internal rate of return that sets observed market value of equity equal to book value plus the present value of expected future earnings, proxied by analyst one year ahead, two year ahead and long-term growth in earnings forecasts. Our final sample after exclusions for missing data items consists of 4,200 firm-years.[18]

[16] The coding scheme was developed by Cook-ESG, and uses key words and combinations of words to identify relevant sections of text. The dictionaries were developed by an iterative process to avoid incidence of false positives. The dictionaries are too extensive to reproduce in this paper, but are available from CookESG.

[17] While our main tests do not use winsorized values, in sensitivity tests, we winsorize all continuous variables (market capitalization, total assets, total liabilities, book value of equity and earnings before interest and tax) at the one percent level for both tails of the distribution. Results of these tests are qualitatively similar to those reported. Thus we do not find evidence that outliers are driving our results.

[18] Note that for consistency in observations reported across tests the sample selection process requires non-missing variables for all tests yielding lower firm-years observations (especially due to the required analyst-related data). We run the different tests with the inclusion of all available observations for each test. Results are not materially different for any of the tests.

Summary statistics for the variables used in the empirical analysis are reported in Table 1. The statistics of the climate risk indicators reveals physical risks are the most common (46% of the observations), followed by regulatory risk (39%), non-specific (37%) and finally renewable (23%). *RawScore* ranges from 0 to 961, with an average of 21. Fifty-six per cent of the firm years (untabled) include reports of some aspect of climate risk.

The financial variables used in Equations (1) and (1a), market value of equity (*MVE)*, book value of equity (*BVE)*, and earnings (*EARNS)* exhibit skewness. This reflects the nature of the firms in the Russell 3000, which has a large number of small firms and fewer extremely large firms. Following Barth, and Clinch (2009), we use these variables for our main tests. When we scale the variables by shares outstanding, however, the distributions are much less skewed (variables *MV_ps*, *BV_ps*, and *E_ps*, respectively). We repeat our analyses using these scaled variables.

[Insert Table 1 about here]

Given the broad nature of climate risk, we further investigate the frequency of material climate risk across industries as reported in Table 2. The largest industry representation is Business Services (13%). For this group, climate risk is not ubiquitous; the most common type of climate risk is physical risk, with only 16% of industry members reporting such risk. Unsurprisingly, a high percentage of firms in industries that have been traditionally viewed as "dirty", including the Coal, Utilities and Petroleum and Natural Gas report having climate risk. These three industries comprise about 10.8% of the total firm-year observations in our sample and across all climate risk categories, 67%-100% of observations report existence of climate risk. These industries also have the highest mean *RawScore*, indicating that not only do they tend to discuss risk more often, but also, they tend to have much more discussion about the nature of the risks. However, climate risk appears to affect all industries; each of the 46 industries represented in our sample contains firms that report some aspect of material climate risk. A perhaps surprising result is that the Candy & Soda industry members consistently report existence of Physical Risk (92%), Regulatory Risk (92%) and Non-Specific Risk (92%). This industry also has the largest variance in reporting across climate risk classifications, as only 23% report Renewable Technology Risk.[19] The smallest percentages per industry of observations that report any of the climate change risks are within the Printing and Publishing and Medical Equipment with an average of 4%, and 6% across all the Climate risk specifications, respectively. These two industries comprise about 3.3% of the total firm-year observations in our sample.

[Insert Table 2 about here]

Table 3 reports pairwise correlations among the regression variables. There is a strong correlation across all climate risk classifications with a correlation of about 55% between Physical and Regulatory risks and the smallest correlation of about 43% between Physical and Renewable risks. As expected, the financial measures tend to exhibit high correlations with each other.

[Insert Table 3 about here]

V. Results

Our principal tests are based on estimation of Equations (1) and (1a) detailed in Table 4. As expected, the estimated coefficients of both book value and earnings are positive and statistically significant across all models. Also as expected, the sign of the estimated coefficient

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[19] While the Candy & Soda industry's product seems like it would be relatively environmentally benign, the industry tends to have widely distributed production facilities and complicated distribution channels, which could be adversely affect by climate-related events.

of each of the reported climate risk indicators is significantly negative. Column (6) reports results of using *RawScore* as the measure of climate risk. This combines all of the risk classifications and weights them by extent of disclosure. In the model, the coefficient of *RawScore* is significantly negative. In Column (7), the coefficient of *ALL* (the sum of the individual climate risk dummies), is also negative.[20] Our results are consistent with a significant negative association between firm's reported exposure to climate risk and its market value of equity.

