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The Usefulness of Climate Change Risk Disclosure: Evidence from SEC FR-82

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THE USEFULNESS OF CLIMATE CHANGE RISK DISCLOSURE: EVIDENCE FROM SEC FR-82

DISSERTATION

A dissertation submitted in partial fulfillment of
requirements for the degree of Doctor of Philosophy in the
College of Business and Economics
at the University of Kentucky

By

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ABSTRACT OF DISSERTATION

THE USEFULNESS OF CLIMATE CHANGE RISK DISCLOSURE:
EVIDENCE FROM SEC FR-82

On February 8, 2010, the SEC issued an interpretive guidance, SEC FR-82, (guidance hereafter) and required public firms to disclose climate change risk in their 10-Ks. However, this guidance has been controversial. Using firm-year observations from the Russell 3000 Index, this paper shows the following findings regarding the usefulness of climate change risk disclosure. First, a review of the legislative process leading to the 2010 guidance suggests that institutional investors and Democratic politicians play a key role in lobbying the SEC to require the climate change disclosure. Second, firms with climate change risk disclosures have lower future return on assets, driven mainly by lower profit margin. Third, these firms also have lower earnings persistence and smaller forward earnings response coefficient (FERC). Fourth, an event study reveals that these firms experience significantly lower cumulative abnormal return during the 5-days around the 10-K filing date, indicating that investors may incorporate this information into their investment decisions. Fifth, textual analysis indicates that less readable climate change risk disclosure exacerbates the aforementioned effects. Sixth, these firms have lower future firm value, indicating that the climate change risk disclosure signals future firm value. Lastly, tests show that climate change disclosure in the 10-K is more informative than that *voluntarily* disclosed in the Carbon Disclosure Project (CDP) survey, indicating that SEC-mandated disclosure provides information incremental to voluntary disclosure. Overall, this paper documents the usefulness of climate change risk disclosure required under SEC FR-82.

KEYWORDS: Climate Change Risk, Disclosure, SEC FR-82, Usefulness

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

Climate change risk is driven by changes in regulations (e.g., carbon emission reduction, cap-and-trade, and carbon taxes), changes in physical climate parameters (e.g., severe weather) and changes in other climate-related developments (e.g., changing business trend and consumer behavior) (Carbon Disclosure Project (CDP) 2009; Matsumura et al. 2014). According to the estimation of OECD (Organization for Economic Co-operation and Development), on average, climate change will cost the global macro-economy a 1% to 3.3% reduction in GDP (OECD 2015). In term of likelihood and impact, climate change related events are one of the top five global risks the world faces for seven consecutive years from 2011 to 2017 (World Economic Forum 2017).[1] In a recent technical bulletin, the Sustainability Accounting Standards Board (SASB) reports that climate change will significantly affect 93% of the equity market value in the US, totaling $27.5 trillion, and that these risks cannot be diversified away (SASB 2016).[2]

The vast majority of institutional investors (approx. 78%) believe that climate change risk is a material risk to their investment portfolios (Institutional Investors Group on Climate Change 2011). The attention from institutional investors on climate change has increased over 21-fold from 2003 to 2015 (CDP 2015). Despite the increasing interest in climate change risk from investors, the disclosure of climate change risk was "scant" and "inconsistent" (California Public Employees' Retirement System (CalPERS) et al. 2007).

[1] Climate change related events include climate change, storms and cyclones, flooding, rising greenhouse gas emissions, water supply crises, extreme weather events, major natural disasters, and failure of climate change mitigation and adaptation.

[2] http://using.sasb.org/wp-content/uploads/2016/10/Climate-Risk-Technical-Bulletin-101816.pdf?submissionGuid=b614853c-daa9-4fb9-9a73-9791ba84d35c
In this framework, SASB evaluates the financial impact including revenue, cash flow and opearting, asset value and financing impacts. It indentifies the climate change risk from climate regulation, physical effects and transition to a low-carbon resilient economy.

Meanwhile, institutional investors and other stakeholders have continuously pressured the Securities and Exchange Commission (SEC) to mandate and regulate climate-change disclosure.[3] Investors argued that "more and better" climate change risk disclosure will facilitate their investment decisions (CalPERS et al. 2007, page 2).

In response to the demands from institutional investors and other stakeholders, the SEC issued the *Commission Guidance Regarding Disclosure Related to Climate Change* (SEC FR-82) (guidance hereafter) on February 8, 2010. For the first time, this guidance mandated that certain climate change-related issues be disclosed in 10-Ks. Specifically, the regulation required disclosure of (1) the impact of climate change legislation and regulation, (2) the impact of international accords on climate change, (3) the indirect consequences of regulation or business trends, and (4) the physical impacts of climate change.

The guidance, however, has not been without controversy. Proponents believe the guidance to be useful, as the disclosures contain useful information regarding evolving climate-related challenges, which historically were opaque (Investor Network for Climate Risk 2010). Opponents, on the other hand, argue that the information disclosure is not decision-useful (SEC Commissioner Casey 2010). In addition, opponents believe the guidance requires firms to comprehensively review climate change matter, which is "both unnecessary and excessively burdensome" (Edison Electrical Institute 2010). Similarly, Attorney Generals of 14 states (2016) expressed their concerns that climate change disclosure will create "a flood of irrelevant information" that "does little to help the investors."[4] The 112th Congress even considered repealing the climate disclosure guidance

[3] Other stakeholders include state officials, law enforcement, and other non-governmental organizations.
[4] The 14 states include Oklahoma, Alabama, Arizona, Arkansas, Florida, Georgia, Michigan, Montana, Nebraska, Nevada, South Carolina, Texas, Utah, and West Virginia. Available at: https://www.sec.gov/comments/s7-06-16/s70616-289.pdf

as they questioned its effectiveness. However, this guidance is still "alive" and effective to date.

On October 29, 2015, 35 members of Congress wrote a letter to SEC Chair (Mary J. White), requesting an update on the 2010 guidance. In this letter, the Congressmen asked the SEC the following:

"*What has the SEC done to assess the effectiveness of the Climate Change Guidance in providing meaningful disclosures to investors? For example, has the SEC asked investors for their thoughts on how the Climate Change Guidance could be improved for their benefit?*"[5]

On April 13, 2016, the SEC requested for comments on this guidance in a concept release, asking whether the current disclosure is "adequate" to investors to evluate firms' climate change risk. (SEC 2016, page 215).[6]

To date, the research on environment risk has focused on the effects of *voluntary* environmental information disclosure. For example, Matsumura et al. (2014) consider the effect of carbon emission disclosure on firm value using a survey and document a negative relation between firm values and carbon emission. Using a sample from the Australian Stock Exchange 200 index, Li et al. (2014) illustrate that the cost of capital is positively related to emission intensity. Similarly, using ratings of firms' corporate social responsibility (hereafter, CSR), Chava (2014) finds a positive relationship between firm-specfic environmental concerns and cost of capital. However, little is known about the usefulness of climate change risk disclosure under the mandatory disclosure regime implemented by the SEC in 2010.

[5] https://cartwright.house.gov/media-center/press-releases/cartwirght-senators-reed-and-schatz-lead-bicameral-letter-urging-sec-to

[6] The concept release is "Business and Financial Disclosure Required by Regulation S-K" (Release No. 33-10064; 34-77599; File No. S7-06-16).

This paper aims to address this question: is climate change risk disclosure required under SEC FR 82 useful to investors? Following the information theory (Lev 1989, page 156), a message is considered as useful if it can change the receiver's beliefs (e.g., earnings perception), and this change of beliefs triggers a significant action (e.g., change in stock price). Accordingly, this paper selects future earnings, earnings persistence, market reaction, and forward earnings response coefficient (FERC) as the measures of usefulness.

Using firm-year observations from the Russell 3000 Index from 2010 to 2014, I document several interesting relations between climate risk disclosure and measures of disclosure usefulness. First, firms that disclose climate change risk have lower future ROA. It appears that profit margin, not the asset turnover, drives this poor performance. Second, disclosing firms have lower earnings persistence and a lower forward earnings response coefficient (FERC). Third, disclosing firms experience significantly lower short-window cumulative abnormal return around the 10-K filing date. This finding is consistent with investors incorporating climate change risk information into their investment decisions. Additionally, I find that firms with disclosed climate change risk have lower future firm value as measured by Tobin's Q. Taken together, these results suggest climate change risk disclosures under SEC FR-82 are useful to investors for assessing firms' future prospects and climate change risk.

In a subsequent analysis, I apply textual analysis techniques to determine how the readability of the disclosure affects the perceptions of investors. Using a climate change risk disclosure subsample, I find that the previously described results are accentuated when the climate change risk disclosure is less readable. This result indicates that the stock market views disclosing companies who may be obscuring their reporting to be riskier.

This paper contributes to the literature in several ways. First, this paper provides the initial evidence on the usefulness of mandatory climate change disclosure. The results suggest that climate change risk disclosure provides decision-relevant information to investors. This paper contributes to the current debate on the costs and benefits of this specific SEC guidance. The findings of the paper directly respond to Congress's inquiry about the usefulness of the disclosure to investors. Moreover, this paper provides empirical evidence in response to the SEC's request for comment on this guidance. Specifically, my results show that the information disclosed under this requirement is useful to investors and helps investors to evaluate material climate change risk.

Second, Leuz and Wysocki (2016) call for more research on the process of how regulation arises. This paper reviews the legislative process that led to the SEC 2010 guidance. I find both institutional investors and Democratic politicians play an active role in pressuring the SEC to regulate and mandate climate change disclosure (see more detailed discussion in Section 2). The actions of investors and politicians to persuade the SEC is an example of interest group theory—groups lobby for or against regulation in their own interest (Stigler 1971; Becker 1983; Scott 1997).

Third, this paper contributes to textual analysis literature. Prior literature investigates the effects of textual characteristics (e.g. readability) on firm performance (Li 2008), earnings persistence (Li 2008), investment efficiency (Biddle et al. 2009), trade volume (Miller 2010), analyst forecast (Lehavy et al. 2011) and management forecast (Guay et al. 2016). However, most of the previous papers generally focus on the readability of the whole 10-K text or management discussion and analysis (hereafter, MD&A). This paper, instead, pinpoints a unique section of the 10-K, climate change risk disclosure, and

examines whether readability of this disclosure has an important valuation implication. In the climate change risk disclosure subsample, this study finds less readable text predicts lower future earnings, lower earnings persistence, smaller market reaction, and smaller FERC. The results are consistent with managerial obfuscation hypothesis (Li 2008).

The remainder of this paper is organized as follows. Section 2 discusses the legislative process and summary of SEC 2010 guidance. Section 3 reviews prior studies and theory and develop the hypotheses. Section 4 describes the research design including sample development and variables measurement. Section 5 presents descriptive statistics of main variables and results of each hypothesis. Section 6 provides evidence on additional tests. Section 7 provides evidence on robustness checks. Section 8 concludes this study.

2. Legislative Process and Summary of SEC 2010 Guidance

In a literature review on financial reporting regulation, Leuz and Wysocki (2016) suggest that the researchers should pay more attention to the political process "by which disclosure and reporting regulation arises" (Page 601). Interest group theory (Stigler 1971; Becker 1983; Scott 1997) suggests that groups lobby for or against regulation in their own interest. One example of interest group theory in financial reporting is the lobbying process around the passage of the Sarbanes-Oxley Act of 2002 (hereafter, SOX 2002). Analyzing lobbying process of SOX 2002, Thornburg and Roberts (2008) find that accounting profession (AICPA and Big 4 firms) uses political contribution to manage the relation with lawmakers and exerts influence on the legislative process. Still under the setting of SOX 2002, Shapiro and Matson (2008) find that business interests (e.g. Department of Commerce and Financial Executive International) lobby Congress to resist or hamper the internal control regulation.

2.1 Legislative Process

2.1.1 Prior to 2010: Lobbying from Institutional Investors and Democratic Politicians

The impact of climate change has grown in significance as extreme weather patterns increase in frequency and severity and regulators respond with environmental legislation. Increasing environmental regulations impose compliance costs for firms and lead to shifts in the demand for products and services.[7] Physical climate change risk (e.g., extreme weather) interrupts normal operation, logistics, and distribution activities, which hurts firm performance. Institutional investors recognized the importance of climate change risk and began lobbying the SEC to take action. They sent a petition letter to the SEC stating that climate change risk becomes very important to firms and the disclosure on that risk should be mandated and included in "securities laws and the Commission's rules" (CalPERS et al. 2007, page 8).

Starting from 2007, institutional investors and other stakeholders issued 26 petition letters lobbying the SEC to mandate climate change disclosure (Appendix A). They believed that the ability of investors to evaluate and price the effect of climate change risk depends on climate-related information disclosure (CalPERS et al. 2007; BCIMC 2009). 68 people and entities are signatories on the 26 petitions to the SEC. Politicians (38%) and institutional investors (37%) make up the majority of signatories—See Appendix B. All of the politicians are affiliated with the Democratic Party. The vast majority of them are State Controllers or Treasurers, who are generally the trustees of state pension funds, which

[7] As public interests in climate change increases significantly, regulations relating to this issue arise gradually. Clean Air Act (1963) is one of the firsts federal law to control air pollution in U.S. In 2007, Supreme Court classified carbon dioxide as an air pollutant, which enables EPA started to set new regulations on GHG emissions. EPA (2009) issued a proposed role to require mandatory GHG emission reporting for large emitting facilities.

makes their interests closely aligned to other institutional investors like CalPERS.

