Does Climate-Related Information in Stock Price Affect Firm Investment?*

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Abstract

Focusing on temperature as a proxy for climate, I examine whether climate-related information in stock price affects a firm's investment. I construct firm return sensitivity to abnormal temperature as a proxy for this information content. Using data over 1970-2021, I find that the information content is positively associated with a firm's investment and this positive relation weakens when the firm's investment opportunity expands. The same pattern arises in the relations between the information content and firm performance and firm value. The results suggest that climate-related-information-driven investment is value-enhancing and that stock market rewards firms for making such investment. The significantly negative relation between investment sensitivity to stock price and climate exposure is consistent with the notion that the climate-related information incorporated into stock price is already known to managers.

JEL Codes: G14, G31, G32, Q51, Q54

Keywords: return sensitivity to temperature, stock information content, climate change, firm investment, investment-q sensitivity, investment-cashflow sensitivity

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Abstract

Focusing on temperature as a proxy for climate, I examine whether information in stock price on firm exposure to climate change affects a firm's investment. I construct firm return sensitivity to abnormal temperature as a proxy for this information content. Using data over 1970-2021, I find that the information content is positively associated with a firm's investment and this positive relation weakens when the firm's investment opportunity expands. The same pattern arises in the relations between the information content and firm performance and firm value. The results suggest that climate-related-information-driven investment is value-enhancing and that stock market rewards firms for making such investment. The significantly negative relation between investment sensitivity to stock price and climate exposure is consistent with the notion that the climate-related information incorporated into stock price is already known to managers.

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"Weather is not just an environmental issue, it is a major economic factor. At least $1 trillion of our economy is weather-sensitive."

(William Daley, former commerce secretary, sworn testimony to Congress; 1998)

1. Introduction

Climate has profound effects on economic outcome and human society (e.g., Hsiang, Burke, and Miguel, 2013; Dell, Jones, and Olken, 2014). The findings of the emerging climate finance literature suggest that climate change can impact both macroeconomy and individual firms. The bulk of the literature investigates the interactions between climate change and financial markets (see Giglio, Kelly, and Stroebel (2021) for a survey of the literature). A large body of those studies pay particular attention to how climate change influences asset prices and investor activities via its psychological effects (like affect, mood, and sentiment) on market participants (e.g., Saunders, 1993; Hirschleifer and Shumway, 2003; Kamstra, Kramer, and Levi, 2003; deHaan, Madsen, and Piotroski, 2017). To the contrary, relatively fewer studies examine the effects of climate change on firm-level activities.

Meanwhile, one key role of stock market is information production, i.e., to aggregate all available information, public and private alike, in the price formation/discovery process. The feedback effect literature posits that real-sector decision makers can learn information new to them from the price and use the information to guide their decisions (see Bond, Edmans, and Goldstein (2012) for a survey of the literature). Given the impact of climate on financial markets, it is natural to expect that stock price should incorporate and reflect information about climate. Nevertheless, a study about the feedback effect of climate-related information is lacking.

Our paper fills in the gap by intersecting the climate finance literature and the feedback effect literature. Specifically, from the angle of information role of stock market, I assess the effects of climate-related information in stock price on firm investment, and in turn, firm performance, and firm valuation.

In implementation, I focus on temperature as our proxy for climate for several reasons. First, temperature change is a primary measure of climate change in the ongoing and contentious public debate over the impact and importance of climate change on society. In recent years, the United Nations Framework Convention on Climate Change (UNFCCC) has advocated to limit global warming to 1.5°C above pre-industrial levels. Second, a vast literature in economics has long established that temperature bears the strongest individual correlation between climate and macroeconomic outcomes (e.g., Dell, Jones and Olken, 2009 & 2012; Burke, Hsiang, and Miguel, 2015). Third, in financial markets, as an asset class introduced in 1997 and traded in exchanges in 1999 and popularly used by economic agents to hedge their climate exposure, climate derivatives are often based on changes to indexes that measure changes in average daily temperatures.

I estimate firm-level return sensitivity to abnormal temperature and use it as a proxy for climate-related information in stock price. Using data over 1970-2021, I conduct fixed-effects regressions to investigate the effects of climate-related information in stock price on firm investment. I find that such information affects firm investment both directly and indirectly via investment opportunity. Specifically, the climate-related information in stock price is significantly and positively related to future investment and that this positive relation weakens as a firm's investment opportunity expands. I obtain similar results when using alternative return sensitivities to abnormal temperatures or to absolute abnormal temperature to proxy for the climate-related information in stock price. Moreover, the relations are much stronger in the recent period than in the earlier period.

I proceed to investigate possible economic explanations. The *Q* theory posits that firm investment is determined by marginal productivity of capital, i.e., marginal *Q*. In empirical works, the significant relations between variables other than average *Q* and firm investment can reflect either the existence of financial constraints or informational role of those variables for marginal *Q*. Our evidence refutes the financial constraint explanation for the documented relations between return sensitivity to climate and firm investment. Instead, our evidence points to the information role of climate sensitivity for capital productivity. As further evidence of the information role of climate sensitivity, I assess the effects of climate-related information in stock price on firm performance and firm valuation. Like firm investment, both firm performance and firm value relate significantly and positively with the return sensitivity to climate, and the positive relations attenuate in firm investment opportunity.

Taken together, our results suggest that climate-related-information-driven investment is value-enhancing and that stock market rewards firms for making such investment. Moreover, the significantly negative relations between the climate sensitivity and the investment-price sensitivity as well as the investment-cashflow sensitivity are consistent with the notion that the climate-related information impounded into stock price is already known to managers.

Our paper contributes to the climate finance literature in general, and specifically the study of the effects of climate on firm-level activities. Activities examined in earlier works include risk management (Perez-Gonzalez and Yun, 2013), sales (Addoum, Ng, and Ortiz-Bobea, 2020; Kirk, Stice, and Stice, 2022), earnings (Addoum, Ng, and Ortiz-Bobea, 2023), annual reporting (Nagar and Schoenfeld, 2022), and executive compensation contracting (Armstrong, Glaeser, and Huang, 2022), to name a few. Our work differs from those studies in several dimensions. I focus on corporate investment, which has not been studied yet. More importantly, I approach this subject from the angle of the informational role of stock market, which is a novice to this field. I find that the climate-related information impounded into stock price has nontrivial effects on firm investment, and in turn, firm performance, and firm valuation.

Our study is somewhat like Cuculiza, et al. (2022) in that both our paper and theirs estimate firm-level return sensitivities to abnormal temperature. They focus on pricing and activities of market participants (like analysts and institutional investors) related to the sensitivities. In contrast, I shed light on managers' investment decision associated with these sensitivities.

Our paper is naturally related to the literature studying the effects of financial markets on real sector (i.e., the "feedback effect"). The literature centers on the idea that financial markets aggregate all sources of information available, thus contain useful information for firms to learn and improve their decisions (see Bond, Edmans, and Goldstein (2012) for a survey of the literature). As one example of the feedback effect, firm investment responds to investment opportunities and such response varies with respect to the amount of information in stock prices (e.g., Chen, Goldstein, and Jiang, 2008; Bakke and Whited, 2010; Huang and Kang, 2017). Although in a similar theme, our study adds to this literature by expanding the information source to climate and by showing that such information impounded into stock price is likely not new to managers but still affects firm investment in a nontrivial way.

The rest of the paper is organized as follows. Section 2 describes data, variables, and sample construction. Section 3 presents empirical results on the relations between climate-related information in stock price and firm investment. Section 4 discusses possible economic explanations for the relations. Section 5 analyzes the relations between climate-related information in stock price and firm performance and firm valuation. Section 6 concludes.

2. Data, Variables, and Sample Construction

I obtain U.S. temperature data from the National Ocean and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI). The data consist of daily temperature from 1895 to 2020 for over 42,323 climate observation stations in the United States. Stock returns and firm financial information are from Center for Research in Security Prices (CRSP) Monthly Files and Standard & Poor's Compustat Annual File, respectively. I use a firm's historical SIC to assign the firm to one of the Fama-French 48-industry classifications. I exclude financial firms (SICs between 6000 and 6999) from our sample. I use firm headquarter state information, if unavailable then supplemented with firm incorporation state information, to merge the temperature dataset and the CRSP/Compustat datasets.

2.1 Abnormal temperature and climate sensitivity

One key variable of our empirical study is the firm-level climate sensitivity measure. I obtain this measure in steps. First, using the NOAA temperature data, I calculate the monthly average temperature in a U.S. state as an average of daily temperatures recorded at each observation site located in the state within a month. I then construct state-level monthly abnormal temperature (*tanom*) as the difference between each month's average monthly temperature in a state and the state's average monthly temperature for the same month over the past 50 years. For robustness, I also calculate an alternative state-level monthly abnormal temperature (*tanom30*) using the state's past 30-year average of monthly temperature for the same month as the benchmark temperature. Similarly, I construct US-wide monthly Abnormal Temperature (*tanom_us* and *tanom30_us*) as the US average temperature in a month minus the 50- or 30-year average of US average temperature of the same month, where the US-wide temperature is an equal-weighted average of state temperatures. Abnormal temperature measures the change in temperatures: a positive (negative) value in the variable implies that the average temperature for a given month is higher (lower) than the historical average temperature of the same month. As done in the literature (e.g., Cao and Wei, 2005; Cuculiza, et al., 2023), I use the abnormal temperature variable as our measure of climate change in this study.

