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Sea Level Rise and Portfolio Choice

Sea Level Rise and Portfolio Choice

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UCLA Climate Adaptation

Research Symposium 2021

Impacts of Sea Level Rise

- Global sea level rise (SLR) can be higher than 6 feet (Sweet et al., 2017) and the rate of SLR currently tracks the worst case scenario laid out by the IPCC (Slater et al., 2020).
  - And accelerating due to CO_2 already generated.

- 3 feet SLR will **permanently** inundate areas currently home to 2 million people; 6 feet would inundate homes of 6 million people (Hauer et al., 2016).

- Coastal communities also vulnerable to **temporary** flooding due to chronic tidal events and extreme weather events such as hurricanes (Ghanbari et al., 2019).

- SLR in the media and Google trends echo these concerns. ▸ SLR in Media ▸ Google Trends

Housing and Sea Level Rise

- Two primary physical channels:
  1. Slowly rising oceans eventually and permanently flooding coastal areas.
  2. More severe and more frequent storm surges, hurricanes, nuisance flooding, etc.

- Both physical channels can adversely affect home values and thus, the housing wealth of households (Bernstein et al., 2019; Baldauf et al., 2020; Keys and Mulder, 2020).

- Importantly, both channels also have substantial uncertainty:
  1. Uncertain timing of permanent inundation as scientists frequently update forecasts of SLR with new findings.
  2. Extreme weather events have high uncertainty in expected costs, timing, and frequency.

Sea Level Rise and Portfolio Choice

- Owner-occupied housing is the largest asset class in most households' portfolios (Guiso and Sodini, 2013; Gomes et al., 2020).
- Value of real estate is inextricably linked to the land it is built on and therefore exposed to SLR risks.

Sea Level Rise and Portfolio Choice

- Owner-occupied housing is the largest asset class in most households' portfolios (Guiso and Sodini, 2013; Gomes et al., 2020).
- Value of real estate is inextricably linked to the land it is built on and therefore exposed to SLR risks.
  - What instrument hedges against SLR risks? Individual investors largely constrained to self-insure (Engle et al., 2020).
  - Flood insurance insufficient and take-up very low, even in risky areas (Kousky et al., 2018).

Sea Level Rise and Portfolio Choice

- Owner-occupied housing is the largest asset class in most households' portfolios (Guiso and Sodini, 2013; Gomes et al., 2020).
- Value of real estate is inextricably linked to the land it is built on and therefore exposed to SLR risks.
  - What instrument hedges against SLR risks? Individual investors largely constrained to self-insure (Engle et al., 2020).
  - Flood insurance insufficient and take-up very low, even in risky areas (Kousky et al., 2018).
- Combined with the illiquid nature of housing markets (Campbell, 2006), SLR risk constitutes an undiversifiable background risk.
  - Background risks, under general conditions, make households less willing to take other types of risks (e.g., financial risks).

Literature / Contribution

Existing Papers

- Climate *AND*
  - Real estate, e.g., Bernstein et al. (2019), Baldauf et al. (2020), Murfin and Spiegel (2020).
  - Financial markets, e.g., Goldsmith-Pinkham et al. (2020), Seltzer et al. (2020), Ilhan et al. (2021), Bolton and Kacperczyk (2020).
- Determinants of portfolio choices:
  - Labor income risk, e.g., Betermier et al. (2012), Fagereng et al. (2018).
  - Human capital risk, e.g., Cocco et al. (2005), Jansson and Karabulut (2020).
  - Entrepreneurial risk, Heaton and Lucas (2000).

This Paper

- First paper connecting climate risks to household portfolio decisions.
- SLR exposed households participate less in the stock market, leaving the positive equity premium on the table.

Preview of Findings

- Compared to unexposed homeowner neighbors, SLR exposed homeowner households:
    1. have a lower propensity to participate in the stock market,
    2. hold a smaller share of financial wealth in risky assets,
    3. more likely to exit from and less likely to enter into the stock market.
- No effect of SLR exposure on renters, corroborating a homeownership channel.
- Following the staggered adoption of state-led climate change adaptation plans, households' willingness to take financial risks increases.
- The effect is driven by long-run SLR risks and it is aggravated at times when households' attention to climate change is elevated.

Data

Household Survey Data

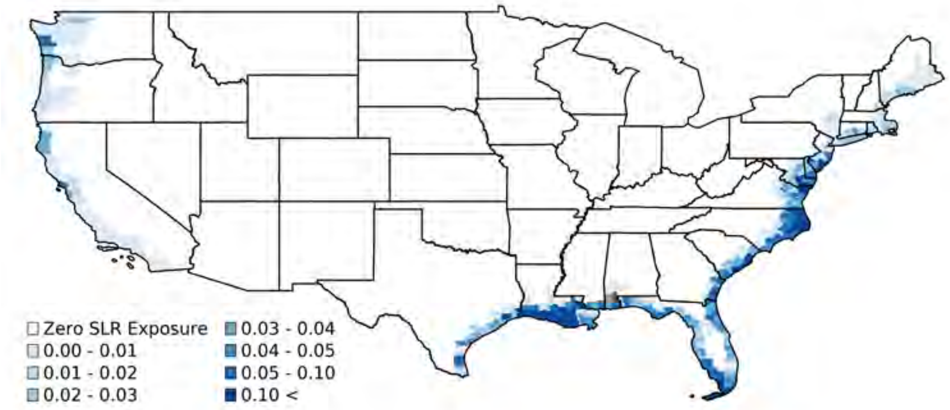
- Household financials and demographics from the Panel Study of Income Dynamics:
  - 10 waves between 1999-2017, collected every two years.
  - Question about stock holdings first divided into non-IRA and IRA in 1999.
- I use the restricted PSID data which includes zip code and Census Block information:
  1. Minimize measurement error for the SLR measure, computed at the Census Block level.
  2. Allows comparison of households within the same neighborhood (i.e., zip code).
- Choice of outcome variables is motivated by Giannetti and Wang (2016) and Brunnermeier and Nagel (2008):
  - Equity Participation, Risky Share, Entry, Exit.

Sea Level Rise Data

- NOAA sea level rise maps (1-foot increments). Takes into account:
  - ground elevation,
  - local and regional tidal variation,
  - hydrological connectivity,
  - man-made hydraulic features (e.g., pipes, bridges, levees).
- Does not account for vertical land motion (Murfin and Spiegel, 2020).

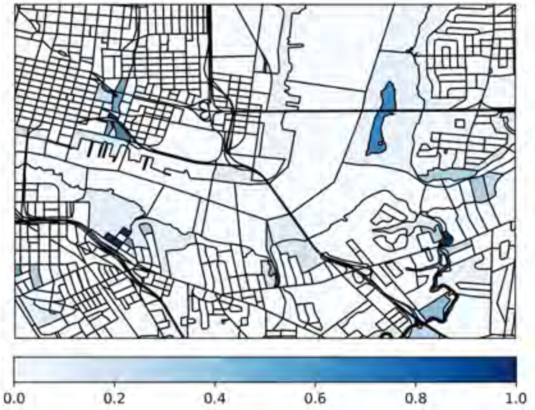
  ▸ VLM across the U.S.
- *Elevation* and *distance-to-coast* may be correlated with housing amenities such as beach access and improved views, add as controls.

Geographic Dispersion of SLR Exposure in the U.S.

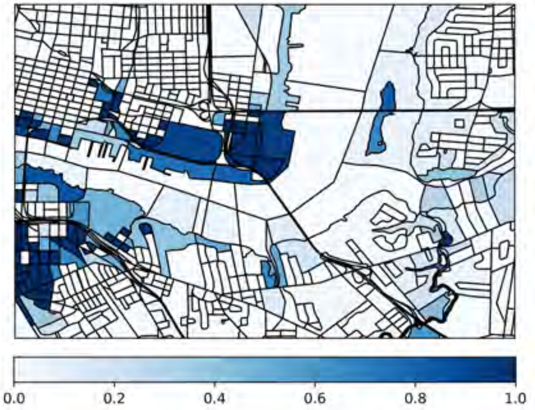


SLR of Census Blocks around the TIAA Bank Field Stadium

3 feet SLR Exposure



6 feet SLR Exposure



Empirical Model + Results

SLR Exposure and Stock Market Participation for Homeowners

I start by investigating the relationship between SLR exposure and the dynamics of household stock market participation for **homeowners**:

$$\text{Participation}_{i,j,t} = \alpha + \beta \cdot \text{SLR Exposure (3ft)}_{i,j,t} + \gamma \cdot \text{X}_{i,j,t} + \text{c}_{j,t} + \epsilon_{i,j,t}$$

for household i, located in zip code j in time t. $c_{j,t}$ refers to zip code by year fixed effects. Standard errors are clustered at the household level.

Control Variables

Demographics and Education:

Age

Age Squared

Divorced (1/0)

Married (1/0)

Non-White (1/0)

Family Size

College Education (1/0)

High School Education (1/0)

Wealth, Income, and Others:

Total Income

Wealth, excl. home equity

House Value

Home Insurance (1/0)

Elevation (ft)

Distance-to-Coast (km)

Vertical Land Motion (ft)

Baseline Results

Dependent variable:	Equity Participation	Equity Participation (incl. IRAs)	Risky Share	Entry	Exit
	(1)	(2)	(3)	(4)	(5)
SLR Exposure (3ft)	-0.392***	-0.265*	-0.353***	-0.224**	1.133**
	(-3.59)	(-1.92)	(-4.78)	(-2.49)	(2.20)
Controls	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes
Obs.	14,173	14,168	11,012	8,532	1,166
Adj. R^2	0.36	0.41	0.32	0.20	0.17

Baseline Results - Economic Magnitude

1 std. increase in SLR Exposure (3ft) decreases the propensity to participate in the stock market by 1.8 percentage points. $\rightarrow$ 6% decrease since mean participation rate for homeowners is 30%.

1 std. increase in SLR Exposure (3ft) decreases the financial wealth invested in risky assets by 1.6 percentage points. $\rightarrow$ 9% decrease since mean risky share invested in financial wealth for homeowners is 15%.

Similar in size to the impact of one-standard-deviation increase in uninsurable labor income risk estimated in Fagereng et al. (2017) and Palia et al. (2014).

Economic Mechanism I/II

- One may argue that changes in the house prices of SLR exposed houses could also generate the same patterns, as opposed to background risk.

Economic Mechanism I/II

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- Difficult to disentangle, but house price changes are unlikely to be the only mechanism:
  - All regressions are conditional on wealth and home value.
  - Zip code-by-year FEs absorb changes in local economic conditions, including changes in regional house prices.

Economic Mechanism I/II

- One may argue that changes in the house prices of SLR exposed houses could also generate the same patterns, as opposed to background risk.
- Difficult to disentangle, but house price changes are unlikely to be the only mechanism:
  - All regressions are conditional on wealth and home value.
  - Zip code-by-year FEs absorb changes in local economic conditions, including changes in regional house prices.
- Sample split based on median house price growth: House Price Growth Split
  - The effect is still present in locations with high house price growth.

$\Rightarrow$ Second moment effects of SLR exposure matter for portfolio choice.

Economic Mechanism II/II

- I rule out other alternative explanations one may be concerned about.
  - **Differences in risk preferences:** control for risk aversion (Kimball et al., 2009).

