Climate Change and Corporate Culture of Innovation: Evidence from Earnings Conference Calls

Viput Ongsakul
NIDA Business School
National Institute of Development Administration (NIDA)
&
Securities and Exchange Commission of Thailand
Bangkok, Thailand

Pandej Chintrakarn
Mahidol University International College
Nakhon Pathom, Thailand

Pornsit Jiraporn
Great Valley School of Graduate Professional Studies
The Pennsylvania State University
Malvern, PA 19335, U.S.A.

Pattanaporn Chatjuthamard
Sasin School of Management
Chulalongkorn University
Bangkok, Thailand

Climate change and corporate culture of innovation: Evidence from earnings conference calls

Structured Abstract

Purpose

Exploiting novel measures of climate change exposure and corporate culture generated by a powerful textual analysis of earnings conference calls, we explore the effect of firm-specific climate change exposure on corporate innovation through the lens of corporate culture.

Design/Methodology/Approach

We apply the standard regression analysis as well as a variety of sophisticated techniques, namely propensity score matching, entropy balancing, and an instrumental variable analysis with multiple alternate instruments.

Findings

We find that more exposure to climate change risk results in more innovation as indicated by a significantly stronger culture of innovation. Our findings are consistent with the notion that firms more exposed to climate change risk are pressed to be more innovative in order to adapt to the various challenges resulting from climate change. Finally, we also find that the effect of firm-level exposure on innovation is considerably less pronounced during uncertain times.

Originality

We are among the first studies to take advantage of a novel measure of firm-specific exposure to climate change and investigate how climate change exposure influences an innovative culture. Since climate change is a timely issue, our findings have important implications for multiple stakeholders, such as shareholders, executives, and investors in general.

JEL Classification: G30, Q54, Q55, O31

Keywords: climate change, innovation, corporate culture, textual analysis, machine learning

I. Introduction

Climate change is accelerating, as indicated by the observed rise in the average temperature, as well as the disastrous effects of the sea-level rise and climate-related environmental catastrophes (Ginglinger and Moreau, 2022). As the effects of climate change become increasingly apparent, an intense debate has arisen over whether capital markets are paying sufficient attention to the financial repercussions (Sautner et al., 2023). Consequently, a nascent, albeit quickly expanding, body of research has emerged to study the effects of climate risk on corporate outcomes, practices, and actions (Matsumura, Prakash, and Vera Munoz, 2014; Bolton and Kacperczyk, 2021; Huynh and Xia, 2021; Chava, 2014; Javadi and Masum, 2021; Hossain et al., 2022; Choi, Gao, and Jiang, 2020; Painter, 2020; Heo, 2021). Clearly, this is a crucial area of the contemporary literature.

We contribute to this important debate by investigating the effect of firm-specific climate change exposure on corporate culture of innovation using data on corporate culture. Our study is one of the earliest to investigate innovation via the lens of corporate culture. To assess company cultural values, we employ a unique measure of corporate culture built from powerful machine learning algorithms and earnings call transcripts (Li, Mai, Shen, and Yan, 2021). Earnings calls, as an effective external communication platform, mainly involve CEOs (and sometimes CFOs) speaking to financial analysts and often express a company's set of values (Graham et al. 2022; Li, Mai, Shen, and Yan, 2021). This machine learning-based technique has recently been embraced in the literature (Li, Mai, Shen, and Yan, 2021; Ongsakul, Chatjuthamard, Jiraporn, and Chaivisuttangkun, 2021; Likitapiwat et al., 2022).

A significant obstacle facing climate change research is the difficulty of quantifying firm-level climate change vulnerability (Sautner, van Lent, Vilkov, and Zhang, 2023; Heo, 2021). Our

study utilizes data from Sautner, van Lent, Vilkov, and Zhang (2023), who use an advanced textual analysis to create firm-level metrics of climate change exposure. This measurement is basically based on the frequency of certain climate change related bigrams in earnings conference call transcripts. Sautner, van Lent, Vilkov, and Zhang (2023) demonstrate that their approach is effective in capturing firm-level climate change vulnerability.

Theory suggests that climate change vulnerability may either stimulate or inhibit corporate innovation. On the one hand, climate change produces a great deal of uncertainty in several dimensions, making it hard for companies to make plans. Such uncertainty probably motivates firms to put off their investments in innovation as well as in other areas (Bernanke, 1983; McDonald and Siegel, 1986), potentially leading to a weaker culture of innovation. By contrast, in anticipation of the numerous changes brought about by climate change, businesses spend more in innovation to adapt to the new business environment of the future. As a result of the realization that the present business model is becoming outdated owing to the effects of climate change, companies make more effort to be innovative, resulting in a stronger culture of innovation.

Based on a large sample of over 45,000 observations, our results reveal that a culture of innovation is significantly strengthened when firm-specific climate exposure is more serious. Our results reinforce the notion that businesses are driven to be more innovative in anticipation of the consequences of climate change. Better innovation should allow the firm to cope with climate change more effectively. Importantly, it should be noted that we account for firm fixed effects in our regression analysis. Therefore, our results are unlikely tainted by the omitted-variable bias. To further ensure that our results are robust, we perform a variety of robustness checks, namely propensity score matching (PSM), entropy balancing, and an instrumental variable analysis with alternative instruments. All the robustness tests confirm our conclusion, with more firm-level

exposure to climate change bringing about a stronger innovative culture. Endogeneity appears unlikely, making it likely that our conclusion reflects a causal influence, not just a mere correlation. Moreover, using the economic policy uncertainty (EPU) index to measure uncertain times, we document that the effect of firm-level exposure on innovation is considerably weaker during stressful times.

Our results contribute to several vital areas of the literature. First, this research contributes to an emerging area of the literature on the effects of climate change on corporate outcomes. For instance, climate change vulnerability has been found to bring about a higher cost of external capital (Chava, 2014; Javadi and Masum, 2021). Similarly, several recent studies identify climate change exposure as a critical risk factor with consequential and long-term corporate policy implications (Addoum, Ng, and Ortiz-Bobea, 2020; Bansal, Kiku, and Ochoa, 2016; Painter, 2020).We add to this expanding body of research by showing that climate change exerts a significant effect on corporate innovation, as shown by an innovative culture. As far as we are aware, our study is the first to document such findings.[1]

Second, our results enrich the literature in corporate innovation. Numerous factors have been linked to innovation in several recent studies (Lin, Liu, and Manso, 2021), such as leveraged buyouts (Lerner et al., 2011), institutional ownership (Aghion et al., 2013), stock liquidity (Fang et al., 2014), employee stock options (Cheng et al., 2015), analyst coverage (He and Tian, 2013),

[1] While we adopt the same measure of climate change exposure as Sautner et al. (2023), we extend their work in several important ways. First, we show that firm-specific exposure to climate change has a significant impact on corporate innovation using an innovative culture as our proxy for innovation. Although Sautner et al. (2023) document a significant effect of climate change exposure on several variables, such as green patents and forward-looking firm risk, they do not explore an innovative culture. Second, our findings demonstrate that firm-level climate change exposure influences corporate culture. This is a crucial finding as prior research rarely investigates corporate culture in empirical settings due to the difficulty in measuring corporate culture. Third, we employ sophisticated analytical tools that are not used in Sautner et al. (2023), such as entropy balancing.

firm transparency (Brown and Martinsson, 2018), venture capital (Chemmanur et al., 2014), credit default swaps (Chang et al., 2019), banking and financing variables (Brown et al., 2009; Cornaggia et al., 2015; Acharya and Xu, 2017; Gu et al., 2017), labor unions (Bradley et al., 2016), supply chains (Chu et al., 2018), and shareholder litigation rights (Lin, Liu, and Manso, 2021). We aptly extend this crucial strand of the literature by identifying climate change vulnerability as one of the significant determinants of corporate innovation.

