# Climate change risk and the value of cash holdings

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**Abstract**

In this paper, we investigate the effects of the firm-level climate change risk on the marginal value of corporate cash holdings. The underlying idea is that climate change risks would induce firms to increase their demand for capital, which may also lead to an increase in the value of the cash holdings. As the climate change risk is an uncertainty for firms, investors would also positively evaluate the firm's excess cash for precautionary purposes. A regression analysis finds a positive association between the firm-level climate change risk and the value of cash holdings. Furthermore, we also test how the green swan and financial constraint level affect the relationship. Subsample analysis shows that the market positively values the cash holdings of firms that are more sensitive to climate change and that are more financially constrained. Various robustness tests confirm that the baseline regression results are not necessarily driven by endogeneity.

**Keywords**: climate change risk, climate change exposure, marginal value of cash holdings, corporate cash holdings, Green swan

## 1. Introduction

In January 2020, the Bank for International Settlements (BIS), a gathering of central banks in each country, coined the term 'Green Swan' (Bolton et al., 2020). The BIS report warns that climate change will have economic shocks such as rapid inflation but reduced productivity. The report argues that climate change may reduce economic productivity because resources would be scarce due to extreme climate changes. Furthermore, climate changes may also reduce the labor's working hours due to extreme cold or heat waves. Since these climate change risks affect not only human life and ecosystems but also capital markets, both governments and companies are paying attention. For this reason, research on climate change risk has been actively conducted in business, economics, and corporate finance. In this paper, we investigate whether climate change risk has any effects on the marginal value of cash holdings.

Denis and Sibilkov (2010) document that corporate cash holdings can have more value when other sources of funds, including cash flows, are insufficient to meet firms' demand for capital. In other words, the higher the demand for capital, the higher the value of cash holdings, ceteris paribus. Furthermore, Bates et al. (2018) find that capital market frictions such as product market competition, credit market risk, and within-firm diversification are main drivers of the increase in the value of cash holdings in recent decades.

Consistent with this view, we posit that climate change risks may induce firms to increase their demand for capital, which may also lead to an increase in the value of their cash holdings. Recent theoretical work shows that the climate change risk increases the firm's uncertainty (Barnett et al., 2020). To hedge such rising frictions, firms have large motivations to hoard cash. Empirical evidence finds that firms significantly increase their cash holdings in response to increase in climate changes (Heo, 2021). However, how the market responds to the firm's precautionary savings to climate change risks is yet unexplored. As the climate change risk is an uncertainty for firms, governments, economists and households, the market would also positively value the firm's decision to hoard more cash.

To examine our conjecture, we employ the idea from Sautner et al. (2020) and use their measures to proxy the firm-level climate change risk disclosure. Previous studies use the Global Climate Risk Index (CRI) or climate-induced sea level rise to proxy for climate change risk (Huang et al., 2018; Painter, 2020; Ding et al., 2021). However, these proxies have limitations in that they measure country-level or state-level climate risk. Sautner et al. (2020) introduce a machine learning-based method that identifies firm-level climate change exposures from conversation in earnings conference calls. The method captures exposures related to opportunity, physical, and regulatory shocks associated with climate change at firm-level. In addition to the firm-level climate change risk variable, we also borrow the empirical model of Faulkender and Wang (2006) to estimate the marginal value of cash holdings by examining how changes in cash holdings affect the market value of equity capital.

Our empirical results first confirm the positive association between the firm-level climate change risk and the value of cash. The findings imply that firms with exposure to the climate change risk have $0.52 larger marginal value of cash holdings compared to firms with non-exposure to the climate change risk. Furthermore, results also imply that investors positively value the firm's precautionary savings when the firm discloses climate change risk related descriptions. As the climate change risk is a friction for firms (Engle et al., 2020; Giglio et al., 2021), investors tend to value the firm's decision to hoard cash for precautionary purposes. Even if the regression analysis confirms that the investors positively value the firm's excess cash when the firm discloses climate change risks, the results may be biased due to endogeneity concerns. To somewhat mitigate such problems, we employ several robustness tests. Specifically, we employ a firm fixed effects model and propensity score matching (PSM) approach. Regardless of the robustness tests, we find that the baseline regression results and the statistical significance are unchanged.

Further to the baseline estimation, we also test several subsample analyzes to investigate whether the relationship between the firm's climate change risk disclosure and the value of corporate cash holdings are affected by other sources. We first examine the green swan channel. The idea is that the climate change risk effects would depend on the firm's labor intensity and raw material price sensitivity.

Subsample analysis confirms that the value of cash for climate change would be higher in the group of firms with higher corporate labor intensity and higher sensitivity to climate change risks. We also test the effects of the financing conditions. Shareholders may not appreciate the excess cash of a firm with a high level of financing for climate change risks. On the other hand, investors would recognize the cash holdings of a firm that lacks financing ability as the firm would need cash for risk-hedging purposes. Using firm age, credit rating and leverage ratio to proxy the financial status, we find that investors positively value the excess cash when the firm is young (below median), when the firm does not have credit rating, and when the firm's leverage is high (above median).

The contribution of the research is twofold. First, we provide empirical evidence on investigating determinants of the value of corporate cash holdings. In the frictionless market, the marginal value of a dollar of cash for shareholders should exactly be a dollar. The cost of obtaining and maintaining that reserve equals its expected benefit. However, due to several frictions there exists a variation in the marginal value of cash (Faulkender and Wang, 2006; Dittmar and Mahrt-Smith, 2007). To date, studies have vastly focused on the agency conflict based explanations. For instance, Dittmar and Mahrt-Smith (2007) find that the marginal value of cash holdings is positively associated with the index of shareholder rights and is also positively associated with the amount of shares held by institutional blockholders. Furthermore, Liu and Mauer (2011) document a negation relationship between CEO's risk-taking incentives and the marginal value of cash holdings. Authors attribute the findings to stockholder-bondholder conflicts. Departing from the agency conflict view, our paper complements arguments that the precautionary motivation can explain much of the rise in the cash holdings (Bates et al., 2009; Bates et al., 2018). Specifically, we show that the increased climate change risk and exposure affect investors to value the corporate cash holdings more, which eventually increases the marginal value of cash holdings.

Our paper also contributes to the growing literature on the climate change risk, especially how the risk affects the financial market. Engle et al. (2020) and Giglio et al. (2021) state that climate change is becoming a large uncertainty for firms and households. Giglio et al. (2021) first discuss various approaches to incorporating climate risk in macro finance models. Authors also discuss how investors can use these assets to construct portfolios that hedge against climate risk. Extensive empirical literature on climate risk has vastly explored the pricing of climate risks across a large number of asset classes, including real estate, equities, and fixed income securities. Under such financial frictions, companies are likely to hedge against such risks by, for example, increasing the corporate cash holdings (Myers and Majluf, 1984). Studies have long documented that cash holdings help mitigate several risks (Froot et al., 1993). In other words, under higher climate change risk exposure, the market would value the cash more as it could be used to mitigate risks associated with such events that may lead to future liquidity shortage (Holmstrom and Tirole, 2000). Consistent with the conjecture, we suggest that the investors are aware of the climate change risk exposure, and that they respond to the risks by valuing the corporate cash more. This is also because the cash could act as a safety guard against increasing physical, regulatory, or transition threats imposed by climate change (Masum et al., 2020). Prior studies have mainly focused on quantifying the climate change risks (Engle et al., 2020; Giglio et al., 2021). Recently, few studies have examined how climate change risk exposure affects the corporate cash holdings (Heo, 2021; Masum et al., 2021). However, to the best of our knowledge, this paper is the first that empirically investigates how the market responds to the firm's precautionary savings to hedge against the climate change risks.

