# Corporate Climate Risk: Measurements and Responses

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# Outline

# Motivation

- Climate issues present severe challenges for businesses and the society at large.
- Both the increase in the incidence and severity of climate events (flooding, hurricanes, wildfires etc.), and the chronic climate change (global warming, sea level rise etc.) could lead to unprecedented risk exposures to companies.
- “Climate" and “weather" are among the most frequently discussed by executives, more than “Trump", “the dollar", “oil", and “recession" (S&P Ratings, 2018).

# Research Questions

- In this paper, we construct several novel measures of corporate climate risk at the firm level using earnings call transcript data.
- We analyze the determinants of the corporate climate risk and decompose it to expected and unexpected components.
- We provide external validation by exploring its relationship with capital market reactions.
- We study the effect of climate risk on firm responses, such as investment and employment.

# Preview of Findings

- We construct a set of firm-level climate risk measures and validate that it identifies climate-related risk.
  - Predictive of stock return volatility and credit spread
- Most of the variation reflects firm-level idiosyncratic risk, unexplained by the aggregate trends, location, sector or even firm fixed effects.
- We also analyze topics discussed on the call regarding corporate functions and corporate responses related to climate risk.
- Firms with high unexpected climate risk increase their investment in the next two years.

# Data Sources

1. Transcripts of Earnings Conference Calls
   - Over 7,000 firms listed in the US between 2002 and 2018 from Thomson Reuters' StreetEvents
2. Standard and Poor's Compustat
   - Firm $\times$ quarter level investment, and basic balance sheet (*e.g.*, total assets) and income statement; Firm x year level employment
3. Option Metrics and CRSP
   - Stock implied and realized volatility, respectively
4. TRACE and S&P RatingsXpress
   - Bond credit spread and credit rating, respectively
5. Natural disasters from SHELDUS

# Climate Risk Measures

- Corporate climate risk could mean any uncertainty facing a firm that is related to changes in climate or weather conditions: backward or forward looking; expected or unexpected.
- We measure it based on the share of conversations on earnings calls that centers on climate and weather keywords associated with risk or uncertainty.
  - A library of climate and weather keywords from sources including FEMA, Wikipedia, textbooks, and Weather Channel news
  - A library of words related to risk and uncertainty
  - Our methodology adapts that of Hassan et al. (2019) on political risk

# Top Seeds or Bigrams Used in Constructing $ClimateRisk_{i,t}$

| Severe Climate Events = 1 | | | Non-Severe Climate Events = 0 | | |
|---|---|---|---|---|---|
| Unigram or Bigram | fweight | Frequency | Unigram or Bigram | fweight | Frequency |
| hurricane | 131615.15 | 32358 | weather | 27805.21 | 6488 |
| hurricanes | 58098.81 | 14514 | temperatures | 654.82 | 132 |
| storms | 32356.28 | 7991 | climate change | 479.89 | 122 |
| drought | 20051.06 | 4832 | the flood | 447.09 | 110 |
| earthquake | 16459.00 | 3957 | the snow | 306.53 | 77 |
| flooding | 15273.25 | 3826 | precipitation | 280.60 | 51 |
| severe winter | 5605.61 | 1345 | heating season | 278.79 | 52 |
| tsunami | 5228.59 | 1307 | greenhouse gas | 276.31 | 72 |
| wildfire | 3657.77 | 1052 | high water | 269.97 | 73 |
| wildfires | 3652.17 | 918 | air quality | 241.66 | 59 |
| storm related | 3183.99 | 803 | the ice | 231.03 | 61 |
| storm losses | 2485.17 | 416 | degree days | 216.56 | 41 |
| the floods | 2420.79 | 614 | snowfall | 198.20 | 44 |
| polar vortex | 2195.62 | 545 | air pollutants | 196.48 | 47 |
| storm activity | 2111.31 | 507 | mild winter | 188.77 | 48 |
| snowstorm | 1978.01 | 488 | rainfall | 178.90 | 43 |
| tropical storm | 1914.30 | 466 | normal winter | 170.70 | 36 |
| earthquakes | 1854.27 | 464 | winter conditions | 170.45 | 43 |

# Top Risk Words Used in Constructing $ClimateRisk_{i,t}$

| Risk Word List | | |
|---|---|---|
| risk | speculative | jeopardize |
| risks | fear | unsettled |
| uncertainty | reservation | unpredictability |
| variable | hesitant | dilemma |
| chance | gamble | skepticism |
| possibility | risky | hesitancy |
| pending | instability | riskier |
| uncertainties | doubtful | unresolved |
| uncertain | hazard | unsure |
| doubt | tricky | irregular |
| prospect | sticky | jeopardy |
| bet | dangerous | suspicion |
| variability | tentative | risking |
| exposed | hazardous | peril |
| likelihood | queries | hesitating |
| threat | danger | risked |

# Climate Risk Definition

- We define the climate risk measure as:

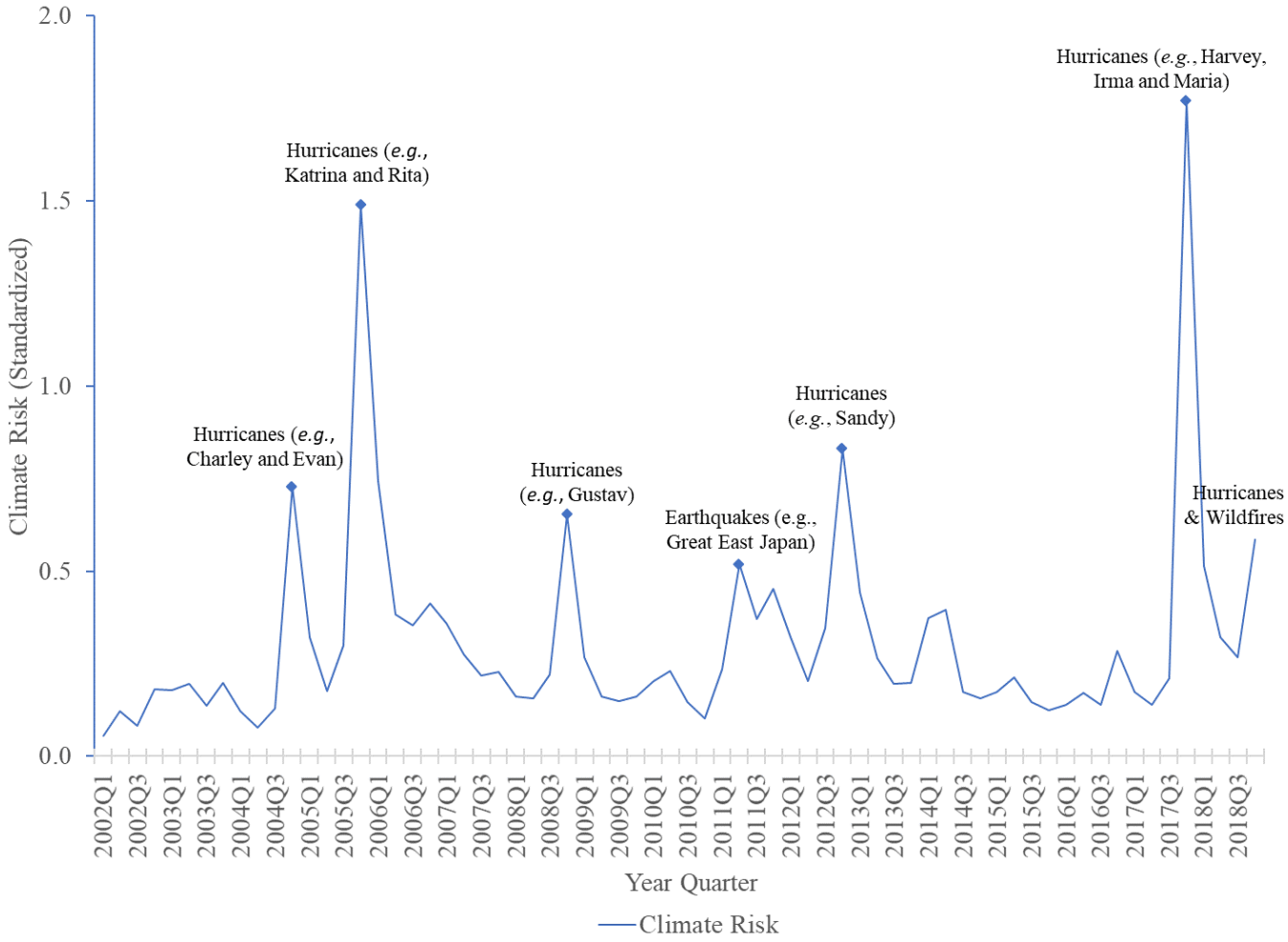
$$ClimateRisk_{i,t} = \frac{\sum_{b \in B_{i,t}} (¶[b \in GC] \times ¶[\mid b - r \mid < 3\ Sentences] + ¶[b \in EC])}{B_{i,t}}$$

where $¶[\cdot]$ is the indicator function, $GC$ is the set of words in the library of non-extreme climate events, $EC$ is the set of words in the library of extreme climate events, $r$ is the position of the nearest synonym of risk or uncertainty in the risk synonym library, $R$.