Third, our research contributes significantly to the corpus of knowledge on corporate culture. Previously, corporate culture has been analyzed from a theoretical standpoint (Cremer, 1993; Van den Steen, 2010; Li, Mai, Shen, and Yan, 2021; Weber, Shenkar, and Raveh, 1996; Graham, Grennan, Harvey, and Rajgopal, 2022). However, there has been little empirical investigation on corporate culture (Graham et al., 2022; Guiso et al., 2015). We fill this critical gap in the literature. Our work is the first to show an empirical relationship between an innovative culture and firm-specific climate change risk, which is a pressing and crucial topic. Our findings indicate that firm-specific climate change exposure is conducive to a corporate culture of innovation.

Our study's findings have practical implications for a broad audience. Managers, shareholders, and investors gain insight into the positive aspect of climate change, as we demonstrate its role in spurring corporate innovation. Additionally, regulators can use our findings to inform climate-related policies, understanding that climate change has significant effects that must be considered in regulation. Environmentalists, too, can appreciate the tangible impact of climate change on corporate behavior, noting its substantial influence on innovation within financial and capital markets.

Our research advances the application of sophisticated textual analysis techniques to explore three critical topics in contemporary literature: climate change, corporate innovation, and corporate culture. Textual analysis, a technique rooted in data science, offers a compelling way to measure climate change exposure and corporate culture, two intangible facets that significantly influence financial outcomes. By scrutinizing corporate disclosures, i.e., earnings call transcripts, with advanced algorithms, this method distills complex narratives into quantifiable metrics. It enables analysts to track how frequently and contextually climate change is discussed or how a company articulates its cultural values. As companies increasingly intertwine climate and cultural narratives with their strategic directions, this form of analysis could reveal a correlation between a company's engagement with climate issues or its cultural ethos and its financial agility, innovative capacity, or risk profile. This could pave the way for new insights into how companies navigate and potentially thrive amid the creative disruption sparked by climate change.

II. Pertinent research and hypothesis development

Our research applies a novel text-based framework that encapsulates corporate culture and a company's unique sensitivity to climate change. We probe into the influence that climate change exposure exerts on corporate innovation, as reflected through the lens of an innovative culture. In doing so, we present two contrasting hypotheses that explore the potential impacts of climate change exposure on nurturing a culture rich in innovation. The innovation reduction hypothesis argues that increased exposure to climate change brings about reduced innovation, as uncertainty prompts firms to delay investments in innovation due to the risk and irreversibility associated with them. Conversely, the innovation enhancement hypothesis contends that heightened climate change exposure incites more innovation, as companies invest in adapting to anticipated changes, with a sense of urgency overriding the caution that uncertainty might otherwise warrant.

a. Climate change

Climate change is advancing rapidly, as evidenced by the reported rise in the average temperature and the catastrophic impacts of the sea-level rise and weather-related natural disasters (Ginglinger and Moreau, 2022). Multiple recent publications strongly stress that climate risk influences the valuation of financial assets, such as stocks, bonds, as well as real estate valuation (Bernstein et al., 2019; Painter, 2020; and Seltzer et al., 2022; Ginglinger and Moreau, 2022). Most institutional investors seriously consider climate risk a troublesome issue (Krueger et al., 2020).

According to a large body of recent research on climate risk related to corporate outcomes, climate risk places businesses in unfavorable situations with reduced firm valuations, negative stock market reactions, and higher costs of capital (Matsumura, Prakash, and Vera Munoz, 2014; Bolton and Kacperczyk, 2021; Huynh and Xia, 2021; Chava, 2014; Javadi and Masum, 2021; Hossain et al., 2022). Recent research reports that climate change does, in fact, expose companies to large additional vulnerabilities. Choi, Gao, and Jiang (2020), for example, show that stocks of carbon-intensive companies suffer in unusually warm weather. According to Bolton and Kacperczyk (2021), equities of companies with higher overall CO^2 emissions receive better returns. According to Painter (2020), the credit spread for long-term municipal bonds is much larger for communities located in coastal regions exposed to a sea level rise. Heo (2021) demonstrates that companies raise their cash holdings when subject to more climate risk.

The above studies suggest that the impact of climate risk on corporate outcomes and strategies constitutes a recent, albeit rapidly rising, strand of the literature. We add to the body of research in this area by investigating the influence of firm-specific climate change exposure on corporate innovation using data on corporate culture obtained from cutting-edge machine learning

algorithms. Although prior research has examined the effects of climate change on various corporate outcomes, no research in this area has focused on corporate innovation. We address this important void in the literature.

b. Corporate culture of innovation

Innovation is of paramount importance. According to a 2015 OECD study, innovation accounts for approximately fifty percent of a country's overall GDP growth, with the effects varying by economic development stage (He and Tian, 2018; Likitapiwat et al., 2022). According to economic researchers, technical innovation is responsible for around 85 percent of a nation's economic growth (He and Tian, 2018; Likitapiwat et al., 2022). According to Xu (2020), innovation is influenced by a variety of economic forces, including the development of financial markets (Hsu et al., 2014), access to equity markets (Acharya and Xu, 2017), credit supply (Chava et al., 2013; Cornaggia et al., 2015), organizational form (Li et al., 2018), and legislation and judicial frameworks (Acharya et al., 2013; Francis et al., 2018). In a cross-country study, Bhattacharya et al. (2017) demonstrate that national election uncertainty has a greater impact on technical innovation than a country's policies.

Despite a large volume of research on corporate innovation, none of the prior studies concentrate on the effect of climate change on corporate innovation. We fill this crucial gap in the literature using advanced data on corporate culture generated by a textual analysis of earnings conference calls. Our research pertinently combines two critical areas of the literature, i.e., climate change and corporate innovation.

Corporate culture is the common views and values that are present within a corporation (Cremer, 1993; Van den Steen, 2010; Li, Liu, Mai, and Zhang, 2021). Corporate culture is

important because employees will ultimately face challenging decisions that cannot be fully regulated in advance (O'Reilly, 1989; Griffin, Li, and Xu, 2021). Corporate culture is an intangible asset intended to respond to unexpected events as they occur (Li, Liu, Mai, and Zhang, 2021). The finance literature has, with a few exceptions, ignored the potential relevance of corporate culture. This is especially apparent thirty years after the "incomplete contract" revolution (Grossman and Hart, 1986; Guiso, Sapienza, and Zingales, 2015; Likitapiwat et al., 2022). If contracts are inadequate, culture and values may unquestionably assist in reducing the inefficiencies induced by the contractual environment's inadequacy (Guiso, Sapienza, and Zingales, 2015; Likitapiwat et al., 2022).

A few noteworthy studies on corporate culture have been produced. Guiso, Sapienza, and Zingales (2015), for instance, leverage a unique data set compiled by the Great Place to Work Institute (GPTWI), which conducts extensive employee surveys at over 1,000 U.S. enterprises. They indicate that high levels of perceived integrity are positively associated with advantageous outcomes, such as greater output, profitability, improved labor relations, and appeal to prospective job seekers. Notably, Li, Mai, Shen, and Yan (2021) assess the five corporate culture values of innovation, integrity, quality, respect, and teamwork for 62,664 firm-year observations from 2001 to 2018 using one of the most advanced machine learning techniques, the word embedding model, and 209,480 earnings call transcripts. They demonstrate that corporate culture is associated with important business outcomes, such as operational efficiency, risk-taking, earnings management, executive compensation design, firm value, and deal-making, and that the relationship between culture and performance is stronger in times of economic uncertainty.

d. The innovation reduction hypothesis

This view posits that more climate change exposure leads to less innovation. Climate change exposure raises a great deal of uncertainty in several ways. According to the literature, it is best for companies facing uncertainty to postpone investments since reversing investments is difficult. Hence, uncertainty raises the value of the option to wait (Bernanke, 1983; McDonald and Siegel, 1986). Consistent with this notion, prior research shows that firms cut down on investments in the presence of uncertainty. For instance, Gulen and Ion (2016) and Jens (2017) show that companies defer investments on fixed assets when faced with policy or political uncertainty. Employing implied volatility from stock options to represent firm-specific uncertainty, Stein and Stone (2013) demonstrate that implied volatility decreases capital investments. Investments in innovation are already more risky than other types of investments due to their uncertain nature of success.