The paper is organized as follows. In Section 2, we review related literature and develop the testable hypotheses. We then discuss how we have obtained the firm-level climate change risk exposure data and other variables to measure the marginal value of cash holdings in Section 3. Section 4 presents the main findings of the paper and also provides several robustness test results. We then discuss the results on further tests on Section 5. We discuss and conclude on Section 6.

## 2. Hypothesis Development

Initially proposed by Faulkender and Wang (2006), extensive literature has studied how the marginal value of cash holdings change under diverse circumstances. Faulkender and Wang (2006) has first examined the cross-sectional variation in the marginal value of corporate cash holdings that arises from differences in corporate financial policy. Authors use a revised event study methodology that examines market returns over firm fiscal years to test empirical predictions about the cross-sectional variation in the market value of cash. They find that for the mean firm-year in the sample, the marginal value of cash equivalent is less than $1. Such difference suggests that the market perceives the presence of market frictions that make raising outside capital costly, which is consistent with the agency cost literature (Jensen and Meckling, 1976).

On the other hand, another strand of literature also argues that other underlying mechanisms that may explain the value of cash exist. Bates et al. (2018) find that the value of corporate cash holdings has significantly increased in recent decades.[1] Authors argue that such monotonic increment during the past decades is predominantly driven by the secular trends in market competition and risks and within-firm diversification. Furthermore, Bates et al. (2009) suggest that firms increase cash holdings due to the precautionary motives rather than the agency conflicts motivations. Authors find that market frictions like product market competition, credit market risk, and within-firm diversification are main drivers of the increase in the value of cash holdings in recent decades. For example, Irvine and Pontiff (2009) and Fresard (2010) show that corporate cash holdings are useful assets when the market friction is high. That is, firms save cash for the precautionary purposes (Opler et al., 1999; Duchin, 2010; Faulkender et al., 2019). This view of precautionary motives of corporate cash holdings commonly shows that firms have motivations and incentives to save cash if the firms are exposed to certain uncertainties.[2]

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[1] Bates et al. (2018) find that on average, $1 of cash is valued at $0.61 during the 1980s, $1.04 in the 1990s, and $1.12 in the 2000s.

[2] There are several types of potential uncertainties and frictions on the management. Opler et al. (1999) for instance show that a financing uncertainty is one reason why firms hoard precautionary savings. Duchin (2010) further shows that cash flow uncertainty is another reason why firms increase the level of cash holdings. On the

Further to well-known corporate frictions such as financing uncertainties and cash flow uncertainties, recent studies have begun to recognize the climate change risk as another important firm-level uncertainty. Climate change risk similarly is also an uncertainty for firms, governments and households. Hugon and Law (2019) argue that climate change would negatively affect over two-thirds of firms - directly and adversely. That is, in addition to firms that are directly damaged by climate changes, other firms are also indirectly affected by regulations and policies related to climate change (Batten, 2018). Climate change may directly affect the firm's labor supply as global warming may reduce the working hours due to extreme heats, or the extreme weather events may negatively affect productivity. There is ample anecdotal evidence that climate change risk has devastating effects on the climate change risk exposed firms and on the overall economy. For instance, power outages across Texas caused by historically cold weather in 2021 have shut down semiconductor plants clustered around Austin, further disrupting a supply chain that has already been falling short of customer needs. Ian King of Bloomberg commented on 18th of February, 2021 that "NXP Semiconductor NV, one of the largest makers of chips used by automakers, has idled two plants in the Austin area, the company said early Wednesday. Samsung Electronics Co., the world's second largest semiconductor maker, also closed down production at its Austin site, the South Korean company said. Infineon Technologies AG, another large supplier of chips to the automotive industry, said its Austin plant has been shut down because the power was turned off." Firms thus have motivations to hoard excess cash to hedge against climate change risks (Masum et al., 2020; Heo, 2021).

If climate change risk is a concern for a firm, and the firm increases its cash holdings to hedge against potential upcoming risks, then the market may positively value the excess cash. Denis and Sibilkov (2020) show that the value of excess cash increases when funds are insufficient to meet the demand for capital. Authors argue that hedging needs of financially constrained firms increase the value of the cash holdings. If that is true, then climate change risks may induce firms to increase their risk

similar ground, Harford et al. (2014) argue that the refinancing friction induces managers to save more cash.

hedging demand, and the demand may also be positively valued by the market, which increases the marginal value of excess cash. We therefore hypothesize as follows:

***Hypothesis:*** *Climate change risk is positively associated with the marginal value of the corporate cash holdings.*

## 3. Data and Methodology

### *3.1. Climate change risk variable*

We refer to measures introduced by Sautner et al. (2020) to calculate the firm-level climate change risk and climate change exposure measures. While studies have long investigated and suggested indices to measure the level of climate risk, those studies were often limited at country- or industry-level (Huang et al., 2018; Painter, 2020; Ding et al., 2021). Therefore, it was difficult to use such indices in the corporate finance literature as they do not capture the variations among firms. By overcoming the problems, Sautner et al. (2020) provided a firm-level climate change risk level. Authors incorporate machine learning algorithms to create a set of bigrams that are closely related to climate change. The algorithm counts the frequency of climate change bigrams in the transcripts of the firm's conference calls. Bigrams such as “renewable energy”, “clean energy”, “greenhouse gas” are examples of bigrams that occur the most in the transcripts of analyst conference calls. We then divide the frequency of certain climate change bigrams in the transcript and divide them by the total number of bigrams in the transcript to construct the first measure: *climate change exposure*.

We also define the *climate change risk* measure, which is the main variable of interest of our paper. Sautner et al. (2020) construct the risk measure which is associated with the climate shocks. Similar to the *climate change exposure* variable, authors count the relative frequency of climate change bigrams with the words “risk” or “uncertainty”. Therefore, the *climate change risk* variable captures firm-level climate change risks related to physical and regulatory shocks associated with climate changes.

### *3.2. Marginal value of corporate cash holdings*

In addition to the firm-level climate change risk and exposure variables, we also borrow the empirical model of Faulkender and Wang (2006) to estimate the marginal value of cash holdings by examining how changes in cash holdings affect the market value of equity capital. We first calculate a firm's annualized stock returns and the market value of the firm using the Center for Research in Security Prices (CRSP) and Compustat databases. We use the returns to the 5x5 Fama and French portfolio from Kenneth French's data library.

Following the prior value of cash holdings literature (e.g, Faulkender and Wang, 2006; Dittmar and Mahrt-Smith, 2007), we use the Compustat database to calculate the control variables such as: change in cash, change in earnings, change in non-cash, change in R&D expense, change in interest expense, change in dividend payouts, lagged cash amount, leverage ratio, net financing ratio and firm size.