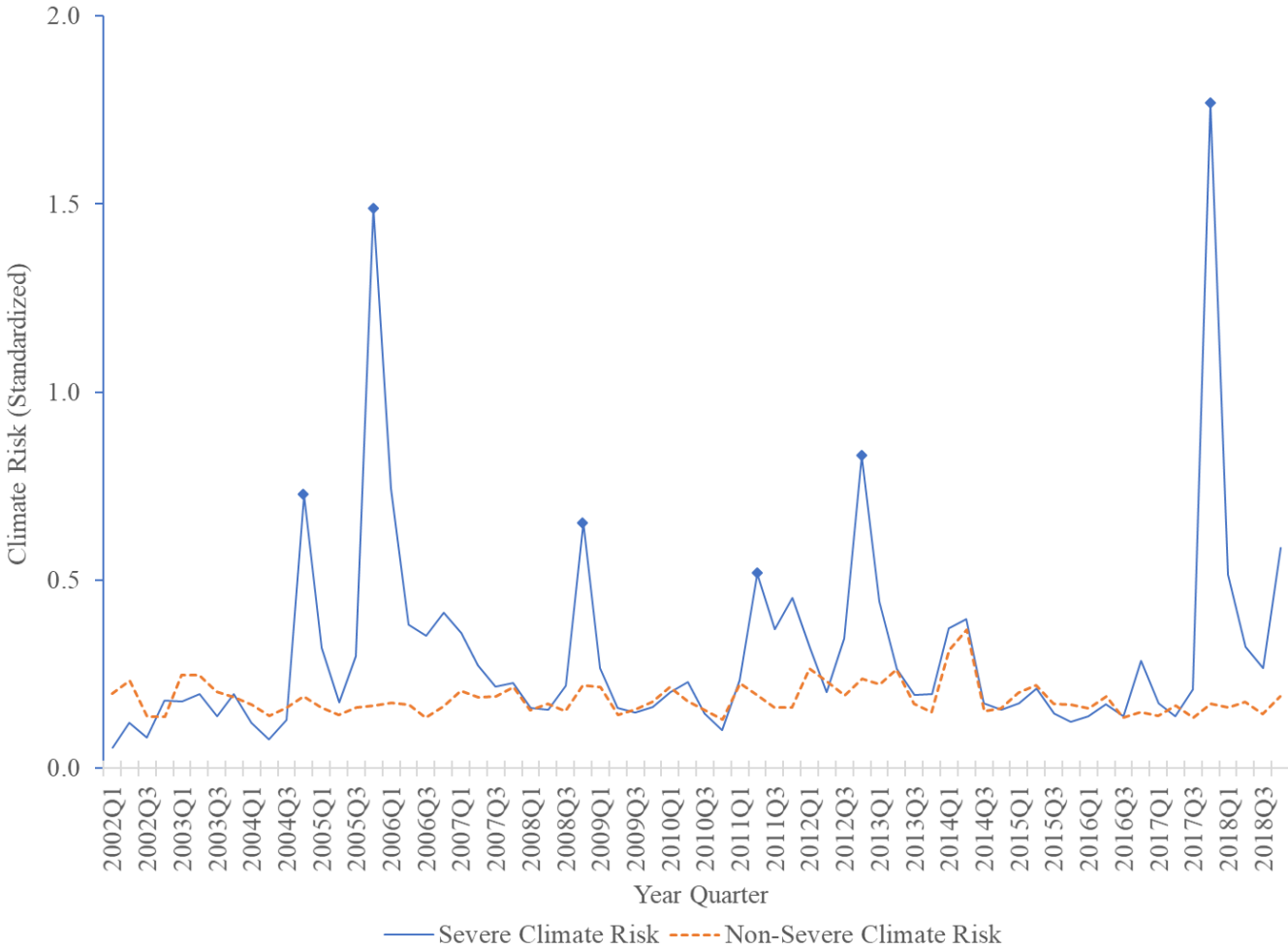
# Transcripts with the Highest $ClimateRisk_{i,t}$

| Firm name | CRisk | Call date | Severe climate risk | Non-Severe | Text surrounding bigram with highest weight |
|---|---|---|---|---|---|
| Marriott Vacations Worldwide Corp | 218.23 | 2-Nov-17 | Hurricane Irma, Hurricane Maria, storms | | has obviously been a very active hurricane season, 2 storms in particular, Hurricanes Irma and Maria, affected our operations most directly |
| Cal Dive International Inc | 193.80 | 30-Oct-08 | Hurricane Gustav, Hurricane Ike, storms | uncertainty +weather | for Cal Dive after hurricanes all four operations bases in texas and louisiana were damaged and took on water but we had implemented our emergency plans |
| California Water Service Group | 188.98 | 27-Apr-17 | drought, mudslide | | and so the drought expense is really minimal for this quarter in 2017 as compared to the height of the drought last year |
| Fortress Investment Group LLC | 186.21 | 3-Nov-04 | hurricane, hurricanes, storms | | Hurricanes interrupted service at the railroad and also interrupted many of our customers' businesses |
| Kerr-Mcgee Corp | 176.13 | 28-Sep-05 | Hurricane Katrina, Hurricane Rita, hurricanes, storms, flooding | | Kerr-McGee typically builds in an allowance of about 3% of our expected annual Gulf of Mexico production volumes to allow for weather-related disruptions during the July through October hurricane season |
| Conn's Inc | 159.36 | 26-Nov-08 | hurricane, hurricanes, storms | | Sales were negatively impacted by two hurricanes and mandatory evacuations for most of the Gulf Coast |
| Edison International | 156.67 | 30-Oct-18 | mudslides, wildfire | | we advocated for reforms to mitigate the risk of catastrophic wildfires and fairly allocate financial responsibility among the multiple causes which contribute to wildfires. |
| Aaron's Inc | 154.01 | 27-Oct-17 | hurricane, hurricanes, storms, flooding | | Hurricanes Irma and Harvey presented extraordinary challenges for our teams |
| Energy Transfer LP | 146.08 | 10-Nov-08 | hurricane | | This amount reflects the negative impact of Hurricanes Gustav and Ike |
| Benchmark Electronics Inc | 145.31 | 2-Feb-12 | flooding, thailand flood | | Our revenues were significantly impacted by the Thailand flood disaster |
| PG&E Corp | 145.18 | 5-Nov-18 | wildfire, drought | risk+weather, doubt+weather | And then I'll walk you through our Community Wildfire Safety Program proposal, the multi-year effort targeted at wildfire risk mitigation that continues to evolve and expand. |