In addition to the studies discussed above, several other studies also report negative effects of uncertainty. For instance, Goel and Ram (2001) examine annual data from nine OECD nations from 1981 to 1992 and report that uncertainty has a significant negative influence on R&D expenditures. According to Kang et al. (2014), economic policy uncertainty, which interacts with uncertainty at the enterprise level, hinders corporate investment decisions. Likewise, Wang et al. (2017) discover that policy and market uncertainties have a detrimental influence on corporate R&D expenditure, using data from Chinese listed companies. Finally, Bhattacharya, Hsu, Tian, and Xu (2017) document that economic policy uncertainty generated by government reforms inhibits company innovation. All of these studies imply that climate change exposure, which exacerbates the degree of uncertainty firms have to deal with, likely brings about less innovation.

Furthermore, another area of the literature that is related to this hypothesis concerns how firms use postponement to cope with uncertainty. Alderson (1950) was the first to introduce this

concept from the standpoint of marketing management. Alderson's approach provides a foundation for understanding how to deal with uncertainty (forced by consumer expectations) by deferring product differentiation. Buckling (1965) introduces postponement into the distribution channel, concentrating on where and by whom inventories in the channel should be positioned. Since then, there has been a surge of interest in postponement in the literature (Zinn and Bowersox, 1988; Feitzinger and Lee, 1997; Pagh and Cooper, 1998). The benefits of postponement have been determined to include cost savings in transportation, assorting, storage, and obsolescence by postponing a product's variety, volume, weight, and/or value increases, and, more significantly, ultimate configuration (Yang, Burns, and Backhouse, 2013).

The notion of postponement in the presence of uncertainty is relevant to our hypothesis because it implies that companies likely postpone investments in innovation during uncertain times. Climate change exposure creates a considerable amount of uncertainty. When subject to a higher level of uncertainty related to climate change, innovation is expected to decline. Firms going through uncertainty likely have fewer resources devoted to the promotion of an innovative culture, resulting in a weaker culture of innovation.

e. The innovation enhancement hypothesis

On the other hand, it can be argued that more climate change exposure fosters more innovation. Anticipating the various changes brought about by climate change, companies invest more in innovation in order to adapt to the new environment of the future. Realizing that the current way of doing business is becoming obsolete due to the impact of climate change, firms are motivated to be more innovative. In support of this argument, prior research finds that firms increase innovation in the presence of more uncertainty (He, Ma, and Zhang, 2020; Shen, Zhang,

Liu, and Hou, 2020). Those that fail to adjust to the effect of climate change may experience much more difficulty in the future than those that promote rapid adaptation through innovation.

Additionally, it may be argued that innovation efforts are irreversible, which increases the benefit of waiting when uncertainty is high. But, from the standpoint of corporate rivalry, when a corporation decides to wait, it may lose the chance to dominate the market, and the consequent losses are far more than the cost of innovation and the value of waiting. According to game theory, the waiting value of a company's innovation activities is determined by the behavior of its competitors. If competitors innovate during the waiting period, the value of waiting will be diminished or eliminated. Therefore, firms that are exposed to climate change should not delay their innovation efforts, as doing so may result in the erosion of their long-term competitive advantage (He, Ma, and Zhang, 2020; Kulatilaka and Perotti, 1998). This view thus suggests that more climate change exposure produces a stronger culture of innovation.

Consistent with this argument, He, Ma, and Zhang (2020) report greater corporate innovation when economic uncertainty is high, using a large sample of Chinese firms. In particular, they find that Chinese firms produce significantly more patents during uncertain times, suggesting that companies are not only not deterred by uncertainty, but even more motivated to be innovative during uncertain times. Likewise, Shen, Zhang, Liu, and Hou (2020) document a positive effect of economic policy uncertainty on corporate innovation with the effect being more pronounced in more competitive industries.

III. Sample construction and variable description

a. Sample formation

We start with a sample of corporate culture provided by Li et al. (2021). Then, we merge the sample with the data on firm-specific climate change exposure provided by Sautner et al.

(2023). Firm characteristics are from COMPUSTAT. We obtain the data on climate policy uncertainty from Gavriilidis (2021). Outliers are winsorized at the 1% and 99% as necessary. The final sample consists of 45,896 firm-year observations from 2001 to 2018. Our sample is from the U.S. due to data availability. Our sample is among the most comprehensive in the literature in this area. The five largest industries represented in our sample are business services, instruments and related products, electronic and other electric equipment, industry machinery and equipment, and electric, gas, and sanitary service.

b. Climate change exposure

We employ the data generated by Sautner et al. (2023) to estimate firm-level climate change exposure. Sautner et al. (2023) use transcripts of earnings conference calls to create firm-specific time-varying indicators of climate change vulnerability. A sophisticated machine learning approach is adopted by Sautner et al. (2023) to capture sets of climate change related bigrams. The frequency of various climate change bigrams in the transcript is counted and divided by the overall number of bigrams in the transcript. This metric essentially represents the incidence of climate change events or shocks at the company level (Heo, 2021). More detailed information on the construction of this measure is available in Sautner et al. (2023).

Earnings conference calls have been a significant tool for companies to communicate with its stakeholders, investors, and analysts during the last few decades. Managers frequently use this occasion to emphasize their financial accomplishments in favorable times and to assuage anxieties in difficult times (Hossain et al., 2022). Therefore, this is a sensible approach to capture firm-specific climate change exposure. Also, according to Hossain et al. (2022), this metric enjoys a few important advantages. First, this unique measure is shown to correspond well with other

significant economic parameters identified in previous research (for example, public awareness of climate change) (Sautner et al., 2023; Hossain et al., 2022).

Second, this metric is superior to utilizing carbon emissions, natural catastrophes, or pollution statistics, which many current climate change-related studies employ. For example, carbon emission figures are normally accessible only for firms who reveal them voluntarily, leaving out a large number of polluters that choose not to report this information. The climate risk measurement supplied by Sautner et al. (2023) encompasses a far larger spectrum of companies (Hossain et al., 2022). Owing to the advantages of this measure highlighted above, it has been rapidly embraced by several recent studies (Hossain et al., 2022; Heo, 2021).

c. Measuring a culture of innovation

According to Li, Mai, Shen, and Yan (2021), word embedding, a natural language model based on artificial neural networks, can understand the context-specific connotations of words and phrases. Using this model, they deploy a novel semi-supervised machine learning approach to construct a culture lexicon and analyze corporate culture values. Guiso, Sapienza, and Zingales (2015) recognize the top five corporate culture attributes as innovation, integrity, quality, respect, and teamwork. Using this approach, Li, Mai, Shen, and Yan (2021) examine hundreds of thousands of earnings call transcripts from 2001 to 2018 to establish ratings for these qualities. In addition, they conduct a number of empirical tests to confirm their unique measurement and demonstrate its superiority to a variety of other methods. Li, Mai, Shen, and Yan (2021) divide the total number of words in the document into the weighted word count associated with each corporate culture attribute to estimate the frequency of each corporate culture characteristic in each firm-year. More details about the construction of this measurement can be found in Li, Mai, Shen, and Yan (2021).

In this research, we concentrate on an innovative culture and employ the innovative culture score as our major variable. Specifically, the innovative culture score is derived by dividing the weighted number of words associated with innovative activities by the total number of words in the text. The greater the number of innovation-related terms used in earnings conference calls, the higher the innovative culture score, and the company is classified as possessing a stronger culture of innovation. This is the same measure of innovation used by Li, Mai, Shen, and Yan (2021), who thoroughly validate this new measure using more common metrics of innovation, such as patents, R&D, and the KLD database's innovation score, and find that the new measure is strongly validated by the conventional metrics of innovation. According to Li, Mai, Shen, and Yan (2021), the text-based measure of innovation captures what previous measures do not and should be used to complement the traditional measures of innovation.