[Insert Table 4 about here]

A separate econometric issue discussed in the valuation literature regards scale effects (e.g. Barth et al. 2009; Lo 2005). While our primary variables of interest are indicators, and therefore are less subject to scale effects, we are also concerned with the influence of scale effects on the estimated coefficients of the reported accounting measures, as well as the overall explanatory power of the models. Following Barth et al. (2009), we scale all levels in Equation (1) by common shares outstanding. This yields the restricted model expressed in Equation (3), where *MV_ps, BV_ps* and *E_ps* are respectively *MVE, BVE* and *EARNS,* scaled by the number of shares outstanding. As before, we estimate both restricted (omitting *CR)* and unrestricted (including *CR*) versions of the model:

$$MV\_ps_t = \beta_0 + \beta_1 BV\_ps_t + \beta_2 E\_ps_t + \gamma CR_t + \varepsilon_t \qquad (3)$$

The results of estimating these models are summarized in Table 5 and are consistent with those of the base models in Table 4 discussed above. All climate risk variables are negative and

[20] We run the model with *ALL* rather than including all four dummy variables in the same model because of correlations among the risk categories. See the sensitivity analysis section for further discussion.

significant. Taken together, the results of our valuation tests suggest that market value for firms with material climate risk is lower. While our measures are relatively coarse, we can assess the economic significance of exposure to climate risk. The average estimated marginal effect of having material climate risk across categories ranges from is $1.08 to $2.13 billion.

[Insert Table 5 about here]

Table 6 reports model estimates for the ICC in Equation (2). The models include fixed effects for the Fama-French 48 industry classifications and year. Consistent with the literature and our expectations, results indicate that larger firms have a significantly lower ICC, and firms with a higher book to market ratio (*BtoM*) have a higher ICC. Columns 2-5 indicate that with the exception of physical risk, all measures of climate risk are positive and significant. This is consistent with firms facing significant climate risk having a higher ICC. The increase in ICC for the significant climate risk variables ranges from 19 to 25 basis points. Composite measures of risk (*RawScore* and *All*) both indicate a significant positive association between climate risk and the ICC.

[Insert Table 6 about here]

To provide additional insights into market perception of climate risk, we replace the simple dummy variable for each type of climate risk with a more refined measure. In addition to *RawScore*, which is a measure of the overall extent of disclosure, the Ceres-CookESG database reports the percentage of disclosure in each report that relates to each type of climate risk. For each category of risk, we multiply the raw score (an overall measure of climate risk disclosure) by the percentage of disclosure for each category to derive a measure of the extensiveness of disclosure within each category.[21] Consistent with a greater degree of risk resulting in more extensive disclosure, we use these measures to proxy for the extent of climate risk exposure in each category. Tables 7 and 8 provide results of estimating the market valuation (Table 7) and ICC (Table 8) models with our continuous measure of climate risk. In Table 7, all categories of climate risk are negatively and significantly associated with market value. These results are consistent with results using dummy variables in Table 4. In Table 8, only the regulatory and renewable risk categories are significantly different from zero.[22]

[Insert Table 7 and Table 8 about here]

VI. Additional analysis

To provide evidence that our results are related to market perceptions of risk rather than environmental performance, we include a measure from KLD Research and Analytics as part of MSCI, which comprises an index related to environmental concerns and strengths. This measure has been used in the sustainability accounting research to proxy for environmental performance (Dhaliwal et al. 2011; Ge, and Liu 2015). In the process of assigning the KLD scores, the data are collected from various sources, including both voluntary and mandatory disclosures (frequently outside of firm financial statements, but required by various governmental entities). These data are analyzed by the KLD analysts, resulting in an index of strengths and an index of

[21] The database does not provide individual scores for each category.

[22] In untabled analysis, we use these scores in a factor analysis to provide a refined measure for *ALL*. The factor analysis results in a single factor. Results using the factor score are consistent with our main results: the coefficient of the combined measure is significantly negative in the market valuation Equation (1a) and (3), and significantly positive in Equation (2).

concerns. Consistent with the literature (e.g., Chava 2014), we calculate an overall measure (*ENV_NET*) that subtracts the concerns score from the strengths score.[23]

Table 9 shows the regression results for our main tests with the inclusion of the variable *ENV_NET*. Panel A reports regression results for the market valuation analysis. As expected and consistent with the literature, the coefficient of *ENV_NET* is positive and significant in all models. Our risk measures continue to be negative and significant in all models. Thus, our measure of risk is not subsumed by environmental performance. Results for the ICC model (Panel B) show also similar results with respect to our climate risk indicators although *ENV_NET* is insignificant. Overall our results are not sensitive to the inclusion of *ENV_NET*.