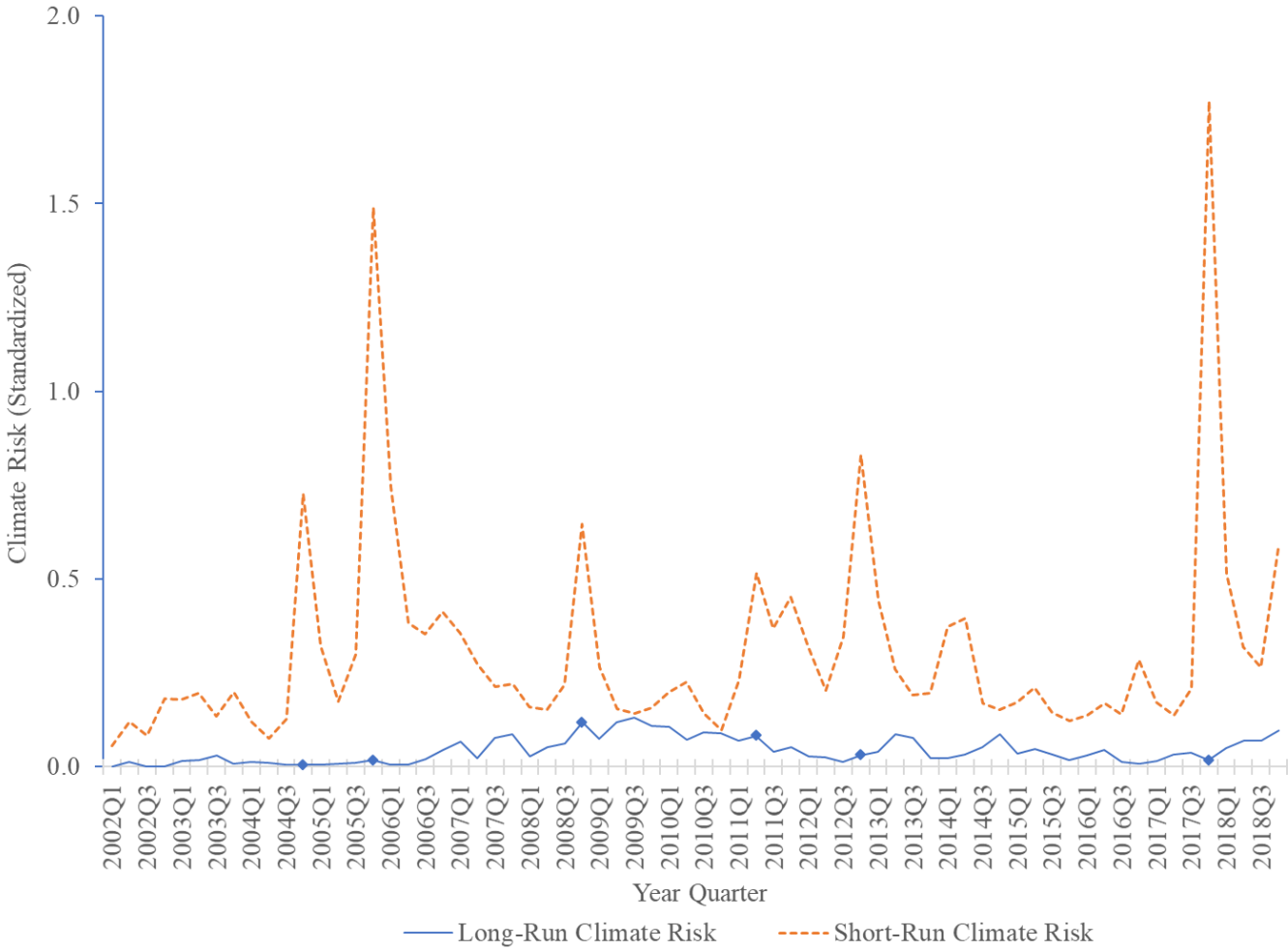
# Corporate Climate Risk Measures



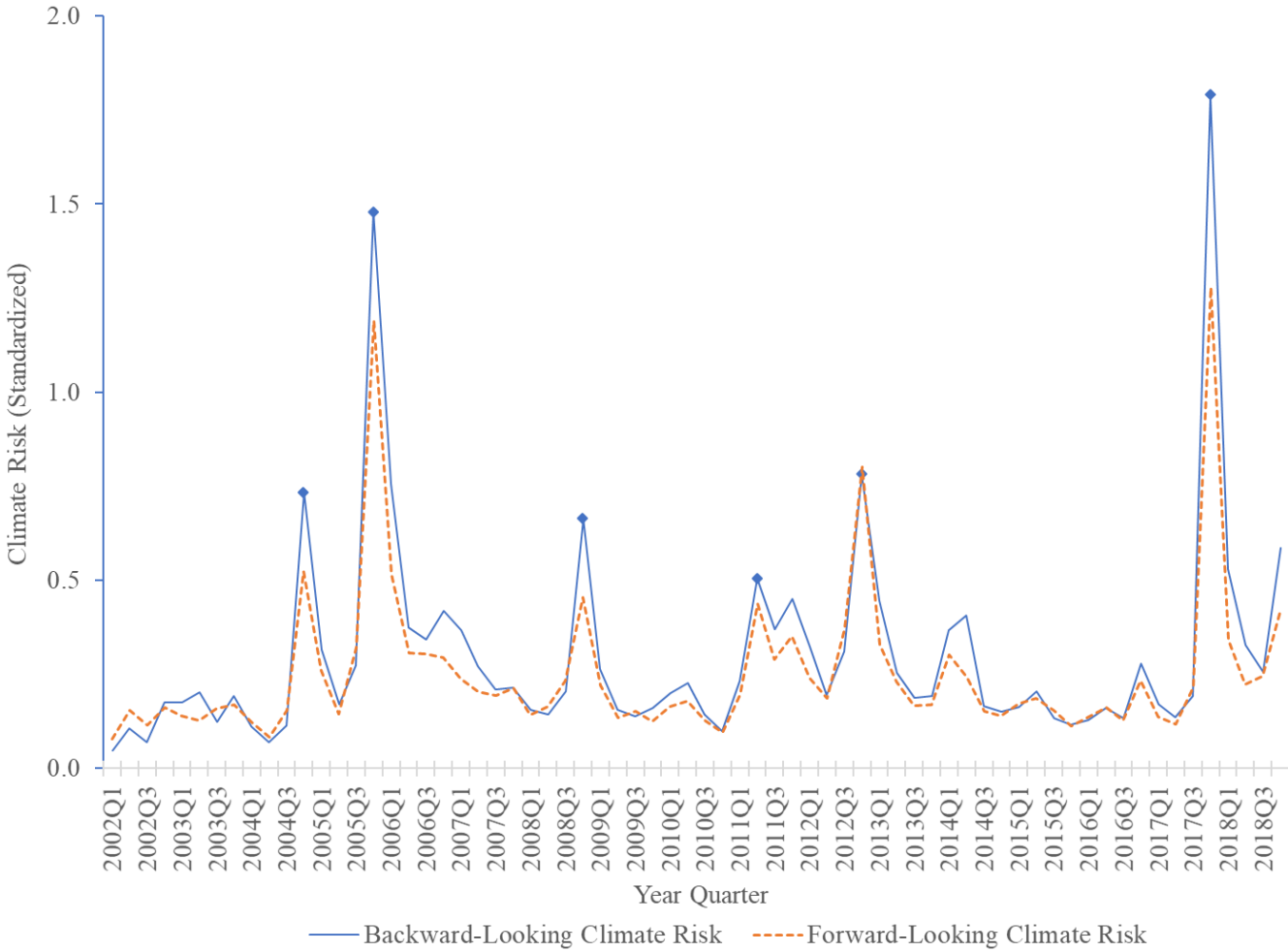
# Severe and Non-Severe Climate Risk