Another key advantage is that the text-based innovation measure is available for a far larger number of firms as it can be constructed for any company that has earnings conference calls. In contrast, it is common knowledge that R&D statistics for more than half of COMPUSTAT's companies are unavailable. Even fewer corporations have patents. Using this new innovation metric, we can study a far larger set of firms, which dramatically increases the strength and relevance of our research.

d. Additional variables

We incorporate several variables that may influence innovation according to the literature (Lin, Liu, and Manso, 2021; Griffin, Li, and Xu, 2021; Jiraporn, Lee, Park, and Song, 2018). In particular, we account for firm size (Ln of total assets), profitability (EBIT/total assets), leverage (total debt/total assets), capital investments (capital expenditures/total assets), R&D expense (research and development/total assets), cash holdings (cash holdings/total assets), dividend

payouts (dividends/total assets), asset tangibility (fixed assets/total assets), and discretionary spending (SG&A expense/total assets). We add year fixed effects to account for possible variations over time. To mitigate any endogeneity ascribable to omitted variables, we include firm fixed effects. The variable definitions are listed in the Appendix. Table 1 displays the summary statistics for all the variables.

e. Empirical methods

Essentially, we estimate the following regression analysis:

$$Culture\ of\ Innovation_{it} = \alpha + \beta_1(Climate\ Change\ Exposure)_{it} + \beta_2(Controls)_{it}$$

where i indexes firms and t indexes years.

To enhance the robustness of our results, we employ a variety of empirical strategies. To address potential endogeneity concerns in our study, which could arise from the omitted variable bias, measurement errors, or simultaneity, we carefully select a set of empirical strategies. By incorporating year- and firm-specific fixed effects in our regression analysis, we control for unobserved heterogeneity that could be correlated with both the independent and dependent variables, thus mitigating the bias in our estimates. Propensity score matching (PSM) and entropy balancing are utilized to create a balanced dataset that simulates a randomized experiment, ensuring that the treatment and control groups are comparable on all observed covariates. This helps to reduce the selection bias and model dependency. Lastly, our instrumental variable analysis provides a method for obtaining consistent estimates when the explanatory variables are correlated with the error term, by introducing instruments that are correlated with the endogenous explanatory variables but uncorrelated with the error term. Together, these methods form a comprehensive approach to strengthen the validity of our findings by addressing the various sources of endogeneity.

IV. Results

a. Baseline regression analysis

Table 2 shows the baseline regression results where the dependent variable is the innovative culture score from Li et al. (2021). Standard errors are clustered at the firm level. Model 1 has climate change exposure as the only variable, while Model 2 includes all the control variables. The coefficients of firm-specific climate change exposure in Model 1 and Model 2 are both significantly positive. The results reinforce the prediction of the innovation enhancement hypothesis. To adapt to the changing environment of the future, firms spend more in innovation in anticipation of the consequences of climate change. It is noteworthy that we control for firm fixed effects. Our results are therefore unlikely tainted by the endogeneity bias that can be attributed to unobserved heterogeneity.

b. Propensity score matching (PSM)

Because most of the exposure to climate change risk comes from outside the firm, endogeneity is not likely. We also execute additional analysis to minimize endogeneity further. Using propensity score matching, we further validate our findings (Rosenbaum and Rubin, 1983; Lennox, Francis, and Wang, 2012; Likitapiwat et al., 2022). The sample is divided into quartiles depending on exposure to climate change. The treatment group comprises of data from the highest distribution quartile (highest exposure). Based on nine firm characteristics, we then choose the most comparable observation from the remainder of the sample for each observation in the treatment group (i.e., the nine control variables included in the regression analysis). Consequently, our treatment and control firms are nearly identical in every visible aspect, excluding their susceptibility to climate change.

We perform diagnostic testing to check that our matching is accurate. In particular, after executing propensity score matching, we run a logistic regression predicting whether any firm characteristics are related to the probability of being included in the treatment group. None of the coefficients are statistically significant, suggesting that our treatment and control groups are statistically indistinguishable.

Then, we run a regression analysis where innovation is the dependent variable using the propensity-score matched sample and show the results in Table 3. Exposure to climate change has a statistically significant positive coefficient, indicating that more exposure greatly promotes an innovative culture. Since the PSM results are consistent, it is unlikely that endogeneity would taint our conclusion. We also estimate the economic significance of the effect of climate change exposure and find that a rise in firm-specific exposure by one standard deviation improves innovation by 2.1%. The effect of firm-level exposure is thus not only statistically significant but is also economically non-trivial.[2]

c. Entropy balancing

To further reduce endogeneity, we employ a unique approach known as entropy balancing to remove disparities in observable characteristics between the treatment and control groups. This method is gaining traction in the social sciences as a means of addressing problems associated with conventional propensity score matching (PSM) (McMullin and Schonberger, 2020; Hainmueller, 2012; Likitapiwat et al., 2022). Entropy balancing, according to Gaver and Utke (2019), ensures that covariate imbalance improves after matching. Additionally, entropy balancing improves

[2]We estimate the economic magnitude as follows. The coefficient of climate change exposure in Table 3 Panel B is 9.385. One standard deviation of climate change exposure is 0.00257. Therefore, a rise in climate change exposure by one standard deviation raises innovation by 0.00257*9.385, which is 0.0241. Because one standard deviation of the innovation score is 1.147, a rise by 0.0241 represents a 2.1% increase in innovation.

testing efficiency by preventing the loss of data and random matches (Hossain, Hossain and Kryzanowski, 2021; Likitapiwat et al., 2022).

Our entropy balancing technique is as follows. As our treatment group, we select companies in the top quartile of climate change exposure. The remaining sample is referred to as the control group. Then, using entropy balancing, we verify that the mean, variance, and skewness of the observations in the two groups are similar. Table 4 displays the regression results for the entropy-balanced sample. The coefficient of climate change exposure remains positive and significant, showing the beneficial effect of climate change exposure on an innovative culture once more.

d. Instrumental variable analysis (IV)

To further reduce possible endogeneity, we also perform an instrumental variable analysis. Our first instrumental variable is the climate policy uncertainty index developed by Gavriilidis (2021). Based on a powerful textual analysis, this index captures the frequency of climate policy related terms in major newspapers and is expected to represent the degree of climate policy uncertainty at the macro level. For any given firm, climate policy uncertainty at the macro level is plausibly exogenous. It is also a reasonable assumption that climate policy uncertainty influences innovation through firm-specific climate change exposure. Therefore, we use this variable as our instrument.

Table 5 shows the results. Model 1 is the first stage where firm-specific exposure is the dependent variable. As expected, the coefficient of the climate policy uncertainty index is significantly positive, suggesting that climate uncertainty at the macro level is a significant determinant of firm-level climate change exposure. Model 2 is the second-stage regression where the dependent variable is innovation. The coefficient of firm-level exposure instrumented from the

first stage is significantly positive, confirming our prior results where more exposure produces more innovation.

To ensure that our results are robust, we execute additional analysis. We exploit the fact that part of climate change risk is local, i.e., local climate patterns affect firms located in the same area. Because local firms share local climate patterns, they share similar climate change exposure. This assumption is reinforced by Heo (2021), who reports that firm-specific exposure can be explained by the frequency of natural disasters in the state in which the firm is located. Therefore, we adopt as our instrument the average value of firm-specific exposure of firms located in the same city. The results are shown in Table 6. Model 1 shows that the average value of firm-specific exposure has significant explanatory power as expected. In Model 2, the coefficient of firm-level exposure is significantly positive, consistent with our prior findings. As robustness checks, we use the average value of firm-level exposure of firms located in the same state as our instrument and, in another check, combine instrumental variable analysis with propensity score matching and entropy balancing. Untabulated results show consistent results and support the same conclusion.

d. The role of economic uncertainty

Additionally, we incorporate economic uncertainty in our analysis. The exploration of the role of uncertain times as a moderating factor holds significant importance for several compelling reasons. First, it can be contended that climate change exposure serves as a mere proxy for overall economic uncertainty. Hence, to ensure the validity of our findings, it is crucial to incorporate a measure of economic uncertainty in our analysis. By accounting for the general degree of economic uncertainty, we can disentangle the specific impact of climate change exposure from the broader economic landscape.

Second, our research aims to shed light on the influence of firm-level climate change exposure during economically stressful periods. The Great Recession of 2008 serves as a prime example of a time characterized by immense uncertainty, which consequently had far-reaching effects on corporate policies and outcomes. By examining the impact of climate change exposure within such economically challenging contexts, we can gain a nuanced understanding of how firms navigate and respond to climate-related risks when confronted with broader economic turmoil.