Institutional investors also lobbied Congress to pressure the SEC to regulate climate change disclosure. The U.S. Senate Banking Subcommittee on Securities, Insurance, and Investment held a hearing on "*Climate Disclosure: Measuring Financial Risks and Opportunities*" on October 31, 2007. Four witnesses who testified in the hearing believed that the SEC should promptly issue regulatory guidance and mandate firms to disclose the impact of climate change.[8] On December 6, 2007, Two Senators (Chris Dodd and Jack Reed) wrote a letter to SEC Chairman, Christopher Cox, demanding the SEC to issue guidance "to ensure that investors have access to material climate change information."[9] Both Chris Dodd and Jack Reed are Democrats and Christopher Cox is a Republican.

2.1.2 The year 2010: Dispute about the Guidance in the SEC

In spite of significant pressure from institutional investors and Congress, the SEC was unresponsive to demands for regulating climate change risk disclosure until 2009 when Mary Schapiro was appointed Chair. On January 15, 2009, Senator Chris Dodd and Senator Jack Reed wrote a second letter to the SEC, again calling for climate change disclosure regulation. One year later, on January 27, 2010, the guidance was passed by a slim margin, 3-2. Chair Mary Schapiro (Independent, but Democratic appointee), Commissioner Elisse Walter (Democratic), and Luis Aguilar (Democratic) voted in favor of the guidance, stating

[8] The four witnesses include Ms. Mindy Lubber (President of Ceres a sustainability activity organization), Mr. Russell Read (Chief Investment Officer, CalPERS), Mr. Jeffery Smith (Environmental Law Partner of Cravath, Swaine, and Moore LLP), and Dr. Gary Yohe (Professor of Economics & Environmental Studies, Wesleyan University). Please note that Cravath, Swaine, and Moore LLP is a New York and London based law firm.

[9] Chris Dodd is the Chair of Senate Committee on Banking, Housing, and Urban Affairs and Senator Jack Reed is Chair of Subcommittee on Securities, Insurance, and Investment. The letter is available to download at http://www.banking.senate.gov/public/index.cfm/2007/12/banking-committee-chairman-dodd-and-securities-subcommittee-chairman-reed-urge-sec-to-issue-guidance-on-disclosure-of-corporate-climate-risk

that the proposed disclosure requirement would help investors to get "reliable information" related to climate change risk and help "investors in their decision making." [10, 11] Commissioners Kathleen Casey (Republican) and Troy Paredes (Republican) who voted against the guidance argued, the regulation is totally "unnecessary" and "unrelated to investor protection". [12]

In summary, institutional investors and Democratic politicians play a key role in lobbying the SEC to regulate climate change disclosure. Eventually, the SEC passed the guidance with a party line vote, indicating the importance of political ideology and party politics in the legal process. This legislative process is consistent with interest group theory (Stigler 1971; Becker 1983; Scott 1997), which suggests that groups lobby for or against regulation in their own interest.

2.2 Summary of SEC 2010 Guidance

In the 2010 guidance, the SEC requires all publicly traded companies to disclose the following in their 10-K annual reports: (1) the impact of climate change legislation and regulation, (2) the impact of international accords on climate change, (3) the indirect consequences of regulation or business trends, and (4) the physical impacts of climate change. The guidance requires publicly traded companies to disclose climate change information in the following sections of their 10-K annual reports: (1) Item 101: Description of Business, (2) Item 103: Legal Proceedings, (3) Item 503: Risk Factors, and (4) Item 303: Management's Discussion and Analysis.[13]

[10] https://www.sec.gov/news/speech/2010/spch012710mls-climate.htm
[11] http://www.sec.gov/news/speech/2010/spch012710laa-climate.htm.
[12] https://www.sec.gov/news/speech/2010/spch012710klc-climate.htm
[13] See the SEC's Commission Guidance Regarding Disclosure Related to Climate Change, Final Rule, February 8, 2010, available at https://www.sec.gov/rules/interp/2010/33-9106fr.pdf

3. Theory, Literature, and Hypothesis Development

3.1 Climate Change Risk and Future Performance

Climate change risk may influence future performance in many ways. First, regulatory risk, i.e., emerging environmental regulations regarding climate change, can lead to significant increases in compliance and energy costs, adversely affecting future profitability. The Environmental Protection Agency (EPA) has issued a series of regulations on carbon emission that address climate change, since 2009.[14] Those regulations cost U.S. economy an estimated $353 billion annually (Young 2012). To meet the regulation requirements, firms direct more resources towards emission control, which increases operating costs and reduces profits. In addition, EPA regulations lead to significant increases in energy costs. The average retail electricity rate increases an estimated 11% to 14% annually, due in large part to the EPA's Clean Power Plan (NERA 2015).[15] At the state-level, Renewable Portfolio Standards (RPS) programs' Cap-and-Trade systems, and Carbon Tax Schemes were issued in 37 states to reduce carbon emission, significantly increasing corporate compliance, energy, and operating costs.[16, 17,]

[14] These regulations include "Clean Power Plan Rule", National Emission Standard for Hazardous Air Pollutants, "GHG Tailoring Rule (2010)" "Cross-State Air Pollution" "The National Program for Greenhouse Gas Emissions (GHG) and Fuel Economy Standards" "Prevention of Significant Deterioration"

[15] NERA Economic Consulting, 2015, Energy and Consumer Impacts of EPA's Clean Power Plan, http://www.americaspower.org/wp-content/uploads/2015/11/NERA-CPP-Final-Nov-7.pdf

[16] By 2016, 37 states have adopted or enacted mandatory RPS programs, requiring a certain percentage of renewable electricity generation (electric power comes from renewable sources) (NCSL, 2016). These new regulations force firms to seek renewable or clean energy supply. However, the cost of renewable energy is much higher than fossil fuel (e.g., Coal, Gasoline, and Natural Gas), thus, negatively impact firms' performance.

[17] Under the framework of "Global Warming Solutions Act" (2006), California launched a cap-and-trade program in 2012, which allows trade firms carbon emission allowance. California firms has paid 1.12 and 3.40 billion to buy the carbon emission credit in year 2014 and 2015, respectively, clearly increasing firms' operating costs. Details are available on https://www.arb.ca.gov/cc/capandtrade/auction/results_summary.pdf

In its 2013 10-K, Ford Motor Company stated:

"*If the agencies seek to impose and enforce extreme fuel economy or GHG standards in spite of unfavorable market conditions or inadequate technology development, we likely would be forced to take various actions that could have substantial adverse effects on our sales volume and profits.*"[19]

Costco Wholesale Corp. stated similar concerns in 2013 10-K:

"*Increased U.S. and foreign government and agency regulations to limit carbon dioxide and other greenhouse gas emissions may result in increased compliance costs and legislation or regulation affecting energy inputs that could materially affect our profitability.*"

Second, physical climate change risk (e.g., extreme weather) can interrupt normal operations and disrupt logistics and distribution (Lowitt 2014), increasing both operating and non-operating cost (e.g., repairing cost or replacement cost) (Risky Business Project 2016).[20]

Wal-Mart made a similar disclosure of the impact of physical climate change risk in its 2011 10-K:

"*The occurrence of one or more natural disasters, such as hurricanes, cyclones, typhoons, tropical storms, floods, earthquakes, tsunamis, weather conditions such as major or extended winter storms, droughts and tornados, whether as a result of climate change or otherwise, severe changes in climate and geo-political events in a country in which we operate or in which our suppliers are located could adversely affect our operations and financial performance.*"

[18] As of year 2016, California and some counties of Colorado, Maryland and Washington have implemented carbon tax, aiming at reduction of carbon emission. Moreover, based on a research from Institute of Energy Research (2009), this cap-and-trade program will increase significantly increase energy price.

[19] GHG means Greenhouse Gas.

[20] In a letter to SEC Secretary, Risky Business Project (2016) mentioned the following examples of how physical climate parameter affect U.S. economy. For example, "Agricultural companies: Extreme weather events, heat, and humidity can materially affect the industry's production efficiency and supply chain. Commercial and residential real estate: Sea level rise and increased storms are expected to have significant consequences on coastal property and infrastructure. Manufacturing industry: Dangerous levels of extreme heat and rising seas may cause large disruptions in supply chain operations and labor productivity—especially as many manufacturing plants are located in high-risk areas such as the Southeast."

Time Warner Cable Inc. explained the impact of physical climate change in their 2013 10-K:

"*TWC's network and information systems are also vulnerable to damage or interruption from power outages, natural disasters (including extreme weather arising from short-term weather patterns or any long-term changes)…. Any of these events could have an adverse impact on TWC and its customers, including degradation of service, service disruption, excessive call volume to call centers and damage to TWC's plant, equipment, data, and reputation.* "

Third, other risk related to climate change includes decreased consumers demand for goods or services with heavy greenhouse gas emissions, and potential reputation loss due to violating climate change regulations, emission activities, or negative public perception.[21] Clearly, reduced product demand will adversely affect firms' future earnings. Moreover, loss in reputation may lead to decreased product demand and induce tightened scrutiny, both of which adversely affect firms' operations.

FedEx mentioned the other risk of climate change in its 10-K of 2013:

"*Moreover, even without such regulation, increased awareness and any adverse publicity in the global marketplace about the GHGs emitted by companies in the airline and transportation industries could harm our reputation and reduce customer demand for our services, especially our air express services*."

Based on the descriptions provided by the corporations in their 10-Ks, it is clear that exposure to climate change risk (i.e., regulatory risk, physical climate change risk, and other risk) has adverse effects on the exposed firms. From this, I propose the following hypothesis:

H1: Firms with disclosed climate change risk have poorer future financial performance.

[21] One famous example of reputation loss due to climate change is Volkswagen emissions scandal (2015).

3.2 Climate Change Risk and Uncertainty

The extant literature in both accounting and economics emphasizes that the operational environment places multiple constraints upon the firm (Child 1972; Govindarajan 1984). The external environment can influence firms' information systems and organizational structure (Gordon and Narayanan 1984). Environmental uncertainty theory predicts that variances in earnings increase as external uncertainty increases (Milliken 1987). Ghosh and Olsen (2009) examine how environmental uncertainty impacts on earnings variance. Measuring environmental uncertainty with the variation of sales and analysts' forecast dispersion, they find a positive correlation between environmental uncertainty and earnings variance. Climate change risk—regulatory risk, physical risk, and other risk—creates external uncertainty (Chava 2014; Matsumura et al. 2014).

From the regulatory risk perspective, many policies relating to climate change are in their infancy which creates greater uncertainty. "During these early stages, climate change policy uncertainty is high, perhaps at its peak" (IEA 2007). Specifically, existing climate change regulation might be modified or newly adopted. Regulatory changes lead to varied requirements with different compliance costs. Since firm operations are subject to these regulations, greater climate regulation uncertainties may lead to higher earnings volatility and lower earnings persistence.

Alpha Natural Resources, Inc. described the effects of regulation uncertainty in its 2013 10-K:

"*Considerable uncertainty is associated with these GHG emissions initiatives. The content of new treaties or legislation is not yet determined and many of the new regulatory initiatives remain subject to review by the agencies or the courts.* "

Woodward Inc. stated the effects of regulation uncertainty in its 2014 10-K:

"*We expect the uncertainty regarding government renewable mandates and subsidies will contribute to continued volatility in the renewable energy industry*."

From the physical risk perspective, Blackrock (2015) suggests that weather patterns become harder to predict as climates become more extreme. Moreover, a changing climate makes natural disasters less predictable and exposes the firm's operations and supply chain to environmental uncertainty. Due to increasingly unpredictable weather patterns, physical climate change risk significantly affects firm operations, leading to more volatile and unpredictable earnings.

In its 2013 10-K, ARC Group Worldwide disclosed the impact of physical risk:

"*In addition, over the past several years, changing weather patterns and climatic conditions, such as global warming, have added to the unpredictability and frequency of natural disasters in certain parts of the world and created additional uncertainty as to future trends and exposures*."

The Federated National Holding Co states the uncertainty of physical risk in its 2014 10-K:

"*The occurrence of claims from catastrophic events could result in substantial volatility in our results of operations or financial condition for any fiscal quarter or year*."

From other risk perspective, the interaction between climate change and consumer behaviors, and business trends also brings higher uncertainty to firm operations.

As Pacific Ethanol stated the uncertainties generated from other climate change risk in its 2013 10-K:

"*Future demand for ethanol is uncertain and may be affected by changes to federal mandates, public perception, consumer acceptance and overall consumer demand for transportation fuel*."

Dichev and Tang (2009) investigate the relationship between earnings volatility and earnings predictability. They find that earnings predictability decreases when earnings volatility increases. In summary, potential regulation, unpredictable weather patterns, and

changes in consumer behaviors and business trends increase the uncertainty of firm operations, making earnings less predictable. Therefore, I propose the following hypothesis:

H2: Firms with disclosed climate change risk have lower earnings persistence.

3.3 Climate Change Risk and Market Reaction

Empirical research suggests that stock price reflects changes in investors' valuation of the firm (Lambert 1996; Holthausen and Watts 2001). Valuation theory also suggests firm performance (e.g., earnings, cash flows, and dividend policy) and risk are two determinants of stock price or firm value (Miller and Modigliani 1961; Lang and Stulz 1994; Ohlson 1995; Ohlson and Juettner-Nauroth 2005). More specifically, the stock price is positively correlated with firm performance and negatively correlated with firm risk. Using a theoretical model, Ohlson and Juettner-Nauroth (2005) find that expected EPS and EPS growth is positively correlated with stock price. Moreover, the prior literature suggests that one of the important determinants of firm risk is earnings persistence (Easton and Zmijewski 1989; Collins and Kothari 1989). As discussed in sections 3.1 and 3.2, firms that disclose climate change risk have poorer financial performance and lower earnings persistence, both of which lead to lower stock price. Since the guidance requires firms to disclose the climate change risk in annual reports (e.g. 10-Ks), I expect that market reaction to be more negative for firms with disclosed climate change risk during 10-K filing period.