  ▸ Risk Aversion

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  - **Endogenous choice of housing location:** repeat the analysis in a sample of households who never moved. ▸ Nevermovers

Economic Mechanism II/II

- I rule out other alternative explanations one may be concerned about.
  - **Differences in risk preferences:** control for risk aversion (Kimball et al., 2009).
    ▸ Risk Aversion
  - **Endogenous choice of housing location:** repeat the analysis in a sample of households who never moved. ▸ Nevermovers
- Rental markets are liquid & renters have no home equity $\rightarrow$ SLR Exposure poses little to no threat to renters:
  - Placebo tests on a sample of only renters reveal statistically insignificant estimates.
    ▸ Renters

State-led Climate Change Adaptation Plans

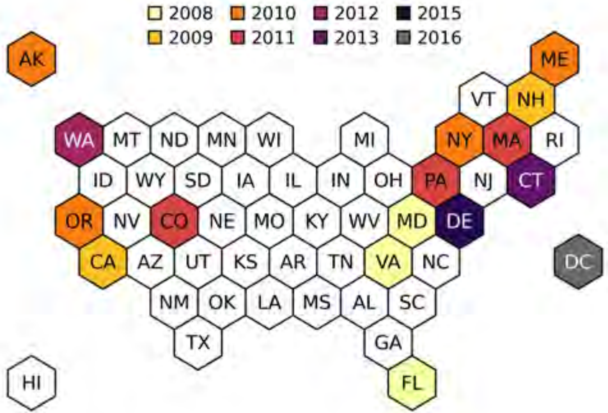
- A lingering concern of endogeneity might still remain.
- 17 states and D.C. finalized state-led climate change adaptation plans as preparation against the adverse effects of climate change.
  - Shock to households' (perceived) SLR risks.
- These plans include measures like:
  - Reforming the flood insurance system such that affordable rates are available for all households and coverage is broad.
  - Building and financing new levees and flood walls that can withstand strong hurricanes.
  - Promoting resilient design and discouraging development in areas that cannot be adequately protected.
  - Introducing disclosure regulations about flooding and SLR risks of houses during sales.

State-led Climate Change Adaptation Plans

- These plans signal the state governments' commitment to protect the state residents and the environment.
    1. If plans are credible, households' willingness to participate in the stock market should increase after adoption.
    2. If not, should observe no change in portfolio allocation decisions or even a further decrease because plans make SLR risks more salient.
- Staggered nature of these plans do not seem to follow a predictable pattern.

State-led Climate Change Adaptation Plans - Timeline

- The timing of these plans are not clustered geographically.
- Not all coastal states have finalized a plan.



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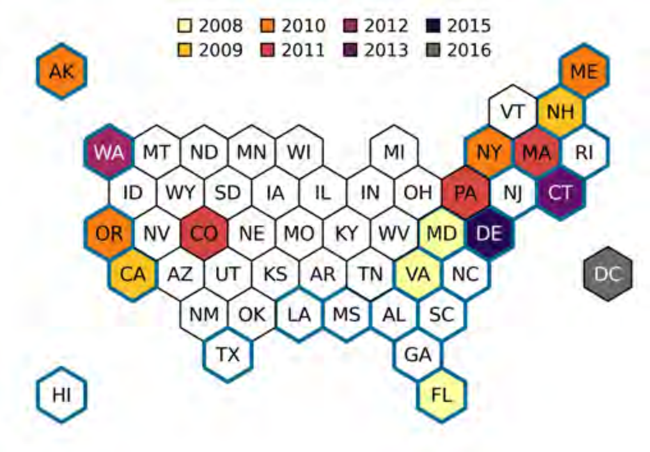


State-led Climate Change Adaptation Plans

Dependent variable:	Equity Participation		Risky Share	
Sample:	Full	Drop Un-treated	Full	Drop Un-treated
	(1)	(2)	(3)	(4)
SLR Exposure x Post SCCAP	0.561**	0.521**	0.346**	0.416***
	(2.32)	(2.07)	(2.22)	(2.82)
SLR Exposure	-0.296***	-0.215	-0.262***	-0.289***
	(-3.66)	(-1.50)	(-4.77)	(-4.12)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Controls x Post SCCAP	Yes	No	Yes	No
Obs.	14,173	7,941	11,012	5,906
Adj. R^2	0.36	0.39	0.32	0.33

Interpretation
+ Additional Evidence

Long- vs. Short-run SLR Risks

- So far remained agnostic, but potentially different implications for households.
  - NOAA's SLR maps aim to capture long-run SLR risks.
  - Rising sea levels are expected to increase short-run flooding events, i.e., storm surge flooding, tropical storms, and hurricanes (Marsooli et al., 2019; Knutson et al., 2020).
- NOAA storm surge exposure as a proxy of immediate flood risk.
  - Only available for East and Gulf coasts.
- Run a horse race between SLR Exposure and Storm Surge Exposure.

Long- vs. Short-run SLR Risks - Results

Dependent variable:	Equity Participation	Equity Participation (incl. IRAs)	Risky Share	Entry	Exit
	(1)	(2)	(3)	(4)	(5)
SLR Exposure (3ft)	-0.391***	-0.245*	-0.366***	-0.259***	0.796
	(-3.50)	(-1.78)	(-4.61)	(-3.04)	(1.58)
Storm Surge Exposure	0.020	0.067	0.010	0.145	-0.049
	(0.13)	(0.89)	(0.07)	(1.41)	(-0.10)
Controls	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes
Obs.	6,585	6,583	4,685	4,088	485
Adj. R^2	0.43	0.51	0.35	0.31	0.25

Attention to Climate Change and Salience of Flood Risks

- Several papers in the literature emphasize the role of attention to climate change and salience of flood risks.
  - Baldauf et al. (2020) show SLR exposed houses trade at a discount when attention is high.
  - Hu (2020) finds low salience of flood risks might lead low flood insurance take-up.
- The effect is amplified at times when attention to climate change is high.
  - WSJ climate attention index from Engle et al. (2020). ▸ WSJ
  - Elevated attention following a top 10 costliest hurricane in *unaffected* neighboring states (Baldauf et al., 2020). ▸ Hurricane_{st}

Past Flooding Experiences and Differences in Political Beliefs

- If SLR Exposure is correlated with having experienced a flooding incident, reduced stock market participation may be due to costs directly incurred.
  - Flooding related disasters from FEMA Presidential Disaster Declaration database.
  - No evidence that past flooding experiences are the driver. ▸ Past Experiences
- Bernstein et al. (2020) recently documented that Republicans tend to own SLR exposed homes and not Democrats.
  - I use data from the MIT Election Lab on Presidential elections.
  - No evidence that differences in political beliefs drive the results. ▸ Republican Share

Conclusion

- I identify a unique source of background risk through a homeownership channel, which will likely become more important in the future.
- Households exposed to SLR risks reduce stock market participation.
- Following the adoption of climate adaptation plans, households in adopting states increase their stock market participation, implying these plans are credible signals of state governments' commitment towards protecting residents.

Appendix

Sea Level Rise in the Media

Back

THE WALL STREET JOURNAL.

Rising Sea Levels Reshape Miami's Housing Market

Properties on the coast now trade at discounts as flood waters and 'king tides' damp enthusiasm for oceanfront living

A pedestrian walks along a flooded sidewalk along Alton Road near Michigan Avenue on Aug. 1, 2017, in Miami.

THE WALL STREET JOURNAL.

Bracing for Sea Rise, Miami Beach Fights Tide of Angry Residents

Andres Asion says his family house in Miami Beach, Fla., is at greater risk of flooding since the city has raised the roads.

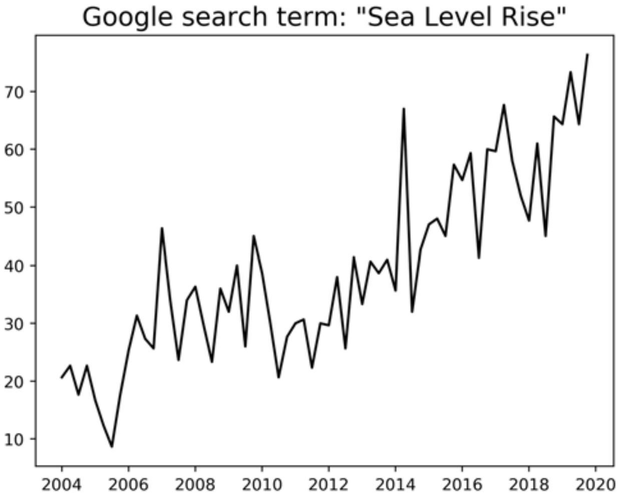
Rising Seas Could Menace Millions Beyond Shorelines, Study Finds

As climate change raises sea levels, storm surges and high tides will push farther inland, a team of researchers says.

San Francisco airport, which sits on tidal marshlands, is getting a $587 million makeover to raise its sea wall.

Builders of a new real estate development in a Mission Creek are raising the old roads by as much as 10 feet.

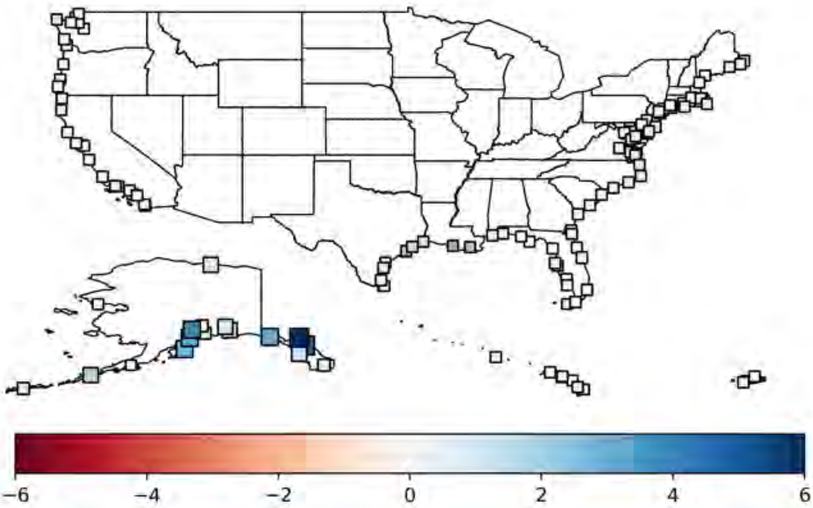
Google Trends for "Sea Level Rise" ▸ Back



Shortcomings of the Vertical Land Motion Measure ▸ Back

- RSLR is based on historical trends in regional mean sea levels using data from 142 tidal stations.
- For each census tract, RSLR trend is defined as the weighted average trend of the two nearest water stations.
  - Introduces potentially large measurement errors.
  - Historical trends likely underestimate reality as SLR forecasts are updated frequently, NOAA measure is agnostic to how much sea level rise there will be.
- NOAA states: "...the effects of subsidence and rebound are sufficiently unknown that they may compound or offset each other in unpredictable ways, such that **including only some processes may cause greater error** than including them."

Vertical Land Motion across the U.S. ▸ back



Sample Split by House Price Growth Back

Sample split by the median house price growth in each state-year, calculated based on the Zillow Home Value Index over the last 5 years for each zip code.