### *3.3. Samples*

This study is based on a sample of U.S. public firms found in the Compustat database for the period 2002 to 2017. Our sample is started in 2002 as climate change risk data of Sautner et al. (2020) is calculated from 2002. And following prior studies (e.g., Faulkender and Wang, 2006; Louis et al., 2012), we exclude firms operating in financial services and utilities industries. After matching the climate change risk and exposure measures to other calculated measures, we are left with 34,375 firm-year observations, spanning from the period 2002 to 2017.

## 4. Main Results

*4.1. Descriptive statistics*

[PLEASE INSERT TABLE 1 AROUND HERE]

Panel A of Table 1 reports the descriptive statistics of the data used in the paper. It should be noted that the average of both the climate risk measure and the climate exposure measure are zeros with negative median values, indicating that the measures are positively skewed. Furthermore, we find that the mean value of the dummy variable indicating whether a firm has disclosed any climate change risk related variable is approximately 0.129. This means that approximately 12.9% of the public firms disclose climate change risk words on the conference call. At the same time, we find that the average climate change exposure dummy is 0.5. This means that while 50% of the public firms recognize and disclose climate change related phrases on their conference call, only 12.9% of the firms actually recognize climate change as a risk. Statistics of other measures are similar to those from recent value of cash holdings literature.

Panel B of Table 1 reports the univariable analysis results comparing the firms that report climate change risk related words on their conference call with firms that do not. We find statistically significant t-values for change in change in earnings, change in non-cash level, change in interest expenses, cash holdings, leverage ratio, net financing ratio and firm size measures. In other words, we find that firms that expose climate risks are larger in size, hoard more cash and more levered, on average. However, interpreting the univariate analysis contains endogeneity concerns. Therefore, we employ pooled OLS regression models controlling for other measures and fixed effects included.

*4.2. Baseline estimation results*

We use the following baseline regression model to investigate the relationship between the firm-level climate change risk and the value of cash holdings.

$$r_{i,t} - R_{i,t} = \beta_0 + \beta_1 \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta_2 Climate\ \ risk_{i,t} + \beta_3 Climate\ \ risk_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta' \times X + \varepsilon_{i,t}$$

where $r_{i,t} - R_{i,t}$ is the excess stock return, $r_{i,t}$ and $R_{i,t}$ are firm *i*'s stock and benchmark returns, respectively, in fiscal year *t*, $\Delta \mathrm{C}_{i,t}$ is the change in cash holdings from year *t* – 1 to year *t*, and $M_{i,t-1}$ is the market value of equity at the end of year *t* – 1. We include $Climate\ \ risk_{i,t}$, a firm-level climate change risk from conversation in earnings conference calls, and its interaction term with $\frac{\Delta C_{i,t}}{M_{i,t-1}}$ to capture the effect of climate change risk on the market value of cash. In addition, $X$ contains the control variables used by Faulkender and Wang (2006). Our variable of interest is $Climate\ \ risk_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}}$. Here, a positive and statistically significant $\beta_3$ suggests that higher firm-level climate change risk increase the value of cash holdings.

[PLEASE INSERT TABLE 2 AROUND HERE]

Regression analysis results are reported in Table 2. Column 1 reports the baseline regression results without any climate risk measures. Column 2 reports the results where we add the change in cash variable interacted with the climate risk measure. Column 3 provides the results for the change in cash variable interacted with the climate risk dummy measure. We first note that coefficients and their significance of the baseline model (Column 1) are similar to Faulkender and Wang (2006) and other value of cash holdings literature indicating that the estimation is well-conducted. Both Columns 2 and 3 report positive association between the climate change risk and the value of cash holdings. Coefficients are positive and significant. Specifically, Column 3 shows that firms reporting climate change risk words on their conference call have larger marginal value of cash holdings compared to the firms that do not expose such words. In terms of the economic significance, Overall findings confirm the conjecture that the market positively values the firm's precautionary savings to hedge against climate change risks.

[PLEASE INSERT TABLE 3 AROUND HERE]

With that said, we further investigate the effects of the climate change exposure and the marginal value of corporate cash holdings. The idea is that the effect of the climate change risk should be significant when a firm recognizes climate change as a risk and discloses it rather than simply expose climate change related phrases. The estimation results are reported in Table 3. Column 1 reports results where we only include climate change exposure measure interacted with the change in cash. Column 2 reports results for climate change exposure indicator variable. Column 3 and 4 further includes the climate change risk measure and climate change risk dummy measure specified in Table 2, respectively. Comparing the significance of the coefficients between climate change exposure measures and climate change risk measures, we find statistically significant results only when the firm recognizes climate change as a risk (Columns 3 and 4). In other words, the market positively values the excess cash of the firm only when the market recognizes the purpose of hoarding cash as a climate risk-hedging purpose.

### *4.3. Robustness tests*

Even if the baseline regression results confirm that the market positively evaluates the climate change risk disclosed by the firm, the results may be biased due to endogeneity problems. Therefore, in this subsection, we employ several robustness tests such as firm-fixed effects and PSM to verify that the results are not driven by endogeneity.

#### *4.3.1. Firm-fixed effects*

[PLEASE INSERT TABLE 4 AROUND HERE]

In the baseline estimation, we have commonly included industry and year fixed effects to control for unobserved heterogeneity at industry level and year level. However, the analysis may still not capture the unobserved variations among firms. To somewhat mitigate the concern, we include firm-fixed effects. The regression results are reported in Table 4. Columns 1 and 2 provide results for the climate change risk measure and climate change risk indicator variable, respectively. Columns 3 and 4 provide results for climate change exposure measure and the indicator variable, respectively. We find consistent results with the baseline regression result. This confirms that the main findings are not potentially driven by the firm-level unobserved heterogeneity.

#### 4.3.2. Propensity score matching

We further employ propensity score matching tests to validate the main results. Rosenbaum and Rubin (1983) introduce the matching method to reduce bias due to observed covariates. The propensity score is a conditional probability assigned to a particular treatment given a vector of observed covariates. To conduct the test, we match the firms that disclose any climate change risk phrases on their conference call to firms that do not list those phrases. We use all control variables, industry and year as confounding measures during the matching procedure. We use one-to-one neighborhood matching for matching the samples. If the matching is well-conducted, then the difference in control variables over treatment and control groups should not be statistically significant.

[PLEASE INSERT TABLE 5 AROUND HERE]

The matching results are provided in Panel A of Table 5. We find that the t-statistics for all confounding measures are statistically insignificant, indicating that the samples are well-matched. Panel B of Table 5 reports the regression analysis results where we use a climate risk variable and match climate change risk disclosing firms to non-disclosing firms. Furthermore, Panel C of Table 5 provides the results where we use a dummy climate risk variable to match the firms. Regardless of the matching procedure, we consistently find a positive association between the firm's climate change risk disclosure and the value of cash holdings. The overall PSM approach confirms that the baseline estimation results are not potentially driven by endogeneity.[3]

## 5. Further Analysis

Further to the baseline estimation, we also test several subsample analyzes to investigate whether the relationship between the firm's climate change risk disclosure and the value of corporate cash holdings are affected by other sources.

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[3] We have also conducted one-to-three and one-to-five matching procedures, and the statistical significance is unchanged.