Based on the above arguments, I propose the third hypothesis:

H3: Firms with disclosed climate change risk experience more negative market reaction, during 10-K filing period.

3.4 Climate Change Risk and Forward Earnings Responses Coefficients (FERC)

Prior literature (Collins and Kothari 1989; Teoh and Wong 1993; Teets and Wasley 1996; Lennox and Park 2006; Wilson 2008; Chan et al. 2012; Mian and

Sankaraguruswamy 2012) examines the relationship between earnings and contemporaneous return (current ERC). In my paper, I focus on the forward earnings responses coefficients, which means the relationship between future earnings and current returns. Climate change is usually consided as one type of exougenous shocks (Eboli et al. 2010; Leichenko 2011; Wheeler and Von Braun 2013). As Tucker and Zarowin (2006) demonstrate, a shock influences changes in future earnings but may not affect current earnings. Clearly, climate change is more related to future uncertainty and may affect FERC, not current ERC.

Following rational structural uncertainty theory, Brav and Heaton (2002) argue that investors usually places less weight on the more uncertain signals. Francis et al. (2007) examine the post-earnings-announcement-drift (PEAD) under the rational structural uncertainty theory. They find that PEAD could be partly explained by the higher information uncertainty of stocks. Consistent with the arguments in Brav and Heaton (2002) and Francis et al. (2007), firms that disclose climate change risk have future earnings with high information uncertainty. Thus, investors may place less weight on the future earnings information of these firms, leading to a lower FERC.

Based on the above arguments, I propose the fourth hypothesis:

H4: Firms with disclosed climate change risk have lower FERC.

4. Research Design

4.1 Sample Selection

On July 2014, a free web tool was created by Ceres and CookESG to provide the climate change disclosure excerpts from public firms' SEC filings.[22] Through this web tool,

[22] http://tools.ceres.org/resources/tools/sec-sustainability-disclosure/@@ceres-search-s3

the public can easily access and obtain the climate change disclosure information and according categories, including regulatory risk/impact, physical risk/impact, non-specific climate disclosure, and renewable energy/clean technology/energy efficiency. My initial sample of Russell 3000 index firms is taken from the Ceres and CookESG Research website from 2010 to 2014. The Russell 3000 index is comprised of 98% of the US equity market capitalization. 2010 is chosen as the initial year because the guidance is effective for fiscal years ending after February 8, 2010. I end the sample collection in 2014 because several of my forward-looking and financial data availability analyses end in 2015. In constructing the sample, I remove all financial service industries (SIC 6000-6999) observations since their financial reporting differ from non-financial firms. Next, I delete all observations with insufficient data to calculate the dependent and control variables. The final sample consists of 8,797 to 9,264 firm-year observations, depending on different models. This represents a 30.31% to 33.83% reduction from the initial sample.

4.2 Climate Change Risk Disclosure

4.2.1 Dichotomous Climate Change Risk

In the 2010 guidance, the SEC requires firms to disclose impact of legislation and regulation, international accord, indirect consequences of regulation or business trends, and physical impacts of climate change in firms' annual report. Since climate change risk refers to the risks driven by regulation, physical climate parameters and other climate-related development (CDP 2009; Matsumura et al. 2014), I manually classify the climate change disclosure into three risk categories: regulatory risk (including international or domestic regulation), physical risk, and other risk.

Regulatory Risk equals one if a firm reports being subject to climate change

regulation, which includes but is not limited to EPA's regulations, Clean Air Act, Renewable Energy Act, Paris Agreement, Kyoto Protocol, renewable portfolio standard (RPS), European Union Emission Trading System, Cross-State Air Pollution Rules, United Kingdom's Carbon Reduction Commitment, emissions trading schemes, and carbon tax or carbon fees, and zero otherwise. *Physical Risk* equals one if a firm reports being subject to a physical climate change risk, which includes but is not limited to floods, hurricanes, droughts, storms, water availability, extreme temperatures, temperatures change, severe weather, sea level change, or change of these weather conditions, and zero otherwise. *Other Risk* equals one if a firm reports being subject to other climate change risk, which includes but is not limited to business trends, changing consumer preference or behavior, potential reputation loss, and other climate change related matters, and zero otherwise. Climate Change Risk equals one if a firm discloses any climate change risk, including *Regulatory Risk*, *Physical Risk*, and *Other Risk*, and zero otherwise.

As this paper mentioned in Section 4.1, Ceres and CookESG Research provide four types categories of climate disclosure: non-specific climate disclosure, regulatory risk/impact, physical risk/impact, renewable energy/clean technology/energy efficiency. I do not directly use these provided categories as the proxy of climate change risk due to potential misclassification. First, the website consistently classifies certain keywords as some type of climate change risk but actually they are not. For example, it classifies "materially adversely affect/impact" as regulatory risk.[23] Again, even when a firm claims "*at this time we do not expect any of these new laws, regulations or activities to have a material adverse effect on our results of operations, financial condition or long-term*

[23] E.g., See the 10-K excerpt of annual report of AutoNation Inc (Ticker: AN) of year 2013.

liquidity," the website still classifies the firm as "regulatory risk".[24] Second, the website does not distinguish risk from opportunity. For example, Emcore Corp disclosed the following in its 2012 annual report: "*We believe the market for terrestrial solar power generation solutions will grow as solar power generation technologies improve in efficiency, as global prices for non-renewable energy sources (i.e., fossil fuels) continue to fluctuate, and as concern over the effects of fossil fuel-based carbon emissions on global warming grows*." One primary segment of this company is solar power generation. Clearly, this disclosure indicates climate change will bring opportunity for this firm. However, the website classifies this as "Non-Specific Climate Disclosure." Directly using "Non-Specific Climate Disclosure" as a measure of climate change risk is problematic.[25]

4.2.2 Descriptive Statistics of Climate Change Risk

Figure 1 reports the percentage of firms that disclose climate change risk in SEC 10K filing. From this figure, I find that over half of observations disclose at least one type of climate change risk. Among the three types of climate change risks, the most frequent risk is physical risk, followed by regulatory and other risk. Before 2014, there is a clear increasing trend of disclosure of climate change risk, indicating more firms realize the importance of the impact of climate change.

[24] This 10-K excerpt is from annual report of Owens Corning (Ticker: OC) of year 2012.
[25] In a robustness check, I also tried to use website provided categories as the measures of climate change risk. For example, I identify "regulatory risk/impact" as regulatory risk, "physical risk/impact" as physical risk, and "non-specific climate disclosure" as other risk. In general, I find qualitatively and quantitatively similar results.

Figure 1
Percentage of Firms that Disclose Climate Change Risk in SEC 10K filing

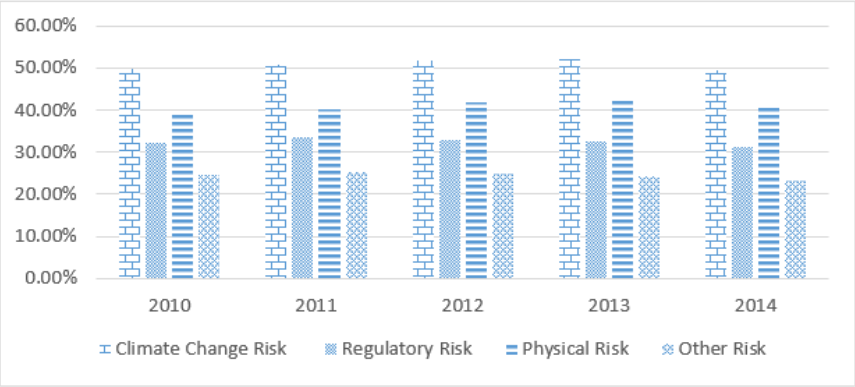
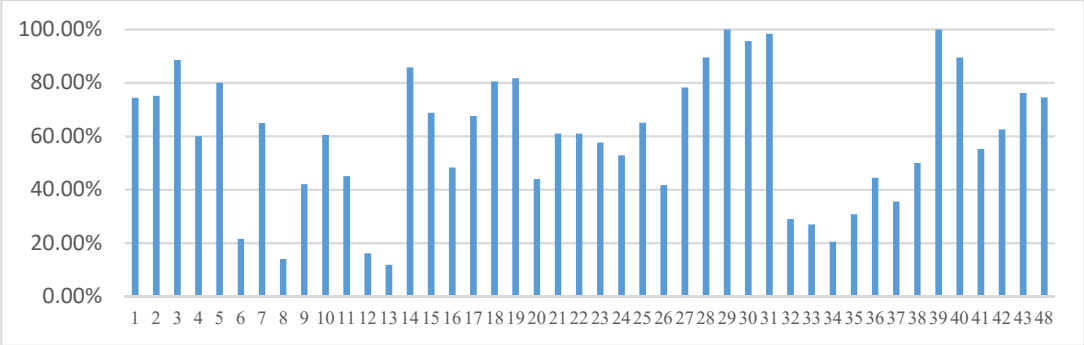


Figure 2
Percentage of Firms that Disclose Climate Change Risk by Fama-French Industry (2010-2014)



Code	Fama-French Industry	Percentage
1	Agriculture	74.36%
2	Food Products	75.12%
3	Candy & Soda	88.57%
4	Beer & Liquor	60.00%
5	Tobacco Products	80.00%
6	Recreation	21.57%
7	Entertainment	64.90%
8	Printing and Publishing	14.06%
9	Consumer Goods	42.07%
10	Apparel	60.43%
11	Healthcare	45.03%
12	Medical Equipment	16.14%
13	Pharmaceutical Products	11.80%
14	Chemicals	85.71%
15	Rubber and Plastic Products	68.75%
16	Textiles	48.28%
17	Construction Materials	67.54%
18	Construction	80.51%
19	Steel Works Etc	81.68%
20	Fabricated Products	44.00%
21	Machinery	60.97%
22	Electrical Equipment	60.93%

Code	Fama-French Industry	Percentage
23	Automobiles and Trucks	57.65%
24	Aircraft	52.86%
25	Shipbuilding, Railroad Equipment	65.00%
26	Defense	41.67%
27	Precious Metals	78.26%
28	Non-Metallic and Industrial Metal Mining	89.47%
29	Coal	100.00%
30	Petroleum and Natural Gas	95.53%
31	Utilities	98.30%
32	Communication	29.01%
33	Personal Services	26.97%
34	Business Services	20.43%
35	Computers	30.82%
36	Electronic Equipment	44.43%
37	Measuring and Control Equipment	35.55%
38	Business Supplies	50.00%
39	Shipping Containers	100.00%
40	Transportation	89.50%
41	Wholesale	55.21%
42	Retail	62.50%
43	Restaurants, Hotels, Motels	76.17%
48	Other	74.51%

Figure 2 reports the percentage of firms that disclose climate change risk by Fama-French 48-industry. The five lowest climate change risk industries are pharmaceutical products, printing and publishing, medical equipment, business services, and recreation. On the contrary, the five highest climate change risk industries are coal, shipping containers, utilities, petroleum and natural gas, and transportation. The considerable variance of climate change risk across Fama-French industries suggests the need for controlling industry fixed effects. In addition, this big variation in climate change risk across Fama-French industries is generally consistent with my expectation: climate sensitive and heavy emission industries are more likely to disclose climate change risk in their annual reports.

4.2.3 Fog Index of Climate Change Disclosure

To further investigate the effects of the readability of climate change disclosure on the dependent variables, following Li (2008) and Lehavy et al. (2011), I measure the readability of climate change disclosure texts (obtained via Ceres and CookESG Research) using fog index:

Fog Index = 0.4*(Average words per sentence + Percent of complex words) (1)

where the complex word refers to one with three or more syllables. Higher fog index thus indicates less readability. Fog index is scaled by 100 for ease of interpretation of coefficients.

5. Tests and Results

5.1 Climate Change Risk and Future Performance

To test Hypothesis 1, I follow Gunny (2010) and estimate two equations to determine the relation between climate change and future performance. Model (2) is shown below:

$$AdjROA_{t+1} = a_0 + a_1 Climate\ Change\ Risk\ Measures_t + a_2 AdjROA_t + a_3 Ln\ (Assets)_t + a_5 Return_t + a_6 Z\text{-}Score_{t-1} + IND + YEAR + \varepsilon_{t+1} \quad (2)$$

where t refers to the fiscal year. There are four climate change risk measures as defined above: *Climate Change Risk*, *Regulatory Risk*, *Physical Risk*, and *Other Risk*. $AdjROA_t$ is the industry-adjusted *ROA*, which equals firm-specific *ROA* minus the median *ROA* for firms in the same Fama-French 48 industry and year.[26] Following Gunny (2010), this paper uses industry-median adjusted to control the performance variances related to industry characteristics. *ROA* is calculated as income before extraordinary items (*IB*) divided by lagged total assets (*AT*). *Ln(ASSETS)* is the natural logarithm of total assets (*AT*). *MB* is the market to book ratio, which equals the market value of equity divided by book value of equity (*CEQ*). *Return* is the buy-and-hold return in year t. *Z-Score* is a financial health measure. To control for industry and year fixed effects, I also include industry and year indicators.