[Insert Table 9 about here]

Rather than simply measuring performance, KLD includes measures that represent proactive initiatives (comprising the main measures included in environmental strengths) and damaging actions (comprising the main measures included in environmental concerns) (Matsumura et al. 2014). In alignment with prior literature, to isolate the effect of environmental performance, we re-estimate our models replacing *ENV_NET* with *ENV_CON*. Panel A in Table 10 includes the regression results for the market valuation analysis. The coefficient of *ENV_CON* is negative and significant in all columns. With the exception of the models for *NonSpecific* and *RawScore*, all climate risk variables are negative and significant. These results suggest that out measures contain additional material information regarding specific climate risks. Panel B reports regression results for the ICC equation. Consistent with Table 6, all risk measures (with the

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[23] In our sample, approximately 64% of the firm-year observations show neither strengths nor concerns (i.e., both measures have a 0 score). In addition, 17% (31%) the KLD measures have a score different than zero for environmental concerns (strengths), respectively.

exception of *Physical*) are positive and significant. As expected and consistent with Chava (2014),[24] *ENV_CON* is positive and significant in most specifications. Overall our results are not sensitive to the inclusion of *ENV_CON*.

[Insert Table 10 about here]

It is possible that the market would view firms' proactive initiatives (KLD strengths) as a means of mitigating climate risk. However, further analysis (untabled) including only the environmental strengths does not change our results for the climate risk measures, and none of the models show significant results for the strengths variable. Thus, it appears that market valuations are not consistent with expectation that proactive initiatives mitigate the risk.

Our results are also robust to a number of different model specifications (untabled). For the valuation models, we split *BVE* into total assets and total liabilities (such as in Matsumura et al. 2014) and use revenue as an alternative deflator. For the ICC models, we omit leverage as an additional independent variable. We also estimate models on a year-by-year basis and including firm fixed-effects to address the potential correlated omitted variable problem in our panel (in line with Amir et al. 2015) and we find similar results across all different specifications.

VII. Discussion and Conclusions

The impact of climate risk on companies is significant and multi-faceted. Companies already face increasing impacts on operations as climate change magnifies these risks. These impacts include supply and distribution chains disruptions due to flooding, such as the impact of 2011 floods in Thailand on the automobile industry (e.g., Haraguchi et al. 2014), increased

[24] Although our results for environmental concerns is consistent with Chava (2014), he finds a significant positive coefficient for his net measure (calculated to be net concerns). However, we find no significant results for our net measure. This may be due to changes in the KLD universe of firms and refinement of their measures, since our sample periods do not overlap.

capital and regulatory costs due to greenhouse gas reduction mandates, such as required purchase of carbon emissions permits requirements in the European Union (EU-Commission 2003) and California (Nunez, and Pavley 2006), and renewable fuel offset requirements for petroleum refiners (Energy independence security act of 2007), and more. Climate change can also impact the availability of raw materials and resources such as water and energy. Extreme events such as storms and floods can threaten buildings and machinery, increasing maintenance and insurance costs, with the potential for having to replace damaged assets.

The nature of climate risk makes the probability, magnitude, and timing of impacts on firms diffuse and difficult to evaluate. Although there is evidence that specific environmentally-related risks are recognized by the market (e.g., the case of carbon emissions examined by Matsumura et al. 2014), it is unclear whether market valuations incorporate a more general form of overall climate risk. For example, a considerable portion of such risks may be diversifiable, and therefore, not priced.

We examine whether climate risk is associated with market value and the implied cost of capital by employing disclosure of different types of climate risk as indication of the existence of such risk. We find evidence consistent with lower market values and higher costs of capital for firms that face material climate risk. Market valuation is consistent with recognition of not only overall climate risk, but also different forms of this risk, including risk related to increasing regulation, physical impacts, renewable technology/energy efficiency, and non-specific climate risks. The market appears to view these risks as undiversifiable. Our results are generally robust to different forms of the models.

Our analysis is subject to some limitations. The primary limitation is use of the disclosure of climate risk as our proxy for existence of material climate risk. We assume that disclosure of material climate risk is mandatory. As a result, our measure is quite coarse and could be viewed as voluntary, rather than mandatory disclosure. In addition, it is arguable that all firms face climate risk. However, we believe that these aspects work against our finding significant results. If all firms face material climate risks or our proxy is too coarse, then we should not find significant differences between disclosers and non-disclosers. Further, contrary to our results, evidence in the environmental accounting literature indicates that initiation of voluntary general corporate responsibility disclosures (Dhaliwal et al. 2011) is associated with *higher* firm value and *lower* cost of capital. Firms that do not disclose carbon emissions (a voluntary disclosure) are penalized, relative to firms that disclose these emissions (Matsumura et al. 2014).

In addition, our measure of climate risk does not differentiate between positive and negative aspects of risk. This limitation is driven by use of the Ceres-CookESG disclosure data. Future research could refine the measure, examining differences in valuation of climate risk versus strategies that firms employ which are designed to help manage the risk. Our robustness tests incorporating KLD measures begin to address this issue, but more work could be done to find measures that refine this analysis.

As climate change impacts become more frequent and larger in magnitude, companies will face increasing costs and climate-related risks, which will impact shareholder value. Although specific impacts and their timing are difficult to ascertain, the market appears to view climate risk as real and undiversifiable. The market incorporates this risk into both market valuation and the cost of equity capital. If climate change continues to worsen, more firms are likely to face material climate risks and as a result, be penalized by the market.