*5.1. Green swan channel*

We first analyze the green swan mechanism. Through the discussion of green swans, Bolton et al. (2020) warn that rapid climate change would cause inflation of raw material prices and impair labor productivity due to heat waves and abnormal climates. Therefore, we examine whether the relationship between climate change risk and excess cash would depend on firms' labor intensity and raw material price sensitivity. We conjecture that the value of cash for climate change would be higher in the group of firms with higher corporate labor intensity and higher sensitivity to climate change risks. This is because the higher the firms' labor intensity, the greater the risk of a decrease in labor productivity. Also, according to Hsu and Wang (2013), industries such as manufacturing are more sensitive to climate change risks than industries such as services. This is because manufacturing firms are more sensitive to labor productivity and raw material prices. To allow the coefficients to vary depending on the labor concentration, we split the sample based on the median value of the employees-to-sales ratio. Following Hsu and Wang (2013), we also divide samples into a climate change sensitive group and climate change less sensitive group by their 2-digit SIC code.[4] Furthermore, Painter (2020) finds that interest in environmental changes in the market has increased rapidly after a Stern review in 2006. Thus, to examine its effect, we divide the sample into before-and-after the publishing of Stern review. We expect that the climate change effects on the marginal value of cash holdings would be positive after the time when climate change is recognized as a risk to companies.

[PLEASE INSERT TABLE 6 AROUND HERE]

Subsample analysis results are reported in Table 6. Panel A reports results where we divide firms into two groups by the median employees-to-sales ratio level. Panel B provides results where we

[4] With reference to Hsu and Wang (2013), we defined the firms belonging to agriculture, forestry, and fishing (01-09), mining (10-14), construction (15-17), and manufacturing (20-39) as a group sensitive to climate change.

divide firms by their industry sensitivity towards climate risks. Lastly, Panel C reports subsample analysis before-and-after the publishing of Stern review (2006). Subsample tests confirm the hypothesis. We find that the positive association between the level of climate change risk exposure and the excess return is significant only when the employees-to-sales ratio is high (above median), when the firm belongs to climate risk sensitive industries (agriculture, forestry, fishing, mining, construction and manufacturing industries), and years after Stern review was published.

### *5.2. Financial constraints channel*

With that said, we further examine the effects of the financing conditions. Underlying mechanism behind the test is that depending on the financial constraint level, the investors would value the excess cash accordingly. Faulkender and Wang (2006) state that the value of excess cash is determined by whether a firm is capital-constrained or not. Thus, the financial constraint level also plays an important role in our study. Shareholders will not appreciate the excess cash of a firm with a high level of financing for climate change risks. On the other hand, investors would positively recognize the cash holdings of a firm that lacks financing ability as the firm would need cash for risk-hedging purposes. To test the effects, we divided the samples according to the level of financial constraint. We use the firm age, credit rating information and leverage ratio to measure the financial constraint level.

[PLEASE INSERT TABLE 7 AROUND HERE]

Table 7 reports the results of the subsample analysis. Panel A of Table 7 provides estimation results where we divide the sample by the median firm age value. Panel B of Table 7 reports the result where we divide the firms by the existence of the credit rating information. Lastly, Panel C of Table 7 shows results where we divide firms by the average market leverage ratio. Subsample analysis again confirms the conjecture. Specifically, analysis results show that the investors positively value the excess cash when the firm is young (below median), when the firm does not have credit rating, and when the firm's leverage is high (above median). The findings generally complement the prior studies that investors value the excess cash of more financially constrained firms (e.g., Denis and Siblikov, 2020).

### *5.3. Cash holdings and dividend payout*

[PLEASE INSERT TABLE 8 AROUND HERE]

Finally, we investigate the effects of climate change risks on corporate cash holdings and payout policies. Our baseline results unidirectionally show that the market positively values the firm's precautionary savings to hedge against climate change risks. If that is true, then the firm would also have large incentives to hoard more cash and distribute less to investors to protect themselves from potential future risks from climate changes. The results are reported in Table 8. Column 1 of Table 8 reports the regression results for examining the effects of the climate risk on the cash holdings scaled by the assets. Column 2 of Table 8 provides results for the dividend payouts. Consistent with the baseline conjecture, we find that the climate change risk is positively associated with the cash holdings while the risk is negatively associated with the dividend payouts. That is, firms that expose more climate change related risks to the investors also tend to manage the firm more conservatively by hoarding more cash and distributing less. The findings are also consistent with prior literature that finds that the climate change risk is positively associated with the excess cash hoarding (Heo, 2021; Masum, 2020).

## 6. Conclusion

This research attempts to examine the relationship between the firm-level climate change risk and the value of cash holdings. Prior study commonly finds that demand for capital increases the value of a firm's excess cash (Denis and Sibilkov, 2010). Hedging against frictions, such as competition risks and uncertainties, is one reason among several channels that increase firm’s demand for capital. In this manner, we specifically investigate how the market evaluates firm’s excess cash to hedge climate change risk. While literature that the climate change risk is a growing uncertainty for firms (Barnett et al., 2020) and that firms increase their cash holdings in response (Heo, 2021) exist, relating the climate risk to the value of cash is not studied. The underlying mechanism is that climate risks would induce firms to increase their demand for capital, which may also lead investors to positively value the excess cash holdings.

The baseline estimation results show that the firm-level climate change risk is positively associated with the value of corporate cash holdings. In terms of the magnitude, marginal value of a dollar for firms with exposure to the climate change risk is $0.52 larger than that of firms with non-exposure to the climate change risk. This also implies that investors positively value the firm’s precautionary savings when the firm discloses climate change risk related descriptions. We also find that the results are not necessarily driven by endogeneity as we employ several robustness tests such as a firm fixed effects model and PSM. Further to the baseline estimation, we also examine how the green swan and financial constraint level affect the relationship between the firm-level climate change risks and the value of corporate cash holdings. Various examinations confirm that the market positively values the cash holdings of firms that are more sensitive to climate change and more financially constrained.

This paper first contributes to the research by suggesting one undiscussed determinant of the value of cash holdings. Our findings show that the climate change risk is an uncertainty that affects the firm’s cash holding decisions, and such decisions are also positively valued by the market. In the manner that the value of cash holdings can be partially explained by the precautionary motives, this paper also complements arguments that the precautionary motivation can explain much of the rise in the cash holdings (Bates et al., 2009; Bates et al., 2018). Our paper also contributes to the growing literature on the climate change risk, especially how the risk affects the financial market. We suggest that the investors are well-aware of the climate change risks recently and that investors also positively evaluate the excess cash. This is because the cash could act as a safety guard against increasing physical, regulatory, or transition threats imposed by climate change (Masum et al., 2020). Taking a step ahead from previous discussions that focused on how to quantify the climate change risks and whether a firm's managerial decisions reflect such risks, we examine how the market responds to the firm’s excess cash.