Second, I follow Cuculiza et al. (2023) to estimate a firm's stock return sensitivity to temperature changes. Specifically, I regress the firm's excess stock return against the excess market return and abnormal temperature as follows:

$$r_{i,t} - r_{f,t} = \alpha_i + \beta_i(r_{m,t} - r_{f,t}) + \delta_i tanom_{s,t} + \varepsilon_{i,t}. \quad (1)$$

In equation (1), $r_{i,t}$ is stock return of firm *i* in month *t*, $r_{f,t}$ is the Fama-French risk-free rate in month *t*, $r_{m,t}$ is the market return in month *t* measured as the CRSP value-weighted index return, and $tanom_{s,t}$ is the abnormal temperature in month *t* of state *s* in which firm *i*'s headquarter is located. For each firm *i* in month τ, I estimate equation (1) using the past 60 months of data up to month τ, requiring at least 48 monthly observations.[1] In some subsequent analyses, I also use other abnormal temperature measures in lieu of *tanom* in equation (1) for estimations. Given that the Compustat data are available from 1960 and the first few years of data coverage is sparse, our estimates of equation (1) start from 1970 and on.

The coefficient on abnormal temperature, δ_i, characterizes firm *i*'s return sensitivity to temperature changes after controlling for the stock's systematic risk. A positive (negative) δ_i

[1] For robustness, we also estimate equation (1) over a rolling 15-year window (i.e., 180 months), requiring a minimum of 10 years (120 months) of observations. The results are similar and available on request.

indicates that firm *i*'s stock return tends to move in the same (opposite) direction as the temperature change. The measure thus gives a firm's value exposure to temperature changes. This measure is also indicative of the information content in stock return about a firm's exposure to climate change: the higher in magnitude the coefficient is, the more information the firm stock return has about the firm's climate exposure. Depending on abnormal temperature measures used in equation (1), I obtain different estimates of δ_i. I accordingly label these estimates as *TIR* and *TIR30* for sensitivity to state-level temperature changes, and *TIR_US* and *TIR30_US* for sensitivity to US-wide temperature changes. In one exercise, I also use the absolute value of state-level abnormal temperature in equation (1) and label the ensuing estimate of δ_i as *TIR_ABS*.

To avoid the look-ahead bias in examining the effect of stock price's climate-related information on firm investment, I merge the monthly firm-level climate exposure estimates with the annual accounting data to the last fiscal year-end month. Our sample consists of 122,469 firm-year observations with 10,297 firms in the 1970-2021 period.

Figure 1 graphs average US abnormal temperatures during 1970-2020. There is a clear trend of rising temperatures in US, especially when I inspect the yearly abnormal temperature series. The abnormal temperature becomes increasingly more positive in the recent two decades. Indeed, average abnormal temperature equals 0.63 in this 50-year period, meaning that US temperature increases by an average of 0.63 Fahrenheit degrees relative to the historical level.

Figure 2 plots the year-by-year average and median return sensitivities to abnormal temperature, *TIR* and *TIR_US*, from 1970 to 2020. Overall, both series experience several cycles during the period and their values become smaller in magnitude in the recent decade. Notably, although having similar time-series dynamics, *TIR* exhibits predominantly smaller fluctuations than *TIR_US*.

2.2 Other variables

To investigate the effects of stock price information content about climate sensitivity on firm investment, I estimate the following model:

$$I_{i,t} = \lambda_i + \rho_t + \theta_1 Q_{i,t-1} + \theta_2 TIR_{i,t-1} + \theta_3 Q_{i,t-1} TIR_{i,t-1} + \Gamma Controls + \eta_{i,t}. \quad (2)$$

In equation (2), $I_{i,t}$ is firm i's investment in year t, λ_i and ρ_t are firm- and year-fixed effects, $Q_{i,t-1}$ is firm i's normalized market price in year *t-1*, $TIR_{i,t-1}$ is firm i's return sensitivity to abnormal temperature in year *t-1*, and $Controls$ represents a set of control variables. The firm-fixed effects control for unobserved time-invariant firm characteristics that can affect the relation of interest. The inclusion of year-fixed effects not only helps address potential time trends in some of the variables but also controls for the effects of macroeconomic and economy-wide business conditions.

I use three measures of corporate investment: capital expenditure (*CAPX*), capital expenditure plus R&D (*CAPXRD*), and change in total assets (CHGAT), all scaled by beginning-of-year assets and expressed in percentages. Following the literature (e.g., Chen, Goldstein, and Jiang, 2007; Bakke and Whited, 2010; Huang and Kang, 2017), I focus on *CAPXRD* as the primary measure of firm investment and use *CAPX* and *CHGAT* for robustness check. I calculate Q as the sum of market value of equity, debt in current liabilities, total long-term debt, and preferred stock carrying value minus deferred taxes and investment tax credit, scaled by the beginning-of-year book value of assets. I construct the climate sensitivity measure TIR as explained above, and I also use variants of this measure in equation (2).

$Controls$ includes the following commonly used variables in prior studies on investment: $CF_{i,t-1}$, $RET3YR_{i,t}$, and $INV\_AT_{i,t-1}$. *CF* is income before extraordinary items plus depreciation and amortization expenses, scaled by year-end total assets. *RET3YR* is annualized stock excess return over the next three years. *INV_AT* is the inverse of beginning-of-year assets. I include CF and/or its interaction with TIR to control for the effect of cash flow on investment (e.g., Fazzari, Hubbard, and Petersen, 1988). I use $RET3YR$ to control for managers' market timing of investment (e.g., Baker, Stein and Wurgler, 2003). I include INV_AT to control for the effect of firm size and to purge the mechanical correlations between $I_{i,t}$ and some explanatory variables because they are all scaled by beginning-of-year assets.

To isolate the effect of financial constraint on investment, I also include some financial constraints proxy in equation (2) as additional control variables. *FIRMAGE* is the number of years since CRSP starts covering the firm. *LNMV* and *LNAT* are respectively logarithm values of market capitalization and total assets, both adjusted for inflation calculated based on the consumer price index. *ZSCORE*, *OSCORE*, *KZIND*, and *SAIND* are respectively Altman's (1968) Z-score, Ohlson's (1980) O-score, Kaplan-Zingales' (1997) index, and Hadlock and Pierce's (2010) Size-Age index. I multiply *ZSCORE* by negative one so that, like the other three measures, high ZSCORE values correspond to severe financial constraints. I follow Bakke and Whited (2010) to construct KZ_q by excluding Q from *KZIND*. In calculating *SAIND*, I follow Hadlock and Pierce (2010) to winsorize the book value at $4.5 billion in 1995 dollars and cap the number of years a firm appears in Compustat at 37 years. Table 1 details the constructions of *ZSCORE*, *OSCORE*, *KZIND*, and *SAIND*.

I further examine the effects of stock price information content about climate sensitivity on firm performance and firm value. I thus estimate a modified equation (2) as follow:

$$Y_{i,t} = \lambda_i + \rho_t + \theta_1 Q_{i,t-1} + \theta_2 TIR_{i,t-1} + \theta_3 Q_{i,t-1} TIR_{i,t-1} + \Gamma Controls + \eta_{i,t}. \quad (3)$$

In equation (3), $Y_{i,t}$ is either firm *i*'s performance or value in year *t*. I use three measures of firm performance: return-on-assets (*ROA*), asset turnover (*ASSETURN*), and total factor productivity

(*TFP*). *ROA* is the ratio of income before extraordinary items divided by beginning-of-year assets. *ASSETURN* is the ratio of total sales to total assets. *TFP* is the residual of the pooled regression of logged total sales against logged number of employees and logged net value of property, plant, and equipment. I use *Q* as a measure of firm value. Based on the prior studies of firm performance and firm value (e.g., Giroud and Muller, 2011; Perez-Gonzalez and Yun, 2013), $Controls$ in equation (3) consists of a different set of variables than in equation (2): firm age and firm size, both in logarithm values (LNFIRMAGE and LNAT), book leverage (*BKLEV*), and Herfindahl-Hirschman Index (*HHI*). I compute *BKLEV* as the ratio of total debt, i.e., the sum of short-term and long-term debts, to total assets. *HHI* is the sum of squared market shares, with market share defined as the ratio of a firm's sales to the total sales of the firm's industry using the Fama-French 48-industry classification.

To reduce the impact of outliers, I winsorize all variables at their respective 1 and 99 percentiles. Table 1 summaries those variables.

3. Results

3.1 Basic Results

In this section I assess the relations between climate-related information content in stock price and corporate investment. Table 2 reports the estimation results of equation (2). The dependent variable is *CAPXRD* in Columns (1)-(3), *CAPX* in Columns (4)-(6), and *CHGAT* Columns (1)-(3), respectively. In Columns (1), (4) and (7), I include Q_{t-1}, TIR_{t-1} and the interaction of Q_{t-1} and TIR_{t-1}, in addition to the firm-fixed effects and year-fixed effects, as explanatory variables in equation (2). In Columns (2), (5) and (8), I add three control variables, CF_{t-1}, $RET3YR_t$, and INV_AT_{t-1} in equation (2). In Columns (3), (6) and (9), I further add the interaction of CF_{t-1} and TIR_{t-1} as another explanatory variable in equation (2).