Third, it is conceivable that firms perceive and evaluate the risks associated with climate change differently from risks arising from other factors. By incorporating economic uncertainty into our analysis, we can differentiate between the distinctive risks posed by climate change and the more conventional risks inherent in the economic environment. This differentiation is crucial for comprehending how firms prioritize and allocate resources to address climate change-related challenges amidst various uncertainties.

Finally, prior research demonstrates that firms exhibit different behaviors during economic downturns. An illustrative example of the relationship between economic conditions and firm behavior can be observed when the economy experiences a period of weakness. During such times, consumers often become more price sensitive due to reduced confidence in the overall economic outlook (Gordon et al., 2013). This heightened price sensitivity stems from a desire to exercise caution and preserve financial resources amidst economic uncertainty. As a result, firms need to adjust their strategies to accommodate the changing consumer behavior.

Interestingly, economic downturns also present firms with unique opportunities for aggressive innovation. Research by Steenkamp and Fang (2011) suggests that during periods of economic adversity, firms that embrace innovation and introduce new products or services can reap significant benefits later when the economy improves. During economic downturns,

competitors may be less inclined or capable of pursuing innovation, creating a relative advantage for firms that seize the opportunity. As a result, firms that actively innovate and provide compelling solutions during economic downturns can position themselves favorably in the market and potentially achieve higher returns. By acknowledging the interplay between economic conditions and firm behavior, we gain insights into the dynamic nature of the business environment. Economic fluctuations have the power to shape consumer preferences, altering their price sensitivity and purchase decisions. Simultaneously, firms can strategically leverage these fluctuations, capitalizing on the unique advantages offered by different economic contexts. Understanding these dynamics is essential for businesses seeking to navigate economic uncertainties effectively and maximize their performance.

To explore these issues, we adopt the economic policy uncertainty index (EPU) devised by Baker, Bloom, and Davis (2016), which is based on a textual analysis of newspaper articles related to economic uncertainty and has been widely utilized in the recent literature. We first include EPU as a control variable. Moreover, we create an interaction term between EPU and firm-level climate change exposure. The interaction term is expected to reveal the effect of firm-specific exposure on innovation during uncertain times.

Table 7 displays the regression results with the three models corresponding to the full sample, propensity score matching, and entropy balancing. First, it should be noted that the coefficient of firm-specific exposure by itself still exhibits positive and significant coefficients in all models even after including EPU as a control variable, indicating that the effect of climate change exposure on innovation is distinct, not subsumed by economic uncertainty in general. As far as the interaction term, the coefficients are significantly negative in all models, implying that the effect of firm-specific exposure on innovation is substantially less pronounced during uncertain

times. Our study is the first to investigate the interaction between climate change exposure and economically uncertain times.

V. Conclusions

A fledgling but constantly growing body of research has developed to examine the effects of climate risk on the outcomes, strategies, and actions of corporations (Matsumura, Prakash, and Vera Munoz, 2014; Bolton and Kacperczyk, 2021; Huynh and Xia, 2021; Chava, 2014; Javadi and Masum, 2021; Hossain et al., 2022; Choi, Gao, and Jiang, 2020; Bolton and Kacperczyk, 2021; Painter, 2020; Hong, Li, and Xu, 2019; Heo, 2021). In this article, we uniquely contribute to this important area of the literature by shedding light on the effect of firm-specific climate change exposure on corporate innovation through the lens of corporate culture. Our novel measures for climate change exposure and corporate culture are generated by a powerful textual analysis of earnings conference calls and represent a critical breakthrough in how firm-level exposure and corporate culture are quantified.

Based on a large sample of over 45,000 observations, our findings show that when firm-specific climate exposure is more severe, a culture of innovation is greatly reinforced. Our findings support the premise that firms are pushed to be more innovative in order to prepare for the different challenges brought about by climate change. Better innovation should enable the company to better deal with climate change. To confirm the robustness of our results, we employ a number of robustness checks, including propensity score matching (PSM), entropy balancing, and instrumental variable analysis using alternative instruments. All of the robustness tests support our conclusion that more firm-level exposure leads to a better innovative culture. Endogeneity seems to be improbable, and thus our results most likely reflect a causal influence, rather than just a correlation. Furthermore, using the EPU index to gauge uncertainty, we show that the effect of

firm-level climate change exposure on innovation is significantly less pronounced during uncertain times. Our results make useful contributions to several vital areas of the literature, namely, climate change, corporate innovation, corporate culture, and textual analysis in empirical finance.

The results of our study offer several implications of practical value. First, our results should be useful to managers, shareholders, and investors in general, who have strong interest in how climate change influences corporate policies and actions. We show one bright side of climate change by demonstrating that more climate change exposure raises corporate innovation. Second, regulators should be interested in our research as they ponder possible regulations in response to climate change. Our results inform them of an important effect of climate change, which should be taken into consideration when any regulation or legislation is deliberated. Third, environmentalists also benefit from our results as they have a better understanding of how climate change affects corporate practices. Our results reveal that the effect of climate change exposure is crucial and palpable in financial and capital markets as it exerts a significant influence on corporate innovation, which is one of the most crucial corporate outcomes.

Our study utilizes a sophisticated approach to measuring climate change exposure and its impact on corporate innovation culture, yet it is not without limitations. The reliance on textual analysis of earnings conference calls for gauging corporate culture and climate change exposure could potentially miss nuances that are not verbally expressed or are outside the scope of these discussions. Moreover, the use of sophisticated statistical techniques, while robust, may not fully account for all latent variables or the dynamic nature of innovation processes over time. The findings also suggest a diminished effect of climate exposure on innovation during uncertain times,

hinting at a complex interplay between external stressors and internal corporate responses that may require a more granular investigation.

Finally, a few possible avenues for future research are noteworthy. Building on the intriguing findings that link firm-specific climate change exposure to a culture of innovation, future research could delve deeper into the nuances of this relationship. A particularly rich area of study might involve examining the mechanisms through which corporate governance shapes a company's innovative responses to climate risks. This could reveal how leadership decisions, strategic priorities, and stakeholder pressures guide the innovation trajectory. Additionally, it would be insightful to investigate the differential impacts of climate change across various industries and regions, considering that the urgency and nature of innovation may vary significantly in response to localized environmental and regulatory contexts.

References

Acharya, V., & Xu, Z. (2017). Financial dependence and innovation: The case of public versus private firms. *Journal of Financial Economics*, *124*(2), 223–243. https://doi.org/10.1016/J.JFINECO.2016.02.010

Addoum, J. M., Ng, D. T., & Ortiz-Bobea, A. (2020). Temperature Shocks and Establishment Sales. *The Review of Financial Studies*, *33*(3), 1331–1366

Aghion, P., van Reenen, J., & Zingales, L. (2013). Innovation and Institutional Ownership. *American Economic Review*, *103*(1), 277–304. https://doi.org/10.1257/AER.103.1.277

Alderson, W. (1950). Marketing efficiency and the principle of postponement, *Cost and Profit Outlook* 3(4), 1-3.