As discussed in Section 3.1, the effective or proposed regulations could lead to additional compliance costs, adversely affecting firms profit margins (net income/net sales). Moreover, new legislation related to climate change may also influence the demand for current products (e.g., fossil fuels or gasoline car), which affects assets turnover (net sales/total assets). Extreme weather also interrupts firms' normal operation, logistics, and

[26] Using two digit SIC industry code does not change the results.

distribution, which increases operating cost and decreases assets turnover ratio. To further exploit the channels between climate change risk and future performance, following DuPont analysis, I decompose ROA into two parts: *Profit Margin* and *Assets Turnover*, and replace ROA with these two parts in the following model (3):

$$AdjProfit\ Margin_{t+1} \text{ or } AdjAssetsTurnover_{t+1} = a_0 + a_1 Climate\ Change\ Risk\ Measures_t + a_2 AdjProfit\ Margin_t \text{ or } AdjAssetsTurnover_t + a_3 Ln\ (Assets)_t + a_4 MB_t + a_5 Return_t + a_6 Z\text{-}Score_{t-1} + IND + YEAR + \varepsilon_{t+1} \quad (3)$$

Panel A Table 1 reports the descriptive statistics of the main variables, including dependent, independent, and control variables. The mean and median of $AdjROA_{t+1}$ are 0.002 and 0.001, respectively. Approximately 52.5% of the firm-year observations in my sample disclose at least one type of climate change risk (*Climate Change Risk*). 33.8%, 42.4% and 25.5% of firm-year observations have regulatory, physical risk, and other risk related to climate change, respectively. With regard to the control variables, on average, firms have *Assets* of $5455.34 million (untabulated), $Ln\ (Assets)_t$ of 7.230, Market to Book ratio (*MB*) of 3.387, *Return* of 0.226, and Z-score of 1.243, respectively. The descriptive statistics are quantitatively similar to the previous studies (e.g., Gunny 2010).

Table 1
Climate-Change Risk and Future Performance

This table presents the regression results of the impact of climate change risk on future performance. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A Descriptive Statistics

Variables	N	Mean	SD	25%	Median	75%
$AdjROA_{t+1}$	9,132	0.002	0.066	-0.036	0.001	0.042
$AdjProfit\ Margin_{t+1}$	9,132	0.001	0.086	-0.040	0.000	0.051
$AdjAssets\ Turnover_{t+1}$	9,132	0.091	0.401	-0.214	0.005	0.342
Climate Change Risk	9,132	0.525	0.499	0.000	1.000	1.000
Regulatory Risk	9,132	0.338	0.473	0.000	0.000	1.000
Physical Risk	9,132	0.424	0.494	0.000	0.000	1.000
Other Risk	9,132	0.255	0.436	0.000	0.000	1.000
Fog Index	4,793	0.244	0.082	0.197	0.238	0.314
$AdjROA_t$	9,132	0.003	0.146	-0.034	0.001	0.043
$AdjProfit\ Margin_t$	9,132	-0.214	1.615	-0.038	0.001	0.050
$AdjAssets\ Turnover_t$	9,132	0.126	0.618	-0.231	0.001	0.345
$Ln\ (Assets)_t$	9,132	7.230	1.730	5.945	7.147	8.415
MB_t	9,132	3.387	5.286	1.436	2.300	3.934
$Return_t$	9,132	0.226	0.523	-0.068	0.138	0.392
$Z\text{-}Score_{t-1}$	9,132	1.243	2.661	0.675	1.547	2.529

The results of the impact of climate change risk on future performance are reported in Table 1, Panel B. The variables of primary interest in Panel B are climate change risk variables: *Climate Change Risk*, *Regulatory Risk*, *Physical Risk*, and *Other Risk*. Column (1) finds that *Climate Change Risk* is negatively related to future performance (coefficient =-0.002, t=-2.02). It means, compared to firms without disclosed climate change risk, the $AdjROA_{t+1}$ of firms with disclosed climate change risk is -0.002 lower, which equals 100% of the sample mean of $AdjROA_{t+1}$, which is also 0.002. The economic significance is non-trivial. Columns (2) – (4) indicate that *Regulatory Risk*, *Physical Risk*, and *Other Risk* are negatively associated with future performance as well. Taken together, these results are consistent with hypothesis 1 that firms with disclosed climate change risk have poorer

future performance.

Table 1(continued)

Panel B Climate-Change Risk and Future Performance

		(1)	(2)	(3)	(4)
Variables	*Pred.*	$AdjROA_{t+1}$	$AdjROA_{t+1}$	$AdjROA_{t+1}$	$AdjROA_{t+1}$
Climate Change Risk	-	-0.002**			
		(-2.02)			
Regulatory Risk	-		-0.005***		
			(-3.90)		
Physical Risk	-			-0.002*	
				(-1.68)	
Other Risk	-				-0.003**
					(-1.98)
$AdjROA_t$	+	0.235***	0.235***	0.235***	0.235***
		(29.99)	(29.95)	(30.01)	(30.00)
$Ln\ (Assets)_t$	+	0.001**	0.001***	0.001**	0.001**
		(2.56)	(3.00)	(2.43)	(2.55)
MB_t	+	0.001***	0.001***	0.001***	0.001***
		(5.44)	(5.41)	(5.44)	(5.45)
$Return_t$	+	0.015***	0.015***	0.015***	0.015***
		(10.39)	(10.42)	(10.40)	(10.39)
$Z\text{-}Score_{t-1}$	+	0.004***	0.004***	0.004***	0.004***
		(8.44)	(8.40)	(8.43)	(8.40)
Intercept		-0.001	-0.002	-0.002	-0.002
		(-0.19)	(-0.33)	(-0.22)	(-0.35)
IND/YEAR		YES	YES	YES	YES
No. of observations		9,132	9,132	9,132	9,132
Adj. R^2		0.416	0.416	0.416	0.416

Table 1 (continued)

Panel C Climate Change Risk and Future Performance

Variables	*Pred.*	(1) *AdjProfit Margin$_{t+1}$*	(2) *AdjProfit Margin$_{t+1}$*	(3) *AdjProfit Margin$_{t+1}$*	(4) *AdjProfit Margin$_{t+1}$*	(5) *AdjAssets Turnover$_{t+1}$*	(6) *AdjAssets Turnover$_{t+1}$*	(7) *AdjAssets Turnover$_{t+1}$*	(8) *AdjAssets Turnover$_{t+1}$*
Climate Change Risk	-	-0.003*				0.007			
		(-1.91)				(1.20)			
Regulatory Risk	-		-0.009***				0.009		
			(-4.66)				(1.46)		
Physical Risk	-			-0.002				-0.003	
				(-1.27)				(-0.52)	
Other Risk	-				-0.005***				-0.003
					(-2.80)				(-0.47)
AdjProfit Margin$_t$	+	0.012***	0.012***	0.012***	0.012***				
		(17.07)	(17.05)	(17.05)	(17.04)				
AdjAssets Turnover$_t$	+					0.501***	0.501***	0.501***	0.501***
						(63.57)	(63.59)	(63.59)	(63.66)
Ln (Assets)$_t$	+	0.012***	0.012***	0.012***	0.012***	-0.032***	-0.032***	-0.031***	-0.031***
		(22.00)	(22.34)	(22.02)	(22.12)	(-19.33)	(-19.37)	(-19.25)	(-19.01)
MB$_t$	+	0.001***	0.001***	0.001***	0.001***	0.001*	0.001*	0.001*	0.001*
		(3.52)	(3.48)	(3.53)	(3.53)	(1.92)	(1.93)	(1.90)	(1.90)
Return$_t$	+	0.022***	0.022***	0.022***	0.022***	0.012**	0.012**	0.012**	0.012**
		(11.66)	(11.68)	(11.66)	(11.64)	(2.09)	(2.08)	(2.08)	(2.07)
Z-Score$_{t-1}$	+	0.010***	0.010***	0.010***	0.010***	0.015***	0.015***	0.015***	0.015***
		(19.44)	(19.33)	(19.43)	(19.37)	(7.75)	(7.77)	(7.75)	(7.73)
Intercept		-0.082***	-0.083***	-0.082***	-0.083***	0.206***	0.208***	0.210***	0.209***
		(-7.01)	(-7.20)	(-7.06)	(-7.18)	(5.55)	(5.60)	(5.64)	(5.63)
IND/YEAR		YES	YES	YES	YES	YES	YES	YES	YES
No. of observations		9,132	9,132	9,132	9,132	9,132	9,132	9,132	9,132
Adj. R^2		0.250	0.251	0.250	0.250	0.708	0.708	0.708	0.708

In Model (3), I decompose ROA into profit margin and assets turnover and report the results in Table 1, Panel C. Column (1) reports the results of regressing *AdjProfit Margin$_{t+1}$* on Climate Change Risk. The results show that climate change risk has a significantly adverse effect on *AdjProfit Margin$_{t+1}$*, suggesting firms with disclosed climate change risk have lower future profit margins. The results in Columns (2) to (4) confirm the findings in Column (1). The results for asset turnover, reported in Columns (5) to (8) are all insignificant. In summary, it appears that the negative relation between climate change risk and future ROA are primarily a function of declining profit margins rather than declining asset turnovers. As the hypotheses development part shows, most of the effects from climate change risk on earnings are cost or expenditure-related. For example,

governmental regulation relating GHG could increase compliance expense and energy cost, which could reduce the gross profit margins but might not influence assets turnover. Physical climate change risk increases operating and non-operating cost of firms, which is also related to profit margins.

Table 1 (continued)

Panel D Readability of Climate Change Risk Disclosure and Future Performance

		(1)	(2)	(3)
Variables	*Pred.*	$AdjROA_{t+1}$	$AdjProfit\ Margin_{t+1}$	$AdjAssets\ Turnover_{t+1}$
Fog Index	-	-0.013*	-0.043***	-0.202***
		(-1.75)	(-3.62)	(-5.44)
$AdjROA_t$	+	0.396***		
		(24.44)		
$AdjProfit\ Margin_t$	+		0.029***	
			(4.57)	
$AdjAssets\ Turnover_t$	+			0.501***
				(42.85)
$Ln\ (Assets)_t$	+/-	0.000	0.010***	-0.031***
		(1.09)	(13.52)	(-13.13)
MB_t	+	0.002***	0.003***	0.004***
		(8.37)	(7.24)	(3.64)
$Return_t$	+	0.018***	0.023***	0.032***
		(9.50)	(8.78)	(3.80)
$Z\text{-}Score_{t-1}$	+	0.006***	0.009***	0.013***
		(8.70)	(9.67)	(3.29)
Intercept		-0.005	-0.073***	0.255***
		(-0.57)	(-5.76)	(5.11)
IND/YEAR		YES	YES	YES
No. of observations		4793	4793	4793
Adj. R^2		0.460	0.193	0.741

Panel D of Table 1 reports the relation between readability of climate change risk disclosure texts and future performance in the disclosing subsample. The results show that *Fog Index* is negatively correlated with $AdjROA_{t+1}$, $AdjProfit\ Margin_{t+1}$, and $AdjAssets\ Turnover_{t+1}$ for disclosing firms. Overall, the results are consistent with managerial obfuscation hypothesis (Li 2008). Managers are inclined to obfuscate information in the 10-K when their firms have lower expected future performance, thus increasing the

information process cost to investors. In contrast, companies with better future performance are likely to have more readable annual reports, distinguishing them from other less readable peers.

5.2 Climate Change Risk and Earnings Persistence

Following Li (2008), this paper constructs a model to test hypothesis 2 regarding the relation between earnings persistence and the measures of climate change risk.

$$\begin{aligned} ROA_{t+1} &= a_0 + a_1 Climate\ Change\ Risk\ Measures_t + a_2 ROA_t \\ &+ a_3 Climate\ Change\ Risk\ Measures_t * ROA_t + a_4 Ln\ (MV)_t + a_5 MB_t \\ &+ a_6 DIV_t + a_7 STD(ROA)_t + a_8 STD(RET)_t + a_9 Firm\ Age_t \\ &+ a_{10} SI_t + a_{11} M\&A_t + a_{12} DE_t + IND + YEAR + \varepsilon_{t+1} \end{aligned} \quad (4)$$

where t refers to the fiscal year. *Ln(MV)* is the natural logarithm of market value in the fiscal year end. *MB* is market to book ratio. *DIV* is an indicator variable that equals one if a firm distributes dividend (DVT) in fiscal year t, and zero otherwise. *STD(ROA)* equals the standard deviation of the ROA in the last five fiscal years. *STD(RET)* equals the standard deviation of the monthly stock returns (RET) in the year t-1, *Firm Age* is the natural logarithm of the number of years since a firm appears in Compustat. *SI* equals special items (SPI) divided by lagged total assets (AT). *M&A* is an indicator variable that equals one if the firm is involved in mergers or acquisitions (AQC), and zero otherwise. *DE* is an indicator variable that equals one if a firm is incorporated in Delaware in fiscal year t, and zero otherwise.

Table 2
Climate Change Risk and Earnings Persistence

This table presents the regression results of the impact of climate change risk on earnings persistence. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A Descriptive Statistics

Variables	N	Mean	SD	25%	Median	75%
ROA_{t+1}	9,126	0.023	0.154	0.007	0.047	0.089
Climate Change Risk	9,126	0.521	0.500	0.000	1.000	1.000
Regulatory Risk	9,126	0.333	0.471	0.000	0.000	1.000
Physical Risk	9,126	0.421	0.494	0.000	0.000	1.000
Other Risk	9,126	0.251	0.433	0.000	0.000	1.000
Fog Index	4,757	0.288	0.215	0.197	0.238	0.316
ROA	9,126	0.025	0.169	0.011	0.049	0.092
Ln(MV)	9,126	7.325	1.565	6.157	7.213	8.406
MB	9,126	3.391	5.301	1.450	2.331	3.996
DIV	9,126	0.491	0.500	0.000	0.000	1.000
STD(ROA)	9,126	0.089	0.158	0.019	0.040	0.089
STD(RET)	9,126	0.102	0.052	0.065	0.092	0.127
Firm Age	9,126	3.011	0.736	2.485	2.996	3.638
SI	9,126	-0.004	0.660	-0.013	-0.003	0.000
M&A	9,126	0.467	0.499	0.000	0.000	1.000
DE	9,126	0.653	0.476	0.000	1.000	1.000

Panel A Table 2 reports the descriptive statistics of the main variables, including dependent, independent, and control variables. Table 2, Panel B, reports the relation between climate change risk and earnings persistence. Consistent with hypothesis 2, the results in column (1) find that firms with disclosed climate change risk have lower earnings persistence than firms without (coefficient = -0.069, t = -1.96). This result suggests that climate change risk introduces uncertainty into a firm's earnings, making future earnings less predictable. Columns (2) - (4) consistently show similar evidence. I also examine the economic significance of climate change risk on earnings persistence. Compared to firms without disclosed climate change risk, the earnings persistence of firms with disclosed

climate change risk is 12.54% lower.[27] This demonstrates that climate change risk has a significant economic impact on earnings persistence.