I focus on CAPXRD as our primary investment measure. In Column (1), the estimated coefficient on Q_{t-1} is 2.139 and statistically significant at the 1% level (standard error =0.062). The result corroborates the finding in the literature that investment responds positively to stock prices. Because the normalize price measure, *Q*, is usually a proxy for investment opportunities, the significantly positive estimate is consistent with the economic theory that investment should correlate positively with investment opportunities. Our focus is on the two coefficient estimates related to *TIR*, which tell the effects of climate-related information in stock price on investment. The estimated coefficient on *TIR* is 0.373 and, with a standard error of 0.086, statistically significant at the 1% level. The estimated coefficient on the interaction of *Q* and *TIR* is -0.176 and statistically significant at the 1% level (standard error=0.052). The results show that the climate-related information in stock price affects investment both directly and indirectly via its interaction with *Q*. That is, the more climate-related information is impounded into the stock price, the larger investment the firm makes, but this relation attenuates as the firm's *Q* increases.

I then add three explanatory variables, *CF*, *RET3YR*, and *INV_AT* into equation (2) and report the results in Column (2). Both the estimated coefficients on *Q* and *TIR* remain positive and statistically significant at the 1% level, and the estimated coefficient on the interaction *Q***TIR* remains negative and significant at the 1% level. Different from earlier findings, the estimated coefficient on *CF* is significantly negative, but as discussed below, the result reverses when I use two other investment measures as the dependent variable of equation (2). The estimated coefficient on *RET3YR* is significantly negative, confirming the result in the prior literature that firms time market to invest, i.e., they increase investment when their stocks are overpriced (e.g., Baker, Stein, and Wurgler, 2003; Chen, Goldstein, and Jiang, 2007; Campello and Graham, 2013). As expected, the estimated coefficient on *INV_AT* is significantly positive as this variable and investment measure share the same scaling variable. In Column (3), I further add the interaction of *CF* and *TIR*. The estimated coefficient on this interaction term is negative and significant at the 10% level. The other estimates retain the same signs and significance levels as in Column (2).

Using two other investment measures, *CAPX* and *CHGAT*, I obtain similar results (Columns (4)-(9)). In particular, the estimated coefficient on *TIR* is significantly positive and the estimated coefficient on *TIR*Q* is significantly negative, corroborating the above results with *CAPXRD* as the investment measure. The only exception is for the estimated coefficient on *CF*. With the two alternative investment measures, this estimate becomes positive and statistically significant at the 1% level, which is consistent with the earlier finding that investment depends positively on cashflow (e.g., Fazzari, Hubbard, and Petersen, 1988; Peters and Taylor, 2017). The positive investment-cashflow relation can reflect either financial constraint (Fazzari, Hubbard, and Petersen, 1988) or informational role of cashflow for capital productivity (Poterba, 1988; Alti, 2003). The coefficient estimate on *TIR*CF* is significantly negative, suggests that firms with more climate-related information in stock price have lower sensitivity of investment to cashflow. To sum up, the key message from the results of Table 2 is that the climate-related information in stock price affects investment both directly and indirectly, and the link between the information and investment weakens as a firm's *Q* increases.

I offer another look into the differential relations between the climate-related information and investment across *Q*. For this purpose, I form three groups of firms based on their *Q* at the last year-end, and then estimate a modified equation (2) by excluding interaction terms for each group of firms. Table 3 reports the results with *CAPXRD* (Columns (1)-(3)), *CAPX* (Columns (4)-(6)), and *CHGAT*(Columns (7)-(9)) as the investment measures. As evident in the table, regardless of the investment measures, the estimated coefficients on *Q* are all significantly positive and decrease monotonically from low-Q firms to high-Q firms. More importantly, the estimated coefficients on *TIR* also decrease monotonically from low-Q firms to high-Q firms. Take as an example when CAPXRD is the investment measure. The estimates on *TIR* are 0.202 and significant at the 5% level for low-*Q* firms, 0.178 and significant at the 10% level for med-*Q* firms, and -0.245 and statistically insignificant for high-*Q* firms. The weakening relations between investment and the climate-related information in stock price across *Q*-sorted groups of firms mirror the negative coefficient estimate on the interaction of *Q* and *TIR* in Table 2.

3.2 Alternative measures of climate-related information in stock price

I calculate abnormal temperature using the past 50-year average temperature as the reference and obtain the above basic results. For robustness, I calculate abnormal temperature using the past 30-year average temperature as the reference. I re-estimate equation (1) with this alternative abnormal temperature measure and label the estimate as *TIR30*. I then replace *TIR* with *TIR30* in equation (2) for estimations. Using an identical structure to Table 2, I report the results in Table 4, Panel A. The results are similar to the estimation results as reported in Table 2. Regardless of the investment measure, the estimated coefficient on *Q* is positive and statistically significant at the 1% level, the estimated coefficient on *TIR30* remains positive and statistically significant at the 5% or lower level, and the estimated coefficient on *TIR30*Q* is negative and significant at the 5% or lower level. Additionally, the estimated coefficient on *CF* is significantly negative when *CAPXRD* is the investment measure and significantly positive when *CAPX* or *CHGAT* is the investment measure. Irrespective of the investment measure, the estimated coefficient on *CF*TIR30* is negative.

The above firm-level climate sensitivity measures are estimated relative to the abnormal temperature in a firm's headquarter state. A firm's main operations are often located in states outside of the headquarter state. To address this issue, I use an alternative abnormal temperature measure based on the US monthly average temperature, *tanom_us,* where the US-wide temperature is the equal-weighted average of state-level temperature across all US states. I define *tanom_us* as the difference between the US-wide temperature in a month and the past 50-year average of US-wide temperatures in the same month. I re-estimate equation (1) by substituting *tanom_us* for *tanom* and denote the affiliated coefficient as *TIR_US*. I then use *TIR_US* in lieu of *TIR* as the measure of firm climate sensitivity in equation (2) estimations. Table 4, Panel B reports the estimation result with this alternative climate sensitivity measure. The key results are somewhat weaker but qualitatively similar. That is, the estimated coefficient on *Q* remains significantly positive, the estimated coefficient on *TIR_US* is positive and largely significant, and the estimated coefficient on *TIR_US*Q* is negative and largely significant.

3.3 Subperiod analysis

For ease of exposition, I use *CPAXRD* as the investment measure in the following analysis. To check whether the climate-related information in stock price has time-varying effects on corporate investment, I conduct a subperiod analysis. Table 5 reports the estimation results, with *TIR* as the measure of such information content. For easy reference, I reproduce in Column (1) the full-sample results as reported in Column (2) of Table 2.

I first split the full sample by the year of 2000 for two reasons: 1) weather derivatives began trading over-the-counter in 1997 and were introduced into exchanges in 1999, which facilitated firms' uses of such assets to hedge their weather exposures; 2) the sample is roughly equally divided into the pre-2000 and the post-2000 (2000 inclusive) subperiods. Columns (2) and (3) of

Table 5 present the results for the pre-2000 and post-2000 subperiods, respectively. As evident in the two columns, firm investment continues to load positively and strongly significantly on *Q* across the two subperiods, consistent with the economic theory of investment. On the other hand, the effects of climate-related information in stock price on firm investment vary between the two subperiods. The estimated coefficient on *TIR* is 0.231 and significant at the 10% level in the pre-2000 subperiod, and it is 0.444 and statistically significant at the 1% level in the post-2000 subperiod. Moreover, the estimated coefficient on *TIR*Q* is -0.084 and statistically insignificant in the pre-2000 subperiod, and it is -0.221 and statistically significant at the 1% level in the post-2000 subperiod. The relation between investment and cashflow varies between the two subperiods too: the estimated coefficient on *CF* is significantly positive in the pre-2000 subperiod but is significantly negative in the post-2000 subperiod. This result is somewhat consistent with the prior finding that the investment-cashflow sensitivity declines over time (e.g., Wang and Zhang, 2021).

I zero in on the post-2000 subperiod and further divide it into two equal-spaced micro periods: 2000-2010, and 2011-2021. Columns (4) and (5) of Tabe 5 list the respective estimation results. The relation between climate-related information in stock price and firm investment shows considerable variations across the two micro periods. The estimated coefficient on *TIR* is 0.154 and not significant at the 10% level in the earlier micro period. This estimate has a much higher value in the later micro period, which equals 1.003 and is statistically significant at the 1% level. The estimated coefficient on *TIR*Q* equals -0.161 in the earlier micro period and -0.289 in the later micro period, both are statistically significant at the 5% level. These results suggest that the indirect effect of climate-related information in stock price on firm investment via *Q* remains relatively stable in the post-2000 subperiod, but the direct effect of such information on investment varies considerably. Investment has become highly sensitive to the climate-related information in stock price, likely due to the increasing society-wide awareness of climate changes and mounting pressure to take actions to tackle the issue over time.

3.4 Magnitude of temperature abnormality

As a firm's operation and performance can be affected by both abnormal increases and abnormal decreases in temperatures, I also estimate a firm's return sensitivity to unsigned abnormal changes in temperature. I thus replace abnormal temperature with its absolute value in equation (1), and I use the affiliated coefficient estimates, *TIR_ABS*, in equation (2) as the firm's climate sensitivity measure. Using the structure of Table 5, I report the results of estimating this modified equation (2) in Table 6.

Column (1) lists the full-sample results. The estimated coefficients on *Q* and *TIR_ABS* are both positive and statistically significant, and the estimated coefficient on *TIR_ABS**Q is negative and marginally statistically insignificant. In Columns (2) and (3), I report the estimation results for the pre-2000 and post-2000 subperiods, respectively. The estimated coefficient on *Q* remains significantly positive in both subperiods, but the estimated coefficient on *TIR_ABS* shows much variation between the two subperiods. It is -0.038 and statistically insignificant in the pre-2000 subperiod and is 0.382 and statistically significant at the 1% level. The coefficient on the interaction term *TIR_ABS*Q* has a negative estimate in both subperiods and is statistically significant only in the post-2000 subperiod. Like in Table 5, the estimated coefficient on *CF* is significantly positive in the pre-2000 subperiod and statistically negative in the post-2000 subperiod.