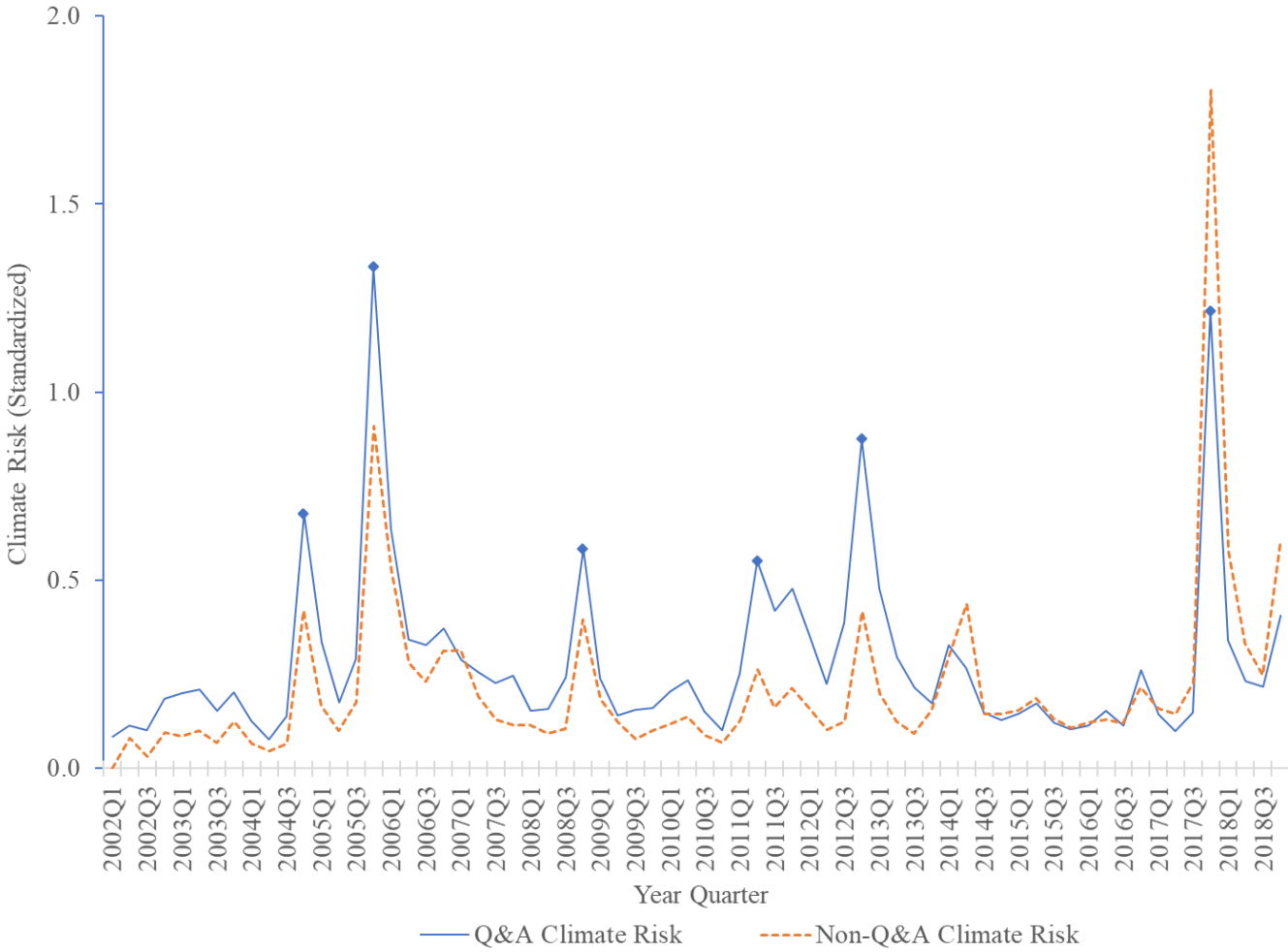
# Long-Run and Short-Run Climate Risk



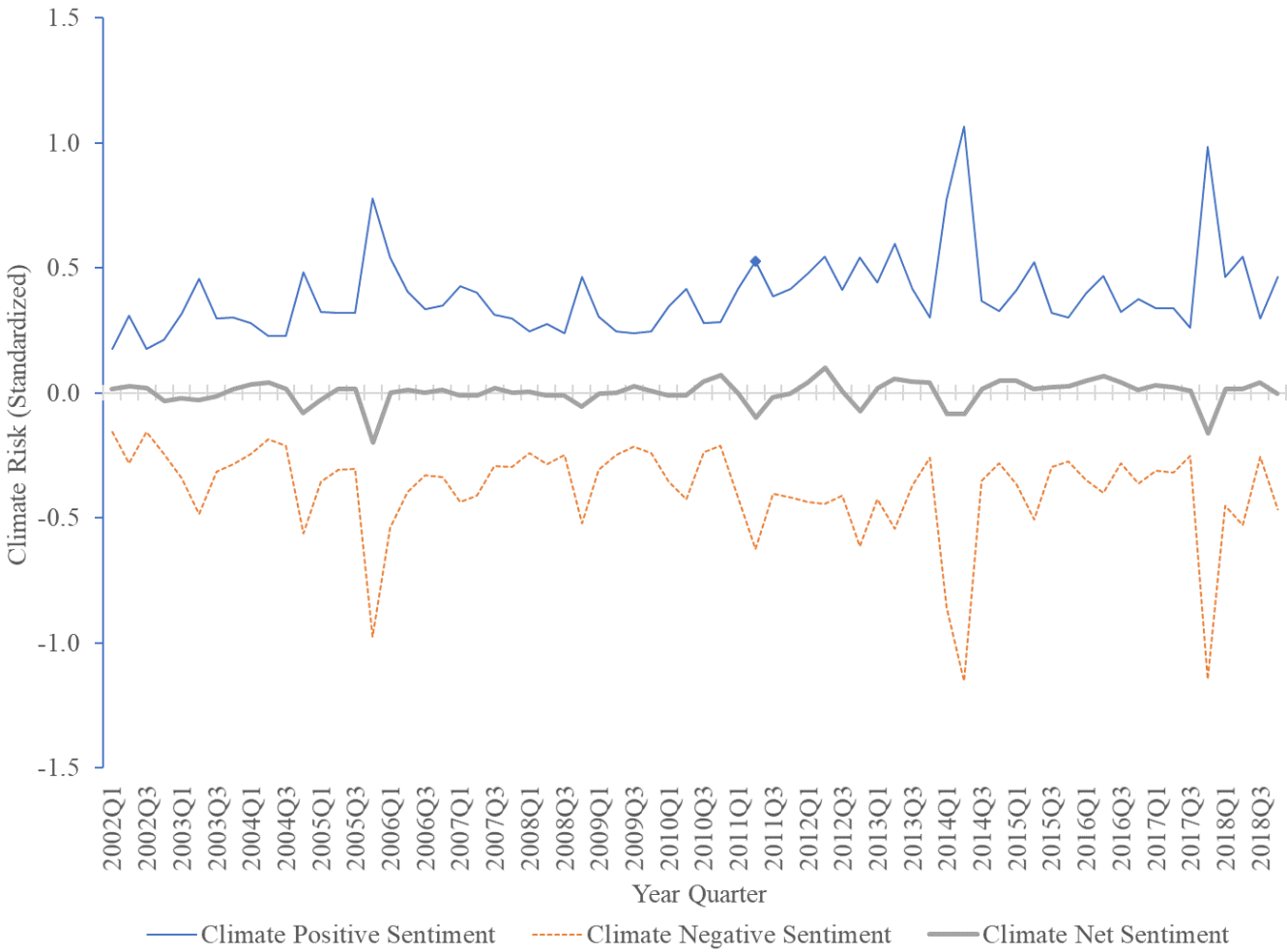
# Backward-Looking and Forward-Looking Climate Risk