Dependent variable:	Equity Participation		Risky Share	
	High House Price Growth	Low House Price Growth	High House Price Growth	Low House Price Growth
	(1)	(2)	(3)	(4)
SLR Exposure (3ft)	-0.297**	-0.548***	-0.324***	-0.376***
	(-2.32)	(-4.75)	(-3.57)	(-3.54)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	8,883	5,290	6,854	4,158
Adj. R^2	0.37	0.34	0.33	0.29

Alternative Explanations - Risk Preferences ▸ Back

1996 PSID ask respondents a series of questions regarding 50-50 chance gambles, allowing one to extract risk aversion (Kimball et al., 2009): ▸ Risky Share

Dependent variable:	Equity Participation			
	Risky Share 1999 incl.	Risk Aversion FEs	Risk Aversion (Kimball et al., 2009)	2007-2009 excl.
	(1)	(2)	(3)	(4)
SLR Exposure (3ft)	-0.683**	-0.562**	-0.564**	-0.288***
	(-2.06)	(-2.24)	(-2.30)	(-2.88)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	6,191	4,993	4,993	11,515
Adj. R^2	0.42	0.32	0.32	0.37

Alternative Explanations - Endogenous Choice of Housing Location ▸ Back

Unobservable factors influencing the location choice may also be correlated with the risk taking behavior of households in the stock market:

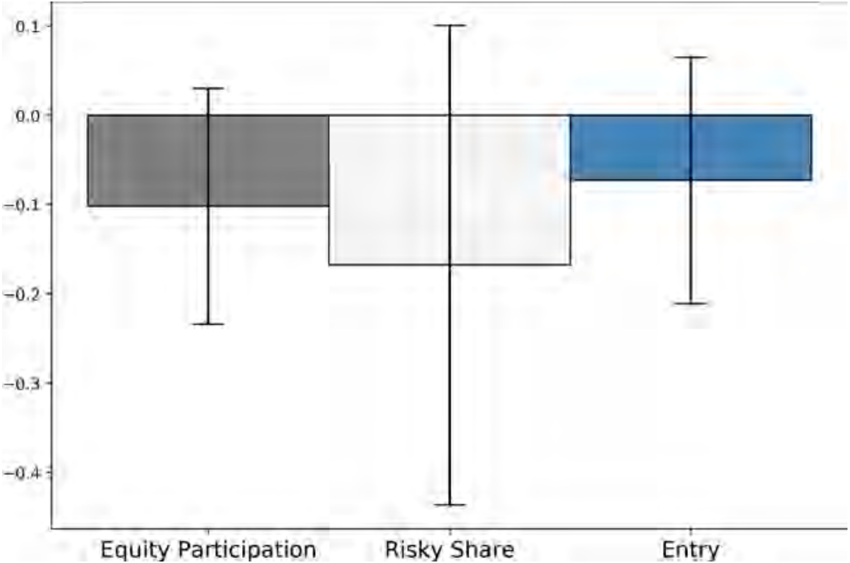
Sample:	Only Nevermovers			
Dependent variable:	Equity Participation	Risky Share	Entry	Exit
	(5)	(6)	(7)	(8)
SLR Exposure (3ft)	-0.436***	-0.314***	-0.281*	1.529***
	(-3.83)	(-2.64)	(-1.68)	(3.47)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	4,692	3,575	2,586	339
Adj. R^2	0.30	0.29	0.14	0.02

Alternative Explanations - Distance to Coast Back

Baldauf et al. (2020) and Murfin and Spiegel (2020) use a 50 km and 30 km restriction, respectively. Goldsmith-Pinkham et al. (2020) use a sample of municipalities in watershed counties. Watershed Counties

Sample:	Distance-to-coast $\leq$ 50 km			
Dependent variable:	Equity Participation	Risky Share	Entry	Exit
	(1)	(2)	(3)	(4)
SLR Exposure (3ft)	-0.523***	-0.474***	-0.298**	1.492***
	(-3.20)	(-4.20)	(-2.09)	(3.32)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	2,972	2,327	1,475	361
Adj. R^2	0.35	0.31	0.30	0.08

Placebo Tests on Renters ▸ Back



Alternative Explanations - Risk Preferences ▸ Back

Dependent variable:	Risky Share			
	Risky Share 1999 incl.	Risk Aversion FEs	Risk Aversion (Kimball et al., 2009)	2007-2009 excl.
	(5)	(6)	(7)	(8)
SLR Exposure (3ft)	-0.625**	-0.442*	-0.446*	-0.283***
	(-2.47)	(-1.83)	(-1.86)	(-4.27)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	5,509	4,030	4,030	8,908
Adj. R^2	0.47	0.28	0.28	0.32

Alternative Explanations - Distance to Coast

Back

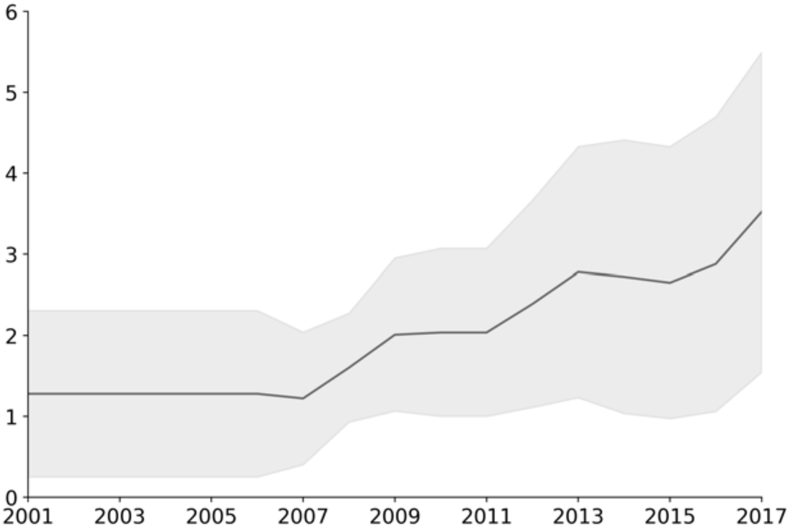
Sample:	Only Watershed Counties			
Dependent variable:	Equity Participation	Risky Share	Entry	Exit
	(5)	(6)	(7)	(8)
SLR Exposure (3ft)	-0.332***	-0.294***	-0.191*	1.110**
	(-2.92)	(-3.43)	(-1.89)	(2.47)
Controls	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes
Obs.	6,041	4,492	3,440	554
Adj. R^2	0.38	0.32	0.27	0.13

State-led Climate Change Adaptation Plans Parallel Trends ▸ Back

	Mean Growth High SLR Exposure (Treated)	Mean Growth Low SLR Exposure (Control)	Difference	p-value	Wilcoxon p-value
Equity Participation Growth	-0.045	-0.005	-0.04	0.28	0.28
Risky Share Growth	-0.0076	-0.0047	-0.0029	0.9285	0.26

Time Series Evolution of Sea Level Rise Projections

Back



Attention to Climate Change and Salience of Flood Risks - WSJ

Back

Dependent variable:	Equity Participation			Risky Share		
Sample:	Full	Distance-to-coast $\leq$ 50 km	Only Nevermovers	Full	Distance-to-coast $\leq$ 50 km	Only Nevermovers
	(1)	(2)	(3)	(4)	(5)	(6)
SLR Exposure (3ft) x High Attention	-0.435*	-0.587**	-0.542**	-0.228	-0.378**	-0.358***
	(-1.80)	(-2.22)	(-2.05)	(-1.44)	(-2.32)	(-3.45)
SLR Exposure (3ft)	-0.219*	-0.316*	-0.192**	-0.262***	-0.337***	-0.160
	(-1.77)	(-1.79)	(-2.26)	(-3.18)	(-2.63)	(-1.53)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	14,173	2,972	4,692	11,012	3,227	3,575
Adj. R^2	0.36	0.36	0.30	0.32	0.31	0.29

Attention to Climate Change and Salience of Flood Risks - Hurricanes

Back

Dependent variable:	Equity Participation			Risky Share		
Sample:	Full	Distance-to-coast $\leq$ 50 km	Only Nevermovers	Full	Distance-to-coast $\leq$ 50 km	Only Nevermovers
	(1)	(2)	(3)	(4)	(5)	(6)
SLR Exposure (3ft) x Hurricane$_{st}$	-0.444**	-0.571**	-0.582**	-0.146	-0.235*	-0.318***
	(-2.03)	(-2.35)	(-2.15)	(-1.18)	(-1.78)	(-2.72)
SLR Exposure (3ft)	-0.238**	-0.344**	-0.219**	-0.298***	-0.394***	-0.203**
	(-2.05)	(-1.99)	(-3.31)	(-3.31)	(-2.89)	(-1.99)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	14,173	2,972	4,692	11,012	2,327	3,575
Adj. R^2	0.36	0.36	0.30	0.32	0.31	0.29

Past Flooding Experiences ▸ Back

Experienced Floods in the Last 2 Years?	No		Yes		Full	
Dependent variable:	Equity Participation	Risky Share	Equity Participation	Risky Share	Equity Participation	Risky Share
	(1)	(2)	(3)	(4)	(5)	(6)
SLR Exposure (3ft)	-0.391**	-0.333***	-0.405***	-0.390***	-0.394**	-0.351***
	(-2.57)	(-3.16)	(-3.65)	(-4.18)	(-2.55)	(-3.23)
SLR Exposure (3ft) x No Recent Disasters					0.009	-0.005
					(0.05)	(-0.03)
No Recent Disasters					-0.136	-0.083
					(-1.49)	(-1.24)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	6,911	5,424	7,208	5,543	14,173	11,012
Adj. R^2	0.35	0.29	0.37	0.34	0.36	0.32

Differences in Political Beliefs ▸ Back

Dependent variable:	Equity Participation			Risky Share		
Sample:	Full	Full	Distance-to-coast ≤ 50 km	Full	Full	Distance-to-coast ≤ 50 km
	(1)	(2)	(3)	(4)	(5)	(6)
SLR Exposure (3ft) x High RepShare	-0.009		-0.095	0.082		0.021
	(-0.44)		(-0.31)	(0.65)		(0.11)
SLR Exposure (3ft) x High RepShare All		-0.153			0.069	
		(-0.67)			(0.53)	
SLR Exposure (3ft)	-0.341*	-0.312*	-0.477**	-0.400***	-0.390***	-0.488***
	(-1.86)	(-1.66)	(-2.15)	(-5.86)	(-5.48)	(-4.83)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Zip Code x Year FEs	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	14,169	14,169	2,972	11,008	11,008	2,327
Adj. R^2	0.36	0.36	0.35	0.32	0.32	0.31

Xia Li

Ph.D. Candidate, Boston University

Physical Climate Risk and Firms' Adaptation Strategy

CLIMATE ADAPTATION
RESEARCH SYMPOSIUM
MEASURING & REDUCING SOCIETAL IMPACTS

UCLA Luskin Center for Innovation

Physical Climate Risk
and
Firms' Adaptation Strategy

UCLA's Adaptation Symposium 2021

Xia Li

9 September 2021

Boston University Questrom School of Business

2

Motivation – increased extreme weather events

Permafrost melt in Russia

Flooding in Chongqing, China 2020. The New York Times

A house burning in Lake Conjola, New South Wales, on New Year's Eve. Matthew Abbott for The New York Times.2020.