I further divide the post-2000 subperiod into two 11-year windows, 2000-2010 and 2011-2021. The estimated coefficient on *TIR_ABS*, significantly positive in both windows, is much larger in the later window than in the earlier window. Specifically, the estimate is 0.175 and statistically significant at the 10% level for 2000-2010, and it is 0.710 and statistically significant at the 1% level for 2011-2021. The estimated coefficient on *TIR_ABS*Q* is negative in both windows and is marginally significant in the later window.

To sum up, the main message in this section is that the climate-related information in stock price, proxied by various variables, affects firm investment both directly and indirectly via *Q* and that the positive relation between such information and investment weakens in *Q*. Additionally, the relations show considerable variations across time and are much stronger in the more recent period than in the earlier period.

4. Possible Economic Explanations

According to the *Q* theory, firm investment is determined by marginal productivity of capital, i.e., marginal *Q*. However, in empirical studies, because marginal *Q* is unobservable, average *Q*, likely a noisy measure of marginal *Q*, is unable to explain the observed pattern in firm investment activities. Instead, other variables, cash flow in particular, are found to have explaining power for investment (e.g., Fazzari, Hubbard, and Petersen, 1988). The positive relation between those other variables and firm investment can reflect either the existence of financial constraints or informational role of those variables for capital productivity. To offer an economic explanation for our above findings, I conduct exercises to rule out the financial constraint story.

Financial constraints affect investment in two ways --- they constrain a firm's capability to make new investment (or even force a firm to reduce investment), and meanwhile, they tighten the link between investment and *Q*.[2] I find a positive coefficient on *TIR* and a negative coefficient on

[2] Investment of financially constrained firms are more sensitive to *Q*, a normalized price, because financing constraints prevent firms from pursuing their optimal investment plans and an increase in stock price may ease these constraints, enabling firms to increase investments. Indeed, the evidence of firms timing markets to invest is consistent with this story (e.g., Baker and Wurgler, 2002; Baker, Stein, and Wurgler, 2003).

*TIR*Q*. To reconcile our finding with the financial constraint story, *TIR* must be negatively related to financial constraint. That is, high-*TIR* (low-*TIR*) firms have low (high) financial constraints. I thus sort firms into three groups based on their *TIR* values and summarize various financial constraint measures for each group. Table 7, Panel A presents the means of the following financial constraint measures: firm age, firm assets, Hadlock and Pierce's (2010) Size-Age index (SAIND), Kaplan-Zingales' (1997) index (KZIND), firm market value (LNMV), Ohlson's (1980) O-score (OSCORE), and negative Altman's (1968) Z-score (ZSCORE). In general, the higher is firm age, firm assets, and firm market value, the less financial constraint/stress the firm faces. The higher is SAIND, KZIND, OSCORE, and ZSCORE, the more financial constraints/stress the firm faces. As shown in Panel A, there does not exist a clearly negative correlation between *TIR* and financial constraint, regardless of the proxy for financial constraint. Instead, there is some evidence pointing to the opposite – high-*TIR* firms have much smaller market value, thus potentially more financial constraint/stress, than low-*TIR* firms.

To rule out the financial constraint explanation more credibly for our findings, I conduct a regression analysis. I modify equation (2) by including financial constraint measures and their interactions with *Q* as additional control variables. Table 7, Panel B reports the estimation results. In Columns (1)-(5), *SAIND*, *KZIND*, *LNMV*, *OSCORE*, and *ZSCORE* are the respective financial constraint proxy.

I discuss three observations of Panel B. First, regardless of the financial constraint proxy, the estimated coefficients on *TIR* and *TIR*Q* remain positive and negative, respectively, and all are statistically significant at the 1% level after controlling for financial distress and its interaction with *Q* in the regressions. The results show that our finding of the relations between climate-related information in stock price and firm investment is not driven by financial constraints. Second, consistent with theoretic reasoning, the financial constraint proxies are related negatively to firm investment (except for *KZIND*) and positively to investment-*Q* sensitivities.[3] Third, regardless of the financial constraint proxy, the estimated coefficients on *TIR*CF* also remain negative, all statistically significant at the 1% level, after controlling for financial distress and its interaction with *Q* in the regressions. The results suggest that our finding of declining investment-cashflow sensitivities with respect to *TIR* is not driven by financial constraints, either.

With the financial constraint explanation out of picture, our finding of a positive relation between *TIR* and investment is thus indicative of the information role of *TIR* for marginal *Q*. That is, *TIR* contains information about capital productivity that is incremental to the information in average *Q*. It is thus of interest to examine whether such information impounded in stock price is new to managers. The sign of the coefficient estimate on *TIR*Q* helps answer it.

The feedback effect literature posits that because stock prices incorporate private information via speculators' trading activities, decision makers on the real side (e.g., firms) can learn such information from the price and guide their decisions (e.g., see Bond, Edmans, and Goldstein (2012) for a survey of the literature). Along this logic, investment will be more responsive to stock price when the price reflects more information that is new to managers (e.g., Chen, Goldstein, and Jiang, 2008; Bakke and Whited, 2010; Huang and Kang, 2017). On the other hand, information already available to managers will weaken the sensitivity of investment to stock price as it has already impacted past investments. Based on this reasoning, our finding of a negative relation between the investment-*Q* sensitivity and the climate exposure implies that the climate-related information

[3] Market value is negatively related to financial constraint. Therefore, when LNMV is the financial constraint proxy (*FC*), the positive estimate on *FC* and the negative estimate on *FC*Q* are consistent with the theoretic reasoning of the effects of financial constraint on investment.

impounded in stock price is not new to managers, rendering them rely less strongly on the price in their investment decisions (when managers have more private information on their own).

Another supporting argument for the information story arises from our above documented effect of the climate-related information in price on the sensitivity of investment to cash flow. That is, the investment-cashflow sensitivity is lower when prices contain more climate-related information, and this relation is not driven by financial constraint. The literature has argued that investments are strongly correlated with cashflows because cash provides information on the profitability of firms' investments beyond stock prices (Alti, 2003). According to this hypothesis, when prices become more informative to managers, managers will rely less on cash and more on prices to obtain information about investment profitability, thereby lowering the investment-cashflow sensitivity. The finding of significantly negative coefficient estimates on *TIR*CF* is consistent with this hypothesis, implying that the climate-related information in stock price enables firms to rely less on cash as a source of information on investment profitability.

5. Firm Performance and Firm Value

In Section 4, I claim that *TIR* contains information about capital productivity so that *TIR* is positively related to investment. In this section, I offer supportive evidence by assessing the effects of the climate-related information in stock price on firms' future operating performance and firm valuation. I expect positive relations in that if informative about capital productivity, the climate-related information in price should help firms make better investment decisions.

I examine firms' ex post performance as measured by return on assets (*ROA*), assets turnover (*ASSETURN*), and total factor productivity (*TFP*). Table 8, Panel A, reports the results of equation

(3) estimations, with *ROA*, *ASSETURN*, and *TFP* as the dependent variables in Columns (1)-(3), (4)-(6), and (7)-(9), respectively.

I first look at the full-sample results listed in Columns (1), (4), and (7). As expected, the estimated coefficients on *TIR* are all positive and statistically significant at the 5% or less level. The result shows that greater amount of climate-related information in stock price is associated with better future firm performance. Interestingly, the estimated coefficients on *TIR*Q* are all negative and statistically significant at the 10% or less level. The result implies that the positive relation between such information and future firm performance weakens as *Q* increases.

I then assess the subperiod results listed in the remaining columns of Table 8, Panel A. Overall, the documented full-sample results are much more pronounced in the post-2000 subperiod than in the pre-2000 subperiod, with *ROA* being the only exception. When *ASSETURN* and *TFP* are the performance measure, the estimated coefficients on *TIR* and *TIR*Q* are all statistically insignificant in the pre-2000 subperiod (Columns (5) and (8)). In contrast, in the post-2000 subperiod, the estimated coefficients on *TIR* are both positive and statistically significant at the 5% or less level, and the estimated coefficients on *TIR*Q* are negative and statistically significant at the 5% and less level (Columns (6) and (9)). The results on *ROA* are much stronger in the pre-2000 subperiod than in the post-2000 subperiod (Columns (2) and (3)).

The results in Table 8, Panel A show that the climate-related information in stock price is positively related to future firm performance and that this relation weakens as *Q* rises. This pattern is identical to the pattern I document for the relation between the climate-related information in stock price and firm investment. Given that the climate-related information in stock price is informative about capital productivity, the two sets of results combined indicate that the climate-information-driven investment is performance-enhancing.

I proceed to assess the effects of the climate-related information in stock price on future firm value. Following the literature, I use *Q* as a measure of firm value (e.g., Giroud and Muller, 2011; Perez-Gonzalez and Yun, 2013). Table 8, Panel B reports the equation (3) estimation results, with columns (1)-(3) corresponding to the whole-period, the pre-2000 subperiod and the post-2000 subperiod, respectively, In Column (1), the estimated coefficient on *TIR* is 0.046 and significant at the 1% level, and the estimated coefficient on *TIR*Q* is -0.019 and significant at the 5% level. The two estimates are statistically insignificant in Column (2). In Column (3), the estimated coefficient on *TIR* is 0.075 and significant at the 1% level, and the estimated coefficient on *TIR*Q* is -0.029 and significant at the 5% level. Clearly, the results are much stronger in the post-2000 subperiod than in the pre-2000 subperiod.