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Table 1. Summary statistics

| *Panel A. Descriptive statistics for all observations* | | | | | | |
|---|---|---|---|---|---|---|
| | N | Mean | Std. Dev. | p10 | Median | p90 |
| *Climate risk* $_t$ | 34,375 | 0.000 | 1.000 | -0.214 | -0.214 | 0.468 |
| *Climate risk-Dummy* $_t$ | 34,375 | 0.129 | 0.335 | 0.000 | 0.000 | 1.000 |
| *Climate expose* $_t$ | 34,375 | 0.000 | 1.000 | -0.393 | -0.252 | 0.431 |
| *Climate expose-Dummy* $_t$ | 34,375 | 0.500 | 0.500 | 0.000 | 0.000 | 1.000 |
| | | | | | | |
| $r_t - R_t$ | 34,375 | 0.028 | 0.562 | -0.470 | -0.039 | 0.527 |
| $\Delta Cash_t$ | 34,375 | 0.019 | 0.529 | -0.083 | 0.003 | 0.098 |
| $\Delta Earning_t$ | 34,375 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| $\Delta Non\text{-}Cash_t$ | 34,375 | 0.042 | 0.697 | -0.087 | 0.005 | 0.117 |
| $\Delta R\&D_t$ | 34,375 | 0.076 | 4.922 | -0.173 | 0.020 | 0.249 |
| $\Delta Interest_t$ | 34,375 | 0.000 | 0.037 | 0.000 | 0.000 | 0.001 |
| $\Delta Dividend_t$ | 34,375 | 0.001 | 0.139 | -0.005 | 0.000 | 0.008 |
| $Cash_{t-1}$ | 34,375 | 0.000 | 0.049 | 0.000 | 0.000 | 0.003 |
| *Leverage* $_t$ | 34,375 | 0.183 | 0.405 | 0.014 | 0.102 | 0.397 |
| *Net Financing* $_t$ | 34,375 | 0.176 | 0.192 | 0.000 | 0.119 | 0.456 |
| *Firm size* $_t$ | 34,375 | 0.036 | 1.143 | -0.082 | 0.000 | 0.162 |

| *Panel B. Univariate analysis* | | | | | |
|---|---|---|---|---|---|
| | Climate risk-Dummy =0 (N=29,947) | | Climate risk-Dummy =1 (N=4,428) | | t-value |
| | Mean | Mean | Mean | Std. Dev. | |
| $r_t - R_t$ | 0.028 | 0.561 | 0.031 | 0.564 | -0.30 |
| $\Delta Cash_t$ | 0.009 | 0.113 | 0.010 | 0.112 | -0.60 |
| $\Delta Earning_t$ | 0.026 | 0.215 | 0.019 | 0.199 | 1.90* |
| $\Delta Non\text{-}Cash_t$ | 0.032 | 0.310 | 0.047 | 0.308 | -3.10*** |
| $\Delta R\&D_t$ | 0.000 | 0.007 | 0.000 | 0.006 | -1.25 |
| $\Delta Interest_t$ | 0.001 | 0.013 | 0.001 | 0.013 | -1.70* |
| $\Delta Dividend_t$ | 0.000 | 0.011 | 0.000 | 0.009 | -1.00 |
| $Cash_{t-1}$ | 0.173 | 0.216 | 0.163 | 0.211 | -2.75*** |
| *Leverage* $_t$ | 0.172 | 0.189 | 0.194 | 0.190 | -7.05*** |
| *Net Financing* $_t$ | 0.023 | 0.163 | 0.034 | 0.171 | -4.15*** |
| *Firm size* $_t$ | 6.830 | 1.958 | 7.395 | 1.984 | -17.90*** |

*Note*: This table presents summary statistics for our main variables. The sample consists of 34,375 firm-year observations that include U.S.-based publicly traded firms from 2002 to 2017. $r_t – R_t$ represents an excess stock return. $\Delta Cash_t$, $\Delta Earning_t$, $\Delta Non\text{-}Cash_t$, $\Delta R\&D_t$, $\Delta Interest_t$, and $\Delta Dividend_t$ indicate the changes in cash holdings, earnings, net assets, research and development expenses, interest expenses, and common dividends from year t-1 to t, respectively. $Cash_{t-1}$ denotes the cash holdings in the prior year. *Leverage* $_t$ and *Net Financing* $_t$ represent firms' market leverage and net financing, respectively. $Climate\ risk_{i,t}$ is a firm-level climate change risk from conversation in earnings conference calls for year t, and $Climate\ exp_{i,t}$ is a variable that simply measures the degree of mention of climate change, not the risk of climate change. And *Climate risk-Dummy* $_t$ and *Climate exp.-Dummy* $_t$ are dummy variables that equals one if the levels of climate change risk are over the median, and zero otherwise. Based on climate risk dummy, Panel B reports the results of univariate analysis on the mean differences of all variables. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 2. Climate change risk and marginal value of cash holdings

| | DV = Excess return | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| $\Delta Cash_t$ | 1.543*** | 1.541*** | 1.486*** |
| | (12.882) | (13.001) | (13.026) |
| $\Delta Cash_t$ * $Climate\ risk_t$ | | 0.168** | |
| | | (1.986) | |
| $Climate\ risk_t$ | | -0.001 | |
| | | (-0.248) | |
| $\Delta Cash_t$ * $Climate\ risk\text{-}Dummy_t$ | | | 0.520** |
| | | | (2.108) |
| $Climate\ risk\text{-}Dummy_t$ | | | -0.005 |
| | | | (-0.641) |
| $\Delta Earning_t$ | 0.151*** | 0.153*** | 0.152*** |
| | (4.988) | (5.057) | (5.054) |
| $\Delta Non\text{-}Cash_t$ | 0.303*** | 0.301*** | 0.303*** |
| | (14.971) | (14.831) | (14.953) |
| $\Delta R\&D_t$ | 1.904** | 1.911** | 1.910** |
| | (2.273) | (2.284) | (2.277) |
| $\Delta Interest_t$ | -2.421*** | -2.403*** | -2.424*** |
| | (-5.001) | (-4.948) | (-4.999) |
| $\Delta Dividend_t$ | 1.669*** | 1.675*** | 1.671*** |
| | (5.272) | (5.292) | (5.269) |
| $Cash_{t-1}$ | -0.074*** | -0.075*** | -0.075*** |
| | (-2.741) | (-2.757) | (-2.792) |
| $Leverage_t$ | -0.444*** | -0.444*** | -0.443*** |
| | (-20.514) | (-20.577) | (-20.573) |
| $Net\ Financing_t$ | 0.014 | 0.012 | 0.012 |
| | (0.275) | (0.238) | (0.252) |
| $\Delta Cash_t$ * $Leverage_t$ | -0.910*** | -0.909*** | -0.904*** |
| | (-5.083) | (-5.067) | (-5.053) |
| $\Delta Cash_t$ * $Net\ Financing_t$ | -2.484*** | -2.513*** | -2.528*** |
| | (-8.091) | (-8.086) | (-8.101) |
| Constant | 0.092*** | 0.092*** | 0.093*** |
| | (16.778) | (16.790) | (16.228) |
| Observations | 34,375 | 34,375 | 34,375 |
| Adjusted R-squared | 0.091 | 0.092 | 0.092 |
| Industry FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |

*Note*: This table contains the results of the following regression model:

$$r_{i,t} - R_{i,t} = \beta_0 + \beta_1 \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta_2 Climate\ \ risk_{i,t} + \beta_3 Climate\ \ risk_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta' \times X + \varepsilon_{i,t}$$