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Table 1: Variables Descriptive Statistics

	mean	sd	p25	p50	p75	min	max
MVE	8.68	28.34	0.60	1.70	5.35	0.04	626.55
ICC	8.09	2.34	6.51	7.91	9.49	3.36	14.18
RawScore	20.54	52.41	0.00	2.00	15.00	0.00	961.00
NonSpecific	0.37	0.48	0.00	0.00	1.00	0.00	1.00
Regulatory	0.39	0.49	0.00	0.00	1.00	0.00	1.00
Physical	0.46	0.50	0.00	0.00	1.00	0.00	1.00
Renewable	0.23	0.42	0.00	0.00	0.00	0.00	1.00
All	1.45	1.55	0.00	1.00	3.00	0.00	4.00
LogMV	0.66	1.62	-0.51	0.53	1.68	-3.27	6.44
BVE	3.14	10.24	0.26	0.68	1.97	0.00	174.00
EARNS	0.54	2.12	0.03	0.08	0.29	0.00	43.67
BtoM	0.49	0.31	0.27	0.43	0.65	0.00	3.44
LEV	0.29	0.24	0.05	0.28	0.47	0.00	0.91
Beta	1.22	0.41	0.95	1.20	1.47	-0.04	2.93
MV_ps	40.58	49.86	16.75	30.89	50.60	0.89	1162.40
BV_ps	15.93	18.82	7.05	12.25	20.51	0.02	445.30
E_ps	2.21	3.04	0.75	1.61	2.80	0.00	98.11

Notes: The table presents the descriptive statistics for the variables used in the main models. See the Appendix A for variable definitions. There are 4200 firm-year observations for each of the variables.

Table 2: Industry Classification and Distribution

Industry Classification	***N***	***Mean Raw Score***	***Material Non-Specific Risk***		***Material Regulatory Risk***		***Material Physical Risk***		***Material Renewable Technology Risk***	
			YES	%	YES	%	YES	%	YES	%
Agriculture	**15**	**11**	1	**7%**	10	**67%**	12	**80%**	2	**13%**
Food Products	**95**	**11**	56	**59%**	51	**54%**	60	**63%**	20	**21%**
Candy & Soda	**13**	**33**	12	**92%**	12	**92%**	12	**92%**	3	**23%**
Beer & Liquor	**16**	**11**	9	**56%**	10	**63%**	10	**63%**	6	**38%**
Tobacco Products	**7**	**8**	5	**71%**	4	**57%**	2	**29%**	0	**0%**
Recreation	**21**	**1**	1	**5%**	3	**14%**	1	**5%**	3	**14%**
Entertainment	**48**	**7**	7	**15%**	12	**25%**	25	**52%**	2	**4%**
Printing and Publishing	**25**	**0**	2	**8%**	0	**0%**	2	**8%**	0	**0%**
Consumer Goods	**75**	**6**	19	**25%**	26	**35%**	22	**29%**	8	**11%**
Apparel	**78**	**6**	12	**15%**	25	**32%**	34	**44%**	2	**3%**
Healthcare	**67**	**6**	6	**9%**	8	**12%**	29	**43%**	0	**0%**
Medical Equipment	**125**	**1**	10	**8%**	4	**3%**	12	**10%**	4	**3%**
Pharmaceutical	**149**	**1**	27	**18%**	15	**10%**	24	**16%**	3	**2%**
Chemicals	**139**	**32**	90	**65%**	97	**70%**	94	**68%**	59	**42%**
Rubber and Plastic	**31**	**5**	10	**32%**	8	**26%**	20	**65%**	9	**29%**
Textiles	**19**	**4**	11	**58%**	10	**53%**	3	**16%**	5	**26%**
Construction Material	**75**	**12**	24	**32%**	26	**35%**	40	**53%**	11	**15%**
Construction	**72**	**27**	22	**31%**	43	**60%**	63	**88%**	31	**43%**
Steel Works	**54**	**18**	33	**61%**	35	**65%**	29	**54%**	21	**39%**
Fabricated Products	**8**	**15**	0	**0%**	3	**38%**	3	**38%**	3	**38%**
Machinery	**208**	**11**	83	**40%**	81	**39%**	98	**47%**	52	**25%**
Electrical Equipment	**41**	**12**	17	**41%**	12	**29%**	21	**51%**	8	**20%**
Automobiles and Truck	**91**	**11**	32	**35%**	39	**43%**	26	**29%**	23	**25%**
Aircraft	**44**	**5**	17	**39%**	14	**32%**	14	**32%**	3	**7%**
Shipbuilding, Railroads	**17**	**10**	8	**47%**	9	**53%**	11	**65%**	3	**18%**
Defense	**17**	**1**	4	**24%**	3	**18%**	3	**18%**	0	**0%**
Precious Metals	**8**	**25**	7	**88%**	6	**75%**	4	**50%**	4	**50%**
Non-Metallic	**23**	**46**	16	**70%**	21	**91%**	21	**91%**	16	**70%**
Coal	**9**	**137**	9	**100%**	9	**100%**	6	**67%**	9	**100%**
Petroleum and Natural	**213**	**86**	191	**90%**	202	**95%**	207	**97%**	175	**82%**
Utilities	**231**	**135**	203	**88%**	217	**94%**	222	**96%**	201	**87%**
Communication	**141**	**2**	10	**7%**	14	**10%**	35	**25%**	4	**3%**
Personal Services	**76**	**2**	15	**20%**	14	**18%**	4	**5%**	6	**8%**
Business Services	**545**	**2**	75	**14%**	57	**10%**	87	**16%**	37	**7%**
Computers	**148**	**3**	29	**20%**	35	**24%**	31	**21%**	20	**14%**
Electronic Equipment	**272**	**4**	76	**28%**	88	**32%**	95	**35%**	34	**13%**
Measuring and Control	**102**	**4**	28	**27%**	15	**15%**	33	**32%**	11	**11%**
Business Supplies	**83**	**16**	37	**45%**	41	**49%**	34	**41%**	23	**28%**
Shipping Containers	**21**	**15**	18	**86%**	21	**100%**	8	**38%**	6	**29%**
Transportation	**150**	**22**	102	**68%**	103	**69%**	120	**80%**	56	**37%**
Wholesale	**167**	**12**	54	**32%**	49	**29%**	89	**53%**	23	**14%**
Retail	**312**	**8**	78	**25%**	109	**35%**	188	**60%**	26	**8%**
Restaurants, Hotels,	**94**	**9**	39	**41%**	35	**37%**	65	**69%**	12	**13%**
Almost Nothing	**55**	**71**	30	**55%**	30	**55%**	31	**56%**	26	**47%**
Total	**4,200**		**1,535**		**1,626**		**1,950**		**970**	