Baker Nicholas Bloom Steven J Davis (2016). Measuring Economic Policy Uncertainty. *The Quarterly Journal of Economics*, *131*(4), 1593–1636. https://doi.org/10.1093/QJE/QJW024

Bansal, R., Kiku, D., & Ochoa, M. (2016). *Price of Long-Run Temperature Shifts in Capital Markets* (No. 22529). National Bureau of Economic Research. https://doi.org/10.3386/w22529

Barnett, M., Brock, W., & Hansen, L. P. (2020). Pricing Uncertainty Induced by Climate Change. *The Review of Financial Studies*, *33*(3), 1024–1066. https://doi.org/10.1093/RFS/HHZ144

Bernanke, B. S. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *The Quarterly Journal of Economics*, *98*(1), 85–106. https://doi.org/10.2307/1885568

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, *134*(2), 253–272. https://doi.org/10.1016/J.JFINECO.2019.03.013

Bhattacharya, U., Hsu, P. H., Tian, X., & Xu, Y. (2017). What Affects Innovation More: Policy or Policy Uncertainty? *Journal of Financial and Quantitative Analysis*, *52*(5), 1869–1901. https://doi.org/10.1017/S0022109017000540

Bolton, P., &Kacperczyk, M. (2021a). Do investors care about carbon risk? *Journal of Financial Economics*, *142*(2), 517–549. https://doi.org/10.1016/J.JFINECO.2021.05.008

Bolton, P., &Kacperczyk, M. (2021b). Do investors care about carbon risk? *Journal of Financial Economics*, *142*(2), 517–549. https://doi.org/10.1016/J.JFINECO.2021.05.008

Bradley, D., Kim, I., & Tianc, X. (2016). Do Unions Affect Innovation? *Https://Doi.Org/10.1287/Mnsc.2015.2414*, *63*(7), 2251–2271. https://doi.org/10.1287/MNSC.2015.2414

Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. *The Journal of Finance*, *64*(1), 151–185. https://doi.org/10.1111/J.1540-6261.2008.01431.X

Brown, J. R., & Martinsson, G. (2018). Does Transparency Stifle or Facilitate Innovation? *Https://Doi.Org/10.1287/Mnsc.2017.3002*, *65*(4), 1600–1623. https://doi.org/10.1287/MNSC.2017.3002

Buckling, L.P. (1965). Postponement, speculation, and the structure of distribution channels, *Journal of Marketing Research*, Feb., 26-31.

Chang, X., Chen, Y., Wang, S. Q., Zhang, K., & Zhang, W. (2019). Credit default swaps and corporate innovation. *Journal of Financial Economics*, *134*(2), 474–500. https://doi.org/10.1016/J.JFINECO.2017.12.012

Chang, X., Fu, K., Low, A., & Zhang, W. (2015). Non-executive employee stock options and corporate innovation. *Journal of Financial Economics*, *115*(1), 168–188. https://doi.org/10.1016/J.JFINECO.2014.09.002

Chava, S., Oettl, A., Subramanian, A., & Subramanian, K. V. (2013). Banking deregulation and innovation. *Journal of Financial economics*, *109(3)*, 759-774. https://doi.org/10.1016/j.jfineco.2013.03.015

Chava, S. (2014). Environmental Externalities and Cost of Capital. *Http://Dx.Doi.Org/10.1287/Mnsc.2013.1863*, *60*(9), 2223–2247. https://doi.org/10.1287/MNSC.2013.1863

Chemmanur, T. J., Loutskina, E., & Tian, X. (2014). Corporate Venture Capital, Value Creation, and Innovation. *The Review of Financial Studies*, *27*(8), 2434–2473. https://doi.org/10.1093/RFS/HHU033

Choi, D., Gao, Z., & Jiang, W. (2020). Attention to Global Warming. *The Review of Financial Studies*, *33*(3), 1112–1145. https://doi.org/10.1093/RFS/HHZ086

Chu, Y., Tian, X., & Wang, W. (2018). Corporate Innovation Along the Supply Chain. *Https://Doi.Org/10.1287/Mnsc.2017.2924*, *65*(6), 2445–2466. https://doi.org/10.1287/MNSC.2017.2924

Cornaggia, J., Mao, Y., Tian, X., & Wolfe, B. (2015). Does banking competition affect innovation? *Journal of Financial Economics*, *115*(1), 189–209. https://doi.org/10.1016/J.JFINECO.2014.09.001

CRÉMER, J. (1993). Corporate Culture and Shared Knowledge. *Industrial and Corporate Change*, *2*(3), 351–386. https://doi.org/10.1093/ICC/2.3.351

Eccles, R., Johnstone-Louis, M., Mayer, C., &Stroehle, J. (2020). The board's role in sustainability: a new framework for getting directors behind ESG efforts. *Harvard Business Review*, *98*(5).

Engle, R. F., Giglio, S., Kelly, B., Lee, H., & Stroebel, J. (2020). Hedging Climate Change News. *The Review of Financial Studies*, *33*(3), 1184–1216. https://doi.org/10.1093/RFS/HHZ072

Fang, V. W., Tian, X., & Tice, S. (2014). Does Stock Liquidity Enhance or Impede Firm Innovation? *The Journal of Finance*, *69*(5), 2085–2125. https://doi.org/10.1111/JOFI.12187

Feitzinger, E. and Lee, H.L. (1997). Mass customization at Hewlett Packard: the power of postponement, Harvard Business Review 75 (1), 116.

Francis, B. B., Kim, I., Wang, B., & Zhang, Z. (2018). Labor law and innovation revisited. *Journal of Banking & Finance*, *94*, 1–15. https://doi.org/10.1016/J.JBANKFIN.2018.06.007

Gaver, J. J., & Utke, S. (2019). Audit Quality and Specialist Tenure. *The Accounting Review*, *94*(3), 113–147. https://doi.org/10.2308/ACCR-52206

Gavriilidis, K. (2021). Measuring Climate Policy Uncertainty. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.3847388

Ginglinger, E., Moreau (2022). *ECGI Working Paper Series in Finance Climate Risk and Capital Structure*. https://ssrn.com/abstract=3327185

Goel, R. K., & Ram, R. (2001). Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries. *Economics Letters, 71(2),* 287-291. https://doi.org/10.1016/S0165-1765(01)00372-X

Gordon, B.R., Goldfarb, A., and Li, Y. (2013). Does price elasticity vary with economic growth? A cross-category analysis, *Journal of Marketing Research*, Feb., 4-23.

Graham, J. R., Grennan, J., Harvey, C. R., &Rajgopal, S. (2022). Corporate culture: Evidence from the field. *Journal of Financial Economics*, *146*(2), 552–593. https://doi.org/10.1016/J.JFINECO.2022.07.008

Griffin, D., Li, K., & Xu, T. (2021). Board Gender Diversity and Corporate Innovation: International Evidence. *Journal of Financial and Quantitative Analysis*, *56*(1), 123–154. https://doi.org/10.1017/S002210901900098X

Grossman, S.J. & Hart, O. (1986). The costs and benefits of ownership: A theory of vertical and lateral integration, Journal of Political Economy 94 (4).

Gu, Y., Mao, C. X., & Tian, X. (2017). Banks' interventions and firms' innovation: Evidence from debt covenant violations. *Journal of Law and Economics*, *60*(4), 637–671. https://doi.org/10.1086/696703/ASSET/IMAGES/LARGE/FG1.JPEG

Guiso, L., Sapienza, P., & Zingales, L. (2015). The value of corporate culture. *Journal of Financial Economics*, *117*(1), 60–76. https://doi.org/10.1016/J.JFINECO.2014.05.010

Gulen, H., & Ion, M. (2016). Policy Uncertainty and Corporate Investment. *The Review of Financial Studies*, *29*(3), 523–564. https://doi.org/10.1093/RFS/HHV050

Hainmueller, J. (2012). Entropy Balancing for Causal Effects: A Multivariate Reweighting Method to Produce Balanced Samples in Observational Studies. *Political Analysis*, *20*(1), 25–46. https://doi.org/10.1093/PAN/MPR025

He, F., Ma, Y., & Zhang, X. (2020). How does economic policy uncertainty affect corporate Innovation?–Evidence from China listed companies. *International Review of Economics & Finance*, *67*, 225–239. https://doi.org/10.1016/J.IREF.2020.01.006

He, J. (Jack), & Tian, X. (2013). The dark side of analyst coverage: The case of innovation. *Journal of Financial Economics*, *109*(3), 856–878. https://doi.org/10.1016/J.JFINECO.2013.04.001

He, J. and Tian, X. (2018), Finance and Corporate Innovation: A Survey. *Asia Pac J Financ Stud*, *47*, 165-212. https://doi.org/10.1111/ajfs.12208

Henderson, R., & Serafeim, G. (2020). Tackling Climate Change Requires Organizational Purpose. *AEA Papers and Proceedings*, *110*, 177–180. https://doi.org/10.1257/PANDP.20201067

Heo, Y. (2021). Climate Change Exposure and Firm Cash Holdings. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.3795298

Hong, H., Li, F. W., & Xu, J. (2019). Climate risks and market efficiency. *Journal of econometrics*, *208*(1), 265-281. https://doi.org/10.1016/j.jeconom.2018.09.015