Next, I examine the relation between climate change risk disclosure readability on earnings persistence. The results reported in Panel C in Table 3 find that the coefficients on ROA_t * *Fog Index* are significantly negative columns (1), indicating that firms with lower readability in climate change risk disclosure have lower earnings persistence. These results are consistent with Li (2008), who finds that firms with less readable 10-Ks have lower earnings persistence.

[27] The economic significance equals 0.069/(0.619-0.069))=12.54%

Table 2 (continued)

Panel B Climate Change Risk and Earnings Persistence

		(1)	(2)	(3)	(4)
Variables	*Pred.*	ROA_{t+1}	ROA_{t+1}	ROA_{t+1}	ROA_{t+1}
ROA_t	+	0.619***	0.614***	0.608***	0.610***
		(34.01)	(35.76)	(33.28)	(35.27)
Climate Change Risk	?	0.001			
		(0.36)			
ROA_t *Climate Change Risk	-	-0.069**			
		(-1.96)			
Regulatory Risk			0.001		
			(0.14)		
ROA_t * Regulatory Risk	-		-0.110**		
			(-2.26)		
Physical Risk				-0.001	
				(-0.50)	
ROA_t * Physical Risk	-			-0.029	
				(-0.79)	
Other Risk					0.002
					(0.79)
ROA_t * Other Risk	-				-0.102**
					(-2.57)
Ln(MV)	+	0.005***	0.005***	0.005***	0.005***
		(6.86)	(7.00)	(6.58)	(6.77)
MB	+	0.001***	0.001***	0.001***	0.001***
		(3.12)	(3.01)	(3.10)	(3.07)
DIV	+	0.002	0.003	0.002	0.003
		(1.14)	(1.28)	(1.13)	(1.26)
STD(ROA)	-	-0.055***	-0.056***	-0.057***	-0.056***
		(-3.27)	(-3.36)	(-3.35)	(-3.35)
STD(RET)	-	-0.173***	-0.171***	-0.173***	-0.171***
		(-4.64)	(-4.59)	(-4.63)	(-4.59)
Firm Age	?	-0.000	-0.000	-0.000	-0.000
		(-0.24)	(-0.18)	(-0.24)	(-0.28)
SI	-	-0.008***	-0.008***	-0.008***	-0.008***
		(-3.61)	(-3.61)	(-3.51)	(-3.53)
M&A	-	-0.003	-0.003	-0.002	-0.003
		(-1.37)	(-1.37)	(-1.30)	(-1.38)
DE	-	-0.006***	-0.005**	-0.005***	-0.005***
		(-2.66)	(-2.55)	(-2.61)	(-2.60)
Intercept		0.031***	0.028**	0.032***	0.029**
		(2.64)	(2.50)	(2.77)	(2.57)
IND/YEAR		YES	YES	YES	YES
No. of observations		9,126	9,126	9,126	9,126
Adj. R^2		0.631	0.631	0.630	0.631

Table 2 (continued)

Panel C Readability of Climate-Change Risk Disclosure and Earnings Persistence

		(1)
Variables	*Pred.*	ROA_{t+1}
ROA_t	+	0.665***
		(28.04)
Fog Index	?	-0.004
		(-0.80)
ROA_t * *Fog Index*	-	-0.146*
		(-1.89)
Ln(MV)	+	0.002***
		(2.80)
MB	+	0.002***
		(7.08)
DIV	+	-0.001
		(-0.25)
STD(ROA)	-	-0.060***
		(-3.60)
STD(RET)	-	-0.165***
		(-5.77)
Firm Age	?	0.001
		(0.35)
SI	-	-0.305***
		(-15.20)
M&A	-	-0.005**
		(-2.23)
DE	-	-0.003
		(-1.53)
Intercept		0.049***
		(3.15)
IND/YEAR		YES
No. of observations		4,757
Adj. R^2		0.489

5.3 Climate Change Risk and Market Reaction

To test hypothesis 3, I follow Loughran and McDonald (2011) and construct the following model (5) to quantify the market's reaction to climate change risk disclosure:

$$CAR[-2,2] = a_0 + a_1 Climate\ Change\ Risk\ Measures_t + a_2 Ln\ (MV)_t + a_3 MB_t + a_4 PRE\_FF_t + a_5 AB\_EPS_t + a_6 Turnover_t + a_7 NASDAQ_t + a_8 INST\_OWN_t + a_9 Reporting\ Lag_t + a_{10} Forecast\ Dis_t + IND + YEAR + \varepsilon_t \quad (5)$$

where t refers to the fiscal year, *CAR[-2,2]* is the 5 day cumulative abnormal return around the 10-K filing date. *DIV* is an indicator variable that equals one if a firm distributes dividend (Compustat: DVT) in fiscal year t, and zero otherwise. *PRE_FF* is the prefile date

Fama-French alpha based on the three-factor model using days [-252, -6] (Tetlock et al. 2008). *AB_EPS* is earning surprise, which equals current EPS minus last year's EPS scaled by the prior year's stock price. Turnover is the natural logarithm of shares traded in days [-252, -6] divided by shares outstanding on the 10-K filing date. $NASDAQ_t$ is an indicator variable equal to one if the company is listed on NASDAQ stock exchange, and zero otherwise. $Reporting\ Lag_t$ is the natural logarithm of the number of days between fiscal year end and the 10-K filing date. $Forecast\ Dis_t$ is the standard deviation of analysts' forecast in fiscal year *t*.

Table 3
Climate Change Risk and Market Reaction

This table presents the regression results of the impact of climate change risk on market reaction around 10K filing date. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A Descriptive Statistics

Variables	N	Mean	SD	25%	Median	75%
CAR[-2,2]	8,797	0.003	0.063	-0.023	0.001	0.027
Climate Change Risk	8,797	0.534	0.499	0.000	1.000	1.000
Regulatory Risk	8,797	0.343	0.475	0.000	0.000	1.000
Physical Risk	8,797	0.432	0.495	0.000	0.000	1.000
Other Risk	8,797	0.258	0.438	0.000	0.000	1.000
Fog Index	4,701	0.287	0.212	0.197	0.238	0.315
Ln(MV)	8,797	7.378	1.551	6.209	7.266	8.458
MB	8,797	3.374	5.315	1.456	2.330	3.971
PRE_FF	8,797	0.004	0.069	-0.033	0.003	0.040
AB_EPS	8,797	0.015	0.116	-0.014	0.006	0.027
Turnover	8,797	1.083	0.451	0.769	1.038	1.360
NASDAQ	8,797	0.482	0.500	0.000	0.000	1.000
Reporting Lag	8,797	3.800	0.325	3.583	3.829	4.043
Forecast Dis	8,797	0.012	0.019	0.002	0.006	0.013

Panel A, Table 3, reports the descriptive statistics of the main variables, including dependent, independent, and control variables. Panel B of Table 3 reports the relation between climate change risk and the market reaction around the 10-K filing date (Column

(1)). The results show that the market reaction to disclosing firms is significantly negative when compared to firms that do not disclose. More specially, the coefficient on *Climate Change Risk* is negative and significant (coefficient = -0.002, t =-1.68). Regarding economic significance, the *CAR[-2,2]* of firms with disclosed climate change risk is -0.002 lower than that of the firm without disclosed climate change risk, which is 66.7% of the mean of *CAR[-2,2]* of the full sample (recall, mean *CAR[-2,2]* = 0.003). Overall, the results support my hypothesis 3, which suggests firms with disclosed climate change risk have lower stock market return.

Table 3 (continued)

Panel B Climate Change Risk and Market Reaction

		(1)	(2)	(3)	(4)
Variables	*Pred.*	*CAR[-2,2]*	*CAR[-2,2]*	*CAR[-2,2]*	*CAR[-2,2]*
Climate Change Risk	-	-0.002*			
		(-1.68)			
Regulatory Risk	-		-0.005***		
			(-3.59)		
Physical Risk	-			-0.003*	
				(-1.84)	
Other Risk	-				-0.005***
					(-3.52)
Ln(MV)	+	-0.001**	-0.001**	-0.001**	-0.001**
		(-2.48)	(-2.14)	(-2.48)	(-2.15)
MB	-	-0.000	-0.000	-0.000	-0.000
		(-0.59)	(-0.72)	(-0.59)	(-0.66)
PRE_FF	+	0.034**	0.033**	0.034**	0.033**
		(2.47)	(2.42)	(2.47)	(2.40)
AB_EPS	+	0.025***	0.025***	0.025***	0.025***
		(3.01)	(3.02)	(3.01)	(3.02)
Turnover	-	-0.001	-0.001	-0.001	-0.001
		(-0.39)	(-0.36)	(-0.38)	(-0.36)
NASDAQ	+	-0.001	-0.002	-0.001	-0.002
		(-0.75)	(-1.28)	(-0.69)	(-1.15)
Reporting Lag	-	0.001	0.001	0.001	0.001
		(0.34)	(0.45)	(0.41)	(0.48)
Forecast Dis	-	-0.044	-0.040	-0.045	-0.041
		(-0.79)	(-0.71)	(-0.80)	(-0.73)
Intercept		0.014	0.012	0.013	0.012
		(1.20)	(1.07)	(1.12)	(1.02)
IND/YEAR		YES	YES	YES	YES
No. of observations		8,797	8,797	8,797	8,797
Adj. R^2		0.010	0.010	0.010	0.010

Table 3 (continued)

Panel C Readability of Climate Change Risk Disclosure and Market Reaction

		(1)
	Pred.	*CAR[-2,2]*
Fog Index	-	-0.004
		(-1.39)
Ln(MV)	+	-0.001
		(-1.58)
MB	-	0.000
		(0.72)
PRE_FF	+	0.039***
		(2.90)
AB_EPS	+	0.022**
		(2.46)
Turnover	-	-0.000
		(-0.08)
NASDAQ	+	0.001
		(0.36)
Reporting Lag	-	0.002
		(0.76)
Forecast Dis	-	-0.040
		(-0.56)
Intercept		-0.013
		(-0.73)
IND/YEAR		YES
No. of observations		4,701
Adj. R^2		0.010

Panel C of Table 3 shows the relation between readability of climate change risk disclosure texts and market reaction in the disclosing subsample. The coefficient of Fog Index is -0.004 and T value is -1.39, which indicate the significance under one-tailed test. I find that firms with less readable climate change disclosure experience lower market reaction around 10-K filing date. These results are consistent with De Franco et al. (2015) who find that the stock market reacts more favorably to analyst reports with higher readability. My results are also in line with previous theoretical work that suggests signals that are more informative are easier to interpret and induce larger stock market reaction (Kim and Verrecchia 1991).

5.4 Climate Change Risk and Forward Earnings Responses Coefficients (FERC)

To test the hypothesis 4, following previous studies (Collins et al. 1994; Lundholm and Myers 2002; Ettredge et al 2005; Tucker and Zarowin 2006; Orpurt and Zang 2009; Choi et al. 2011; Hribar et al. 2014), this paper constructs the following model (6) as forward earnings responses (FERC) test.

$$
\begin{aligned}
R_t = {} & a_0 + a_1 X_{t-1} + a_2 X_t + a_3 X_{t+1} + a_4 R_{t+1} + a_5 \textit{Climate Change Risk Measures}_t \\
& + a_6 \textit{Climate Change Risk Measures}_t * X_{t-1} \\
& + a_7 \textit{Climate Change Risk Measures}_t * X_t \\
& + a_8 \textit{Climate Change Risk Measures}_t * X_{t+1} \\
& + a_9 \textit{Climate Change Risk Measures}_t * R_{t+1} + a_{10} Ln(MV) + a_{11} Ln(MV) * X_{t+1} \\
& + a_{12} LOSS + a_{13} LOSS * X_{t+1} + a_{12} \textit{Size Growth} + a_{13} \textit{Size Growth} * X_{t+1} \\
& + a_{14} EARNSTD + a_{15} EARNSTD * X_{t+1} + IND + YEAR + \varepsilon_{t+1} \qquad (6)
\end{aligned}
$$

where t refers to the fiscal year, R_t and R_{t+1} are the annual stock returns measured over the 12-months ending three months after the firm's fiscal year-end at t and t+1, respectively. X_{t-1}, X_t, and X_{t+1} are income available to common shareholders before extraordinary items for years t-1, t, and t+1, respectively, each deflated by the market value of equity three months after the end of fiscal year t-1. *LOSS* is an indicator variable equal to one if X_{t+1} is negative, and zero otherwise. *EARNSTD* equals the standard deviation of *X* from year t-1 to year t+1. If a_8 is negative, firms with disclosed climate change risk have lower forward earnings response coefficients (*FERC*), and hypothesis 4 will be supported.