Notes: The table presents the firm-year observations across Fama-French 48 Industry Classification. Each climate risk dummy is reported separately with YES indicating the number of indicators that take the value 1 in the specific industry. The column Total counts the total number of firm-year observations for each industry in the sample. The Column 5 reports the number of YES to the total number of the firm-year observations in the specific industry.

Table 3: Correlations Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	***MVE***																
2	***ICC***	-0.05															
3	***RawScore***	0.03	0.07														
4	***NonSpecific***	0.07	0.14	0.44													
5	***Regulatory***	0.06	0.17	0.45	0.75												
6	***Physical***	0.04	0.12	0.39	0.46	0.55											
7	***Renewable***	0.06	0.10	0.55	0.58	0.60	0.43										
8	***All***	0.07	0.16	0.55	0.85	0.89	0.76	0.78									
9	***LogMV***	0.57	-0.20	0.16	0.20	0.19	0.09	0.18	0.20								
10	***BVE***	0.90	0.01	0.09	0.11	0.10	0.09	0.11	0.12	0.53							
11	***EARNS***	0.93	0.01	0.04	0.08	0.08	0.06	0.08	0.09	0.49	0.89						
12	***BtoM***	-0.13	0.52	0.12	0.07	0.12	0.13	0.09	0.12	-0.35	-0.01	-0.08					
13	***LEV***	0.07	0.10	0.25	0.24	0.25	0.20	0.21	0.27	0.22	0.05	0.05	-0.05				
14	***Beta***	-0.18	0.27	-0.07	0.03	0.04	0.00	0.02	0.03	-0.21	-0.16	-0.14	0.10	-0.08			
15	***MV_ps***	0.28	-0.16	0.00	0.02	0.03	0.01	0.01	0.02	0.41	0.17	0.22	-0.26	0.01	-0.14		
16	***BV_ps***	0.14	0.09	0.10	0.12	0.13	0.11	0.11	0.15	0.23	0.18	0.15	0.17	0.00	-0.09	0.69	
17	***E_ps***	0.30	0.04	0.04	0.09	0.08	0.06	0.07	0.09	0.35	0.24	0.33	-0.10	0.06	-0.10	0.77	0.70

Note: The table presents Pearson pair-wise correlations for selected variables. There are 4,200 firm-year observations for each of the variables.