Hossain, A., Masum, A.-A., Saadi, S., Benkraiem, R., & Das, N. (2022). Firm-Level Climate Change Risk and CEO Equity Incentives. *British Journal of Management*, *0*, 1–33. https://doi.org/10.1111/1467-8551.12652

Hossain, A. T., Hossain, T., &Kryzanowski, L. (2021). Political corruption and corporate payouts. *Journal of Banking & Finance*, *123*, 106016. https://doi.org/10.1016/J.JBANKFIN.2020.106016

Hsu, P. H., Tian, X., & Xu, Y. (2014). Financial development and innovation: Cross-country evidence. *Journal of Financial Economics*, *112*(1), 116–135. https://doi.org/10.1016/J.JFINECO.2013.12.002

Huynh, T. D., & Xia, Y. (2021a). Climate Change News Risk and Corporate Bond Returns. *Journal of Financial and Quantitative Analysis*, *56*(6), 1985–2009. https://doi.org/10.1017/S0022109020000757

Huynh, T. D., & Xia, Y. (2021b). Climate Change News Risk and Corporate Bond Returns. *Journal of Financial and Quantitative Analysis*, *56*(6), 1985–2009. https://doi.org/10.1017/S0022109020000757

Javadi, S., & Masum, A.-A. (2021). The impact of climate change on the cost of bank loans. *Journal of Corporate Finance*, *69*, 102019. https://doi.org/10.1016/J.JCORPFIN.2021.102019

Jens, C. E. (2017). Political uncertainty and investment: Causal evidence from U.S. gubernatorial elections. *Journal of Financial Economics*, *124*(3), 563–579. https://doi.org/10.1016/J.JFINECO.2016.01.034

Jiraporn, P., Lee, S. M., Park, K. J., & Song, H. (2018). How do independent directors influence innovation productivity? A quasi-natural experiment. *Applied Economics Letters, 25(7),* 435-441.https://doi.org/10.1080/13504851.2017.1329927

Kang, W., Lee, K., & Ratti, R. A. (2014). Economic policy uncertainty and firm-level investment. *Journal of Macroeconomics, 39,* 42-53. https://doi.org/10.1016/j.jmacro.2013.10.006

Krueger, P., Sautner, Z., & Starks, L. T. (2020). The importance of climate risks for institutional investors. *The Review of Financial Studies, 33(3),* 1067-1111. https://doi.org/10.1093/rfs/hhz137

Kulatilaka, N., & Perotti, E. C. (1998). Strategic growth options. *Management Science, 44(8),* 1021-1031. https://doi.org/10.1287/mnsc.44.8.1021

Lennox, C. S., Francis, J. R., & Wang, Z. (2012). Selection Models in Accounting Research. *The Accounting Review*, *87*(2), 589–616. https://doi.org/10.2308/ACCR-10195

Lerner, J., & Tufano, P. (2011). The Consequences of Financial Innovation: A Counterfactual Research Agenda*. *Http://Dx.Doi.Org/10.1146/Annurev.Financial.050808.114326*, *3*, 41–85. https://doi.org/10.1146/ANNUREV.FINANCIAL.050808.114326

Li, K., Liu, X., Mai, F., & Zhang, T. (2021). The Role of Corporate Culture in Bad Times: Evidence from the COVID-19 Pandemic. *Journal of Financial and Quantitative Analysis*, *56*(7), 2545–2583. https://doi.org/10.1017/S0022109021000326

Li, K., Mai, F., Shen, R., & Yan, X. (2021). Measuring Corporate Culture Using Machine Learning. *The Review of Financial Studies*, *34*(7), 3265–3315. https://doi.org/10.1093/RFS/HHAA079

Li, K., Qiu, B., & Shen, R. (2018). Organization Capital and Mergers and Acquisitions. *Journal of Financial and Quantitative Analysis*, *53*(4), 1871–1909. https://doi.org/10.1017/S0022109018000145

Likitapiwat, T., Treepongkaruna, S., Jiraporn, P., & Uyar, A. (2022). Corporate culture, innovation, and female board representation: Evidence from earnings conference calls. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.4192014

Lin, C., Liu, S., & Manso, G. (2020). Shareholder Litigation and Corporate Innovation. *Https://Doi.Org/10.1287/Mnsc.2020.3626*, *67*(6), 3346–3367. https://doi.org/10.1287/MNSC.2020.3626

Matsumura, E. M., Prakash, R., & Vera-Muñoz, S. C. (2014). Firm-Value Effects of Carbon Emissions and Carbon Disclosures. *The Accounting Review*, *89*(2), 695–724. https://doi.org/10.2308/ACCR-50629

McDonald, R., & Siegel, D. (1986). The Value of Waiting to Invest. *The Quarterly Journal of Economics*, *101*(4), 707–727. https://doi.org/10.2307/1884175

McMullin, J. L., & Schonberger, B. (2020). Entropy-balanced accruals. *Review of Accounting Studies*, *25*(1), 84–119. https://doi.org/10.1007/S11142-019-09525-9/TABLES/7

Ongsakul, V., Chatjuthamard, P., Jiraporn, P., &Chaivisuttangkun, S. (2021). Corporate integrity and hostile takeover threats: Evidence from machine learning and "CEO luck." *Journal of Behavioral and Experimental Finance*, *32*, 100579. https://doi.org/10.1016/J.JBEF.2021.100579

O'Reilly, Charles. (1989). Corporations, Culture, and Commitment: Motivation and Social Control in Organizations. 31. 9-25. 10.2307/41166580.

Pagh, J.D. and Cooper M.C. (1998). Supply chain postponement and speculation strategies: How to choose the right strategy, Journal of Business Logistics 19 (2), 13-33.

Painter, M. (2020). An inconvenient cost: The effects of climate change on municipal bonds. *Journal of Financial Economics*, *135*(2), 468–482. https://doi.org/10.1016/J.JFINECO.2019.06.006

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. https://doi.org/10.1093/BIOMET/70.1.41

Sautner, Z., van Lent, L., Vilkov, G., & Zhang, R. (2023). Firm-level Climate Change Exposure. *Journal of Finance*, 78 (3), 1449-1498.

Seltzer, L. H., Starks, L., Zhu, Q., Chollet, P., Griffin, J., Gustafson, M., Matos, P., Moreau, Q., Niehaus, G., Sautner, Z., & Weitzner, G. (2022). *Climate Regulatory Risk and Corporate Bonds*. https://doi.org/10.3386/W29994

Shen, H., Zhang, M., Liu, R., & Hou, F. (2020). Economic Policy Uncertainty and Corporate Innovation: Evidence From China. *Article in South Asia Economic Journal*. https://doi.org/10.46557/001c.17192

Steenkamp, J.B.E and Fang, E. (2011). The impact of economic contractions on the effectiveness of R&D and advertising: Evidence from U.S. companies spanning three decades, *Marketing Science* 30 (4), 628-645.

Stein, L. C. D., & Stone, E. (2013). The Effect of Uncertainty on Investment, Hiring, and R&D: Causal Evidence from Equity Options. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.1649108

Van den Steen, E. (2010). On the origin of shared beliefs (and corporate culture). *The RAND Journal of Economics*, *41*(4), 617–648. https://doi.org/10.1111/J.1756-2171.2010.00114.X

Wang, Y., Wei, Y., & Song, F. M. (2017). Uncertainty and corporate R&D investment: Evidence from Chinese listed firms. *International Review of Economics & Finance, 47*, 176-200. https://doi.org/10.1016/j.ribaf.2020.101234

Weber, Y., Shenkar, O., &Raveh, A. (1996). National and Corporate Cultural Fit in Mergers/Acquisitions: An Exploratory Study. *Management Science, 42*(8), 1215–1227. https://doi.org/10.1287/mnsc.42.8.1215

Xu, Z. (2020). Economic policy uncertainty, cost of capital, and corporate innovation. *Journal of Banking & Finance, 111,* 105698. https://doi.org/10.1016/J.JBANKFIN.2019.105698

Yang, B., N.D. Burns, and Backhouse, C.J. (2013). Management of uncertainty through postponement, *International Journal of Production Research*, 1049-1064.