, where $r_{i,t} - R_{i,t}$ is an excess stock return for firm i over fiscal year t, $\Delta C_{i,t}$is the change in cash holding from year t-1 to year t, $M_{i,t-1}$is the market value of equity at the end of year t-1, $Climate\ \ risk_{i,t}$ is a firm-level climate change risk from conversation in earnings conference calls for year t, *Climate risk-Dummy* $_t$ is dummy variables that equals one if the levels of climate change risk are over the median, and zero otherwise, and $X$ contains the control variables from Faulkender and Wang (2006). $r_{i,t} - R_{i,t}$ is estimated as the difference between the actual stock return and the 25 Fama and French (1993)'s size and book-to-market portfolio. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Climate change risk, climate change expose, and marginal value of cash holdings

| | DV = Excess return | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Δ Cash $_t$* | 1.541*** | 1.569*** | 1.549*** | 1.556*** |
| | (12.962) | (11.942) | (12.987) | (11.958) |
| *Δ Cash $_t$ * Climate risk $_t$* | | | 0.226** | |
| | | | (2.303) | |
| *Climate risk $_t$* | | | 0.002 | |
| | | | (0.567) | |
| *Δ Cash $_t$ * Climate risk-Dummy $_t$* | | | | 0.596** |
| | | | | (2.358) |
| *Climate risk-Dummy $_t$* | | | | -0.006 |
| | | | | (-0.685) |
| *Δ Cash $_t$ * Climate exp. $_t$* | 0.043 | | -0.087 | |
| | (0.753) | | (-1.490) | |
| *Climate exp. $_t$* | -0.007** | | -0.008** | |
| | (-2.197) | | (-2.241) | |
| *Δ Cash $_t$ * Climate exp.-Dummy $_t$* | | -0.056 | | -0.169 |
| | | (-0.500) | | (-1.516) |
| *Climate exp.-Dummy $_t$* | | -0.001 | | -0.000 |
| | | (-0.162) | | (-0.008) |
| *Δ Earning $_t$* | 0.151*** | 0.150*** | 0.151*** | 0.152*** |
| | (5.015) | (4.992) | (5.028) | (5.047) |
| *Δ Non-Cash $_t$* | 0.302*** | 0.303*** | 0.301*** | 0.303*** |
| | (14.920) | (14.978) | (14.835) | (14.969) |
| *Δ R&D $_t$* | 1.908** | 1.895** | 1.894** | 1.883** |
| | (2.274) | (2.266) | (2.269) | (2.255) |
| *Δ Interest $_t$* | -2.417*** | -2.420*** | -2.395*** | -2.420*** |
| | (-4.992) | (-5.001) | (-4.931) | (-4.990) |
| *Δ Dividend $_t$* | 1.672*** | 1.669*** | 1.685*** | 1.669*** |
| | (5.285) | (5.268) | (5.314) | (5.258) |
| *Cash $_{t-1}$* | -0.074*** | -0.074*** | -0.073*** | -0.075*** |
| | (-2.737) | (-2.739) | (-2.699) | (-2.793) |
| *Leverage $_t$* | -0.445*** | -0.444*** | -0.445*** | -0.443*** |
| | (-20.589) | (-20.507) | (-20.629) | (-20.562) |
| *Net Financing $_t$* | 0.015 | 0.014 | 0.013 | 0.012 |
| | (0.313) | (0.277) | (0.272) | (0.253) |
| *Δ Cash $_t$ * Leverage $_t$* | -0.912*** | -0.913*** | -0.912*** | -0.911*** |
| | (-5.082) | (-5.112) | (-5.101) | (-5.110) |
| *Δ Cash $_t$ * Net Financing $_t$* | -2.487*** | -2.472*** | -2.526*** | -2.498*** |
| | (-8.093) | (-8.112) | (-8.103) | (-8.149) |
| Constant | 0.092*** | 0.093*** | 0.092*** | 0.093*** |
| | (16.789) | (13.853) | (16.758) | (13.746) |
| Observations | 34,375 | 34,375 | 34,375 | 34,375 |
| Adjusted R-squared | 0.091 | 0.091 | 0.093 | 0.092 |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

*Note*: This table contains the results of the following regression model:

$$r_{i,t} - R_{i,t} = \beta_0 + \beta_1 \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta_2 Climate\ \ risk_{i,t} + \beta_3 Climate\ \ risk_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta_4 Climate\ \ exp_{i,t} + \beta_5 Climate\ \ exp_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta' \times X + \varepsilon_{i,t}$$

, where $r_{i,t} - R_{i,t}$ is an excess stock return for firm i over fiscal year t, $\Delta C_{i,t}$ is the change in cash holding from year t-1 to year t, $M_{i,t-1}$ is the market value of equity at the end of year t-1, $Climate\ \ risk_{i,t}$ is a firm-level climate change risk from conversation in earnings conference calls for year t, and $Climate\ \ exp_{i,t}$ is a variable that simply measures the degree of mention of climate change, not the risk of climate change. And *Climate risk-Dummy* $_t$ and *Climate exp.-Dummy* $_t$ are dummy variables that equals one if the levels of climate change risk are over the median, and zero otherwise, and $X$ contains the control variables from Faulkender and Wang (2006). $r_{i,t} - R_{i,t}$ is estimated as the difference between the actual stock return and the 25 Fama and French (1993)'s size and book-to-market portfolio. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Baseline regression with firm fixed effect

| | DV = Excess return | |
|---|---|---|
| | (1) | (2) |
| $\Delta Cash_t$ | 1.385*** | 1.346*** |
| | (12.380) | (12.447) |
| $\Delta Cash_t$ * $Climate\ risk_t$ | 0.130* | |
| | (1.880) | |
| $Climate\ risk_t$ | 0.003 | |
| | (0.649) | |
| $\Delta Cash_t$ * $Climate\ risk\text{-}Dummy_t$ | | 0.371* |
| | | (1.760) |
| $Climate\ risk\text{-}Dummy_t$ | | -0.006 |
| | | (-0.589) |
| $\Delta Earning_t$ | 0.150*** | 0.150*** |
| | (5.491) | (5.478) |
| $\Delta Non\text{-}Cash_t$ | 0.241*** | 0.242*** |
| | (12.770) | (12.857) |
| $\Delta R\&D_t$ | 1.319* | 1.326* |
| | (1.672) | (1.679) |
| $\Delta Interest_t$ | -1.865*** | -1.896*** |
| | (-3.919) | (-3.999) |
| $\Delta Dividend_t$ | 1.888*** | 1.889*** |
| | (6.351) | (6.352) |
| $Cash_{t-1}$ | 0.090** | 0.089** |
| | (2.233) | (2.215) |
| $Leverage_t$ | -0.875*** | -0.875*** |
| | (-22.638) | (-22.651) |
| $Net\ Financing_t$ | 0.124*** | 0.124*** |
| | (2.658) | (2.654) |
| $\Delta Cash_t$ * $Leverage_t$ | -0.652*** | -0.642*** |
| | (-3.892) | (-3.852) |
| $\Delta Cash_t$ * $Net\ Financing_t$ | -2.512*** | -2.527*** |
| | (-8.202) | (-8.179) |
| Constant | 0.142*** | 0.143*** |
| | (15.778) | (15.635) |
| Observations | 34,375 | 34,375 |
| Adjusted R-squared | 0.096 | 0.096 |
| Firm FE | Yes | Yes |
| Year FE | Yes | Yes |

*Note*: This table contains the results of the following regression model:

$$r_{i,t} - R_{i,t} = \beta_0 + \beta_1 \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta_2 Climate\ \ risk_{i,t} + \beta_3 Climate\ \ risk_{i,t} \times \frac{\Delta C_{i,t}}{M_{i,t-1}} + \beta' \times X + \varepsilon_{i,t}$$