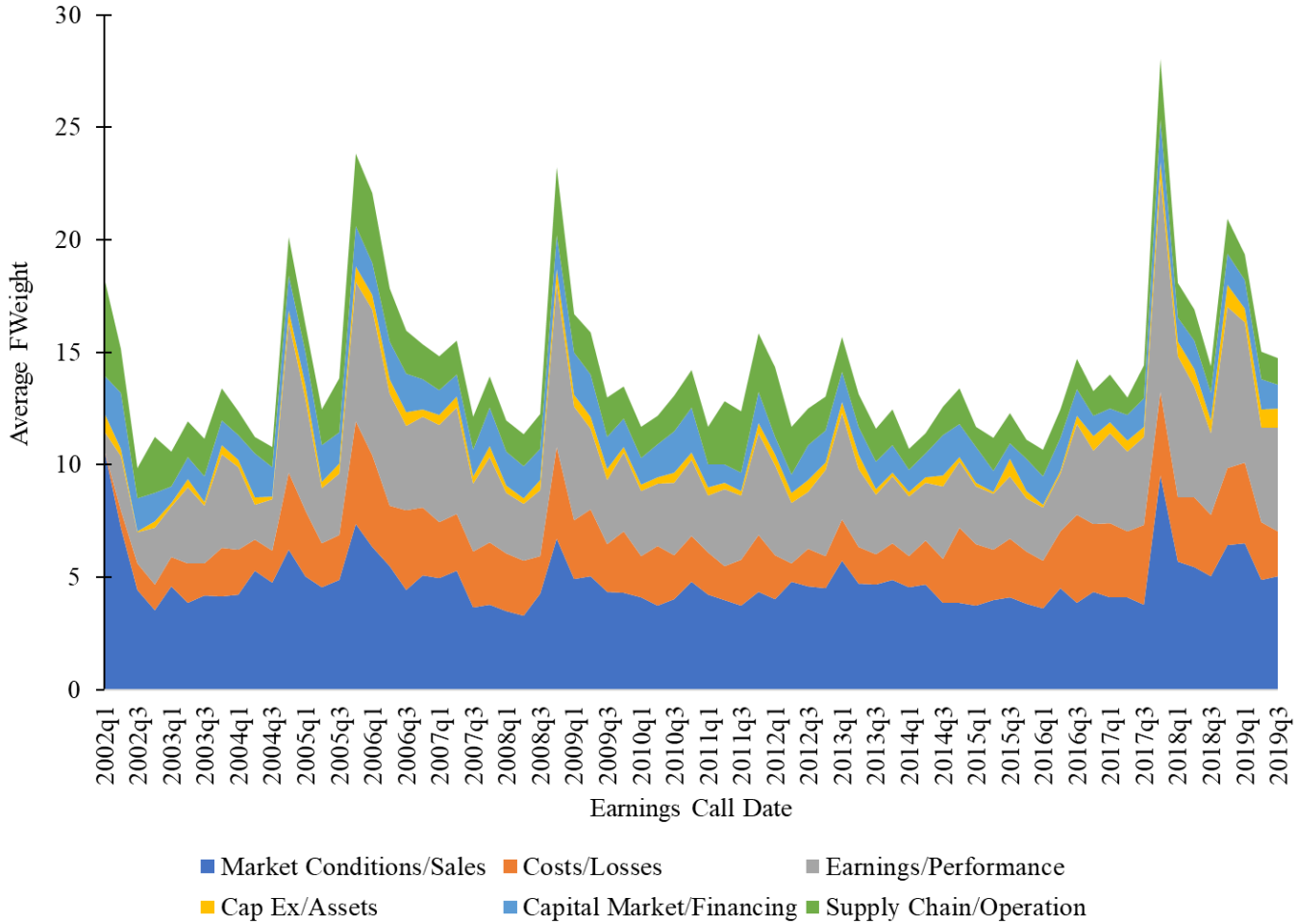
# Q&A and Non-Q&A Climate Risk



# Climate Risk Sentiments



# Evolution of Affected Corporate Functions



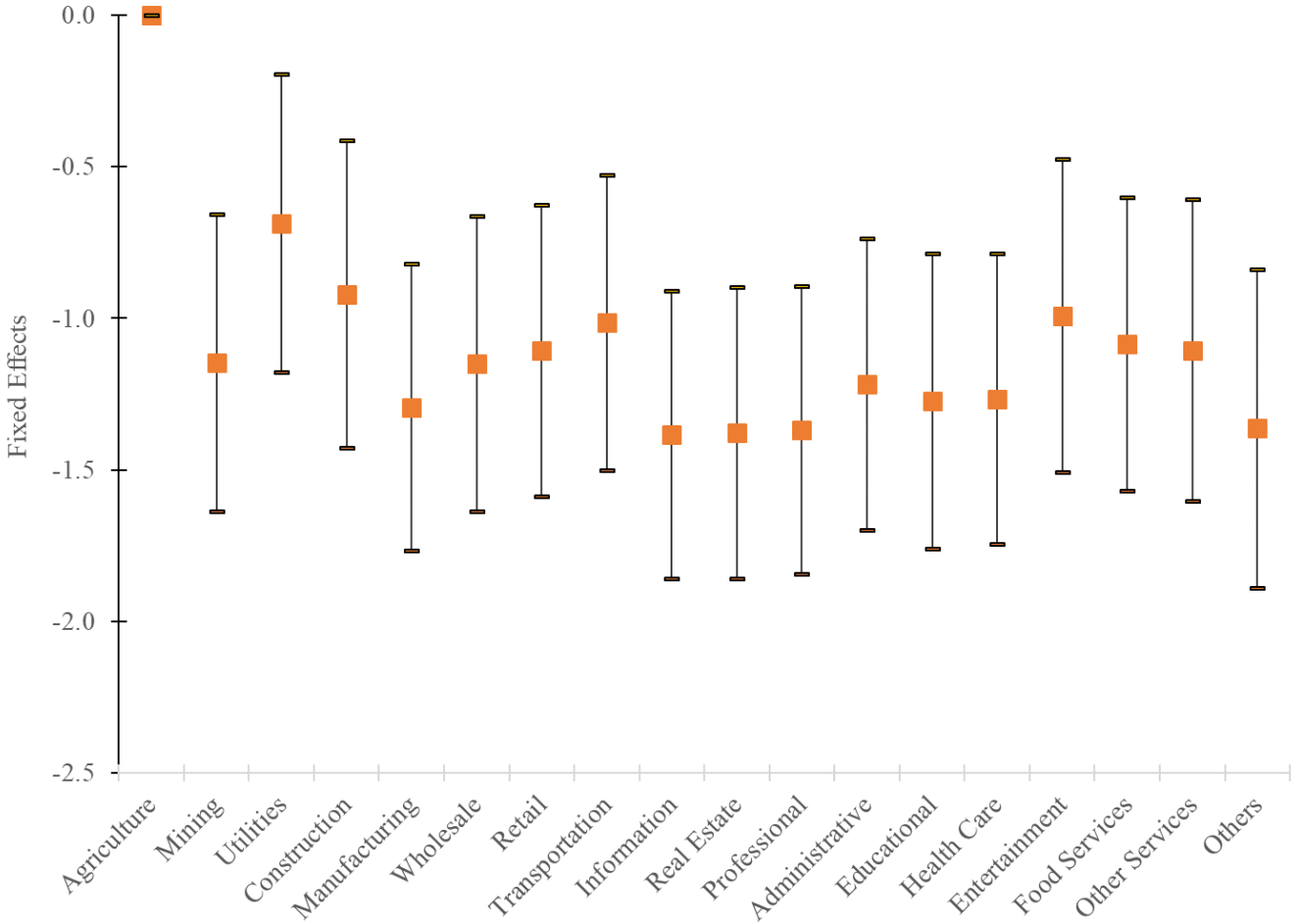
# Affected Functions and Climate Risk Measures

| Dep Var | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Climate Risk$_{i,t}$ | | | | | | | | |
| | Overall | Severe | Non-Severe | Long Run | Short Run | Past-Tense | Forward-Looking | Q&A | Non-Q&A |
| Market/Sales$_{i,t}$ | 0.0613*** | 0.0588*** | 0.0137*** | -0.0030* | 0.0616*** | 0.0632*** | 0.0413*** | 0.0431*** | 0.0471*** |
| | (22.882) | (19.814) | (3.767) | (-1.882) | (22.952) | (22.936) | (11.896) | (11.375) | (10.853) |
| Costs/Losses$_{i,t}$ | 0.0620*** | 0.0635*** | -0.0025 | 0.0035 | 0.0623*** | 0.0654*** | 0.0312*** | 0.0395*** | 0.0397*** |
| | (12.429) | (11.448) | (-0.490) | (0.471) | (12.404) | (12.861) | (5.103) | (6.115) | (5.816) |
| Earnings$_{i,t}$ | 0.0502*** | 0.0527*** | -0.0042 | -0.0020 | 0.0503*** | 0.0520*** | 0.0367*** | 0.0225*** | 0.0480*** |
| | (17.759) | (17.737) | (-1.500) | (-0.987) | (17.759) | (18.151) | (10.301) | (5.988) | (11.308) |
| Cap Ex/Assets$_{i,t}$ | 0.0948*** | 0.0947*** | 0.0060 | 0.0071 | 0.0948*** | 0.0909*** | 0.0898*** | 0.0825*** | 0.0406** |
| | (8.064) | (7.212) | (0.382) | (0.606) | (8.016) | (7.752) | (5.368) | (5.373) | (2.249) |
| Capital Markets$_{i,t}$ | 0.0546*** | 0.0478*** | 0.0425*** | 0.0068 | 0.0545*** | 0.0492*** | 0.0793*** | 0.0906*** | -0.0153 |
| | (5.948) | (4.214) | (2.837) | (1.230) | (5.907) | (5.145) | (7.851) | (8.198) | (-1.259) |
| Supply Chain$_{i,t}$ | 0.0776*** | 0.0814*** | -0.0009 | 0.0005 | 0.0777*** | 0.0757*** | 0.0700*** | 0.0586*** | 0.0549*** |
| | (14.195) | (13.363) | (-0.141) | (0.139) | (14.187) | (13.847) | (9.126) | (8.128) | (6.607) |
| $N$ | 11,620 | 11,620 | 11,620 | 11,620 | 11,620 | 11,620 | 11,620 | 11,620 | 11,620 |
| $R^2$ | 0.574 | 0.527 | 0.397 | 0.332 | 0.574 | 0.576 | 0.279 | 0.415 | 0.472 |
| Adj $R^2$ | 0.501 | 0.596 | 0.485 | 0.217 | 0.501 | 0.504 | 0.385 | 0.315 | 0.381 |
| YQ FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

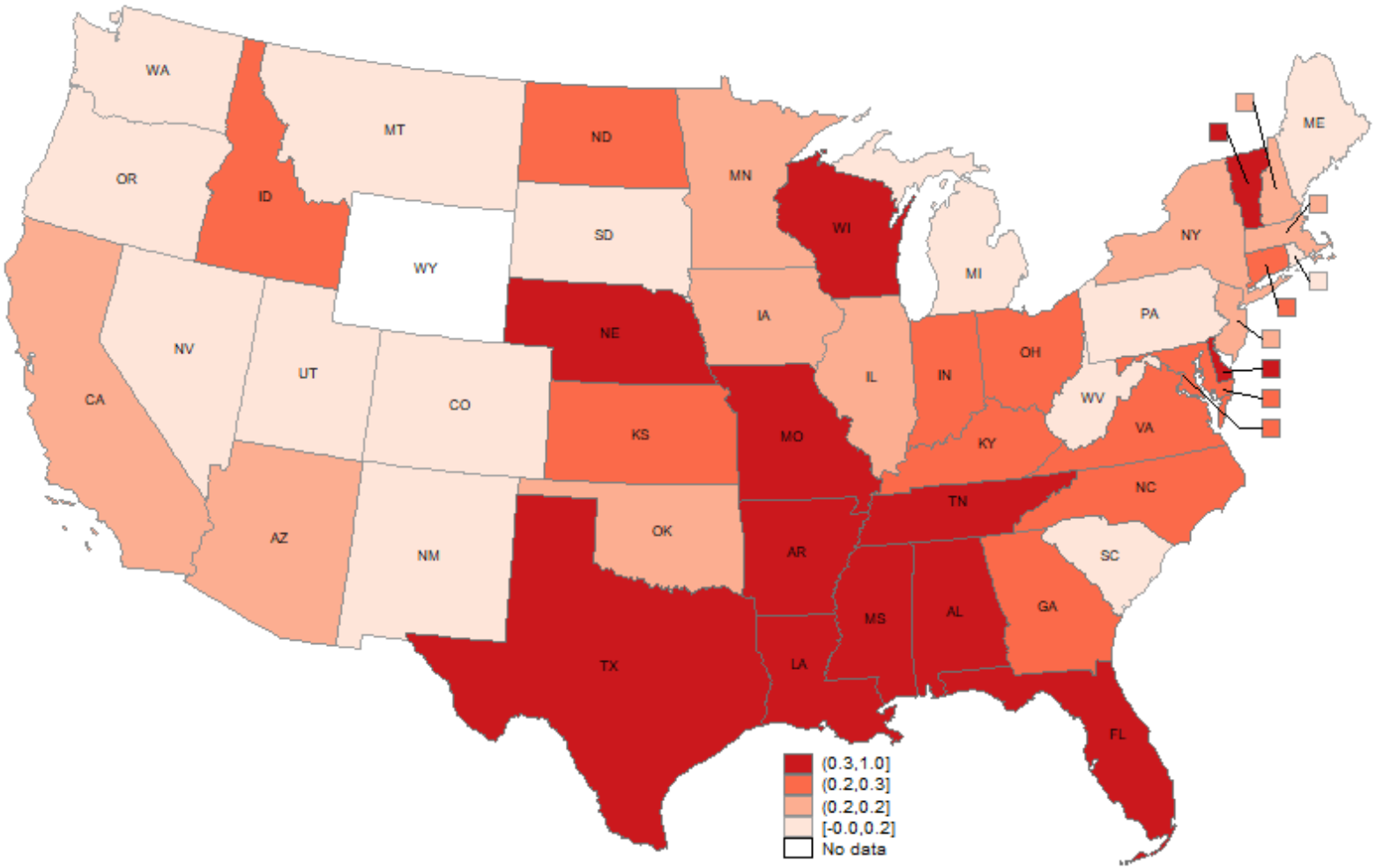
# Determinants of Corporate Climate Risk