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Motivation – more than extreme weather events

Google noted that rising temperatures could increase the cost of cooling its energy-hungry data centers

Climate change produces heat stress in workplaces in Australia

Water shortage shut Coca-Cola plant in India

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Firms' Climate Change Adaptation

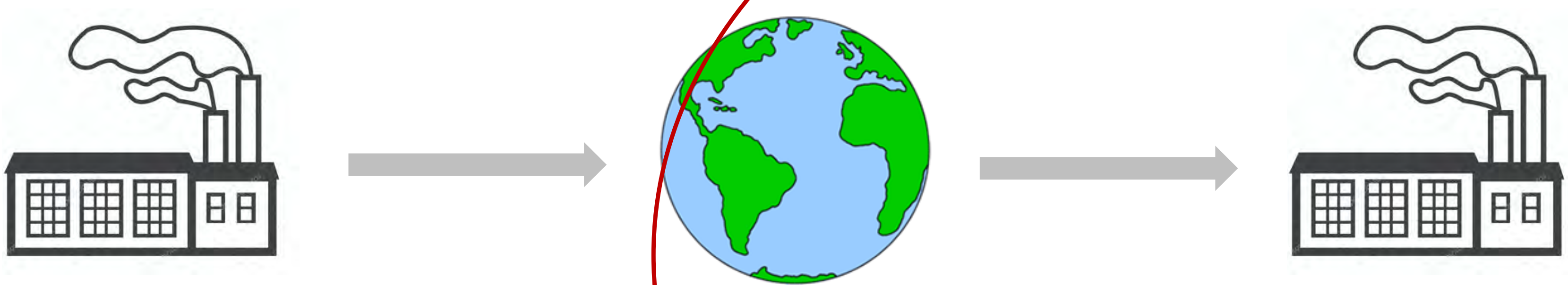
Acute	Floods
	Hurricanes & Typhoons
	Wildfire
Chronic	Heat stress
	Water stress
	Sea level rise

Examples

- ***Operational risk management***: assess risk profile, secure backup plant, raise inventory, purchase insurance
  - Banco Bradesco developed Business Continuity Plan
  - Australian construction firms purchase weather insurance
  - Exelon Generation maintains a diversity of fuel suppliers
- ***Business strategies***: Innovate new technologies, diversify locations, products, and customers.
  - Champagne companies investing in UK
  - Starbucks develops coffee plants/growing practices to make crops more resistant to warmer temperature
  - Energy efficiency technology innovation

Research Gap

This study



Firms' impact on climate change

(Hart and Dowell, 2011; Jira and Toffel, 2013; Kim and Lyon, 2011; Krueger, 2015; Lewis, Walls, and Dowell, 2014; Dowell, Lyon and Pickens, 2020)

Climate Change Mitigation

Impact of climate change on firms

(Bolton and Kacperczyk, 2021; Flammer, Toffel, and Viswanathan, 2021; Linnenluecke et al, 2013)

Climate Change Adaptation

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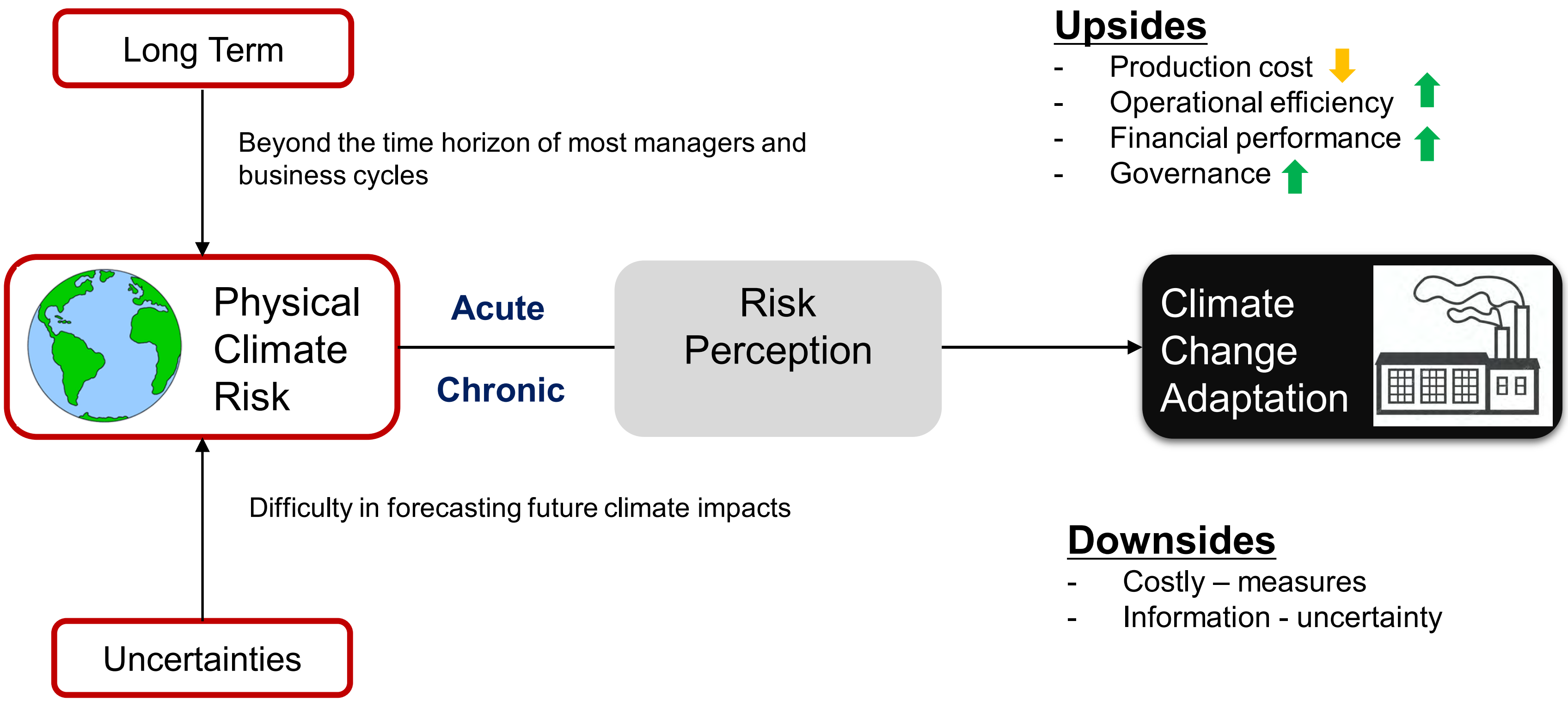
Research Question

Whether and how firms adapt to physical climate risk?

7

Conceptual Framework



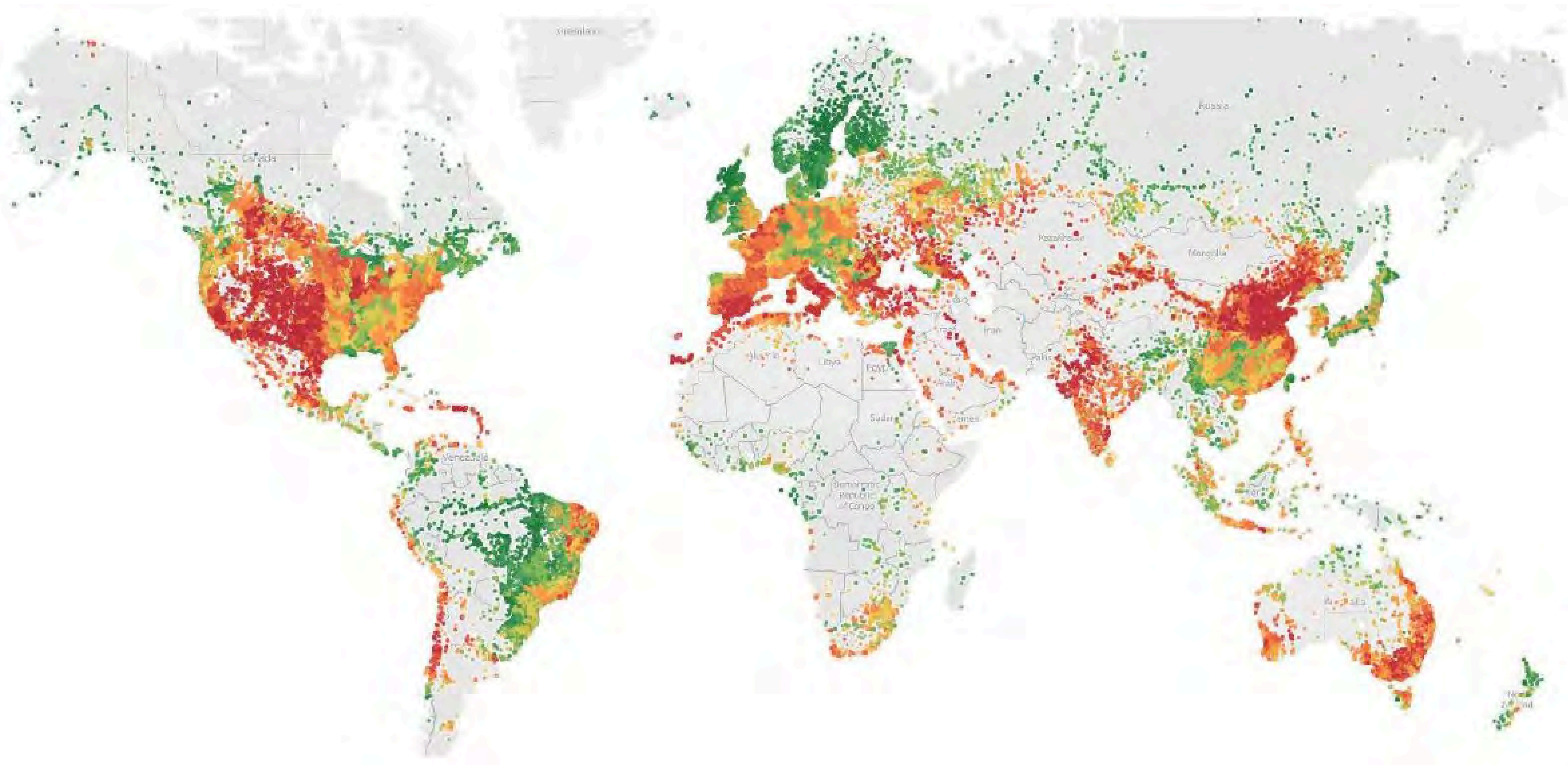
 8

Data

- Firm's physical climate risk - Four Twenty Seven (a Moody's affiliate)
  - 2,233 public firms globally with 1 million + facilities (firm-risk-value chain)
  - Geospatial, historical, and projection models at facility locations