Giroud and Muller (2011) use industry-adjusted *Q* in estimations. As an alternative, I replace firm-time fixed effects with industry-time fixed effects to control for broad trends in industry valuation changes. Columns (4)-(6) in Panel B of Table 8 report the results. The results are quantitatively similar. The estimated coefficients on *TIR* remain positive and statistically significant at the 1% level in the whole period (Column (4)), positive but statistically insignificant in the pre-2000 subperiod (Column (5)), and positive and statistically significant at the 1% level in the post-2000 period (Column (6)). The estimated coefficients on *TIR*Q* remain negative and statistically significant at the 1% level in the whole period and the post-2000 subperiod (Columns (4) and (6)), and negative but statistically insignificant in the pre-2000 subperiod (Column (5)).

It is clear from the results in Table 8, Panel B that the climate-related information in stock price is positively related to future firm value and that this relation again becomes weaker as *Q* rises. This pattern is identical to the patterns I document for the respective relations between the climate-related information in stock price and firm investment/firm performance. Taken together, per the information role of the climate-related information in stock price for capital productivity, these results indicate that the climate-information-driven investment is value-enhancing. That is, investors in the stock market reward firms for making investment induced by the climate-related information in stock price.

6. Conclusion

In this paper I examine the role of climate change in affecting firm investment, firm performance and firm valuation. Different from the extant studies, I approach this subject from the angle of the informational role of stock market. Focusing on temperature as a proxy for climate, I construct firm-level return sensitivity to abnormal temperature as a proxy for the climate-related information in stock rice. Using data over 1970-2021, I find that the climate-related information in stock price is positively associated with a firm's investment and this positive relation weakens when the firm's investment opportunity expands. The relations strengthen considerably in the recent period than in the earlier period. I document the same pattern in the relations between the climate-related information in stock price and firm performance and firm value. The results suggest that climate-information-driven investment is performance-enhancing and that stock market rewards firms for making such investment. The negative relations between climate exposure and investment-price sensitivity as well as investment-cashflow sensitivity are consistent with the notion that the climate-related information incorporated into stock price is already known to managers.

Our study has policy implications. Given the information production role of stock market, it is of interest for regulators and policy makers to facilitate the incorporation of climate-related information into stock price, which economic agents in the real sector such as firms can learn and use to improve their decision-making.

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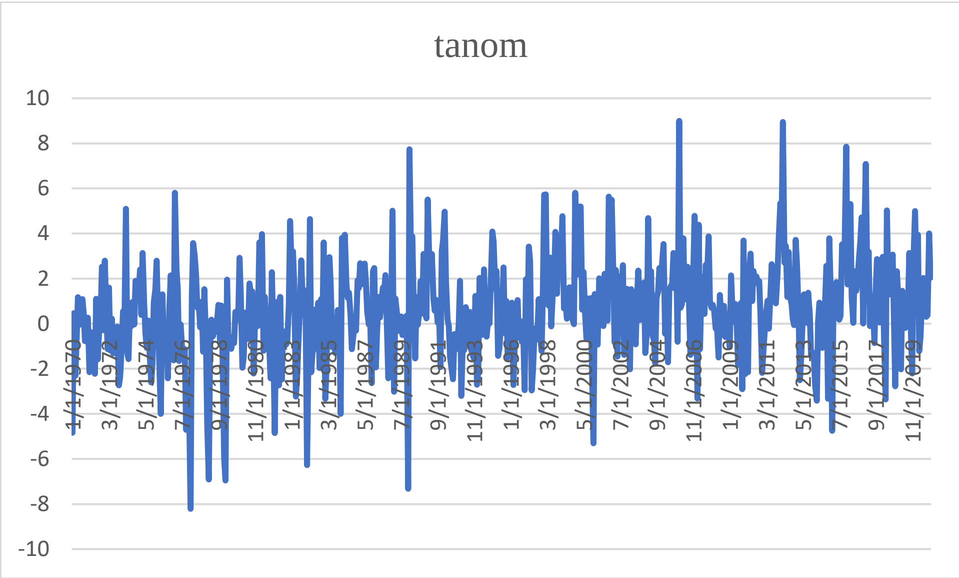
Figure 1. Average State Abnormal Temperatures in US: 1970-2020

This figure plots the US state abnormal temperatures during 1970-2020, with the monthly and yearly series in Panels A and B, respectively. Monthly abnormal temperature is the difference between a month's average temperature and the past 50-year average of monthly temperature for the same month. Yearly abnormal temperature is the average of 12 monthly abnormal temperatures in a calendar year.

Panel A. Monthly abnormal temperature



Panel B. Yearly abnormal temperature

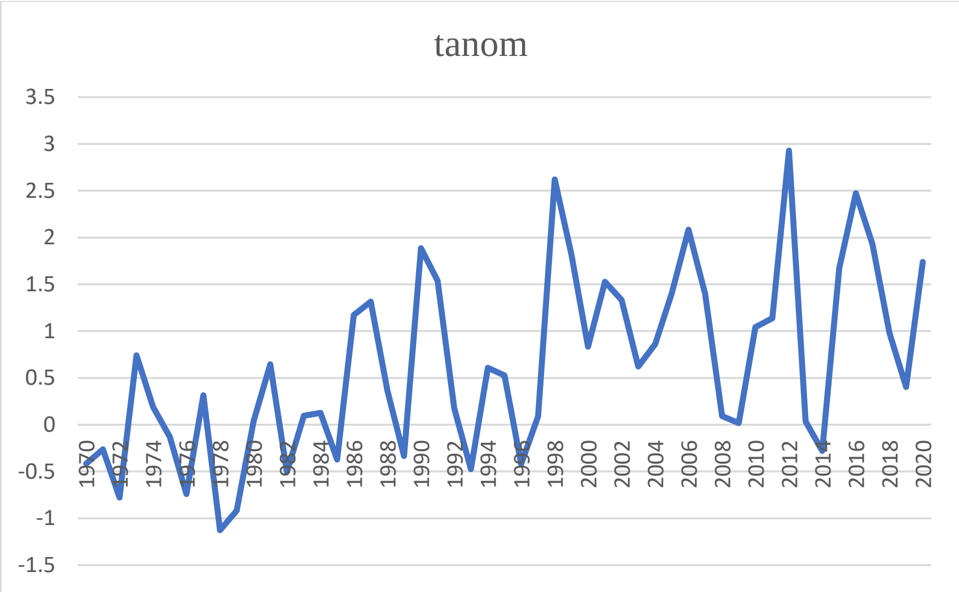
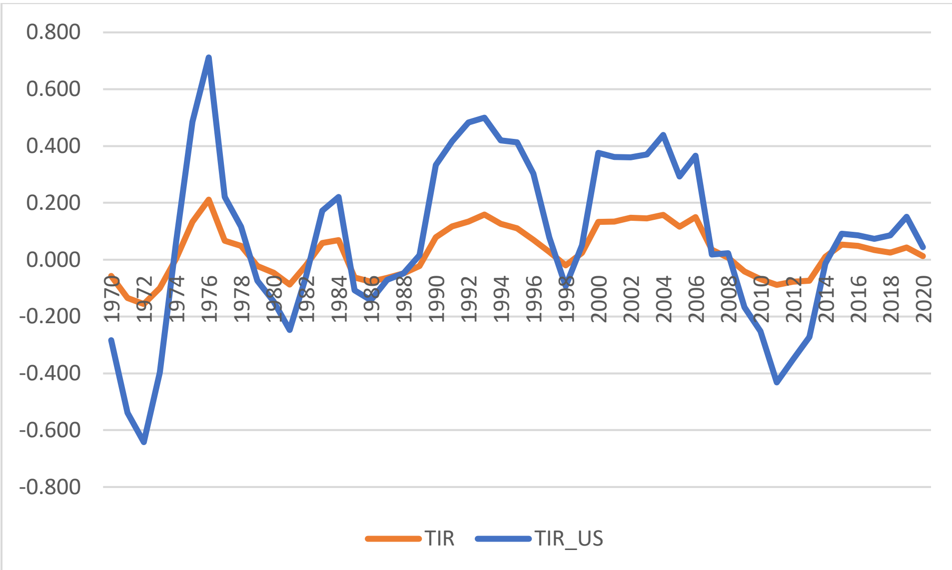


Figure 2. Average and Median Return Sensitivities to Abnormal Temperature: 1970-2020

This figure plots the year-by-year average and median return sensitivities to abnormal temperature during the 1970-2020 period in Panels A and B, respectively. See Table 1 for variable definitions.