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| Dep Var | Climate Risk$_{i,t}$ | | | | | | | | | |
| Disaster$_{c,t-1}$ | 0.3059*** | 0.3131*** | 0.2117*** | 0.2040*** | 0.1972*** | 0.0998*** | 0.1005*** | 0.2053*** | 0.1807*** | 0.1000*** |
| | (13.561) | (13.105) | (10.253) | (10.089) | (10.215) | (4.802) | (4.420) | (10.732) | (9.841) | (4.652) |
| Disaster$_{c,t-2}$ | 0.0170 | 0.0266* | 0.0569*** | 0.0497*** | 0.0435*** | 0.0341** | 0.0368** | 0.0469*** | 0.0462*** | 0.0299* |
| | (1.206) | (1.769) | (3.880) | (3.481) | (3.182) | (2.144) | (2.099) | (3.614) | (3.589) | (1.934) |
| Asset$_{i,t-1}$ | | 0.0570*** | 0.0508*** | 0.0341*** | 0.0326*** | | 0.0288*** | 0.0130 | 0.0132 | 0.0143 |
| | | (8.309) | (7.380) | (5.508) | (5.328) | | (4.642) | (1.239) | (1.298) | (1.417) |
| PPE$_{i,t-1}$ | | 0.6532*** | 0.7215*** | 0.3800*** | 0.3089*** | | 0.3613*** | -0.1108 | -0.0311 | 0.0165 |
| | | (14.381) | (15.633) | (6.994) | (5.620) | | (6.529) | (-1.220) | (-0.361) | (0.199) |
| Book Leverage$_{i,t-1}$ | | 0.0164 | 0.0119 | 0.0360 | 0.0104 | | 0.0235 | -0.1511*** | -0.1003** | -0.0855** |
| | | (0.402) | (0.293) | (0.914) | (0.276) | | (0.616) | (-3.559) | (-2.475) | (-2.168) |
| Tobin's Q$_{i,t-1}$ | | -0.0087* | -0.0147*** | -0.0104** | -0.0074* | | -0.0080* | 0.0038 | 0.0041 | 0.0075** |
| | | (-1.935) | (-3.189) | (-2.365) | (-1.733) | | (-1.840) | (1.047) | (1.174) | (2.116) |
| No Analysts$_{i,t-1}$ | | -0.0787*** | -0.0656*** | -0.0424*** | -0.0423*** | | -0.0332*** | -0.0204* | 0.0026 | 0.0034 |
| | | (-6.504) | (-5.427) | (-3.720) | (-3.713) | | (-2.912) | (-1.892) | (0.256) | (0.348) |
| ..... | | | | | | | | | | |
| $N$ | 139,959 | 117,938 | 117,938 | 117,938 | 117,938 | 139,561 | 117,558 | 117,758 | 117,742 | 117,379 |
| $R^2$ | 0.00425 | 0.049 | 0.129 | 0.146 | 0.158 | 0.211 | 0.249 | 0.306 | 0.350 | 0.395 |
| YQ FE | No | No | Yes | Yes | Yes | No | No | Yes | No | No |
| Sector FE | No | No | No | Yes | Yes | No | No | No | No | No |
| State FE | No | No | No | No | Yes | No | No | No | No | No |
| Sector × YQ FE | No | No | No | No | No | Yes | Yes | No | Yes | Yes |
| State × YQ FE | No | No | No | No | No | Yes | Yes | No | No | Yes |
| Firm FE | No | No | No | No | No | No | No | Yes | Yes | Yes |