Company Name	Country	GICS Industry Group	Operations Risk Score	Heat Stress	Water Stress	Floods	Sea Level	Hurricanes &	Market Risk	Country of Sales	Weather Sensitivi	Supply Chain	Country of Origin	Resource Demand
3i Group Plc	UNITED KINGDOM	Diversified Financials	22.9	22.8	35.6	13.2	10.4	17.2	20.1	20.6	34.6	22.1	33.7	10.2
3M Company	UNITED STATES	Capital Goods	37.0	42.7	44.8	27.3	4.7	19.6	66.1	49.1	75.0	54.2	44.4	62.9
3SBio, Inc.	CHINA	Pharmaceuticals, Biote	68.7	42.2	24.4	15.7	50.0	85.7	79.8	69.8	75.0	62.7	38.7	85.5
58.com Inc.	CHINA	Media & Entertainment	47.4	24.4	81.3	49.7	0.0	0.0	46.5	69.8	25.0	36.3	69.8	2.2
A. O. Smith Corporation	UNITED STATES	Capital Goods	38.2	46.4	47.9	27.4	1.9	18.6	68.9	53.4	75.0	48.5	47.5	48.7
A.P. Møller-Mærsk A/S	DENMARK	Transportation	40.4	35.7	43.3	23.1	30.4	15.1	39.2	45.8	38.0	60.0	42.0	76.7
AAC Technologies Holdings	CHINA	Technology Hardware &	59.3	42.4	51.1	41.1	19.6	46.0	70.0	54.9	75.0	53.9	58.0	48.7
ABB Ltd.	SWITZERLAND	Capital Goods	35.6	40.1	44.9	24.4	9.6	14.5	47.9	46.2	50.7	40.1	49.2	30.3
Abbott Laboratories	UNITED STATES	Health Care Equipment	37.7	38.6	43.3	24.4	9.8	24.6	63.5	45.3	75.0	54.8	31.7	76.9
AbbVie, Inc.	UNITED STATES	Pharmaceuticals, Biote	29.6	36.7	40.8	16.3	12.7	10.5	63.0	44.5	75.0	62.7	38.7	85.5
ABC-MART, INC.	JAPAN	Retailing	48.1	21.7	26.7	33.7	17.2	73.6	42.2	58.1	30.2	30.0	59.1	0.4

Facilities' Exposure to Water Stress



Note: Data from Four Twenty Seven.

10

Data

- Firm Adaptation Disclosure - CDP International
  - 1,500-2,000 public companies globally between 2011 and 2017 (firm-risk-year-value chain)
  - Manual encoding of the climate disclosure text

Company	Climate Risk	RiskDescription	Potential impac	Timehorizon	Direct/Indirect	Likelihood	Magnitude	Management method
3i Group	Uncertainty of physic	Many physical ch	Reduced stock pr	1 to 3 years	Indirect (Supply c	Likely	Medium	The following methods are used to manage uncertainty in physical risk
Abertis Infraestructur	Floods	In Latin America	Increased operational cost		Direct	More likel	Low-medi	Abertis is already managing the risk associated to possible changes in
Abbott Laboratories	Floods	Precipitation ext	Reduction/disru	>6 years	Indirect (Supply c	Unlikely	Low-medi	To manage the impacts from severe weather events, Abbott's Crisis ar
Aberdeen Asset Man	Uncertainty of physic	Potential increas	Reduction/disru	3 to 6 years	Direct	About as li	High	AAM has established country specific business continuity plans in orde
A2A	Water Stress	Climate change	Reduction/disru	3 to 6 years	Direct	Likely	Medium-h	Presence of an organizational function dedicated to the development o
Aalberts Industries	Tropical cyclones (hu	Some of our fact	Reduction/disru	Unknown	Direct	About as li	Low-medium	
Aareal Bank AG	Change in temperatu	As an internation	Increased operat	>6 years	Direct	Unlikely	Low	Aareal Bank Group has enhanced monitoring programs and employs ro
Aareal Bank AG	Floods	As an internation	Increased operat	>6 years	Direct	Unlikely	Low	Aareal Bank Group has enhanced monitoring programs and employs ro

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Data Matching

Climate Risk Driver (Four Twenty Seven)

Disclosed Climate Change Adaptation (CDP)

Firm A Direct Operation

Hurricanes/ Typhoons (score: 45)

Risk Assess	Risk Mgt	Risk Transfer	Technology	Product Diversify	… …	Location Diversify	Corperate Strategy	Innovation	Water Mgt
0	1	0	1	0	0	0	1	0	0

Floods (score: 32)

Risk Assess	Risk Mgt	Risk Transfer	Technology	Product Diversify	… …	Location Diversify	Corperate Strategy	Innovation	Water Mgt
0	1	1	0	0	0	1	1	0	0

Sea Level Rise (score: 19)

Risk Assess	Risk Mgt	Risk Transfer	Technology	Product Diversify	… …	Location Diversify	Corperate Strategy	Innovation	Water Mgt
0	0	0	1	0	0	1	1	0	1

Water Stress (score: 38)

Risk Assess	Risk Mgt	Risk Transfer	Technology	Product Diversify	… …	Location Diversify	Corperate Strategy	Innovation	Water Mgt
0	0	0	1	1	0	0	0	1	1

Heat Stress (score: 51)

Risk Assess	Risk Mgt	Risk Transfer	Technology	Product Diversify	… …	Location Diversify	Corperate Strategy	Innovation	Water Mgt
0	0	0	1	0	0	0	1	0	0

Adaptation Breadth

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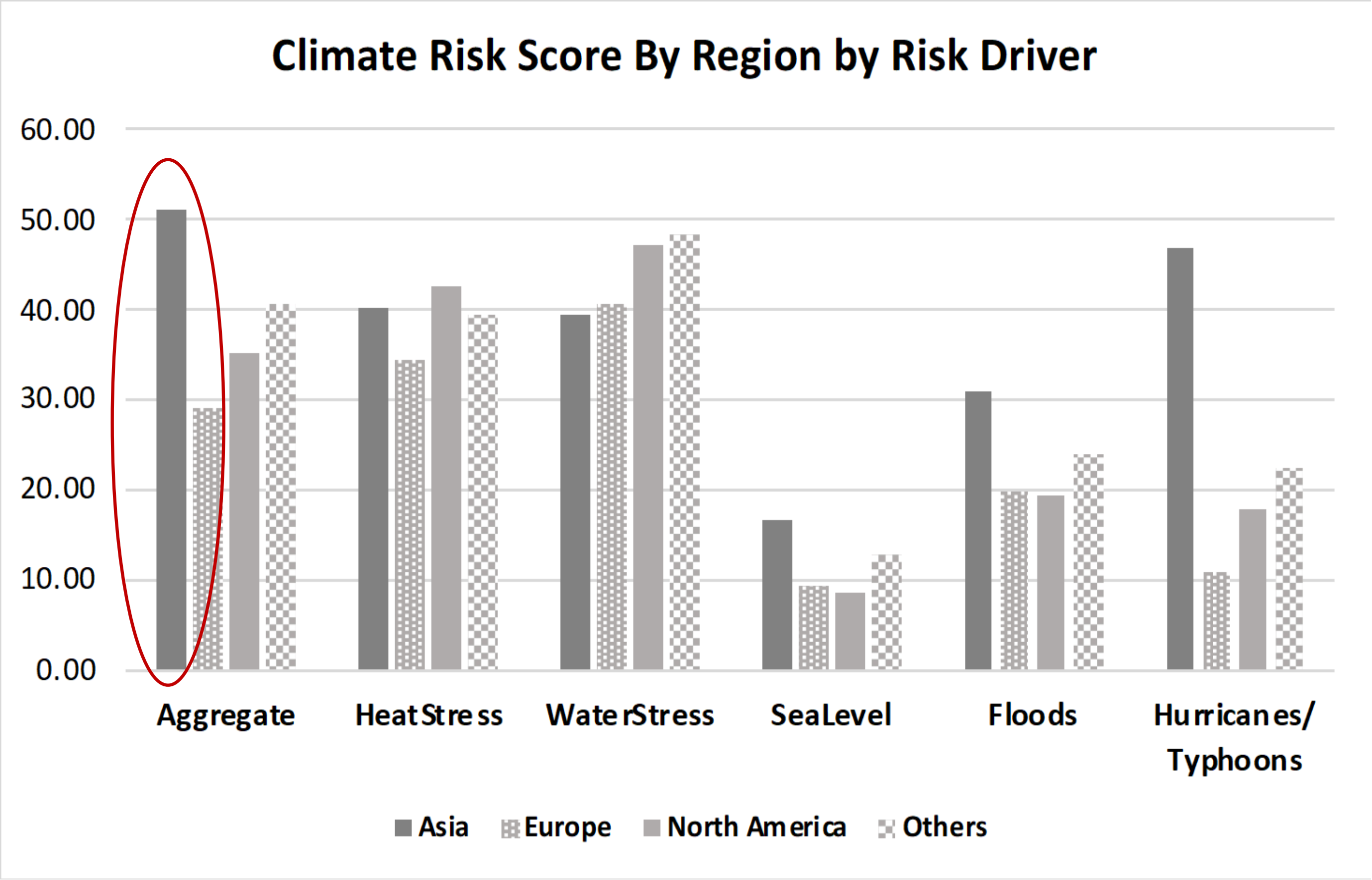
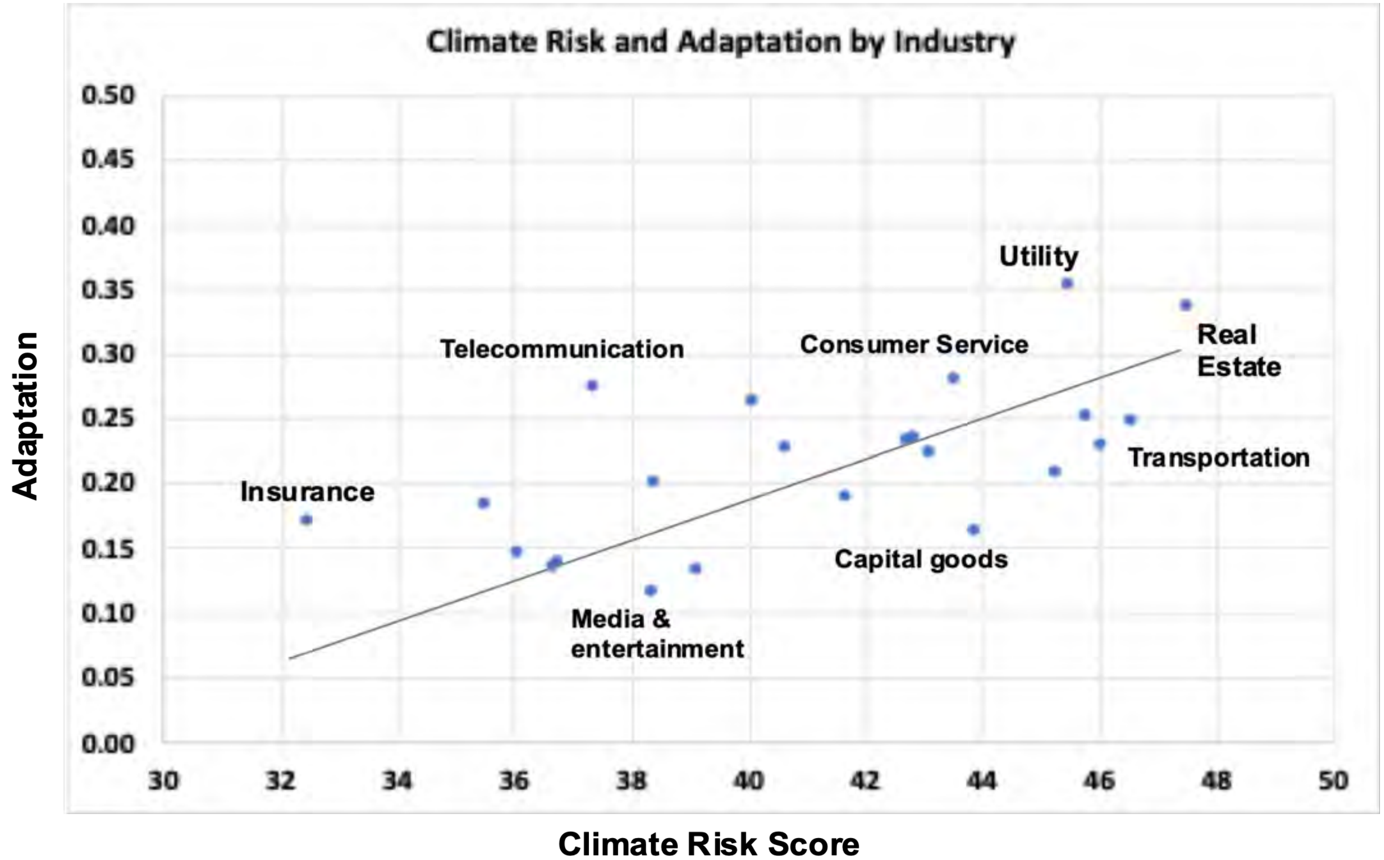
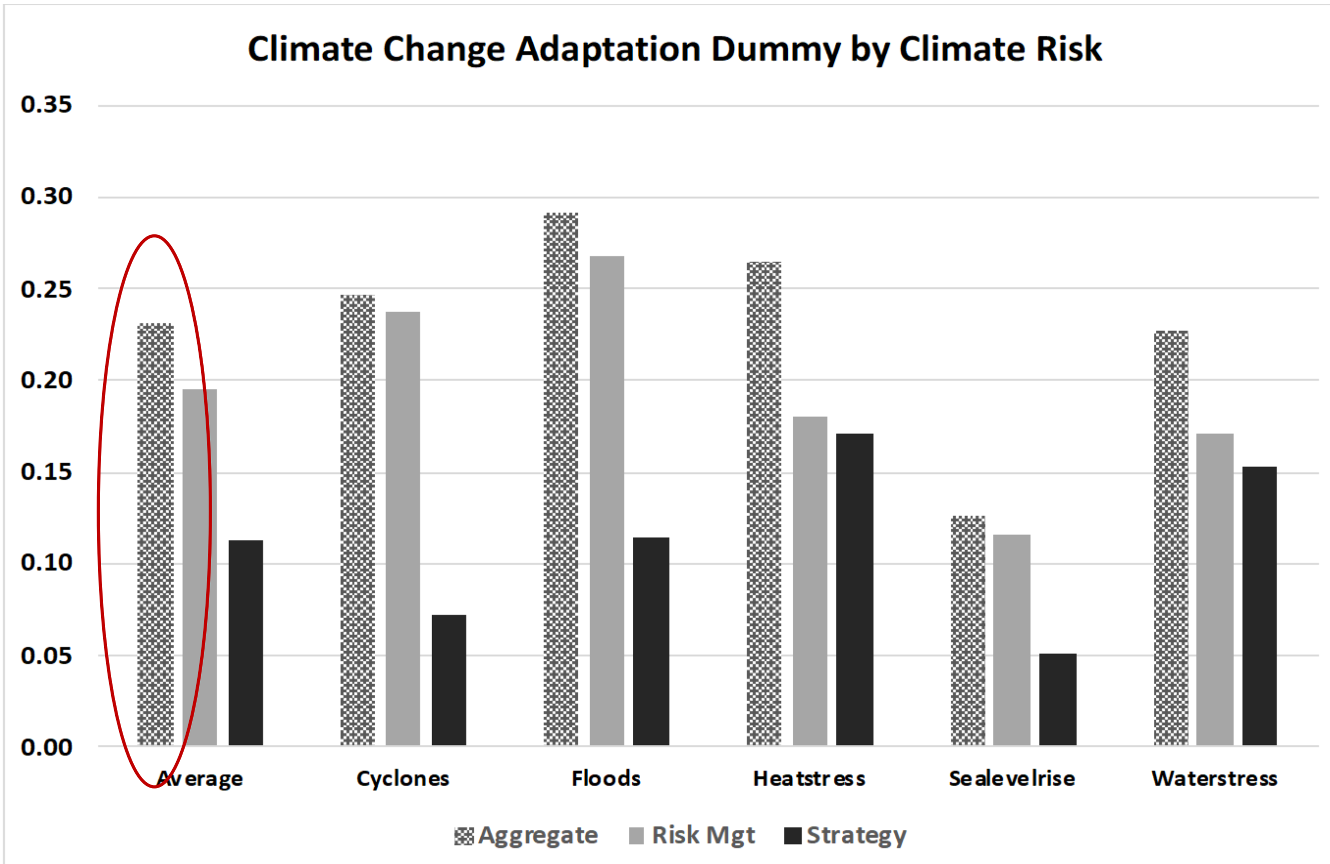
Climate Risk Scores