Panel A. Average sensitivities



Panel B. Median sensitivities

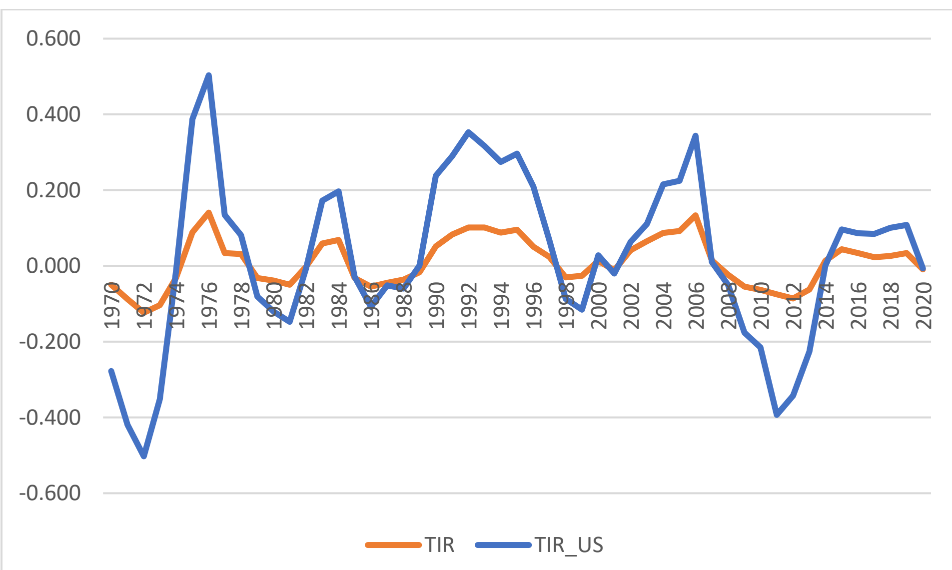


Table 1. Summary Statistics

This table summarizes variables. *CAPX* is capital expenditure scaled by beginning-of-year assets. *CAPXRD* is CAPX plus the ratio of R&D to beginning-of-year assets. *CHGAT* is annual change in assets scaled by beginning-of-year assets. *CAPXRD*, *CAPX*, and *CHGAT* are expressed in percentages. *Q* is the sum of market value of equity, debt in current liabilities, total long-term debt, and preferred stock carrying value minus deferred taxes and investment tax credit, scaled by the beginning-of-year book value of assets. For each firm in each month, we regress the firm's excess stock returns against the excess market return and the abnormal temperature using the past 60 months of data. We calculate headquarter-state-level (US-wide) abnormal temperature in a given month as the difference between the state (US) temperature and one of the two references: the past 50-year average state (US) temperature, and the past 30-year average state (US) temperature, of the same month. We then label the coefficient on the respective abnormal temperature in the regression as *TIR* (*TIR_US)* and *TIR30* (*TIR30_US*) accordingly. The US temperatures are equal-weighted averages of state temperatures. We also use the absolute abnormal temperature to replace abnormal temperature in the regression and designate the affiliated coefficient as *TIR_ABS*. *CF* is income before extraordinary items plus depreciation and amortization expenses, scaled by beginning-of-year assets. *RET3YR* is annualized stock excess return over the next three years. *INV_AT* is the inverse of beginning-of-year assets. *FIRMAGE* is the number of years since CRSP starts covering the firm. *LNMV* and *LNAT* are respectively logarithm values of market capitalization and total assets, both adjusted for inflation, where inflation is the growth rate in consumer price index. *ZSCORE*, *OSCORE*, *KZIND*, and *SAIND* are respectively Altman's (1968) Z-score, Ohlson's (1980) O-score, Kaplan-Zingales' (1997) index, and Hadlock and Pierce's (2010) Size-Age index. We multiply *ZSCORE* by negative one so that, like the other three measures, high ZSCORE values correspond to severe financial constraints. Specifically, $ZSCORE = 1.2 \times wc/lat + 1.4 \times re/lat + 3.3 \times ebit/lat + 0.6 \times me/lt + 0.999 \times sale/lat,$ where wc is current assets (*act*) minus current liabilities (*lct*), *lat* is beginning-of-year assets, *re* is retained earnings, *ebit* is the sum of pre-tax income and interest and related expense, *me* is market value of equity, *lt* is total liabilities, and *sale* is net sales. $OSCORE = -1.32 - 0.407 \times log(at) + 6.03 \times lt/at - 1.43 \times wc/at + 0.0757 \times lct/act - 2.37 \times ni/at - 1.83 \times ffo/lt + 0.285 \times intwo - 1.72 \times oeneg - 0.521 \times chin,$ where *at* is total assets, *ni* is net income, *ffo* is the sum of pretax income and depreciation and amortization, *intwo* is a dummy variable that equals one if the net income from the last two years are negative and zero otherwise, *oeneg* is a dummy variable that equals one if total assets is less than total liabilities and zero otherwise, and *chin* is this year's net income minus last year's net income, divided by the sum of the two years of absolute net income. $KZIND = -1.001909 \times cf/k + 3.139193 \times tltd - 39.3678 \times div/k - 1.314759 \times cash/k + 0.2826389 \times Q,$ where cf is the sum of income before extraordinary items and depreciation and amortization, *k* is net PPE (property, plant, and equipment), *tltd* is total debt (debt in current liabilities plus long-term debt) divided by the sum of total debt and stockholders' equity, div is the sum of common dividends and preferred dividends, and *cash* is cash and short-term investments. We follow Bakke and Whited (2010) to construct KZ_q by excluding Q from KZIND. $SAIND = -0.737 \times Assets + 0.043 \times Assets^2 - 0.040 \times AGE,$ where *Assets* is the log of book assets in 1995 dollars and *AGE* is the number of years the firm appears in Compustat. In calculating *SAIND*, we winsorize the book value and the number of years at $4.5 billion and 37 years, respectively. *ROA* is the ratio of income before extraordinary items divided by beginning-of-year assets. *TFP* is the residual of the pooled regression of logged total sales against logged number of employees and logged net value of property, plant, and equipment. *ASSETURN* is the ratio of total sales to total assets. *BKLEV* is the ratio of total debt, i.e., the sum of short-term and long-term debts, to total assets. We compute the Herfindahl-Hirschman Index (*HHI*) as the sum of squared market shares, with market share defined as the ratio of a firm's sales to the total sales of the Fama-French-48 industry this firm belongs in. All variables are winsorized at the 1 and 99 percentiles. The sample period is from 1970 to 2021 (and 1970-2020 for *TIR*, *TIR30*, *TIR_US*, *TIR30_US* and *TIR_ABS*).

Variable	N	Mean	Stdev	P1	P25	P50	P75	P99
CAPXRD	121,591	11.034	11.515	0.130	3.799	7.597	13.822	67.516
CAPX	121,064	6.731	7.115	0.030	2.176	4.580	8.601	40.959
CHGAT	122,334	13.079	208.209	-51.116	-3.095	5.682	16.172	180.270
Q	122,198	1.646	1.789	0.248	0.714	1.057	1.804	11.801
TIR	121,992	0.037	0.667	-1.870	-0.298	0.013	0.344	2.292
TIR30	121,994	0.039	0.662	-1.846	-0.295	0.015	0.344	2.279
TIR_US	121,992	0.069	0.915	-2.436	-0.423	0.027	0.493	3.263
TIR30_US	121,994	0.075	0.917	-2.439	-0.418	0.029	0.501	3.270
TIR_ABS	121,992	0.070	1.011	-2.934	-0.434	0.044	0.548	3.394
CF	122,372	0.036	0.188	-1.000	0.032	0.078	0.119	0.293
RET3YR	105,823	0.031	0.272	-0.681	-0.124	0.034	0.180	0.858
INV_AT	122,334	0.023	0.049	0.000	0.001	0.005	0.020	0.313
FIRMAGE	122,469	21.245	16.196	5.250	9.667	15.833	27.083	78.667
LNMV	122,344	0.311	2.243	-4.386	-1.342	0.250	1.896	5.609
LNAT	122,334	5.516	2.134	1.162	3.917	5.396	7.016	10.688
ZSCORE	122,351	-3.688	4.868	-28.239	-4.776	-3.080	-1.702	13.130
OSCORE	122,152	-0.977	2.803	-7.722	-2.561	-1.187	0.236	10.502
KZIND	122,466	-4.937	17.760	-135.739	-3.730	-0.502	0.963	9.258
KZ_q	122,198	-5.407	17.779	-135.770	-4.265	-0.906	0.625	8.499
SAIND	122,469	-0.990	1.650	-4.165	-2.223	-1.025	0.156	3.003
ROA	122,238	0.004	0.175	-0.913	-0.008	0.041	0.083	0.305
TFP	118,905	0.042	0.793	-1.983	-0.467	0.012	0.519	2.383
ASSETURN	122,354	1.211	0.821	0.003	0.624	1.085	1.589	4.483
BKLEV	122,443	0.250	0.204	0.000	0.074	0.230	0.373	0.933
HHI	122,469	0.095	0.081	0.013	0.051	0.073	0.110	0.521

Table 2. Basic Results

This table presents fixed-effect regression results concerning the relation between investment and climate exposure. We use return sensitivity to headquarter-state abnormal temperature, with the past 50-year average temperature as the benchmark, to measure climate-related information in stock prices. See Table 1 for variable definitions. Dependent variables (CAPXRD, CAPX and CHGASSET) are expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

	CAPXRD			CAPX			CHGAT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Q_{t-1}	2.139***	1.999***	2.002***	1.186***	1.043***	1.045***	5.941***	4.941***	4.945***
	(0.062)	(0.068)	(0.068)	(0.038)	(0.040)	(0.040)	(0.112)	(0.125)	(0.126)
TIR_{t-1}	0.373***	0.368***	0.422***	0.267***	0.234***	0.269***	0.559***	0.436**	0.508**
	(0.086)	(0.092)	(0.096)	(0.058)	(0.062)	(0.062)	(0.186)	(0.204)	(0.210)
$TIR_{t-1}*Q_{t-1}$	-0.176***	-0.180***	-0.213***	-0.106***	-0.094***	-0.116***	-0.236***	-0.220**	-0.264**
	(0.052)	(0.054)	(0.053)	(0.027)	(0.028)	(0.030)	(0.091)	(0.101)	(0.103)
CF_{t-1}		-2.494***	-2.361***		4.927***	5.011***		18.813***	18.990***
		(0.580)	(0.588)		(0.259)	(0.260)		(0.979)	(0.982)
$TIR_{t-1}*CF_{t-1}$			-0.860*			-0.551***			-1.150
			(0.449)			(0.191)			(0.716)
$RET3YR_t$		-1.900***	-1.898***		-1.651***	-1.650***		-9.516***	-9.512***
		(0.154)	(0.154)		(0.101)	(0.101)		(0.328)	(0.328)
INV_AT_{t-1}		24.146***	24.194***		5.564***	5.595***		109.495***	109.558***
		(3.478)	(3.474)		(1.993)	(1.989)		(6.787)	(6.784)
Observations	119,146	103,008	103,008	118,619	102,584	102,584	119,862	103,584	103,584
Adjusted R^2	0.639	0.646	0.646	0.519	0.536	0.536	0.186	0.209	0.209
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 3. Basic Results: Grouped by One-Period-Lagged Q