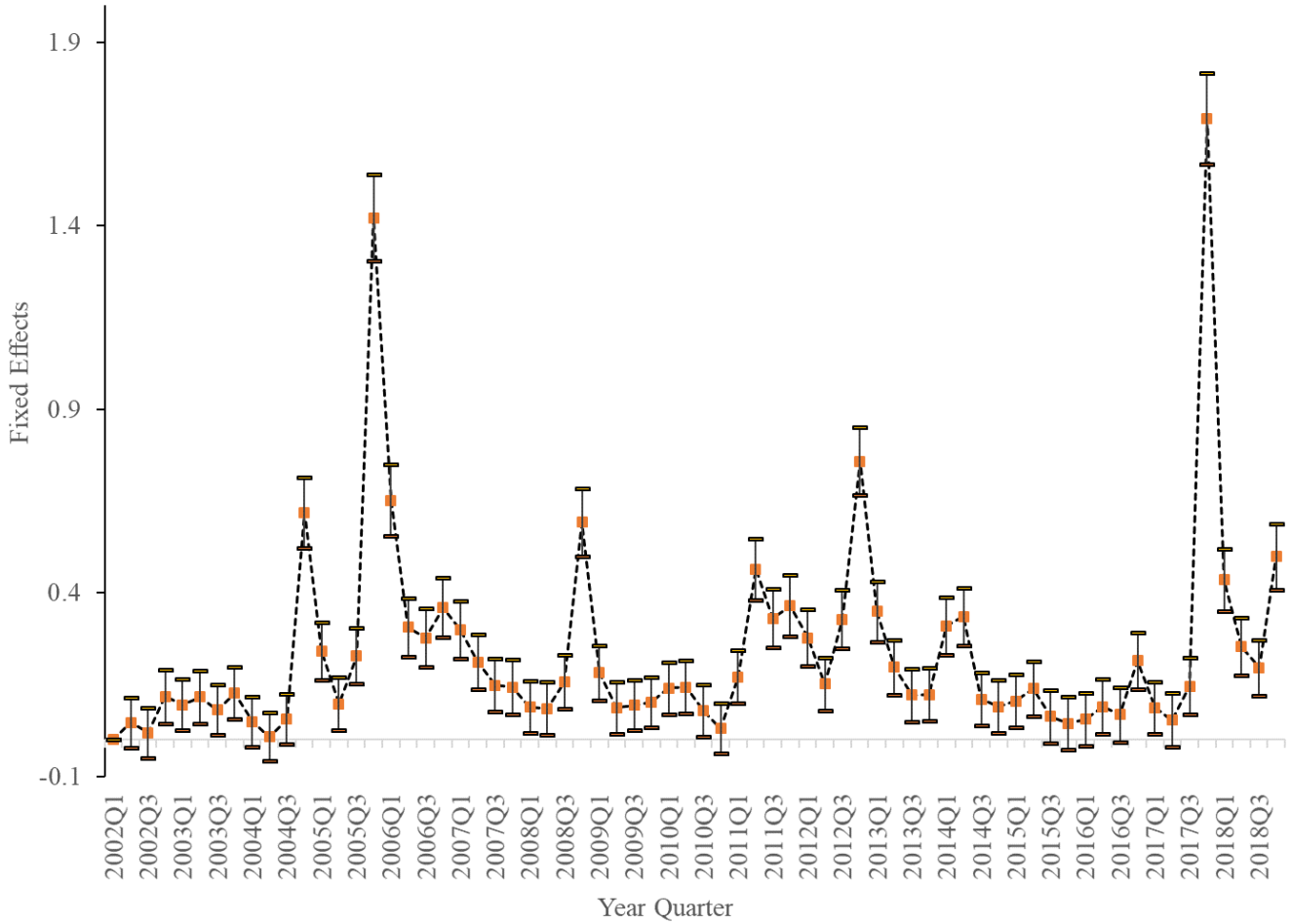
# Climate Risk By Industry



# Climate Risk By State



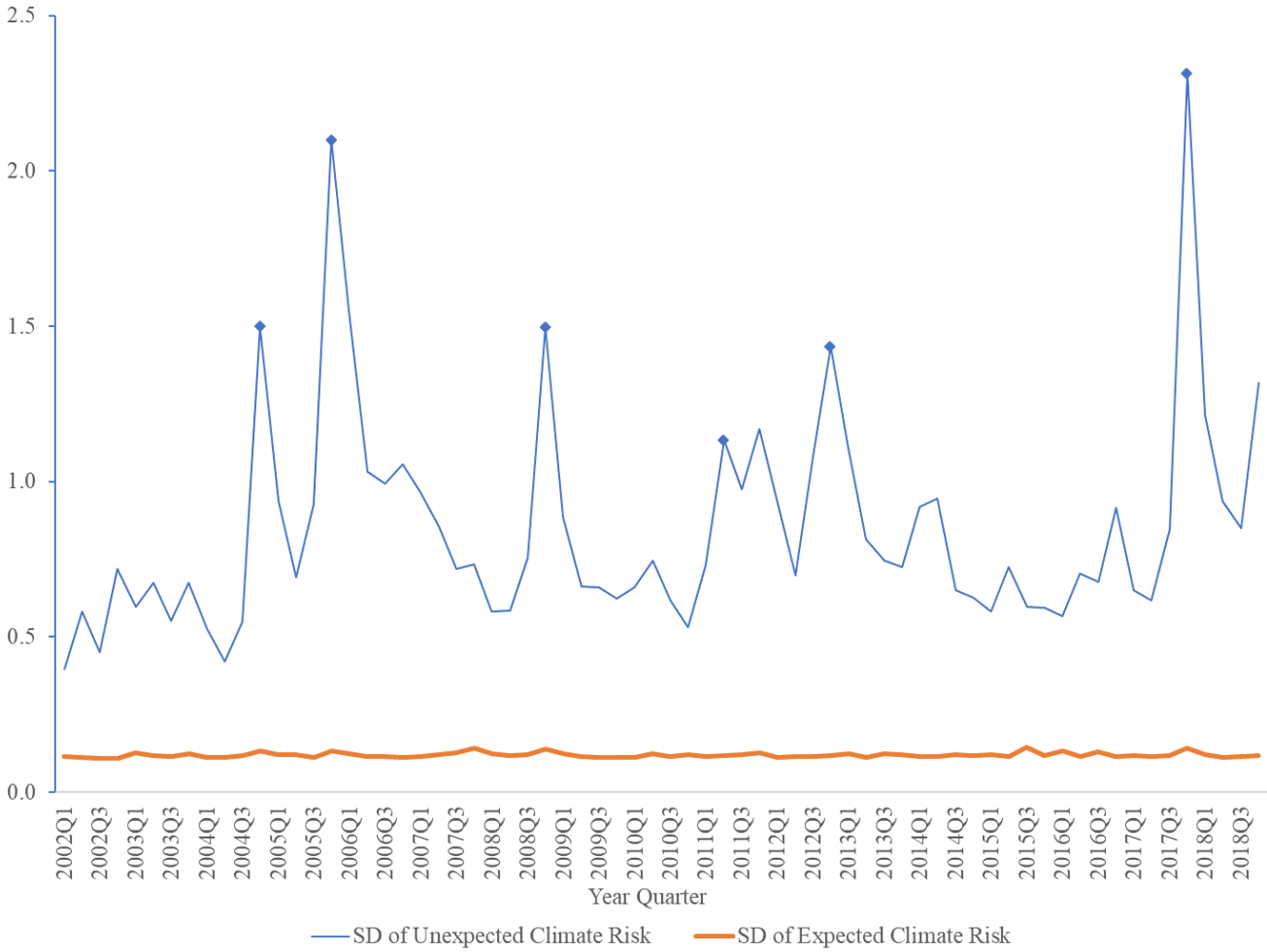
# Climate Risk By Time



# Variance Decomposition

| Controls | $R^2$ None | $R^2$ Natural Disasters | $R^2$ Natural Disasters + Firm Attributes | Improvement in $R^2$ |
|---|---|---|---|---|
| No FE | 0 | 0.004 | 0.049 | |
| YQ | 0.0828 | 0.085 | 0.129 | 0.080 |
| YQ + Sector | 0.133 | 0.135 | 0.147 | 0.098 |
| YQ + State | 0.110 | 0.111 | 0.140 | 0.091 |
| YQ + Sector + State | 0.146 | 0.148 | 0.158 | 0.109 |
| Sector × YQ + State | 0.192 | 0.186 | 0.195 | 0.037 |
| Sector + State × YQ | 0.186 | 0.204 | 0.218 | 0.060 |
| Sector × YQ + State × YQ | 0.235 | 0.235 | 0.249 | 0.091 |
| Firm-Level Variation | 0.765 | 0.765 | 0.751 | |
| Firm + YQ | | 0.275 | 0.281 | 0.032 |
| Firm + Sector × YQ | | | 0.350 | 0.101 |
| Firm + State × YQ | | | 0.365 | 0.116 |
| Firm + Sector × YQ + State × YQ | | | 0.395 | -0.644 |
| Residual | | | 0.605 | |
| Number of States | | 53 | | |
| Number of Sectors | | 64 | | |
| Number of Firms | | 4,483 | | |

# Expected vs. Unexpected Climate Risk



# Validation: Volatility

| Dep Var | Implied Vol$_{i,t}$ | | | | | |
|---|---|---|---|---|---|---|
| Indep Var | Climate Risk | | Expected Climate Risk | | Unexpected Climate Risk | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Climate Risk$_{i,t}$ | -0.0285*** | -0.0029 | 0.5201*** | 0.0952** | -0.0120** | -0.0034 |
| | (-6.257) | (-1.276) | (6.388) | (2.066) | (-2.465) | (-1.476) |
| $N$ | 87,274 | 87,125 | 87,274 | 87,125 | 87,274 | 87,125 |
| $R^2$ | 0.403 | 0.792 | 0.403 | 0.800 | 0.402 | 0.800 |
| Adj $R^2$ | 0.403 | 0.800 | 0.403 | 0.792 | 0.402 | 0.792 |
| YQ FE | No | Yes | No | Yes | No | Yes |
| Firm Attributes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | No | Yes | No | Yes | No | Yes |

# Validation: Controlling for Other Risks

| Dep Var | Implied Vol$_{i,t}$ | | | | | |
|---|---|---|---|---|---|---|
| Indep Var | Climate Risk | | Expected Climate Risk | | Unexpected Climate Risk | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Climate Risk$_{i,t}$ | -0.0037 | -0.0036 | 0.1037** | 0.0950** | -0.0042* | -0.0040* |
| | (-1.549) | (-1.491) | (2.142) | (2.061) | (-1.750) | (-1.692) |
| Total Risk$_{i,t}$ | 0.0148*** | | 0.0147*** | | 0.0148*** | |
| | (4.858) | | (4.805) | | (4.863) | |
| Political Risk$_{i,t}$ | | 0.0082*** | | 0.0081*** | | 0.0082*** |
| | | (3.470) | | (3.428) | | (3.474) |
| Non-Political Risk$_{i,t}$ | | 0.0071*** | | 0.0070*** | | 0.0071*** |
| | | (3.102) | | (3.081) | | (3.103) |
| $N$ | 79,558 | 79,558 | 79,558 | 87,125 | 79,558 | 79,558 |
| $R^2$ | 0.802 | 0.802 | 0.802 | 0.800 | 0.802 | 0.794 |
| Adj $R^2$ | 0.795 | 0.794 | 0.794 | 0.792 | 0.795 | 0.802 |
| YQ FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm Attributes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |

# Validation: Credit Spread

| Dep Var | Credit Spread$_{i,t}$ | | | | | |
|---|---|---|---|---|---|---|
| Indep Var | Climate Risk | | Expected Climate Risk | | Unexpected Climate Risk | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Climate Risk$_{i,t}$ | -0.0923*** | -0.0363** | 0.3993 | 0.0006 | -0.0614*** | -0.0375** |
| | (-4.182) | (-2.334) | (0.845) | (0.002) | (-2.643) | (-2.403) |
| *N* | 25,000 | 24,973 | 25,000 | 24,973 | 25,000 | 24,973 |
| $R^2$ | 0.341 | 0.704 | 0.340 | 0.704 | 0.341 | 0.716 |
| Adj $R^2$ | 0.342 | 0.716 | 0.340 | 0.716 | 0.341 | 0.704 |
| YQ FE | No | Yes | No | Yes | No | Yes |
| Firm Attributes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | No | Yes | No | Yes | No | Yes |

# Corporate Responses

| Industry | Climate Risk | Passive Responses | Proactive Responses |
|---|---|---|---|
| Agriculture | hurricane | recapture lost sales; strengthen customer relationships; improve operational effectiveness | transfer production to other facilities to reduce exposure to future hurricanes |
| | drought | | develop drought tolerant corps |
| Mining | hurricane | inspection; repair work; extend timetable; revise production guidance; evacuation; implement emergency plans | accelerate idle well abandonment |
| Utilities | hurricane | repair | hedge by put options and swap contracts |
| | wildfire | help customers recover and rebuild; conduct patrols | investigate the potential origins and causes; advocate legislative reforms to mitigate wildfire risk; improve safety culture; Community Wildfire Safety Program; proactively shut off power for safety; enhance situational awareness; upgrade system; vegetation management |
| | drought | water contingency shortage plans; provision on wasteful practices; reducing leaks | customer analysis; quantitative analysis of drought responses; improve the efficiency standards; educate community; long-term strategic water use efficiency program |
| Construction | hurricane | repair work; restoration of electrical, power, and cleanup efforts; provide support, financial support, and temporary housing to employees; restore power and put up new infrastructure; deploy people across the organization and away from the storm | preplan with customers before hurricanes make landfall; position the majority of resources in or near impacted areas well in advance of the storms |