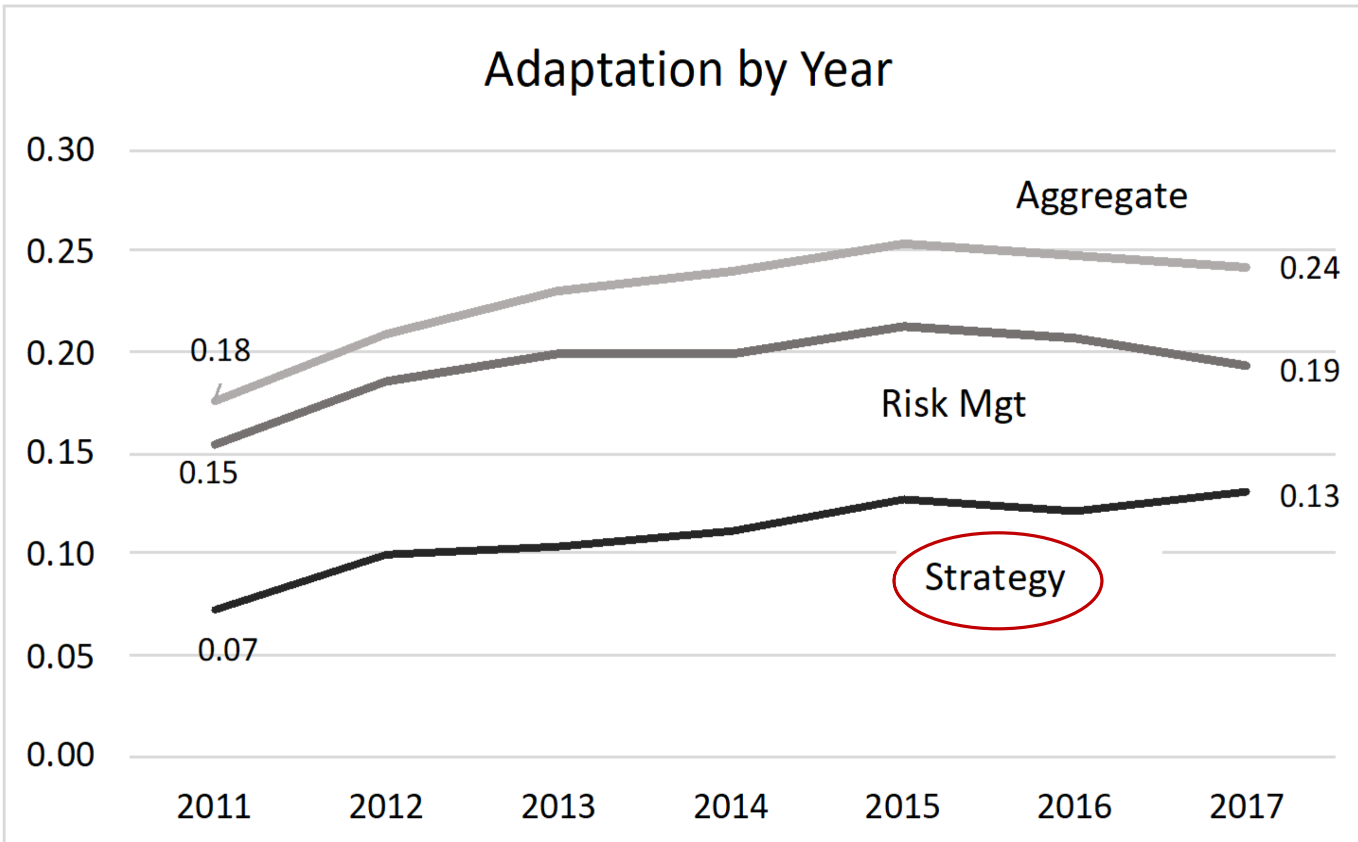
Climate Risk and Adaptation by Industry



Adaptation Percentage Across Firms and Climate Risk Drivers



Adaptation Percentage Over Time



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Method

RQ1: What is the impact of physical climate risk on firms' climate change adaptation strategy?

<u>Baseline Regression</u>

$$Adapt_{\mathrm{irt}} = \alpha_i + \alpha_r + \alpha_t + \beta ClimateRisk_{ir} + \gamma' X_{it-1} + \varepsilon_{irt} \quad (1)$$

- Unit of analysis : firm-risk-year
- Focus on firms' direct operations
- $Adapt_{\mathrm{irt}}$ is a generic term standing for
  - *Overall Adaptation Breadth*; *Risk Management Breadth*; *Business Strategy Breadth* (manually constructed index)
- i indexes firms, r indexes risk, t indexes year
- **α_i are firm fixed effects; α_r are risk fixed effects; α_t are year fixed effects**
- X is the vector of control variables: firm size, ROA, leverage, and cash

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Method

RQ1: What is the impact of physical climate risk on firms' climate change adaptation strategy?

RQ2: What's the trend of impact of physical climate risk on firms' climate change adaptation strategy?