Table 4: OLS Regression Results for Market Value (*MV*) and Climate Risk

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
BVE	0.899***	0.907***	0.909***	0.909***	0.915***	0.916***	0.916***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EARNS	8.607***	8.589***	8.587***	8.578***	8.570***	8.547***	8.569***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NonSpecific		-1.080***					
		(0.000)					
Regulatory			-1.440***				
			(0.000)				
Physical				-1.244***			
				(0.000)			
Renewable					-2.126***		
					(0.000)		
RawScore						-0.013***	
						(0.005)	
All							-0.537***
							(0.000)
N	4200	4200	4200	4200	4200	4200	4200
Adj R^2	0.891	0.891	0.891	0.891	0.892	0.891	0.892

Notes: The table presents results of the regression models of market value, Equations (1) and (1a). See Appendix A for variable definitions. All regressions control for possible correlation of the residuals within time (year) and industry (Fama-French 48 industries classification), with two-way clustering (Petersen, 2009). *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively.

Table 5: OLS Regression Results for Market Value and Climate Risk, using Values Scaled by Shares Outstanding

	(1) Base Model	(2) Material Non Specific Risk	(3) Material Regulatory Risk	(4) Material Physical Risk	(5) Material Renewable Technology Risk	(6) Total Material Risk (Raw Score)	(7) Total Material Risk (# of Risk Categories)
BV_ps	0.816***	0.836***	0.839***	0.839***	0.835***	0.839***	0.848***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
E_ps	8.990***	8.998***	8.963***	8.951***	8.966***	8.921***	8.959***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NonSpecific		-6.705***					
		(0.000)					
Regulatory			-5.953***				
			(0.000)				
Physical				-6.344***			
				(0.000)			
Renewable					-6.795***		
					(0.000)		
RawScore						-0.053***	
						(0.000)	
All							-2.417***
							(0.000)
N	4200	4200	4200	4200	4200	4200	4200
Adj R^2	0.634	0.638	0.637	0.638	0.637	0.637	0.639

Notes: The table presents results of the regression models of market value, scaled by shares (*MV_ps*). See Appendix A for variable definitions. All regressions control for possible correlation of the residuals within time (year) and industry (Fama-French 48 industries classification) with two-way clustering (Petersen 2009). *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively.

Table 6: OLS Regression Results for Implied Cost of Capital (*ICC*) and Climate Risk

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
LogMV	-0.060***	-0.071***	-0.069***	-0.059***	-0.066***	-0.063***	-0.069***
	(0.002)	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)	(0.000)
BtoM	3.891***	3.860***	3.854***	3.894***	3.877***	3.878***	3.855***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LEV	1.785***	1.733***	1.744***	1.788***	1.766***	1.766***	1.738***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Beta	0.643***	0.626***	0.630***	0.643***	0.638***	0.642***	0.633***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NonSpecific		0.248***					
		(0.000)					
Regulatory			0.197***				
			(0.001)				
Physical				-0.017			
				(0.755)			
Renewable					0.188***		
					(0.007)		
RawScore						0.001**	
						(0.033)	
All							0.067***
							(0.001)
Year FE	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y
N	4200	4200	4200	4200	4200	4200	4200
Adj R^2	0.565	0.567	0.566	0.565	0.566	0.565	0.566

Notes: The table presents results of the regression models of the implied cost of capital. See Appendix A for variable definitions. *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively. We control for year and industry (Fama-French 48 industry classification) fixed effects (not reported).

Table 7: OLS Regression Results for Market Value (*MVE*) with Climate Risk Variables Measured as the Percentage Disclosure for Each Category Times *RawScore*

	(1) Base Model	(2) Material Non Specific Risk	(3) Material Regulatory Risk	(4) Material Physical Risk	(5) Material Renewable Technology Risk
BVE	0.899***	0.910***	0.914***	0.908***	0.915***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EARNS	8.607***	8.569***	8.553***	8.569***	8.553***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NonSpecific		-0.044**			
		(0.035)			
Regulatory			-0.033***		
			(0.003)		
Physical				-0.032**	
				(0.022)	
Renewable					-0.062***
					(0.006)
N	4200	4200	4200	4200	4200
Adj R^2	0.891	0.891	0.891	0.891	0.891

Notes: The table presents results of the regression models of market value. See Appendix A for variable definitions. All regressions control for possible correlation of the residuals within time (year) and industry (Fama-French 48 industries classification), with two-way clustering (Petersen, 2009). *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively.

Table 8: OLS Regression Results for Implied Cost of Capital (*ICC*) with Climate Risk Variables Measured as the Percentage Disclosure for Each Category Times *RawScore*

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**
LogMV	-0.060***	-0.061***	-0.064***	-0.060***	-0.063***
	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
BtoM	3.891***	3.886***	3.875***	3.891***	3.876***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LEV	1.785***	1.776***	1.761***	1.786***	1.777***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Beta	0.643***	0.642***	0.640***	0.643***	0.647***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
NonSpecific		0.002			
		(0.339)			
Regulatory			0.003***		
			(0.006)		
Physical				-0.000	
				(0.991)	
Renewable					0.006**
					(0.022)
Year FE	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y
N	4200	4200	4200	4200	4200
Adj R^2	0.565	0.565	0.566	0.565	0.565

Notes: The table presents results of the regression models of the implied cost of capital. See Appendix A for variable definitions. *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively. We control for year and industry (Fama-French 48 industry classification) fixed effects (not reported).