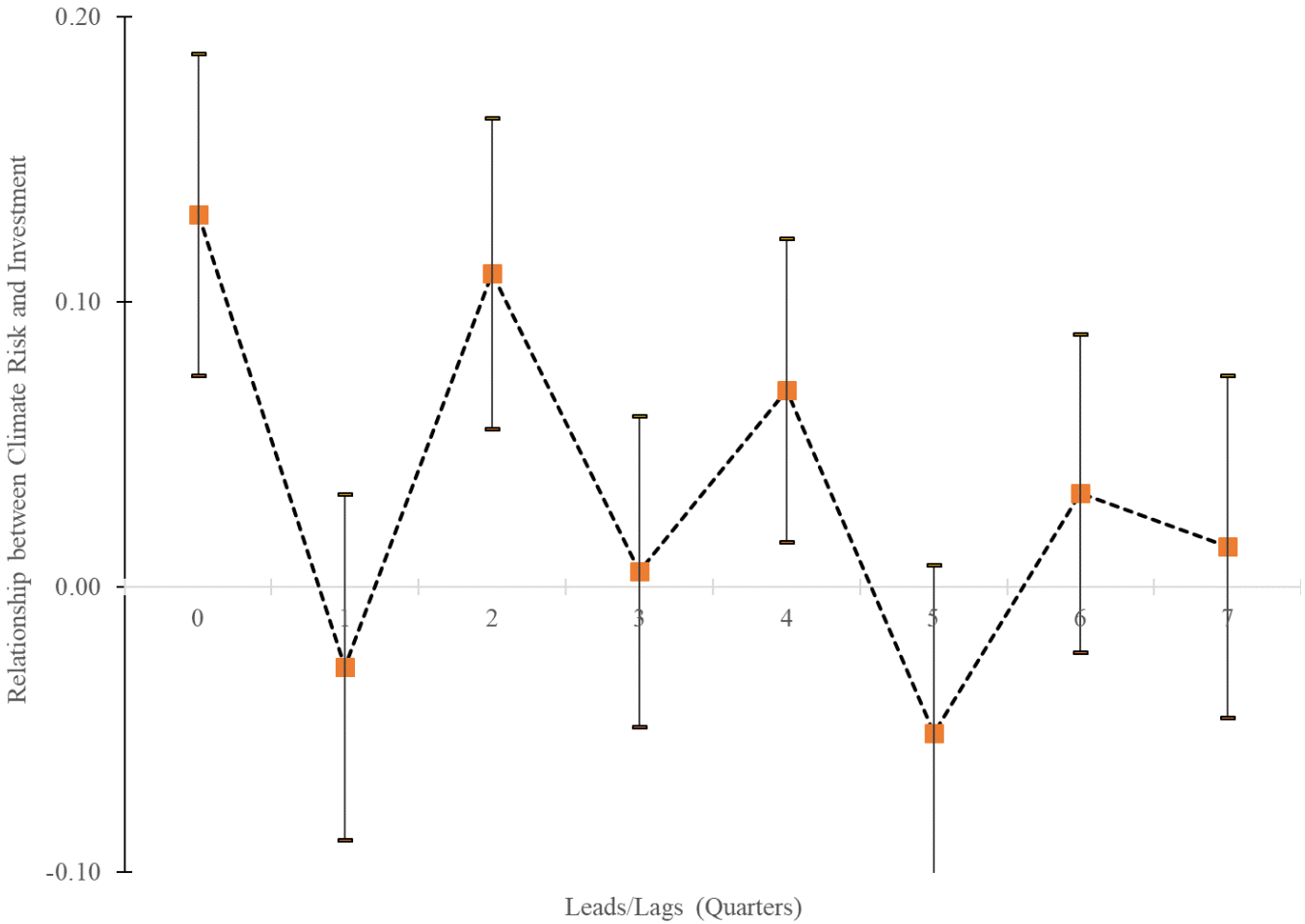
# Corporate Responses

| Industry | Climate Risk | Passive Responses | Proactive Responses |
|---|---|---|---|
| Manufacturing | hurricane, flood | evacuate employees; submit insurance claim; rebuild business | launch hurricane-resistant product; make investments |
| Retail Trade | hurricane | evacuations; redirect products; hire back employees; increase down payments of generator and air-conditioning units during the storm | build inventory to support the hurricane-driven sales increases |
| Transportation | hurricane | clear down trees and debris; restore the railroad to normal operations; filed an insurance claim | inspect tracks and bridges; |
| Information | hurricane | repair cable plant; help restore service to customers; extend the discounted pricing; rebuild or replace damaged plant and equipment | |
| Real Estate | hurricane | temporarily suspend collection activities; replace damage products in customers' homes | board up the stores, prepare for the storms |
| Health Care | hurricane | evacuate residents; arrange generators, refuel, set up communications with the families of residents; clean up the damage; | monitor the Weather Channel, work with local emergency officials, prepare for evacuation before storm; preassemble drinking water, ice, additional electrical generators; board up windows and prepare doors and roofs; secure additional supply chain |
| Accommodation | hurricane | submit insurance claim; recovery efforts; reopen stores; financial aid to employees; work closely with contractors and insurers to put rooms back into service | close restaurants in affected areas before hurricane arrives |

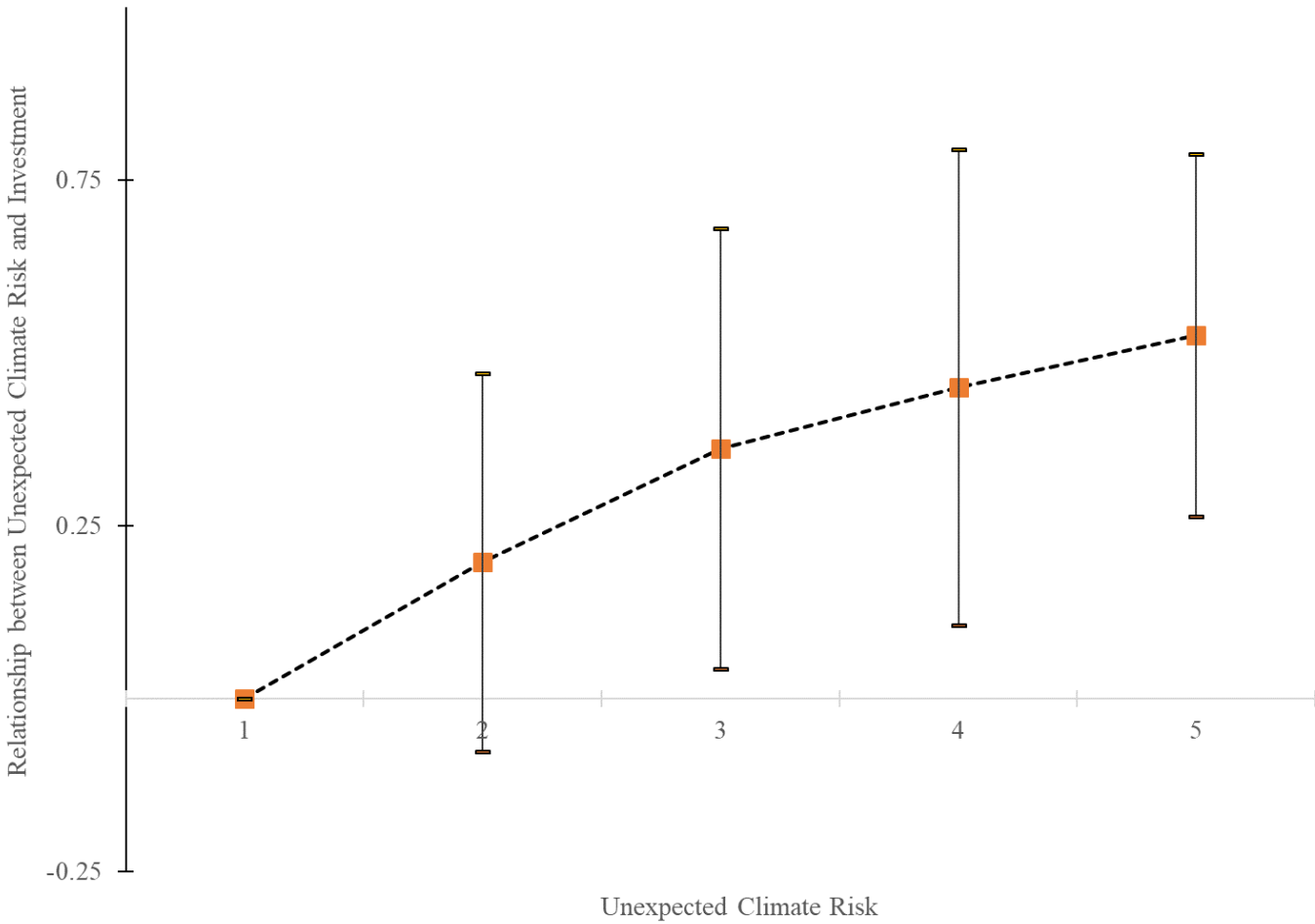
# Corporate Investment

| Dep Var | $\text{Investment}_{i,t} / \text{Capital}_{i,t-1} \times 100$ | | | | | |
|---|---|---|---|---|---|---|
| Indep Var | Climate Risk | | Expected Climate Risk | | Unexpected Climate Risk | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\text{Climate Risk}_{i,t}$ | 0.5410*** | 0.1682*** | -0.6179 | -1.5796** | 0.2587*** | 0.1701*** |
| | (10.597) | (4.065) | (-0.649) | (-2.026) | (4.910) | (4.099) |
| $N$ | 117,313 | 117,144 | 117,313 | 117,144 | 117,313 | 117,144 |
| $R^2$ | 0.061 | 0.393 | 0.0593 | 0.371 | 0.0596 | 0.393 |
| Adj $R^2$ | 0.0609 | 0.371 | 0.059 | 0.393 | 0.060 | 0.371 |
| YQ FE | No | Yes | No | Yes | No | Yes |
| Firm Attributes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | No | Yes | No | Yes | No | Yes |

# Dynamic Relationship



# Nonlinear Relationship



# Conclusions

- We construct a set of new firm-level measures of climate risk by applying a simple textual analysis method to earnings call transcripts.
- Validate that our measure identifies risk related to climate/weather, is predictive of future risk, and is mostly idiosyncratic risk.
- Firms with high unexpected climate risk exposure subsequently increases corporate investment.
- Our paper adds to the growing literature on climate finance. Our measure could be valuable to practitioners, investors, and researchers.