Baseline Regression

$$Adapt_{irt} = \alpha_i + \alpha_r + \alpha_t + \beta ClimateRisk_{ir} + \gamma' X_{it-1} + \varepsilon_{irt} \quad (1)$$

$$Adapt_{irt} = \alpha_{ir} + \alpha_t + \beta 1 \times ClimateRisk_{ir} \times Trend + \gamma' X_{it-1} + \varepsilon_{irt} \quad (2)$$

- Unit of analysis : firm-risk-year
- Focus on firms' direct operations
- $Adapt_{irt}$ is a generic term standing for
  - *Overall Adaptation Breadth*; *Risk Management Breadth*; *Business Strategy Breadth* (manually constructed index)
- i indexes firms, r indexes risk, t indexes year
- **α_i are firm fixed effects; α_r are risk fixed effects; α_t are year fixed effects**
- X is the vector of control variables: firm size, ROA, leverage, and cash
- Trend = Year – 2010 (Dowell, Lyon and Pickens, 2020; Doshi, Dowell, and Toffel, 2013)

Physical Climate Risk and Adaptation: Baseline

	Model 1 - Polled Cross Section			Model 2- Firm Fixed Effects		
	Adaptation Breadth	Risk Mgt Breadth	Strategy Breadth	Adaptation Breadth	Risk Mgt Breadth	Strategy Breadth
lnClimateRisk	0.105	0.109	0.059	0.101	0.102	0.059
	[0.017]***	[0.016]***	[0.016]***	[0.017]***	[0.016]***	[0.017]***
Controls						
Size	0.138	0.125	0.102	-0.03	0.033	-0.112
	[0.033]***	[0.032]***	[0.029]***	[0.057]	[0.057]	[0.074]
Cash	-0.047	-0.045	-0.027	0.002	0.007	-0.01
	[0.021]**	[0.019]**	[0.020]	[0.020]	[0.019]	[0.022]
ROA	0.048	0.028	0.065	-0.018	-0.019	-0.013
	[0.032]	[0.031]	[0.029]**	[0.019]	[0.018]	[0.021]
Leverage	0.003	0.002	-0.005	0.003	-0.004	-0.006
	[0.023]	[0.023]	[0.021]	[0.026]	[0.025]	[0.030]
FirmAge	0.005	0.007	-0.007			
	[0.022]	[0.022]	[0.019]			
Diversity	0.018	0.014	0.017			
	[0.026]	[0.025]	[0.025]			
Multination	0.014	0.003	0.033			
	[0.027]	[0.023]	[0.029]			
Country-Industry-Year	Yes	Yes	Yes			
RiskDriver FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE				Yes	Yes	Yes
Year FE				Yes	Yes	Yes
N	24430	24430	24430	24450	24450	24450
R2	0.188	0.18	0.174	0.036	0.033	0.038

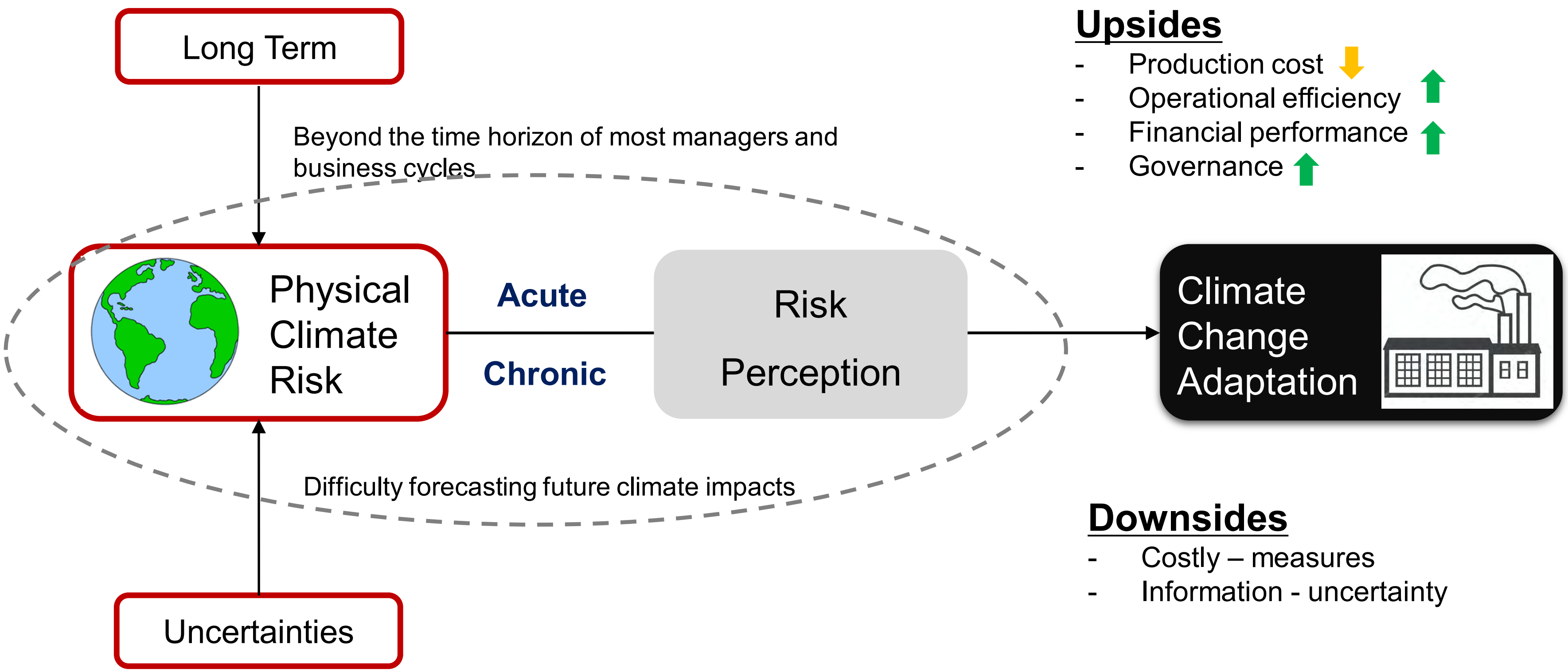
Unit of analysis is Firm-Risk-Year. Sample period is 2011 - 2017. Outcome variable: Climate change adaptation. Adaptation Breadth is constructed by adding up adaptation categories the firms have taken in response to one particular climate risk driver. Adaptation includes aggregated adaptation, and also separated by risk management and business strategy. The main explanatory variable is climate risk score in log form. Robust standard errors clustered at the firm level are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Physical Climate Risk and Adaptation: Trend

	lnAdapt Breadth	lnRiskMgt Breadth	lnStrategy Breadth
TrendXlnClimateRisk	0.125	0.041	0.179
	[0.027]***	[0.028]	[0.029]***
Controls			
Size	-0.029	0.033	-0.111
	[0.043]	[0.042]	[0.057]*
Cash	0.002	0.007	-0.01
	[0.016]	[0.017]	[0.017]
ROA	-0.018	-0.019	-0.013
	[0.015]	[0.014]	[0.016]
Leverage	0.004	-0.004	-0.005
	[0.019]	[0.019]	[0.022]
Year FE	Yes	Yes	Yes
Firm-RiskDriver FE	Yes	Yes	Yes
N	24450	24450	24450
R2	0.014	0.006	0.015

Unit of analysis is Firm-Risk-Year. Sample period is 2011 - 2017.
Outcome variable: Climate change adaptation. Adaptation Breadth is constructed by adding up adaptation categories the firms have taken in response to one particular climate risk driver. Adaptation includes aggregated adaptation, and also separated by risk management and business strategy. The main explanatory variable is climate risk score in log form. Robust standard errors clustered at the firm level are in parentheses.
Trend = Year - 2010, and it interacts with the treatment climate risk. * p<0.10, ** p<0.05, *** p<0.01

Mechanism - Impact and perception



Mechanism - Impact and perception

Physical climate risk ⬆

→ Impact and perception ⬆

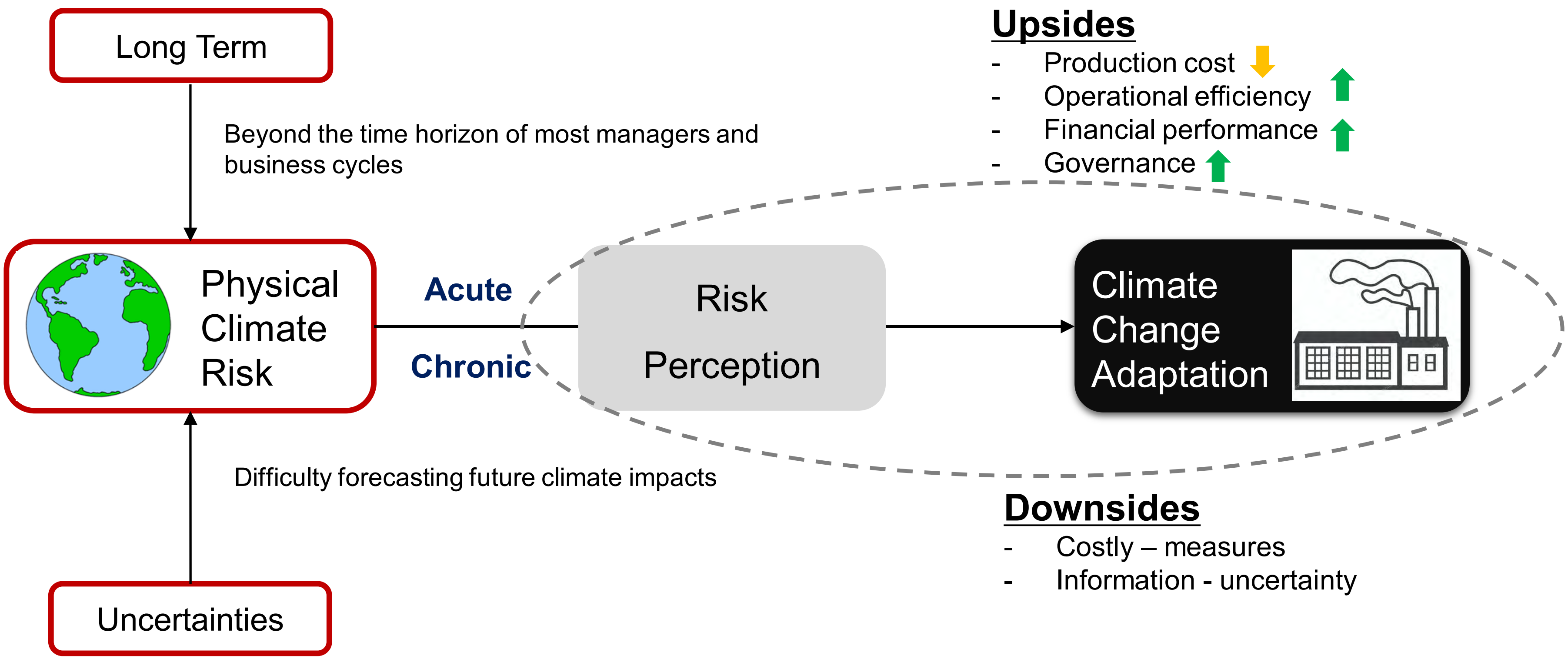
Impact and perception increases <u>over time</u>

	Disclosed Influcing Time	Disclosed Likelihood	Disclosed Magnitude
lnClimateRisk	0.072	0.079	0.079
	[0.015]***	[0.017]***	[0.018]***
Controls			
Size	-0.09	-0.031	-0.061
	[0.060]	[0.042]	[0.049]
Cash	0.012	-0.002	0.001
	[0.020]	[0.017]	[0.016]
ROA	-0.007	0.006	0.007
	[0.022]	[0.020]	[0.019]
Leverage	0.022	0.025	0.02
	[0.024]	[0.020]	[0.021]
RiskDriver FE	Y	Y	Y
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
N	21261	21359	21369
r2	0.262	0.275	0.263

	Disclosed Influcing Time	Disclosed Likelihood	Disclosed Magnitude
TrendXlnClimateRisk	0.235	0.25	0.224
	[0.020]***	[0.021]***	[0.022]***
Controls			
Size	-0.085	-0.026	-0.056
	[0.061]	[0.042]	[0.051]
Cash	0.012	-0.001	0.001
	[0.020]	[0.018]	[0.017]
ROA	-0.005	0.008	0.009
	[0.022]	[0.020]	[0.019]
Leverage	0.019	0.023	0.018
	[0.024]	[0.020]	[0.021]
Year FE	Yes	Yes	Yes
Firm-RiskDriver FE	Yes	Yes	Yes
N	21334	21431	21440
R2	0.098	0.118	0.101