This table presents fixed-effect regression results concerning the relation between investment and climate exposure in three groups of firms formed on their last-year-end's *Q*: Low-*Q* (bottom 30%), Med-*Q* (middle 40%), and High-*Q* (top 30%). We use return sensitivity to headquarter-state abnormal temperature, with the past 50-year average temperature as the benchmark, to measure the climate-related information in stock prices. See Table 1 for variable definitions. Dependent variables (CAPXRD, CAPX and CHGASSET) are expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

	CAPXRD			CAPX			CHGAT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Low-Q	Med-Q	High-Q	Low-Q	Med-Q	High-Q	Low-Q	Med-Q	High-Q
Q_{t-1}	3.604***	3.276***	1.632***	3.190***	2.639***	0.773***	14.074***	11.664***	3.779***
	(0.386)	(0.227)	(0.080)	(0.310)	(0.168)	(0.043)	(1.063)	(0.594)	(0.157)
TIR_{t-1}	0.202**	0.178*	-0.245	0.201***	0.100	-0.123	0.063	-0.093	-0.151
	(0.083)	(0.097)	(0.165)	(0.067)	(0.069)	(0.082)	(0.235)	(0.222)	(0.294)
CF_{t-1}	3.916***	3.742***	-9.135***	5.537***	6.519***	2.429***	21.179***	26.326***	6.084***
	(0.646)	(0.758)	(0.861)	(0.432)	(0.443)	(0.366)	(1.631)	(1.574)	(1.653)
$RET3YR_{t}$	-1.315***	-1.389***	-1.950***	-1.149***	-1.207***	-1.523***	-7.030***	-8.022***	-11.886***
	(0.158)	(0.210)	(0.379)	(0.127)	(0.155)	(0.212)	(0.497)	(0.494)	(0.725)
INV_AT_{t-1}	22.576***	25.071***	26.013***	11.443***	10.409***	3.337	151.460***	124.111***	106.359***
	(5.165)	(4.537)	(4.934)	(3.317)	(2.839)	(2.849)	(16.058)	(11.294)	(9.048)
Observations	29,186	40,304	30,651	29,098	40,141	30,482	29,309	40,646	30,754
Adjusted R^2	0.557	0.587	0.680	0.510	0.578	0.595	0.183	0.190	0.198
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 4. Robustness: Using Alternative Temperature Sensitivity Measures

This table presents fixed-effect regression results concerning the relation between investment and climate exposure. In Panels A and B, the measures of information on climate exposure in stock prices is return sensitivity to state-level abnormal temperature with 30-year average temperature as benchmark and return sensitivity to US-wide abnormal temperature with 50-year average temperature as benchmark, respectively. See Table 1 for variable definitions. Dependent variables (CAPXRD, CAPX and CHGASSET) are expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

Panel A. Return sensitivity to state-level abnormal temperature with 30-year average temperature as benchmark

	CAPXRD			CAPX			CHGAT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Q_{t-1}	2.138***	1.998***	2.001***	1.186***	1.042***	1.044***	5.942***	4.942***	4.945***
	(0.062)	(0.068)	(0.068)	(0.038)	(0.040)	(0.040)	(0.112)	(0.125)	(0.126)
$TIR30_{t-1}$	0.358***	0.349***	0.403***	0.256***	0.224***	0.260***	0.543***	0.410**	0.469**
	(0.087)	(0.094)	(0.097)	(0.059)	(0.063)	(0.063)	(0.187)	(0.205)	(0.211)
$TIR30_{t-1}*Q_{t-1}$	-0.172***	-0.175***	-0.208***	-0.100***	-0.088***	-0.110***	-0.240***	-0.225**	-0.261**
	(0.052)	(0.054)	(0.053)	(0.027)	(0.028)	(0.030)	(0.090)	(0.101)	(0.102)
CF_{t-1}		-2.492***	-2.362***		4.928***	5.015***		18.814***	18.958***
		(0.580)	(0.587)		(0.259)	(0.260)		(0.979)	(0.981)
$TIR30_{t-1}*CF_{t-1}$			-0.866*			-0.580***			-0.960
			(0.448)			(0.193)			(0.729)
$RET3YR_t$		-1.901***	-1.899***		-1.652***	-1.650***		-9.517***	-9.514***
		(0.154)	(0.154)		(0.101)	(0.101)		(0.328)	(0.328)
INV_AT_{t-1}		24.169***	24.208***		5.573***	5.598***		109.527***	109.568***
		(3.479)	(3.474)		(1.992)	(1.989)		(6.786)	(6.785)
Observations	119,148	103,008	103,008	118,621	102,584	102,584	119,864	103,584	103,584
Adjusted R^2	0.639	0.646	0.646	0.519	0.536	0.536	0.186	0.209	0.209
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Return sensitivity to US-wide abnormal temperature with 50-year average temperature as benchmark

	CAPXRD			CAPX			CHGAT		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Q_{t-1}	2.125***	1.996***	1.996***	1.184***	1.044***	1.047***	5.985***	4.995***	4.996***
	(0.063)	(0.068)	(0.069)	(0.039)	(0.041)	(0.041)	(0.116)	(0.129)	(0.129)
TIR_US_{t-1}	0.066	0.116*	0.114*	0.110***	0.129***	0.149***	0.215*	0.334**	0.337**
	(0.062)	(0.066)	(0.069)	(0.042)	(0.044)	(0.045)	(0.132)	(0.146)	(0.151)
$TIR\_US_{t-1}*Q_{t-1}$	-0.032	-0.071*	-0.069*	-0.038*	-0.048**	-0.060***	-0.211***	-0.259***	-0.261***
	(0.036)	(0.038)	(0.039)	(0.020)	(0.021)	(0.022)	(0.066)	(0.075)	(0.076)
CF_{t-1}		-2.481***	-2.488***		4.932***	5.010***		18.814***	18.827***
		(0.580)	(0.588)		(0.259)	(0.263)		(0.979)	(0.987)
$TIR\_US_{t-1}*CF_{t-1}$			0.029			-0.302**			-0.052
			(0.298)			(0.139)			(0.537)
$RET3YR_t$		-1.904***	-1.905***		-1.654***	-1.652***		-9.518***	-9.518***
		(0.154)	(0.154)		(0.101)	(0.101)		(0.328)	(0.328)
INV_AT_{t-1}		24.353***	24.355***		5.687***	5.670***		109.928***	109.925***
		(3.477)	(3.478)		(1.991)	(1.990)		(6.809)	(6.808)
Observations	119,146	103,008	103,008	118,619	102,584	102,584	119,862	103,584	103,584
Adjusted R^2	0.638	0.646	0.646	0.518	0.536	0.536	0.186	0.209	0.209
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. Subperiod Analysis

This table presents fixed-effect regression results concerning the relation between investment and climate exposure in various subperiods. We use return sensitivity to headquarter-state abnormal temperature, with the past 50-year average temperature as the benchmark, to measure information on climate exposure in stock prices. See Table 1 for variable definitions. The dependent variable, CAPXRD, is expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

	(1) Full	(2) <2000	(3) >=2000	(4) 2000-2010	(5) 2011-2021
Q_{t-1}	1.999^{***}	2.071^{***}	1.809^{***}	1.870^{***}	1.542^{***}
	(0.068)	(0.110)	(0.079)	(0.099)	(0.115)
TIR_{t-1}	0.368^{***}	0.231^{*}	0.444^{***}	0.154	1.003^{***}
	(0.092)	(0.135)	(0.124)	(0.142)	(0.239)
$TIR_{t-1}*Q_{t-1}$	-0.180^{***}	-0.084	-0.221^{***}	-0.161^{**}	-0.289^{**}
	(0.054)	(0.094)	(0.066)	(0.072)	(0.135)
CF_{t-1}	-2.494^{***}	6.002^{***}	-5.764^{***}	-4.427^{***}	-5.715^{***}
	(0.580)	(0.760)	(0.643)	(0.689)	(0.978)
$RET3YR_{t}$	-1.900^{***}	-2.920^{***}	-1.572^{***}	-2.208^{***}	-1.776^{***}
	(0.154)	(0.185)	(0.229)	(0.267)	(0.355)
INV_AT_{t-1}	24.146^{***}	26.136^{***}	80.514^{***}	96.131^{***}	86.222^{***}
	(3.478)	(3.377)	(7.301)	(7.750)	(13.720)
Observations	103,008	57,834	44,795	25,502	19,061
Adjusted R^2	0.646	0.596	0.754	0.752	0.815
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes

Table 6. Using Return Sensitivity to Absolute Abnormal Temperature

This table presents fixed-effect regression results concerning the relation between investment and climate exposure in various subperiod. We use return sensitivity to headquarter-state absolute abnormal temperature, with the past 50-year average temperature as the benchmark, as measures of information on climate exposure in stock prices. See Table 1 for variable definitions. The dependent variable, CAPXRD, is expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