Table 4
Climate Change Risk and Forward Earnings Responses Coefficients (FERC)

This table presents the regression results of the impact of climate change risk on forward earnings responses coefficients(FERC). Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A Descriptive Statistics

Variables	N	Mean	SD	25%	Median	75%
R_t	9,264	0.216	0.549	-0.080	0.127	0.374
Climate Change Risk	9,264	0.519	0.500	0.000	1.000	1.000
Regulatory Risk	9,264	0.334	0.472	0.000	0.000	1.000
Physical Risk	9,264	0.419	0.493	0.000	0.000	1.000
Other Risk	9,264	0.252	0.434	0.000	0.000	1.000
Fog Index	3,767	0.277	0.167	0.196	0.236	0.310
X_{t-1}	9,264	0.006	0.134	0.002	0.037	0.059
X_t	9,264	0.011	0.132	0.009	0.043	0.064
X_{t+1}	9,264	0.009	0.147	0.005	0.046	0.068
R_{t+1}	9,264	0.134	0.494	-0.145	0.072	0.300
Ln(MV)	9,264	7.302	1.602	6.109	7.205	8.425
LOSS	9,264	0.221	0.415	0.000	0.000	0.000
Size Growth	9,264	0.298	0.649	0.003	0.136	0.353
EARNSTD	9,264	0.153	0.742	0.019	0.040	0.092

Table 4 (continued)

Panel B Climate Change Risk and Forward Earnings Responses Coefficients (FERC)

	Pred.	(1) R_t	(2) R_t	(3) R_t	(4) R_t
X_{t-1}	-	-0.216**	-0.372***	-0.295***	-0.439***
		(-2.09)	(-4.14)	(-3.23)	(-5.29)
X_t	+	0.200*	0.259**	0.210**	0.264***
		(1.70)	(2.53)	(1.99)	(2.75)
X_{t+1}	+	0.758**	0.793**	0.789**	0.787**
		(2.13)	(2.22)	(2.23)	(2.23)
R_{t+1}	?	-0.091***	-0.087***	-0.090***	-0.085***
		(-4.26)	(-4.44)	(-4.44)	(-4.53)
Climate Change Risk	?	-0.019			
		(-1.36)			
Climate Change Risk $*X_{t-1}$	?	-0.999***			
		(-5.51)			
Climate Change Risk $*X_t$	?	0.261			
		(1.51)			
Climate Change Risk $*X_{t+1}$	-	-0.021**			
		(-2.27)			
Climate Change Risk $*R_{t+1}$	?	0.036			
		(1.16)			
Regulatory Risk	?		0.002		
			(0.10)		
Regulatory Risk $*X_{t-1}$	?		-1.009***		
			(-4.45)		
Regulatory Risk $*X_t$	?		0.122		
			(0.59)		
Regulatory Risk $*X_{t+1}$	-		-0.021**		
			(-2.31)		
Regulatory Risk $*R_{t+1}$	?		0.044		
			(1.24)		
Physical Risk	?			-0.019	
				(-1.33)	
Physical Risk $*X_{t-1}$	?			-1.157***	
				(-5.60)	
Physical Risk $*X_t$	?			0.305*	
				(1.66)	
Physical Risk $*X_{t+1}$	-			-0.027***	
				(-3.43)	
Physical Risk $*R_{t+1}$	?			0.0450	
				(1.41)	
Other Risk	?				0.011
					(0.55)
Other Risk $*X_{t-1}$	?				-1.065***
					(-3.88)
Other Risk $*X_t$	?				0.205
					(0.78)
Other Risk $*X_{t+1}$	-				0.010
					(0.36)
Other Risk $*R_{t+1}$	?				0.056
					(1.36)
Ln(MV)	?	0.003	0.003	0.003	0.004
		(0.68)	(0.78)	(0.80)	(0.81)
Ln(MV) $*X_{t+1}$	+	-0.085**	-0.090**	-0.093**	-0.097**
		(-2.00)	(-2.10)	(-2.19)	(-2.25)
LOSS	?	0.207***	0.207***	0.207***	0.208***
		(14.40)	(14.30)	(14.38)	(14.34)
LOSS$*X_{t+1}$	-	-0.186	-0.179	-0.184	-0.157
		(-1.57)	(-1.51)	(-1.55)	(-1.31)
Size Growth	?	-0.007	-0.005	-0.008	-0.007
		(-0.31)	(-0.20)	(-0.36)	(-0.30)
Size Growth$*X_{t+1}$	+	0.255	0.255	0.266	0.285
		(1.20)	(1.19)	(1.24)	(1.36)
EARNSTD	?	0.020	0.019	0.019	0.019
		(1.20)	(1.16)	(1.16)	(1.13)
EARNSTD$*X_{t+1}$	-	0.005	0.006	0.006	0.007
		(0.36)	(0.41)	(0.40)	(0.44)
Intercept		0.150***	0.125**	0.148***	0.124**
		(2.81)	(2.35)	(2.77)	(2.32)
IND/YEAR		YES	YES	YES	YES
No. of observations		9,264	9,264	9,264	9,264
Adj. R^2		0.191	0.188	0.191	0.186

Panel A Table 4 reports the descriptive statistics of the main variables, including dependent, independent, and control variables. Panel B of Table 4 summarizes the results of climate change risk and the future earnings responses coefficients (FERC). The FERC is smaller for firms with disclosed climate change risk, compared to firms without climate change risk. More specially, the coefficient on *Climate Change Risk* * X_{t+1} is negative and significant (coefficient = -0.021, t = -2.27), in support of hypothesis 4. The economic significance is 2.85%.[28]

The findings are also consistent with rational structural uncertainty theory, which states that investors are inclined to place less weight on uncertain signals (Brav and Heaton 2002). Under this framework, climate change risk creates uncertainties regarding future earnings and leads investors to place less weight on earnings signals, making FERC smaller.

With regard to the control variables, I find that firms with *LOSS* and *EARNSTD* have lower FERC. Both Size and Growth are positively correlated with FERC. Overall, the results of control variables are in line with prior literature (Lundholm and Myers 2002; Choi et al. 2011).

Panel C of Table 4 reports the relation between readability of climate change risk disclosure and forward earnings responses coefficients in the disclosing subsample. The coefficient on the interaction term between *Fog Index*$*X_{t+1}$ is negative and significant (coefficient = -0.095, t = -4.55), which suggests less readable climate change disclosure is associated with smaller FERC. This result shows that investors place less weights on future earnings of those firms with less readable climate change risk disclosure.

[28] The economic significance equals 0.021/(0.758-0.021))=2.85%

Table 4 (continued)

Panel C Readability of Climate-Change Risk Disclosure and Forward Earnings Responses Coefficients (FERC)

		(1)
	Pred.	R_t
X_{t-1}	-	-0.811***
		(-2.64)
X_t	+	0.340
		(1.24)
X_{t+1}	+	1.062*
		(1.68)
R_{t+1}	?	-0.044
		(-0.72)
Fog Index	?	0.016
		(0.26)
Fog Index $*X_{t-1}$	?	-0.361
		(-0.33)
Fog Index $*X_t$	?	-0.267
		(-0.27)
Fog Index $*X_{t+1}$	**-**	-0.095***
		(-4.55)
Fog Index $*R_{t+1}$	?	-0.153
		(-0.83)
Ln(MV)	?	0.001
		(0.22)
Ln(MV) $*X_{t+1}$	+	-0.085
		(-1.17)
LOSS	?	0.212***
		(7.38)
LOSS$*X_{t+1}$	-	-0.391
		(-1.28)
Size Growth	?	0.020
		(0.50)
Size Growth$*X_{t+1}$	+	-0.007
		(-0.02)
EARNSTD	?	0.310
		(1.28)
EARNSTD$*X_{t+1}$	-	2.584
		(1.42)
Intercept		0.104
		(1.39)
IND/YEAR		YES
No. of observations		3,767
Adj. R^2		0.186

6. Additional Tests

6.1 Predict Future Firm Value by Using Climate Change Risk Disclosure

In Sections 3.1, 3.2 and 3.3, I explicitly explain why climate change risk affects future earnings and future uncertainty, which in turn leads to a lower stock return around 10-K filing date. A natural extension is whether climate change risk can be related to the future value of disclosing firms. Following Masulis and Mobbs (2014), I construct the following model (7) to examine the relation between climate change risk and future firm value.

$$\begin{aligned} \textit{Tobin's } Q_{t+1} = {} & a_0 + a_1 \textit{Climate Change Risk Measures}_t + a_2 \textit{Ln (MV)}_t + a_3 \textit{R\&D}_t \\ & + a_4 \textit{Firm Age}_t + a_5 \textit{Cash Flow}_t + a_6 \textit{Cash Flow}_{t-1} \\ & + a_7 \textit{Cash Flow}_{t-2} + a_8 \textit{CAPX}_t + \textit{IND} + \textit{YEAR} + \varepsilon_{t+1} \end{aligned} \quad (7)$$

As Lang and Stulz (1994) suggest, Tobin's Q refers to the ratio between the market value of assets divided by book value of assets and this measure does not need the risk adjustment or normalization across firms.

The results reported in Table 5 document that firms with disclosed climate change risk have significantly lower future firm value, measured by Tobin's Q (coefficient = -0.224, t = -11.42). These findings are consistent with the conjecture that climate change risk is useful in predicting the future firm values of disclosing firms. The economic impact of climate change risk on future Tobin's Q is 15.7% of the sample mean.[29]

[29] -0.224/1.431 = 0.157, where 1.431 is the mean *Tobin's* Q_{t+1} in the sample.

Table 5
Climate Change Risk and Future Firm Value

This table presents the regression results of the impact of climate change risk on future firm value. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

		(1)	(2)	(3)	(4)
	Pred.	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}	*Tobin's* Q_{t+1}
Climate Change Risk	-	-0.224***			
		(-11.42)			
Regulatory Risk	-		-0.277***		
			(-14.02)		
Physical Risk	-			-0.147***	
				(-7.94)	
Other Risk	-				-0.233***
					(-11.86)
Ln $(MV)_t$	+	0.110***	0.115***	0.107***	0.112***
		(15.54)	(16.07)	(15.06)	(15.58)
$R\&D_t$	+	4.189***	4.201***	4.246***	4.246***
		(16.84)	(16.95)	(16.99)	(17.07)
Firm Age	+	-0.198***	-0.200***	-0.201***	-0.199***
		(-15.03)	(-15.25)	(-15.20)	(-15.11)
Cash $Flow_t$	+	1.091***	1.070***	1.106***	1.093***
		(4.21)	(4.16)	(4.24)	(4.21)
Cash $Flow_{t-1}$	+	0.080	0.077	0.083	0.080
		(0.83)	(0.80)	(0.85)	(0.82)
Cash $Flow_{t-2}$	-	-0.122	-0.124	-0.123	-0.124
		(-1.58)	(-1.60)	(-1.59)	(-1.60)
CAPX	+	-0.004	-0.005	-0.004	-0.005
		(-1.18)	(-1.35)	(-1.30)	(-1.42)
Intercept		0.929***	0.852***	0.885***	0.827***
		(8.84)	(8.50)	(8.88)	(8.41)
IND/YEAR		YES	YES	YES	YES
No. of observations		9,515	9,515	9,515	9,515
Adj. R^2		0.392	0.393	0.387	0.390

6.2 Voluntary (Survey) vs. Mandatory (10-K): which is more informative?

Before the issuance of guidance, Carbon Disclosure Project (CDP), already started collecting climate change risk disclosure by surveying S&P 500 starting in the year 2006.[30] The CDP requested company executives to respond to a series of questions regarding climate change, including the existence of climate change risk (regulatory, physical, and other risk), carbon emission intensity, governance and so on. Attendance to the survey is voluntary. The guidance represents an inflection point where climate change risk disclosure went from being voluntary to mandatory.

Using the CDP survey, I classify climate change risk into the same three categories: regulatory (CDP), physical (CDP), and other risk (CDP), same as for the 10-K disclosure under SEC FR-82. If a firm has any of these three categories of risks, I define an indicator variable, *CDP*, as one, meaning the firm is exposed to climate change risk based on the CDP survey, and zero otherwise. Then I repeated all the previous analyses by including both voluntary climate change risk disclosure (i.e., *CDP*) and mandatory climate change risk disclosure in 10-K filings (i.e., *10-K* which is equal to *Climate Change Risk* defined earlier). Table 6 reports the results from this replication.[31] As shown in Panel A, the coefficients on *10-K* and the interaction terms are significant and consistent with the previous results in four out of five regressions. Specifically, the coefficient on ROA_t**10-K* in Column (2) is significantly negative, consistent with Panel B of Table 2. The coefficient on *10-K* in Column (3) is significantly negative, consistent with Panel B of Table 3. The coefficient on *10-K**X_{t+1}* in Column (4) is significantly negative, consistent with Panel B

[30] As of the end of 2015, CDP has 822 institutional investor signatories with $55 trillion assets under management.

[31] The sample size is largely reduced because that this test only contains S&P 500 firms, since CDP is conducted in S&P firms consistently after year 2006.

of Table 4. The coefficient on *10-K* in Column (5) is significantly negative, consistent with Table 5. Moreover, the coefficients on the 10-K disclosure are more negative than those on CDP disclosure in all five regressions and significantly so in two regressions (Panel B of Table 6). Overall, mandatory 10-K disclosure has more predictive power than voluntary CDP disclosure.