Table 9: Sensitivity Tests for the KLD's Net Environmental Scores

Panel A: OLS Regression Results for Market Value (*MV*) and Climate Risk with *ENV_NET*

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
BVE	0.883***	0.893***	0.895***	0.893***	0.900***	0.898***	0.901***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EARNS	8.521***	8.498***	8.495***	8.493***	8.483***	8.473***	8.478***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_NET	1.688**	1.715**	1.715**	1.665**	1.671**	1.635**	1.694**
	(0.035)	(0.029)	(0.028)	(0.035)	(0.028)	(0.039)	(0.028)
NonSpecific		-1.293***					
		(0.000)					
Regulatory			-1.658***				
			(0.000)				
Physical				-1.218***			
				(0.000)			
Renewable					-2.180***		
					(0.000)		
RawScore						-0.011**	
						(0.029)	
All							-0.578***
							(0.000)
N	3915	3915	3915	3915	3915	3915	3915
Adj R^2	0.893	0.894	0.894	0.894	0.894	0.894	0.894

Notes: The table presents results of the regression models of market value, Equations (1) and (1a). See Appendix A for variable definitions. All regressions control for possible correlation of the residuals within time (year) and industry (Fama-French 48 industries classification), with two-way clustering (Petersen, 2009). *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively.

Panel B: OLS Regression Results for Implied Cost of Capital (*ICC*) and Climate Risk with *ENV_NET*

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
LogMV	-0.026	-0.036	-0.034	-0.026	-0.033	-0.030	-0.035
	(0.231)	(0.101)	(0.129)	(0.233)	(0.131)	(0.167)	(0.117)
BtoM	4.038***	4.006***	4.003***	4.039***	4.022***	4.021***	4.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LEV	1.871***	1.820***	1.834***	1.872***	1.850***	1.848***	1.826***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Beta	0.717***	0.702***	0.704***	0.717***	0.709***	0.717***	0.706***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_NET	-0.018	-0.023	-0.021	-0.018	-0.020	-0.015	-0.022
	(0.510)	(0.403)	(0.438)	(0.512)	(0.462)	(0.575)	(0.421)
NonSpecific		0.244***					
		(0.000)					
Regulatory			0.173***				
			(0.004)				
Physical				-0.007			
				(0.907)			
Renewable					0.209***		
					(0.003)		
RawScore						0.001**	
						(0.016)	
All							0.066***
							(0.001)
Year FE	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y
N	3915	3915	3915	3915	3915	3915	3915
Adj R^2	0.574	0.576	0.575	0.574	0.575	0.575	0.575

Notes: The table presents results of the regression models of the implied cost of capital. See Appendix A for variable definitions. *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively. We control for year and industry (Fama-French 48 industry classification) fixed effects (not reported).

Table 10: Sensitivity Tests for the KLD's Total Environmental Concerns

Panel A: OLS Regression Results for Market Value (*MV*) and Climate Risk with *ENV_CON*

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
BVE	0.967***	0.968***	0.968***	0.970***	0.969***	0.968***	0.969***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EARNS	8.568***	8.564***	8.560***	8.553***	8.551***	8.551***	8.551***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_CON	-2.885***	-2.776***	-2.661***	-2.722***	-2.528**	-2.701**	-2.569**
	(0.004)	(0.006)	(0.007)	(0.006)	(0.013)	(0.018)	(0.011)
NonSpecific		-0.410					
		(0.118)					
Regulatory			-0.875***				
			(0.000)				
Physical				-0.783***			
				(0.004)			
Renewable					-1.370***		
					(0.001)		
RawScore						-0.005	
						(0.391)	
All							-0.320***
							(0.000)
N	3915	3915	3915	3915	3915	3915	3915
Adj R^2	0.893	0.893	0.893	0.893	0.893	0.893	0.893

Notes: The table presents results of the regression models of market value, Equations (1) and (1a). See Appendix A for variable definitions. All regressions control for possible correlation of the residuals within time (year) and industry (Fama-French 48 industries classification), with two-way clustering (Petersen, 2009). *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively.