, where $r_{i,t} - R_{i,t}$ is an excess stock return for firm i over fiscal year t, $\Delta C_{i,t}$ is the change in cash holding from year t-1 to year t, $M_{i,t-1}$ is the market value of equity at the end of year t-1, $Climate\ \ risk_{i,t}$ is a firm-level climate change risk from conversation in earnings conference calls for year t, *Climate risk-Dummy* $_t$ is dummy variables that equals one if the levels of climate change risk are over the median, and zero otherwise, and $X$ contains the control variables from Faulkender and Wang (2006). $r_{i,t} - R_{i,t}$ is estimated as the difference between the actual stock return and the 25 Fama and French (1993)'s size and book-to-market portfolio. We include firm and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Propensity score matching

*Panel A. Matched results(1:1)*

| | Treated | Control | t-value |
|---|---|---|---|
| $\Delta Cash_t$ | 0.010 | 0.009 | 0.390 |
| $\Delta Earning_t$ | 0.019 | 0.016 | 0.680 |
| $\Delta Non\text{-}Cash_t$ | 0.047 | 0.044 | 0.450 |
| $\Delta R\&D_t$ | 0.000 | 0.000 | -0.340 |
| $\Delta Interest_t$ | 0.001 | 0.001 | 0.190 |
| $\Delta Dividend_t$ | 0.000 | 0.001 | -1.240 |
| $Cash_{t-1}$ | 0.163 | 0.164 | -0.200 |
| $Leverage_t$ | 0.194 | 0.193 | 0.130 |
| $Net\ Financing_t$ | 0.034 | 0.031 | 0.860 |

*Panel B. Climate risk variable*

| | DV = Excess return | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | 1:1 | 1:3 | 1:5 |
| $\Delta Cash_t$ | 1.328*** | 1.575*** | 1.590*** |
| | (5.161) | (6.926) | (7.310) |
| $\Delta Cash_t$ * $Climate\ risk_t$ | 0.221** | 0.173* | 0.161* |
| | (2.201) | (1.792) | (1.688) |
| $Climate\ risk_t$ | 0.000 | 0.000 | -0.001 |
| | (0.055) | (0.006) | (-0.258) |
| Constant | 0.096*** | 0.096*** | 0.098*** |
| | (7.232) | (10.043) | (10.592) |
| Observations | 6,772 | 11,940 | 15,755 |
| Adjusted R-squared | 0.101 | 0.113 | 0.116 |
| Controls | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |

*Panel C. Dummy climate risk variable*

| | DV = Excess return | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | 1:1 | 1:3 | 1:5 |
| $\Delta Cash_t$ | 1.185*** | 1.492*** | 1.519*** |
| | (4.336) | (6.482) | (6.983) |
| $\Delta Cash_t$ * $Climate\ risk\text{-}Dummy_t$ | 0.822*** | 0.575** | 0.524** |
| | (2.701) | (2.127) | (1.967) |
| $Climate\ risk\text{-}Dummy_t$ | 0.001 | 0.003 | -0.002 |
| | (0.083) | (0.278) | (-0.170) |
| *Constant* | 0.095*** | 0.093*** | 0.097*** |
| | (5.911) | (8.339) | (9.324) |
| Observations | 6,772 | 11,940 | 15,755 |
| Adjusted R-squared | 0.100 | 0.112 | 0.115 |
| Controls | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |

*Note*: This table presents estimated coefficient estimates of the model using the sample based on propensity score matching. We divided the samples in treatment and control groups based on the median value of climate change risk. We create the matched sample by using covariates of all control variables used for baseline regression. The statistics of the matched samples are reported in Panel A. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Subsample analysis1: Green swan channel

| *Panel A. Employees to sales ratio* | | | | |
|---|---|---|---|---|
| | DV = Excess return | | | |
| | (1) | (2) | (3) | (4) |
| | High | | Low | |
| $\Delta Cash_t$ | 1.430*** | 1.352*** | 1.594*** | 1.560*** |
| | (9.709) | (9.881) | (8.831) | (8.650) |
| $\Delta Cash_t$ * *Climate risk* $_t$ | 0.249* | | 0.095 | |
| | (1.830) | | (1.105) | |
| *Climate risk* $_t$ | -0.002 | | 0.003 | |
| | (-0.375) | | (0.613) | |
| $\Delta Cash_t$ * *Climate risk-Dummy* $_t$ | | 0.805** | | 0.288 |
| | | (1.992) | | (0.949) |
| *Climate risk-Dummy* $_t$ | | -0.011 | | 0.004 |
| | | (-0.796) | | (0.373) |
| Constant | 0.071*** | 0.072*** | 0.119*** | 0.118*** |
| | (8.935) | (8.732) | (14.820) | (14.166) |
| Observations | 14,347 | 14,347 | 13,976 | 13,976 |
| Adjusted R-squared | 0.087 | 0.086 | 0.104 | 0.104 |
| Controls | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

| *Panel B. Climate risk sensitive industries* | | | | |
|---|---|---|---|---|
| | DV = Excess return | | | |
| | (1) | (2) | (3) | (4) |
| | Sensitive | | Not sensitive | |
| $\Delta Cash_t$ | 1.699*** | 1.636*** | 1.294*** | 1.255*** |
| | (10.795) | (10.744) | (7.921) | (7.848) |
| $\Delta Cash_t$ * *Climate risk* $_t$ | 0.173* | | 0.134 | |
| | (1.795) | | (0.814) | |
| *Climate risk* $_t$ | -0.000 | | -0.003 | |
| | (-0.088) | | (-0.505) | |
| $\Delta Cash_t$ * *Climate risk-Dummy* $_t$ | | 0.618** | | 0.251 |
| | | (2.068) | | (0.629) |
| *Climate risk-Dummy* $_t$ | | -0.006 | | -0.006 |
| | | (-0.549) | | (-0.451) |
| Constant | 0.100*** | 0.100*** | 0.082*** | 0.083*** |
| | (13.840) | (13.260) | (9.508) | (9.432) |
| Observations | 17,101 | 17,101 | 11,492 | 11,492 |
| Adjusted R-squared | 0.103 | 0.103 | 0.078 | 0.078 |
| Controls | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