Table 6
The Usefulness of Voluntary (Survey) vs. Mandatory (10K) Disclosure

This table presents the regression results of the usefulness of climate change risk in 10K and CDP survey. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A: Usefulness of Voluntary (Survey) vs. Mandatory (10K) Disclosure

		(1)	(2)	(3)	(4)	(5)
	Pred.	*AdjROA* $_{t+1}$	*ROA* $_{t+1}$	*CAR[-2,2]*	R_t	*Tobin's* Q_{t+1}
10-K (β1)	-	-0.002	0.006	-0.005**	-0.460*	-0.194***
		(-0.59)	(1.33)	(-2.34)	(-1.96)	(-5.64)
CDP (β2)	-	0.000	-0.006	-0.001	0.726***	-0.079**
		(0.14)	(-1.08)	(-0.44)	(2.79)	(-2.22)
ROA_t*10-K (β3)*	-		-0.088*			
			(-1.82)			
ROA_t*CDP(β4)*	-		0.050			
			(0.93)			
10-K $\boldsymbol{X}_{t+1}$(β5)*	-				-7.412***	
					(-3.70)	
CDP$\boldsymbol{X}_{t+1}$(β6)*	-				-3.718	
					(-1.46)	
Controls		YES	YES	YES	YES	YES
Intercept		-0.027	0.010	0.003	-1.201	0.648**
		(-0.88)	(0.43)	(0.11)	(-1.00)	(2.06)
IND/YEAR		YES	YES	YES	YES	YES
No. of observations		1,306	1,306	1,306	1,306	1,306
Adj. R^2		0.744	0.469	0.010	0.371	0.632
Panel B: Coefficients Test of Voluntary (Survey) vs. Mandatory (10K) Disclosure						
F Test of β1=β2		0.14		1.48		4.93*
F Test of β3=β4			2.86*			
F Test of β5=β6					1.49	

There are two reasons that may explain the observed phenomenon. First, the scope of the survey is very limited. Firm participation is totally voluntary, and many large

companies did not participate in the CDP survey, including Apple Inc., Amazon, BB&T, Berkshire Hathaway, and Netflix, etc.[32] The low response rates largely constrain the comparability of CDP data with that of the 10-K disclosure. Second, not all of the CDP data is publicly available. Firms must elect to make their responses available to all or specific investors or not at all. According to Matsumura et al. (2014), approximately 19.59% of firms do not consent to their responses being made public. This limited availability restricts ordinary investors from assessing climate change information of firms as well as running reliable analyses.

6.3 Benefits of Disclosure

Based on the results reported in Section 5, firms with disclosed climate change risk exhibit lower future performance, earnings persistence, market reaction to 10-K announcements, FERC and firm value. If the climate change risk disclosure conveys bad news to the market, one might ask why firms decide to disclose this information.

First, disclosing this information an act of regulatory compliance. My sample is post-guidance period meaning firms with material climate change risk should disclose this information in their annual reporting to fulfill the mandatory reporting requirement.

Second, honest disclosure of climate change risk helps firms to avoid litigation. On November 8, 2015, Attorney General of State of New York reached a settlement with Peabody Energy (the world largest coal company) concerning the allegation that the firm misleads investors in their climate change risk disclosures. Peabody was aware that future potential climate change regulation would adversely impact firm's future performance, but

[32] CDP S&P 500 Climate Change Report 2013. https://b8f65cb373b1b7b15feb-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/000/626/original/CDP-SP500-climate-report-2013.pdf?1470233007

it stated the following in 10-K (2011-2014): "*it was not possible to predict the impact that any such laws or regulation may have on Peabody's results of operations, financial condition or cash flow*." In this settlement, Peabody agreed to disclose more potential climate change risk in its SEC filings (page 9).[33] On November 4, 2015, Attorney General of State of New York launched an investigation into Exxon Mobil to determine whether the firm lied to investors about climate change risk. Moreover, Attorney Generals of 17 states have formed a coalition to consider investigations on whether other fossil fuel industry companies also hide their climate change risk to investors or public.

Third, honestly disclosing climate change risk also helps firms maintain a good reputation with stakeholders. Inadequate climate change risk disclosure can incur regulatory scrutiny, such as SEC comment letters. Based on Audit Analytics, I find 80 SEC comment letters regarding climate change disclosure in the sample period: 2010-2014. As previous literature shows, SEC comment letters induce adverse consequences to firms such as higher audit fees (Gietzmann and Pettinicchio 2014) and higher cost of debt (Cunningham et al. 2016).

6.4 Control Disclosure Choice

Even though the 2010 guidance requires firms to disclose climate change impact in their annual reports, firms still have the incentive to suppress potentially bad news. In the first set robustness checks, I employ a Heckman two-stage model (Heckman 1979) to address this potential concern.

In the first stage, following previous environmental disclosure literature (Berthelot et al. 2003; Matsumura et al. 2014), I construct the following model to estimate the

[33] http://ag.ny.gov/pdfs/Peabody-Energy-Assurance-signed.pdf.

likelihood of firms disclosing climate change risk under their annual reports.

$$\begin{aligned} Climate\ Change\ Risk = {} & a_0 + a_1 Coastal\ State + a_2 Ln\ (Assets)_t + a_3 MB_t \\ & + a_4 ENV\_STR_t + a_5 ENV\_CON_t + a_6 CDP_t + a_7 IND\_CCR_{t-1} \\ & + IND + YEAR + \varepsilon_{t+1} \end{aligned} \quad (8)$$

As noted in Lennox et al. (2011), the first stage in a Heckman model must include an exclusion restriction, which refers to an exogenous variable that does not influence the dependent variable in the second stage. I include the variable, *Coastal State*, which equals one if a firm is headquartered in coastal states, and zero otherwise. I expect that firms in coastal states are more likely to be affected by extreme weather and sea-level rise. Thus, I expect that these firms are more inclined to disclose climate change risk. However, firms' geographic position might not influence firms' future performance, earnings persistence, stock market returns, FERC, and firm value.

Following Patten (1991; 1992) and Matsumura et al. (2014), I also include firm size. They find that larger firms are more likely to disclose the environmental information. I also control firm's growth (*MB*). However, following Matsumura et al. (2014), we do not predict a sign for MB. I also include firms' environmental CSR performance: *ENV_STR* and *ENV_CON*, since Walden and Schwartz (1997) and Matsumura et al. (2014) argue that environmental CSR performance plays an important role in determining environmental disclosure. Moreover, if firms disclose climate change risk in CDP survey, I expect that firms are more likely to disclose climate change risk in SEC filings. To control disclosure pressure from peer firms, I also include average industry-level climate change risk in year t-1. To control for industry membership and year effects on climate change disclosure, I also include the industry and year fixed effects.

Table 7 reports the results. As I expected, Panel A of Table 7 shows that *Coastal*

State, Ln (Assets)$_t$, *ENV_CON$_t$*, *CDP$_t$*, *IND_CCR$_{t-1}$* are positively correlated with climate change risk disclosure. Panel B of Table 7 reports the second stage results, and I find that after controlling disclosure choice in my second stage model by including the Inverse Mills ratio (*IMR*), all the results are still robust.

I also test the multicollinearity of the Inverse Mills Ratio (IMR) in the Panel C of Table 7. The Variance Inflation Factor (VIF) of the IMR ranges from 1.52 to 5.24, which is less than the cutoff of 10. The results indicate the multicollinearity of the IMR is not severe.

Table 7
The Usefulness of Climate Change Risk Disclosure: Controlling Disclosure Choice

This table presents the regression results of the usefulness of climate change risk after controlling disclosure choice. Regressions include the year and industry fixed effects. The t-statistics reported in parentheses are based on standard errors that are heteroskedasticity robust. To conserve space, I do not report the coefficient estimates for the year and industry dummies. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels (two-tailed), respectively. All variables are defined in Appendix C.

Panel A Choice of Climate Change Risk Disclosure

	Pred.	(1) *Climate Change Risk*
Coastal State	+	0.102***
		(3.18)
Ln (Assets)$_t$	+	0.133***
		(12.01)
MB$_t$	?	-0.003
		(-1.35)
ENV_STR$_t$	+	-0.010
		(-0.41)
ENV_CON$_t$	+	0.346***
		(6.15)
CDP$_t$	+	0.084
		(1.36)
IND_CCR$_{t-1}$	+	0.858**
		(2.46)
Intercept		-1.061***
		(-3.75)
IND/YEAR		YES
No. of observations		9,808
Pseudo R^2		0.2781

Table 7 (continued)

Panel B The Usefulness of Climate Change Risk Disclosure: Controlling Disclosure Choice

		(1)	(2)	(3)	(4)	(5)
	Pred.	*AdjROAt+1*	*ROAt+1*	*CAR[-2,2]*	R_t	*Tobin'sQ*$_{t+1}$
Climate Change Risk	-	-0.002**	-0.001	-0.003*	-0.015	-0.210***
		(-1.96)	(-0.22)	(-1.98)	(-1.24)	(-10.84)
ROA$_t$ **Climate Change Risk*	-		-0.052***			
			(-3.62)			
*Climate Change Risk*****X**$_{t+1}$	-				-0.020**	
					(-2.25)	
IMR		0.001	-0.009***	-0.000	0.008	0.204***
		(1.43)	(-10.46)	(-0.73)	(1.07)	(14.98)
Controls		YES	YES	YES	YES	YES
Intercept		-0.003	0.055***	0.014	0.123**	0.167
		(-0.43)	(3.53)	(1.19)	(2.19)	(1.45)
IND/YEAR		YES	YES	YES	YES	YES
No. of observations		9,087	9,076	8,738	9,218	9,186
Adj. R^2		0.4145	0.635	0.010	0.189	0.423
Panel C Variance-Inflation-Factors(VIF) of IMR						
		4.98	5.27	1.52	4.05	5.24

7. Robustness Checks

I conduct several robustness tests to check the robustness of my findings. First, I examine that the effects of disclosing multiple climate change risks on dependent variables. Aggregating regulatory, physical and other risks, I create the *Climate Change Risk Index* that ranges from 0 to 3, with a higher value indicating more types of climate change risk. I find that the results are still robust. Second, this paper shows the usefulness of climate change risk disclosure. A natural question is that which type risk is more informative than the others. I employ a horse racing test by putting all three risks in regressions. I find that regulatory risk is more informative than the others for future performance, earnings persistence, and market reaction test. However, I find that physical risk is more useful for FERC test than other risks. Third, the previous results suggest that firms with climate change risk have lower FERC. Another related question is that what is the relationship between climate change risk and current ERC. I find that firms with climate change risk

also have lower current ERC, which is also consistent with rational structural uncertainty theory (Brav and Heaton 2002).

8. Conclusions

8.1 Summary of Conclusions

On February 8, 2010, SEC issued interpretive guidance (SEC FR-82) and required listed firms to disclose climate change risk in their 10-Ks. However, the guidance has been controversial. The essential of the controversy is whether climate change risk disclosure provides useful information to investors and other stakeholders.

Motivated mainly by the current debate, this paper examines the usefulness of climate change risk disclosure using firm-year observations in Russell 3000 Index. First, this paper reviews the legislative process of 2010 guidance. I find that institutional investors and Democratic politicians are the main force in lobbying SEC to regulate climate change disclosure. Moreover, the guidance was passed in the SEC with a clear party-line vote, indicating political ideology and party politics are important in the legal process. These findings are consistent with interest group theory, which argues groups lobby for or against in their own interest. Second, firms that disclose climate change risk under the guidance have lower future ROA and the poor performance is driven by lower profit margin, not by assets turnover. Third, these firms have lower earnings persistence and smaller forward earnings response coefficient (FERC). Fourth, event study reveals that firms with disclosed climate change risk experience significantly lower cumulative abnormal return during 5-days around 10-K filing date, indicating that investors incorporate this information into their investment decisions. Fifth, firms with disclosed climate change risk have lower future firm value as capture by Tobin's Q. Finally, utilizing

textual analysis, I find that less readable climate change risk disclosure texts exacerbates the aforementioned effects. Taken together, this paper shows the usefulness of climate change risk disclosure and supports mandatory disclosure of material climate change risk under SEC FR-82.

8.2 Limitations and Future Directions

Climate change risk disclosure is valuable to investors, as evidence in this paper shows that disclosed climate change risk is associated with future earnings, earnings persistence, FERC, and stock market reaction. However, as we all know, disclosure is not free. The cost of preparing climate change risk disclosure, which represents the firm's private information, may not be trivial. This paper does not directly compare the benefits and costs of climate change disclosure nor express a position on whether the regulation (SEC 2010 FR82) improves or reduces overall social welfare. Similarly, some EPA regulations are also very controversial, which is reflected in media coverage and lawsuits (e.g., Michigan v. EPA).[34] The Supreme Court argues that "*It is not rational, never mind "appropriate," to impose billions of dollars in economic costs in return for a few dollars in health or environmental benefits*".[35] From this perspective, this paper is an initial attempt to show the potential usefulness of these climate change disclosures to investors. In the future, we need more evidence on the cost and benefits of the 2010 guidance.