	(1) Full	(2) <2000	(3) >=2000	(4) 2000-2010	(5) 2011-2021
Q_{t-1}	1.978^{***}	2.061^{***}	1.773^{***}	1.823^{***}	1.570^{***}
	(0.067)	(0.110)	(0.077)	(0.095)	(0.114)
TIR_ABS_{t-1}	0.215^{***}	-0.038	0.382^{***}	0.175^{*}	0.710^{***}
	(0.065)	(0.097)	(0.088)	(0.099)	(0.154)
$TIR\_ABS_{t-1}*Q_{t-1}$	-0.059	-0.005	-0.077^{*}	-0.048	-0.143^{*}
	(0.038)	(0.068)	(0.045)	(0.051)	(0.080)
CF_{t-1}	-2.479^{***}	6.022^{***}	-5.739^{***}	-4.380^{***}	-5.782^{***}
	(0.580)	(0.761)	(0.643)	(0.692)	(0.974)
$RET3YR_{t}$	-1.908^{***}	-2.924^{***}	-1.593^{***}	-2.204^{***}	-1.764^{***}
	(0.154)	(0.186)	(0.229)	(0.267)	(0.354)
INV_AT_{t-1}	24.101^{***}	26.306^{***}	80.585^{***}	96.437^{***}	86.545^{***}
	(3.484)	(3.386)	(7.334)	(7.777)	(13.998)
Observations	103,008	57,834	44,795	25,502	19,061
Adjusted R^2	0.646	0.596	0.754	0.752	0.815
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes

Table 7. Controlling for Financial Constraint/Distress

Panel A summarizes financial constraints in thee *TIR*-sorted groups of firms: low 30%, medium 40%, and high 30%. Panel B presents fixed-effect regression results concerning the relation between investment and climate exposure, controlling for financial constraint/distress. We use return sensitivity to headquarter-state abnormal temperature (*TIR*), with the past 50-year average temperature as the benchmark, to measure climate-related information in stock price. The financial constraint/distress proxies in columns (1)-(5) are Hadlock and Pierce's (2010) Size-Age index (SAIND), Kaplan-Zingales' (1997) index (KZIND), firm size as measured by market value (LNMV), Ohlson's (1980) O-score (OSCORE), and negative Altman's (1968) Z-score (ZSCORE), respectively. See Table 1 for variable definitions. The dependent variable, CAPXRD, is expressed as percentage points of beginning-of-year's book assets. All the regressions control for both firm-fixed effects and year-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

Panel A. Financial constraints across *TIR*-sorted groups of firms

	FIRMAGE	LNAT	SAIND	KZIND	LNMV	OSCORE	ZSCORE
Low TIR	19.470	5.302	-0.798	-5.058	0.069	-0.783	-3.506
Med TIR	24.712	6.042	-1.436	-4.465	0.833	-1.366	-3.861
High TIR	18.365	5.044	-0.596	-5.389	-0.131	-0.669	-3.650

Panel B. Controlling for financial constraints

	(1) SAIND	(2) KZIND	(3) LNMV	(4) OSCORE	(5) ZSCORE
Q_{t-1}	2.015***	2.108***	1.906***	2.146***	2.306***
	(0.073)	(0.071)	(0.077)	(0.072)	(0.081)
TIR_{t-1}	0.379***	0.342***	0.359***	0.398***	0.354***
	(0.093)	(0.091)	(0.092)	(0.092)	(0.092)
TIR_{t-1}*Q_{t-1}	-0.186***	-0.166***	-0.180***	-0.196***	-0.171***
	(0.054)	(0.053)	(0.054)	(0.053)	(0.054)
CF_{t-1}	-2.518***	-2.229***	-3.248***	-1.357**	-2.123***
	(0.568)	(0.573)	(0.571)	(0.535)	(0.559)
TIR_{t-1}*CF_{t-1}	-1.785***	-1.924***	-0.997***	-1.938***	-1.971***
	(0.156)	(0.154)	(0.177)	(0.156)	(0.159)
$RET3YR_t$	26.793***	24.701***	26.514***	21.811***	24.195***
	(3.685)	(3.463)	(3.456)	(3.463)	(3.447)
FC_{t-1}	-0.475***	0.038***	0.984***	-0.097***	-0.017
	(0.148)	(0.005)	(0.086)	(0.033)	(0.023)
FC_{t-1}*Q_{t-1}	0.055	0.006***	-0.110***	0.105***	0.028***
	(0.039)	(0.002)	(0.026)	(0.013)	(0.006)
Observations	103,008	103,008	103,000	103,003	103,006
Adjusted R^2	0.646	0.649	0.648	0.648	0.647
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes

Table 8. Firm Performance and Value

This table presents fixed-effect regression results concerning the effects of climate exposure on firm performance (in Panel A) and firm value (in Panel B). We use return sensitivity to headquarter-state abnormal temperature, with the past 50-year average temperature as the benchmark, to measure information on climate exposure in stock prices. See Table 1 for variable definitions. All the regressions control for both firm-fixed effects and year-fixed effects except in Panel B, Columns (4)-(6), where industry-fixed effects are used in place of firm-fixed effects. The standard errors, reported in parentheses, adjust for both heteroskedasticity and firm-level clustering. *, **, and *** denote (two-sided) statistical significance at the 10%, 5% and 1%, respectively.

Panel A. Firm performance

	ROA			ASSETURN			TFP		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full	<2000	>=2000	Full	<2000	>=2000	Full	<2000	>=2000
Q_{t-1}	0.011***	0.011***	0.011***	-0.007***	-0.016***	-0.001	0.013***	0.012**	0.015***
	(0.001)	(0.002)	(0.002)	(0.003)	(0.004)	(0.003)	(0.003)	(0.005)	(0.004)
TIR_{t-1}	0.005***	0.007***	0.001	0.014***	0.002	0.021***	0.011**	-0.001	0.014**
	(0.002)	(0.002)	(0.002)	(0.005)	(0.007)	(0.006)	(0.005)	(0.008)	(0.007)
TIR_{t-1}*Q_{t-1}	-0.004***	-0.004**	-0.003**	-0.004**	0.001	-0.008***	-0.005*	0.003	-0.011**
	(0.001)	(0.002)	(0.001)	(0.002)	(0.003)	(0.002)	(0.003)	(0.005)	(0.004)
$Lnfirmage_{t}$	-0.014***	-0.019***	0.007	0.102***	0.114***	0.121***	0.003	-0.021	0.074***
	(0.003)	(0.003)	(0.006)	(0.014)	(0.020)	(0.021)	(0.013)	(0.017)	(0.022)
$Lnat_{t-1}$	0.015***	0.002	0.025***	-0.125***	-0.120***	-0.140***	0.025***	0.016*	0.019*
	(0.002)	(0.002)	(0.003)	(0.006)	(0.009)	(0.008)	(0.007)	(0.009)	(0.011)
$Bklev_{t}$	-0.200***	-0.225***	-0.185***	-0.209***	-0.317***	-0.100***	-0.229***	-0.322***	-0.168***
	(0.006)	(0.007)	(0.010)	(0.023)	(0.031)	(0.027)	(0.024)	(0.028)	(0.036)
HHI_{t}	0.042***	0.032**	0.065*	-0.078	-0.099	-0.035	-0.038	-0.047	0.034
	(0.012)	(0.013)	(0.034)	(0.055)	(0.070)	(0.084)	(0.060)	(0.070)	(0.109)
Observations	119,765	65,973	53,215	119,767	65,974	53,215	116,402	64,171	51,656
Adjusted R^2	0.626	0.595	0.673	0.837	0.856	0.864	0.819	0.832	0.802
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B. Firm value, measured by Q

	(1) Full	(2) <2000	(3) >=2000	(4) Full	(5) <2000	(6) >=2000
Q_{t-1}	0.866***	0.823***	0.812***	1.044***	1.060***	1.033***
	(0.010)	(0.015)	(0.014)	(0.007)	(0.010)	(0.009)
TIR_{t-1}	0.046***	0.016	0.075***	0.045***	0.023	0.059***
	(0.013)	(0.018)	(0.019)	(0.011)	(0.015)	(0.015)
$TIR_{t-1}*Q_{t-1}$	-0.019**	0.005	-0.029**	-0.028***	-0.002	-0.042***
	(0.009)	(0.014)	(0.012)	(0.007)	(0.011)	(0.010)
$Lnfirmage_t$	-0.029	0.040	-0.029	-0.029***	-0.033***	-0.034***
	(0.019)	(0.025)	(0.041)	(0.005)	(0.007)	(0.008)
$Lnat_{t-1}$	-0.400***	-0.406***	-0.614***	-0.023***	-0.016***	-0.028***
	(0.011)	(0.017)	(0.020)	(0.002)	(0.003)	(0.003)
$Bklev_t$	-0.141***	-0.019	-0.171***	-0.145***	-0.153***	-0.117***
	(0.037)	(0.051)	(0.064)	(0.020)	(0.023)	(0.033)
HHI_t	-0.058	-0.088	-0.056	0.021	-0.253***	0.961***
	(0.081)	(0.104)	(0.173)	(0.061)	(0.084)	(0.169)
Observations	119,795	66,017	53,200	120,818	66,865	53,953
Adjusted R^2	0.678	0.686	0.685	0.647	0.639	0.640
Fixed effects	Firm & Year	Firm & Year	Firm & Year	Industry & Year	Industry & Year	Industry & Year