| *Panel C. Stern review(2006)* | | | | | | |
|---|---|---|---|---|---|---|
| | DV = Excess return | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| | 2002-2005 (4yrs) | | 2007-2017 | | 2007-2010 (4yrs) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\Delta Cash_t$ | 2.342*** | 2.289*** | 1.278*** | 1.214*** | 1.364*** | 1.299*** |
| | (8.205) | (7.951) | (9.344) | (9.494) | (8.076) | (7.915) |
| $\Delta Cash_t$ * *Climate risk* $_t$ | 0.188 | | 0.187* | | 0.184* | |
| | (0.990) | | (1.833) | | (1.677) | |
| *Climate risk* $_t$ | -0.003 | | -0.000 | | -0.002 | |
| | (-0.375) | | (-0.096) | | (-0.338) | |
| $\Delta Cash_t$ * *Climate risk-Dummy* $_t$ | | 0.381 | | 0.613** | | 0.616* |
| | | (0.906) | | (2.038) | | (1.665) |
| *Climate risk-Dummy* $_t$ | | -0.040 | | -0.001 | | 0.003 |
| | | (-1.610) | | (-0.129) | | (0.222) |
| Constant | 0.085*** | 0.090*** | 0.094*** | 0.094*** | 0.095*** | 0.095*** |
| | (5.765) | (5.726) | (15.036) | (14.501) | (9.985) | (9.316) |
| Observations | 6,742 | 6,742 | 20,050 | 20,050 | 9,633 | 9,633 |
| Adjusted R-squared | 0.122 | 0.122 | 0.093 | 0.093 | 0.081 | 0.081 |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes*: This table presents the results of moderating effects of the green swan mechanism (corporate labor intensity, sensitivity to climate change risks, and Stern review) on the relationship between the value of cash holdings and climate change risk. Panel A provides the results for the subsamples divided by the median value of *Employees to sales ratio*, and Panel B reports the results with *Climate risk sensitive industries*. we defined the firms belonging to agriculture, forestry, and fishing (01-09), mining (10-14), construction (15-17), and manufacturing (20-39) as a group sensitive to climate change. In Panel C, , we divide the sample into before-and-after the publishing of Stern review. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Subsample analysis2: Financial constraints

| *Panel A. Firm age* | | | | |
|---|---|---|---|---|
| | DV = Excess return | | | |
| | (1) | (2) | (3) | (4) |
| | Young | | Old | |
| Δ*Cash* $_t$ | 1.887*** | 1.819*** | 0.950*** | 0.894*** |
| | (11.145) | (11.179) | (6.545) | (6.504) |
| Δ*Cash* $_t$ * *Climate risk* $_t$ | 0.239** | | 0.056 | |
| | (2.017) | | (0.774) | |
| *Climate risk* $_t$ | 0.001 | | -0.002 | |
| | (0.090) | | (-0.516) | |
| Δ*Cash* $_t$ * *Climate risk-Dummy* $_t$ | | 0.613* | | 0.470 |
| | | (1.789) | | (1.428) |
| *Climate risk-Dummy* $_t$ | | -0.005 | | -0.007 |
| | | (-0.316) | | (-0.750) |
| Constant | 0.101*** | 0.102*** | 0.083*** | 0.083*** |
| | (11.534) | (11.166) | (12.230) | (12.103) |
| Observations | 14,785 | 14,785 | 13,809 | 13,809 |
| Adjusted R-squared | 0.099 | 0.098 | 0.086 | 0.087 |
| Controls | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

| *Panel B. Credit rating* | | | | |
|---|---|---|---|---|
| | DV = Excess return | | | |
| | (1) | (2) | (3) | (4) |
| | Not exists | | Exists | |
| Δ*Cash* $_t$ | 1.638*** | 1.575*** | 0.887*** | 0.839*** |
| | (11.909) | (11.819) | (4.456) | (4.237) |
| Δ*Cash* $_t$ * *Climate risk* $_t$ | 0.191* | | 0.070 | |
| | (1.852) | | (0.982) | |
| *Climate risk* $_t$ | 0.000 | | -0.001 | |
| | (0.014) | | (-0.200) | |
| Δ*Cash* $_t$ * *Climate risk-Dummy* $_t$ | | 0.656* | | 0.290 |
| | | (1.862) | | (1.386) |
| *Climate risk-Dummy* $_t$ | | -0.006 | | -0.011 |
| | | (-0.435) | | (-1.078) |
| Constant | 0.084*** | 0.085*** | 0.131*** | 0.133*** |
| | (11.427) | (10.978) | (14.823) | (14.601) |
| Observations | 18,340 | 18,340 | 10,255 | 10,255 |
| Adjusted R-squared | 0.093 | 0.093 | 0.108 | 0.109 |
| Controls | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

| *Panel C. Market leverage ratio* | | | | |
|---|---|---|---|---|
| | DV = Excess return | | | |
| | (1) | (2) | (3) | (4) |
| | High | | Low | |

| | | | | |
|---|---|---|---|---|
| $\Delta$*Cash* $_t$ | 1.437*** | 1.384*** | 1.685*** | 1.623*** |
| | (6.973) | (6.713) | (9.947) | (10.028) |
| $\Delta$*Cash* $_t$ * *Climate risk* $_t$ | 0.130* | | 0.188 | |
| | (1.687) | | (1.305) | |
| *Climate risk* $_t$ | -0.003 | | 0.001 | |
| | (-0.725) | | (0.146) | |
| $\Delta$*Cash* $_t$ * *Climate risk-Dummy* $_t$ | | 0.411* | | 0.638 |
| | | (1.821) | | (1.371) |
| *Climate risk-Dummy* $_t$ | | -0.012 | | -0.007 |
| | | (-1.080) | | (-0.520) |
| Constant | 0.144*** | 0.145*** | 0.093*** | 0.094*** |
| | (17.237) | (16.906) | (10.607) | (10.297) |
| Observations | 14,244 | 14,244 | 14,251 | 14,251 |
| Adjusted R-squared | 0.110 | 0.110 | 0.088 | 0.088 |
| Controls | Yes | Yes | Yes | Yes |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

*Notes*: This table presents the results of moderating effects of the financing conditions (firm age, credit rating information, and leverage ratio) on the relationship between the value of cash holdings and climate change risk. Panel A and C provide the results for the subsamples divided by the median value of firm age and leverage ratio, respectively. The younger the firm, the higher the leverage ratio, the higher the financial constraint. Panel B divides the subsample into groups with and without credit ratings. A group that is not given a credit rating has a high financial constraint. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8. The effects of climate change risks on corporate cash holdings and payout policies

| | (1)<br>Cash<br>/Total Assets | (2)<br>Dividends<br>/Total Assets | (3)<br>Cash<br>/Total Assets | (4)<br>Dividends<br>/Total Assets |
|---|---|---|---|---|
| *Climate risk $_t$* | 0.003*** | -0.000* | | |
| | (2.801) | (-1.689) | | |
| *Climate risk-Dummy $_t$* | | | 0.008*** | -0.001*** |
| | | | (3.293) | (-2.660) |
| Firm size | -0.022*** | 0.002*** | -0.022*** | 0.002*** |
| | (-19.425) | (8.393) | (-19.539) | (8.463) |
| MB | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.946) | (1.106) | (0.943) | (1.110) |
| Lev | -0.052*** | -0.004*** | -0.052*** | -0.004*** |
| | (-7.194) | (-3.202) | (-7.206) | (-3.196) |
| ROA | -0.000 | -0.000* | -0.000 | -0.000* |
| | (-0.867) | (-1.861) | (-0.856) | (-1.882) |
| Constant | 0.317*** | -0.000 | 0.317*** | -0.000 |
| | (37.963) | (-0.104) | (37.952) | (-0.087) |
| Observations | 34,375 | 34,375 | 34,375 | 34,375 |
| Adjusted R-squared | 0.324 | 0.173 | 0.324 | 0.173 |
| Industry FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |

*Notes*: This table presents the effect of the climate change risk on corporate cash holdings and payout policies. Column 1 and 3 of Table 8 report the regression results for examining the effects of the climate risk on the cash holdings scaled by the assets. Column 2 and 4 provide results for the dividend payouts. We include industry and year fixed effects. Standard errors in parentheses are clustered by firm. The t-statistics of the coefficient estimates are in parentheses. *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.