Zinn, W. and Bowersox D.J. (1988). Normative cost models applied to postponement of labeling, packaging, assembly, manufacturing or shipment time, Journal of Business Logistics 9(2), 11-136.

Table 1: Descriptive statistics

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense.

	Mean	Std. dev.	25th	Median	75th
Innovation Score	1.868	1.147	1.043	1.600	2.416
Climate Change Exposure	0.001	0.003	0.000	0.000	0.001
Total Assets	9867.709	53290.610	259.542	1001.953	4138.646
EBIT/Total Assets	0.026	0.193	0.010	0.065	0.113
Total Debt/Total Assets	0.246	0.227	0.033	0.214	0.376
Capital Expenditures/Total Assets	0.050	0.056	0.015	0.032	0.063
R&D Expense/Total Assets	0.051	0.103	0.000	0.001	0.058
Cash Holdings/Total Assets	0.200	0.220	0.038	0.114	0.286
Dividends/Total Assets	0.014	0.030	0.000	0.000	0.017
Fixed Assets/Total Assets	0.511	0.422	0.171	0.387	0.784
SG&A Expense/Total Assets	0.238	0.251	0.053	0.168	0.338

Table 2: The effect of climate change exposure on a culture of innovation

The table presents the results of a firm-fixed-effects regression analysis. The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense

	(1) Innovation	(2) Innovation
Climate Change Exposure	**8.178****	**7.835****
	(2.197)	**(2.112)**
Firm Size		0.026
		(1.517)
Profitability		0.014
		(0.242)
Total Leverage		-0.072*
		(-1.688)
Capital Expenditures		-0.063
		(-0.509)
R&D Investments		0.298*
		(1.929)
Cash Holdings		0.171***
		(2.881)
Dividends		0.381*
		(1.672)
Fixed Assets		-0.019
		(-0.503)
Discretionary Spending		0.082
		(1.274)
Constant	1.859***	1.634***
	(479.014)	(12.220)
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	45,412	45,412
Adjusted R-squared	0.610	0.610

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Propensity score matching

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense

Table 3: Propensity score matching (continued)

	(1) Innovation
Climate Change Exposure	**9.385***** **(2.610)**
Firm Size	0.004 (0.170)
Profitability	-0.041 (-0.615)
Total Leverage	0.049 (0.318)
Capital Expenditures	0.475 (1.428)
R&D Investments	0.364*** (3.601)
Cash Holdings	0.507* (1.674)
Dividends	-0.100** (-1.995)
Fixed Assets	0.074 (0.523)
Discretionary Spending	1.570*** (8.260)
Firm Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	21,924
Adjusted R-squared	0.636

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Entropy balancing

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense

	(1) Innovation
Climate Change Exposure	**8.425****
	(2.388)
Firm Size	0.010
	(0.537)
Profitability	0.004
	(0.052)
Total Leverage	-0.029
	(-0.536)
Capital Expenditures	0.063
	(0.480)
R&D Investments	0.455*
	(1.759)
Cash Holdings	0.319***
	(4.269)
Dividends	0.312
	(1.368)
Fixed Assets	-0.084**
	(-2.011)
Discretionary Spending	0.145
	(1.525)
Constant	1.512***
	(9.653)
Firm Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	45,412
Adjusted R-squared	0.610

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Instrumental variable analysis based on the Climate Policy Uncertainty Index

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). The climate policy uncertainty index is from Gavriilidis (2021). SG&A is selling, general, and administrative expense.

	(1) Climate Change Exposure	(2) Innovation
Climate Policy Uncertainty Index	**0.000004***** **(9.295141)**	
Climate Change Exposure (Instrumented)		**995.659***** **(18.791)**
Firm Size	0.000085*** (3.499738)	0.162*** (9.780)
Profitability	0.000140* (1.911516)	-0.130** (-2.178)
Total Leverage	-0.000236*** (-3.620932)	0.266*** (5.642)
Capital Expenditures	0.000320 (0.940489)	-0.680*** (-5.481)
R&D Investments	0.000375* (1.869107)	0.066 (0.408)
Cash Holdings	0.000169** (2.143497)	0.098 (1.595)
Dividends	0.000188 (0.466019)	1.032*** (4.238)
Fixed Assets	0.000073 (1.029581)	0.176*** (4.319)
Discretionary Spending	0.000140* (1.742024)	0.141** (2.022)
Constant	-0.000013 (-0.064192)	-0.495*** (-4.371)
Firm Fixed Effects	Yes	Yes
Observations	45,412	45,412
Adjusted R-squared	0.786326	0.584

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Instrumental variable analysis (IV) based on companies in the same city

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense.

	(1) Climate Change Exposure	(2) Innovation
Climate Change Exposure (City Average)	**0.734***** **(15.391)**	
Climate Change Exposure (Instrumented)		**15.622**** **(2.254)**
Firm Size	-0.000 (-0.621)	0.026 (1.524)
Profitability	0.000 (0.729)	0.013 (0.224)
Total Leverage	-0.000** (-2.381)	-0.071 (-1.645)
Capital Expenditures	0.000 (0.742)	-0.067 (-0.539)
R&D Investments	0.000 (1.564)	0.295* (1.915)
Cash Holdings	0.000 (1.340)	0.170*** (2.866)
Dividends	0.000 (0.286)	0.382* (1.679)
Fixed Assets	-0.000 (-0.408)	-0.019 (-0.496)
Discretionary Spending	-0.000 (-0.750)	0.083 (1.273)
Constant	0.000* (1.916)	1.625*** (12.159)
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	45,412	45,412
Adjusted R-squared	0.845	0.610

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: The effect of climate change exposure on innovation during uncertain times

The innovation score is from Li et al. (2021), whereas firm-level exposure to climate change is from Sautner et al. (2023). SG&A is selling, general, and administrative expense. The EPU index is from Baker et al. (2016).

	Full Sample	PSM	Entropy Balancing
	(1)	(2)	(3)
	Innovation	Innovation	Innovation
Climate Change Exposure × EPU Index	**-0.275*** **	**-0.236*** **	**-0.225*** **
	(-5.159)	**(-4.100)**	**(-4.147)**
Climate Change Exposure	52.404***	46.053***	45.073***
	(6.974)	(5.973)	(6.093)
Firm Size	0.320***	0.262***	0.284***
	(21.883)	(14.308)	(17.800)
Profitability	0.016	-0.004	-0.021
	(0.262)	(-0.047)	(-0.266)
Total Leverage	0.078*	0.077	0.078
	(1.652)	(1.052)	(1.330)
Capital Expenditures	-0.590***	-0.427***	-0.390***
	(-4.696)	(-2.727)	(-2.943)
R&D Investments	0.573***	0.667*	0.684**
	(3.473)	(1.859)	(2.450)
Cash Holdings	0.276***	0.489***	0.467***
	(4.451)	(4.717)	(5.993)
Dividends	1.395***	1.334***	1.119***
	(5.594)	(4.041)	(4.440)
Fixed Assets	0.344***	0.243***	0.251***
	(8.219)	(4.694)	(5.657)
Discretionary Spending	0.353***	0.261*	0.397***
	(4.974)	(1.728)	(3.758)
EPU Index	-0.000	-0.000	-0.000***
	(-1.019)	(-1.297)	(-2.600)
Constant	-0.729***	-0.625***	-0.786***
	(-6.325)	(-3.988)	(-6.005)
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	45,412	21,925	45,412
Adjusted R-squared	0.578	0.609	0.579

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix

Variable	Definition
Innovation	
Innovation Score	Innovation score based on a culture of innovation
Climate Change	
Climate Change Exposure	Firm-specific exposure to climate change obtained from textual analysis
Firm Characteristics	
Firm Size	Ln (total Assets)
Profitability	EBIT/Total Assets
Total Leverage	Total Debt/Total Leverage
Capital Expenditures	Capital Expenditures/Total Assets
R&D Investments	R&D Expense/Total Assets
Cash Holdings	Cash Holdings/Total Assets
Dividends	Dividends/Total Assets
Fixed Assets	Fixed Assets/Total Assets
Discretionary Spending	SG&A Expense/Total Assets