Panel B: OLS Regression Results for Implied Cost of Capital (*ICC*) and Climate Risk with *ENV_CON*

	(1) **Base Model**	(2) **Material Non Specific Risk**	(3) **Material Regulatory Risk**	(4) **Material Physical Risk**	(5) **Material Renewable Technology Risk**	(6) **Total Material Risk (Raw Score)**	(7) **Total Material Risk (# of Risk Categories)**
LogMV	-0.043**	-0.051**	-0.050**	-0.043**	-0.048**	-0.044**	-0.050**
	(0.049)	(0.019)	(0.024)	(0.049)	(0.027)	(0.043)	(0.023)
BtoM	4.012***	3.984***	3.979***	4.014***	3.999***	4.001***	3.980***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
LEV	1.867***	1.817***	1.831***	1.870***	1.847***	1.848***	1.824***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Beta	0.720***	0.706***	0.708***	0.720***	0.713***	0.720***	0.710***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ENV_CON	0.099**	0.082	0.093*	0.100**	0.086*	0.084*	0.084*
	(0.048)	(0.101)	(0.065)	(0.047)	(0.088)	(0.099)	(0.096)
NonSpecific		0.235***					
		(0.000)					
Regulatory			0.166***				
			(0.005)				
Physical				-0.015			
				(0.788)			
Renewable					0.197***		
					(0.006)		
RawScore						0.001**	
						(0.033)	
All							0.063***
							(0.002)
Year FE	Y	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y	Y
N	3915	3915	3915	3915	3915	3915	3915
Adj R^2	0.574	0.576	0.575	0.574	0.575	0.575	0.575

Notes: The table presents results of the regression models of the implied cost of capital. See Appendix A for variable definitions. *,**,*** denote differences that are significant at the 0.10, 0.05 and 0.01 level, respectively. We control for year and industry (Fama-French 48 industry classification) fixed effects (not reported).

Appendix A

Variable Definitions

Variable	Definition	Source
MVE	Market value of equity (in $billion) at disclosure year (prcc_f* csho)/1000	The merged CRSP - COMPUSTAT
ICC	Implied Cost of Capital in % as in Gebhardt et al. (2001) and multiplied by 100	The merged CRSP – COMPUSTAT and I/B/E/S
RawScore	Raw scores for disclosure extensiveness	Ceres-CookESG database
NonSpecific	An indicator for non-specific risk disclosure	Ceres-CookESG database
Regulatory	An indicator for regulatory risk disclosure	Ceres-CookESG database
Physical	An indicator for physical risk disclosure	Ceres-CookESG database
Renewable	An indicator for renewable technology risk disclosure	Ceres-CookESG database
All	The sum of all the climate risk disclosure indicators per firm-year	Ceres-CookESG database
LogMV	Natural logarithm of market value at disclosure year.	The merged CRSP - COMPUSTAT
BVE	Book value of equity (in $billion) at disclosure year (ceq/1000)	The merged CRSP - COMPUSTAT
EARNS	Earnings before extraordinary items (in $ billion) at disclosure year (epspx*csho)/1000	The merged CRSP - COMPUSTAT
BtoM	Book to Market value of equity at disclosure year	The merged CRSP - COMPUSTAT
LEV	The leverage ratio is defined as the ratio of total debt divided by total market value of assets	The merged CRSP - COMPUSTAT
Beta	Beta estimated from the market model using the daily CRSP stock returns	CRSP
MV_ps	Price per share (prcc_f)	The merged CRSP - COMPUSTAT
BV_ps	Book value per share (BV/prcc_f)	The merged CRSP - COMPUSTAT
E_ps	Earnings per share (epspx)	The merged CRSP - COMPUSTAT

Appendix B

Examples of each of the climate risk classifications:

1. ***Regulatory Risk***

Despite these advanced technology efforts, our ability to satisfy fuel economy, carbon dioxide and other emissions requirements is contingent on various future economic, consumer, legislative and regulatory factors that we cannot control or predict with certainty. If we are not able to comply with specific new requirements, which include higher CAFE standards and state carbon dioxide requirements, then we could be subject to sizeable civil penalties or have to restrict product offerings drastically to remain in compliance.

(General Motors, 10-K, 2013)

2. ***Physical Risk***

Natural disasters could include an earthquake, fire, flood, tornado or severe storm. A catastrophic event could include a terrorist attack. An epidemic could affect our operating activities, major facilities or employees' and customers' health. In addition, some of our inventory and production facilities are located in areas that are susceptible to harsh weather; a major storm, heavy snowfall or other similar event could prevent us from delivering products in a timely manner. Production of certain of our products is concentrated in a single manufacturing site.

(McCormick & Co. Inc., 10-K, 2013)

3. ***Renewable Technology/ Energy Efficiency***

Coal-fired generators could switch to other fuels that generate less of these emissions, possibly reducing the construction of coal-fired power plants or causing some users of our coal to switch to a lower carbon dioxide generating fuel, or more generally reducing the demand for coal-fired electricity generation.

(Alpha Natural Resources, 10-K, 2012)

4. ***Non-Specific***

We have voluntarily set a reduction target of 20% from our 2005 baseline of CO2 emission rate from shipboard operations by 2015. We have already reached a reduction of over 14%. Each of our cruise brands has established objectives, targets and plans within their respective ISO 14001 environmental management systems to reduce fuel consumption rates and resulting CO2 emission rates.

(Carnival Corp, 10-K, 2013)