[34] WSJ, 2011, The United States of EPA. http://www.wsj.com/articles/SB10001424052970204630904577056393981840650
[35] https://www.supremecourt.gov/opinions/14pdf/14-46_10n2.pdf

Appendix A: Summary of Signatories in the Petitions to Request 2010 SEC Guidance

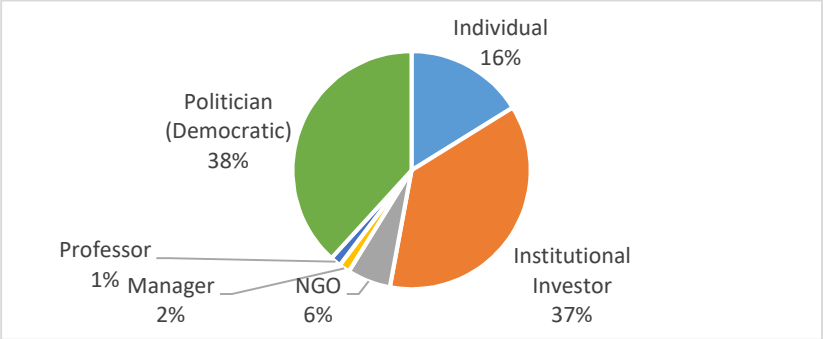
Date	Name of Signatories	Position	Type
9/18/2007	California Public Employees' Retirement System		Institutional Investor
	John Chiang	California State Controller	Politician (Democratic)
	California State Teachers' Retirement System		Institutional Investor
	Bill Lockyer	California State Treasurer	Politician (Democratic)
	Ceres		Institutional Investor
	Environmental Defense		NGO
	F&C Management		Institutional Investor
	Alex Sink	Florida Chief Financial Officer	Politician (Democratic)
	Friends of the Earth		NGO
	Jonathan Miller	Kentucky State Treasurer	Politician (Democratic)
	David G. Lemoine	Maine State Treasurer	Politician (Democratic)
	Nancy K. Kopp	Maryland State Treasurer	Politician (Democratic)
	The Nathan Cummings Foundation		Institutional Investor
	Orin Kramer	New Jersey State Investment Council	Politician (Democratic)
	William C. Thompson	New York City Comptroller	Politician (Democratic)
	Andrew M. Cuomo	New York State Attorney General	Politician (Democratic)
	Thomas P. DiNapoli	New York State Comptroller	Politician (Democratic)
	Richard Moore	North Carolina State Treasurer	Politician (Democratic)
	Randall Edwards	Oregon State Treasurer	Politician (Democratic)
	Pax World Management Corporation		Institutional Investor
	Frank T. Caprio	Rhode Island General Treasurer	Politician (Democratic)
	Jeb Spaulding	Vermont State Treasurer	Politician (Democratic)
9/20/2007	Peter Franchot	Comptroller of Maryland	Politician (Democratic)
10/17/2007	David Purcell	CEO, Climate Appraisal Services	Manager
10/24/2007	Coleman Stipanovich	Executive Director, State Board of Administration of Florida	Politician (Democratic)
11/5/2007	Bennett Freeman	Senior Vice President, Calvert Asset Management Co.	Institutional Investor
11/29/2007	Corey M. Amon	Director of Research, Taplin, Canida & Haba cht	Institutional Investor
11/29/2007	David Thompson	Managing Director, Dwight Asset Management	Institutional Investor
11/30/2007	Stephen A. Eason	Executive Vice President, Smith Breeden Associates, Inc.	Institutional Investor
12/3/2007	C. Thomas Clapp	Executive Director and Chief Investment Officer, Sterling Capital Management LLC	Institutional Investor
2/8/2008	Peter Dunscombe	Chairman, Institutional Investors Group on Climate Change	Institutional Investor
4/15/2008	David P. O'Connor	Senior Vice President, Delaware Investment Advisers	Institutional Investor
5/6/2008	James Lobdell	Unknown	Individual
5/6/2008	Jeffrey Plate	Retired	Individual
5/6/2008	Jason Griffith	Unknown	Individual
5/14/2008	Nancy Herbert	Newground Social Investment	Institutional Investor
5/14/2008	John Harrington	CEO, Harrington Investments Inc.	Institutional Investor
5/23/2008	Anne Mertl Millhollen	Unknown	Individual
5/24/2008	Kathleen Labriola	Unknown	Individual

Appendix A (continued)

Date	Name of Signatories	Position	Type
5/25/2008	Shirley Faircloth	Unknown	Individual
6/9/2009	Mindy S. Lubber	President, Ceres	Institutional Investor
	Kevin L. Doran	University of Colorado Law School	Professor
	Vickie Patton	Deputy General Counsel, Environmental Defense Fund	Institutional Investor
10/8/2009	Anonymous	Unknown	Individual
11/8/2009	Carole Bennett Simmons	Unknown	Individual
11/8/2009	Susan Schneier	Unknown	Individual
11/16/2009	Linda Currie	Unknown	Individual
11/16/2009	Terry Rosson	Unknown	Individual
11/23/2009	Doug Pearce	Chief Executive Officer, British Columbia Investment Management	Institutional Investor
	California Public Employees' Retirement System		Institutional Investor
	John Chiang	California State Controller	Politician (Democratic)
	California State Teachers' Retirement System		Institutional Investor
	Bill Lockyer	California State Treasurer	Politician (Democratic)
	Mindy Lubber	President of Ceres	Institutional Investor
	Denise L. Nappier	Connecticut State Treasurer	Politician (Democratic)
	Vickie Patton	Deputy General Counsel, Environmental Defense Fund	Institutional Investor
	Elizabeth E. McGeveran	Senior Vice President, Investment F&C Management Ltd.	Institutional Investor
	Alex Sink	Chief Financial Officer, State of Florida	Politician (Democratic)
	Michelle Chan	Program Director, Friends of the Earth	NGO
	Richard Metcalf	Director, Laborers' International Union of North America	NGO
	Nancy K. Kopp	Treasurer, State of Maryland	Politician (Democratic)
	Lance E. Lindblom	President & CEO, The Nathan Cummings Foundation	Institutional Investor
	Andrew M. Cuomo	Attorney General, State of New York	Politician (Democratic)
	Thomas P. DiNapoli	New York State Comptroller	Politician (Democratic)
	Janet Cowell	State Treasurer, North Carolina	Politician (Democratic)
	Ben Westlund	Treasurer, State of Oregon	Politician (Democratic)
	Julie Gorte	Senior Vice President, Pax World Management	Institutional Investor
	Jeb Spaulding	Treasurer, State of Vermont	Politician (Democratic)

Data Sources: https://www.sec.gov/comments/4-547/4-547.shtml

Appendix B: Signatories in Petition for 2010 SEC Guidance by Type



Appendix C: Variable Definitions

Variable	Definition
Climate Change Risk Measures	
Climate Change Risk	Climate Change Risk equals one if a firm discloses any type climate change risk in its 10-K, including Regulatory Risk, Physical Risk, and Other Risk, and zero otherwise. Source: Ceres and CookESG Research
Regulatory Risk	Regulatory Risk equals one if a firm reports being subject to climate change regulation, which includes but is not limited to EPA's regulations, Clean Air Act, Renewable Energy Act, Paris Agreement, Kyoto Protocol, renewable portfolio standard (RPS), European Union Emission Trading System, Cross-State Air Pollution Rules, United Kingdom's Carbon Reduction Commitment, emissions trading schemes, and carbon tax or carbon fees, and zero otherwise. Source: Ceres and CookESG Research
Physical Risk	Physical Risk equals one if a firm reports being subject to the physical parameter of the climate change, which includes but is not limited to floods, hurricanes, droughts, storms, water availability, extreme temperatures, temperatures change, severe weather, sea level change, or change of these weather conditions, and zero otherwise. Source: Ceres and CookESG Research
Other Risk	Other Risk equals one if a firm reports being subject to other climate change risk, which includes but is not limited to business trend, changing consumer preference or behavior, potential reputation loss, and other climate change related matters, and zero otherwise. Source: Ceres and CookESG Research
Fog Index	Fog Index=0.4*(average words per sentence + percent of complex words) Where complex word refers to one with three or more syllables. Higher fog index indicates less readability. Fog Index is scaled by 100.
Future Performance Tests	
$AdjROA_{t+1}$	Industry-adjusted ROA, which equals firm-specific ROA minus the median ROA for the same Fama-French industry and year t+1. ROA is calculated as income before extraordinary items (IB) divided by lagged total assets (AT). Source: Compustat
$AdjProfit\ Margin_{t+1}$	Industry-adjusted profit margin, which equals firm-specific profit margin minus the median profit margin for the same Fama-French industry and year t+1. Profit Margin is calculated as income before extraordinary items (IB) divided by sales (SALES). Source: Compustat
$AdjAssets\ Turnover_{t+1}$	Industry-adjusted assets turnover, which equals firm-specific assets turnover minus the median assets tunrover for the same Fama-French industry and year t+1. Assets Turnover is calculated as sales (SALES) divided by lagged total assets (AT). Source: Compustat
$AdjROA_t$	Industry-adjusted ROA, which equals firm-specific ROA minus the median ROA for the same Fama-French industry and year t. ROA is calculated as income before extraordinary items (IB) divided by lagged total assets (AT). Source: Compustat
$AdjProfit\ Margin_t$	Industry-adjusted profit margin, which equals firm-specific profit margin minus the median profit margin for the same Fama-French industry and year t. Profit Margin is calculated as income before extraordinary items (IB) divided by sales (SALES). Source: Compustat
$AdjAssets\ Turnover_t$	Industry-adjusted assets turnover, which equals firm-specific assets turnover minus the median assets turnrover for the same Fama-French industry and year t. Assets Turnover is calculated as sales (SALES) divided by lagged total assets (AT). Source: Compustat
Ln(ASSETS)	Natural logarithm of total assets (AT) in the fiscal year end. Source: Compustat
MB	Market to book ratio refers to market value of equity (PRCC_F*CSHO) divided by book value of equity(CEQ). Source: Compustat
Return	Buy and hold return in year t. $((PRCC\_F_t/AJEX_t)/(PRCC\_F_{t-1} / AJEX_{t-1})-1)$. Source: Compustat
Z-Score	$3.3*(NI_t/AT_{t-1}) + 1.0*(SALES_t/AT_{t-1}) + 1.4*(RE_t/AT_{t-1}) + 1.2*((ACT_t-LCT_t)/AT_{t-1})$. Source: Compustat
IND	Industry fixed effects. Industry refers to Fama-French 48 Industries
YEAR	Year fixed effects.
Earnings Persistence Tests	
ROA_{t+1}	ROA_{t+1} is ROA of year t+1.ROA is calculated as income before extraordinary items (IB) divided by lagged total assets (AT). Source: Compustat
ROA_{t+2}	ROA_{t+2} is ROA of year t+2.ROA is calculated as income before extraordinary items (IB) divided by lagged total assets (AT). Source: Compustat

Ln(MV)	Natural logarithm of market value (CSHO*PRCC_F) in the fiscal year end. Source: Compustat
DIV	Indicator variable that equals one if firm distribute dividend (DVT) in fiscal year t, and zero otherwise. Source: Compustat
STD(ROA)	the standard deviation of the ROA in the last five fiscal years. Source: Compustat
STD(RET)	the standard deviation of the monthly stock returns (RET) in the year t-1. Source: CRSP
Firm Age	Natural logarithm of the number of years since a firm appears in Compustat. Source: Compustat
SI	Special item (SPI) is divided by lagged total assets (AT). Source: Compustat
M&A	Indicator variable that equals one if the firm is involved in mergers or acquisitions (AQC), and zero otherwise; Source: Compustat
DE	Indicator variable that equals one if firm is incorporated in Delaware in fiscal year t, and zero otherwise. Source: Compustat
Market Reaction Tests	
CAR[-2,2]	5 days' cumulative abnormal return around 10-K filing date. Source: CRSP
PRE_FF	The prefile date Fama-French alpha based on 3 factor model by using days [-252, -6]. Source: CRSP
AB_EPS	The earning surprise, which equals current eps minus last year's eps scaled by prior year's stock price Source: Compustat
Turnover	Natural logarithm of shares traded in days [-252, -6] divided by shares outstanding on file date. Source: CRSP
NASDAQ	Indicator variable is stock is listed on NASDAQ stock exchange, 0 otherwise. Source: CRSP
Reporting Lag	Natural logarithm of the number of days between fiscal year end date and 10-K filing date. Source: Compustat
Forecast Dis	The standard deviation of analysts' forecast in the fiscal year. Source: I/B/E/S
Forward Earnings Response Coefficients (FERC)	
R_t, and R_{t+1}	R_t *and* R_{t+1} are the annual stock returns measured over the 12-month periods ending three months after the firm's fiscal year-end at t and t+1, respectively Source: Compustat
X_{t-1}, X_t, and X_{t+1}	X_{t-1}, X_t, and X_{t+1} are income available to common shareholders before extraordinary items for years t-1, t, and t+1, respectively, each deflated by the market value of equity three months after the end of fiscal year t-1, respectively. Source: Compustat
LOSS	Indicator variable that equals one if X_{t+1} is negative, and zero otherwise. Source: Compustat
Size Growth	Total assets growth rate from year t-1 to year t+1. Source: Compustat
EARNSTD	The standard deviation of X from year t-1 to year t+1. Source: Compustat
Firm Value Tests	
Tobin's Q	Following Duchin (2010) and Masulis and Mobbs (2014), Tobin's Q equals (Market Value of Assets)/(0.9*book value of assets+0.1*market value of assets) Where market value of assets is market value of assets is book value of total assets (AT) less book value of equity (CEQ) less deferred taxes (TXTDB) plus market value of equity (CSHO * PRCC_F). Source: Compustat
R&D	R&D expenditure (XRD) divided by total assets (AT). Source: Compustat
Cash Flow	Operating cash flow (OANCF) divided by total assets (AT). Source: Compustat
CAPX	Capital expenditure divided by total assets (AT). Source: Compustat
Mandatory vs Voluntary	
CDP	Indicator variable that equals one if firms disclose climate change risk in CDP survey, and zero otherwise. Source: CDP
10-K	Equals to *Climate Change Risk.* Source: Ceres and CookESG Research
Heckman Two Stage Model	
Coastal State	Indicator variable that equals one if firms headquartered in coastal states, and zero otherwise. Coastal states refer to Alabama, Alaska, California, Connecticut, Delaware, Florida, Florida, Georgia, Hawaii, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Oregon, Rhode

	Island, South Carolina, Texas, Virginia, and Washington. Source: Compustat
ENV_CON	The number of environment concerns in CSR. Source: KLD
ENV_STR	The number of environment strengths in CSR. Source: KLD
CDP	Indicator variable that equals one if firms disclose climate change risk in CDP survey, and zero otherwise. Source: CDP
IND_CCR_{t-1}	Average industry-level climate change risk of 10-K filings in year t-. Source: Ceres and CookESG Research

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