Unit of analysis is Firm-Risk-Year. Sample period is 2011 - 2017. Outcome variable: Disclosed Climate Impacts on firms, including magnitude, influencing time, and likelihood. The greater magnitude and likelihood of the impact and shorter influencing time, the bigger the ratings. Robust standard errors clustered at the firm level are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

Mechanism - Impact and perception



Mechanism - Impact and perception

Impact and Perception ⬆ → Climate Change Adaptation ⬆

	Adaptation Breadth	Adaptation Breadth	Adaptation Breadth
Disclosed Influcing Time	0.594		
	[0.014]***		
Disclosed Likelihood		0.742	
		[0.013]***	
Disclosed Magnitude			0.702
			[0.013]***
Controls			
Size	0.009	-0.019	-0.005
	[0.037]	[0.038]	[0.036]
Cash	0.009	0.016	0.015
	[0.014]	[0.013]	[0.014]
ROA	-0.027	-0.033	-0.035
	[0.015]*	[0.014]**	[0.014]**
Leverage	-0.008	-0.011	-0.006
	[0.017]	[0.016]	[0.016]
Firm-RiskDriver FE	Y	Y	Y
Year FE	Y	Y	Y
N	21334	21431	21440
r2	0.349	0.443	0.424

Unit of analysis is Firm-Risk-Year. Sample period is 2011 - 2017.
The greater magnitude and likelihood of the impact and shorter influencing time, the bigger the ratings.
Robust standard errors clustered at the firm level are in parentheses. * p<0.10, ** p<0.05, *** p<0.01

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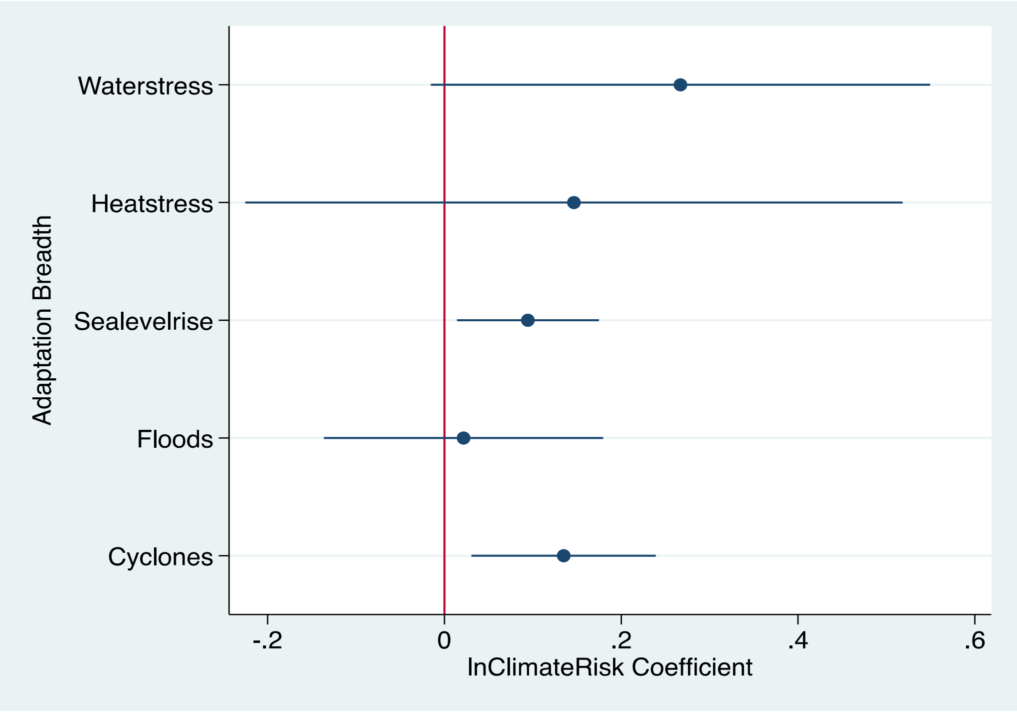
Physical Climate Risk and Adaptation: Heterogeneities across Climate Risk Drivers



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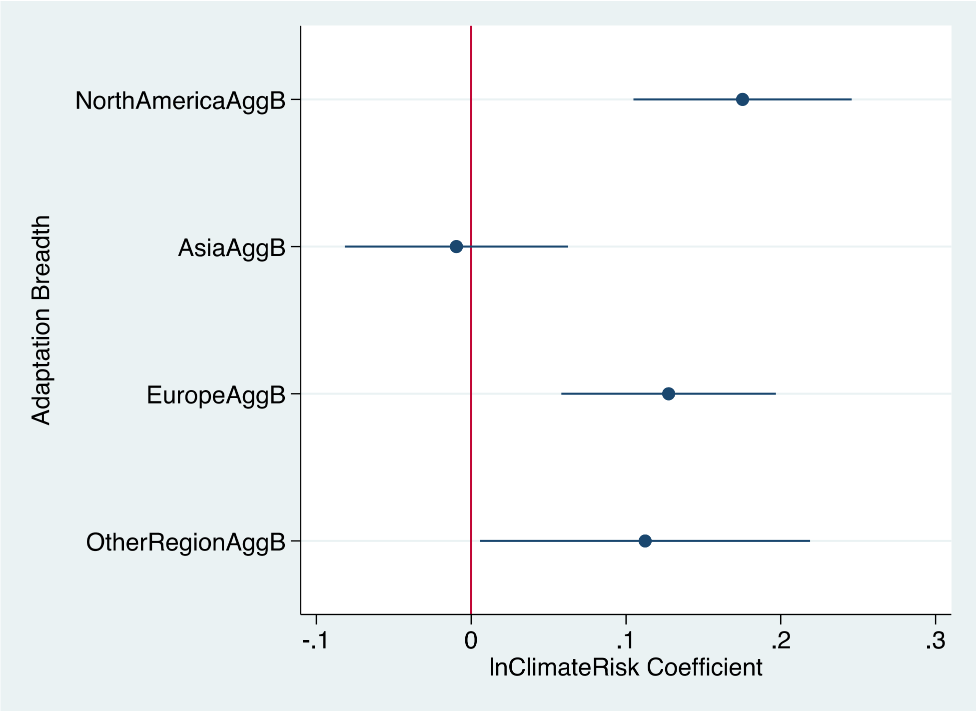
Physical Climate Risk and Adaptation: Heterogeneities across Regions



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Conclusion

- Whether and how do firms adapt to physical climate risk?
  - Research gap: previous literature focuses on climate change mitigation, not adaptation
  - Using a novel dataset of 1,068 public companies across industries that are headquartered in 43 countries during 2011-2017s

- Main findings
  - Stylized facts of firm adaptation by industry, risk, region, across time
    - Average adaptation rate across firms and climate risk drivers is 23%
    - More risk management than business strategy
  - Higher climate risk increases firms' adaptation strategies
    - Impact increases over time, particularly for business strategy
  - Mechanism: climate risk perception
  - Heterogeneities: different climate risks and regions

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Thank you!

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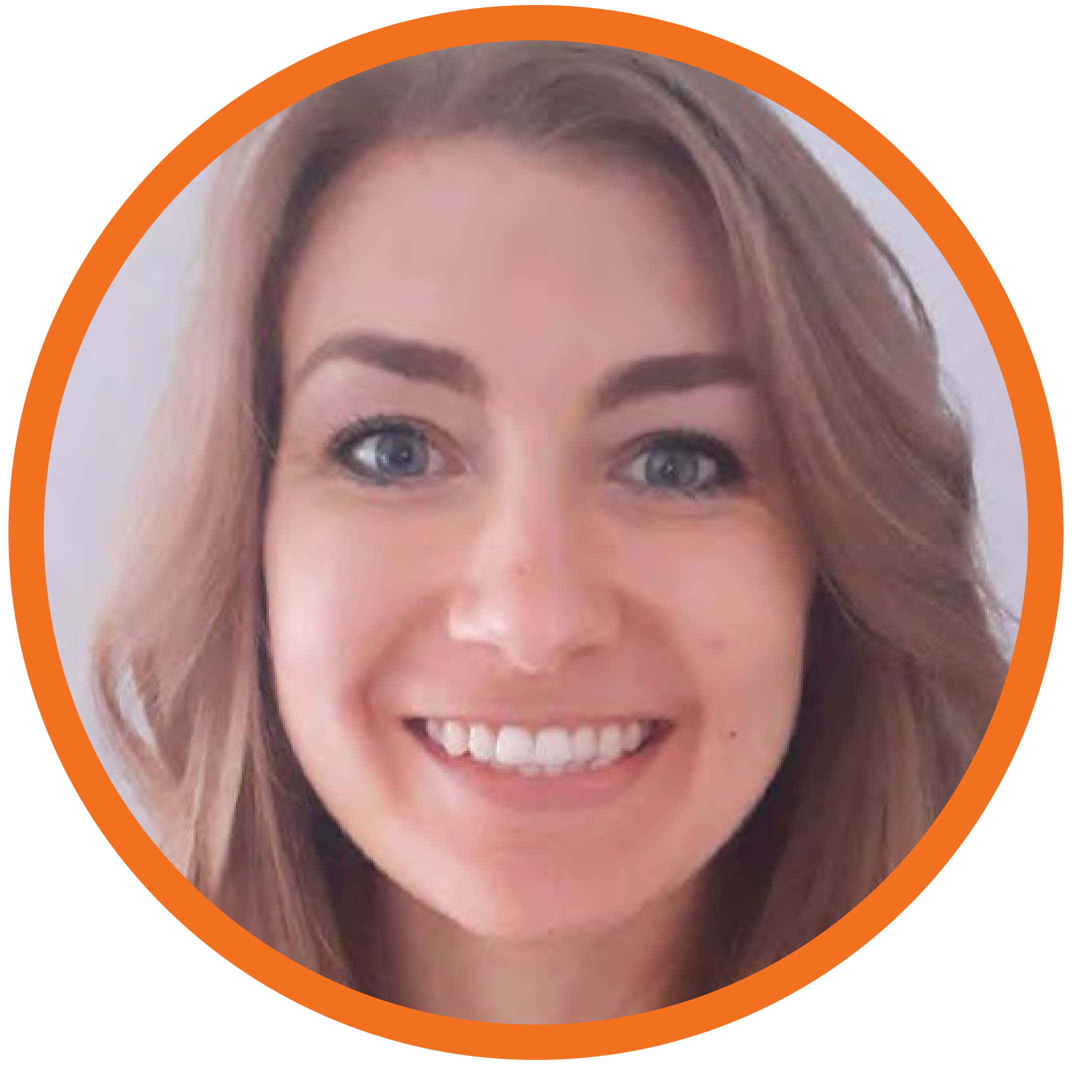

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Heterogeneous Investor Response to Climate Risk: Evidence from Environmental Litigation Risk

Heterogeneous Investor Response to New Risks in Financial Markets: Evidence from Environmental Litigation Risk

Alison Taylor

September 2021

Climate Risks and Lawsuits

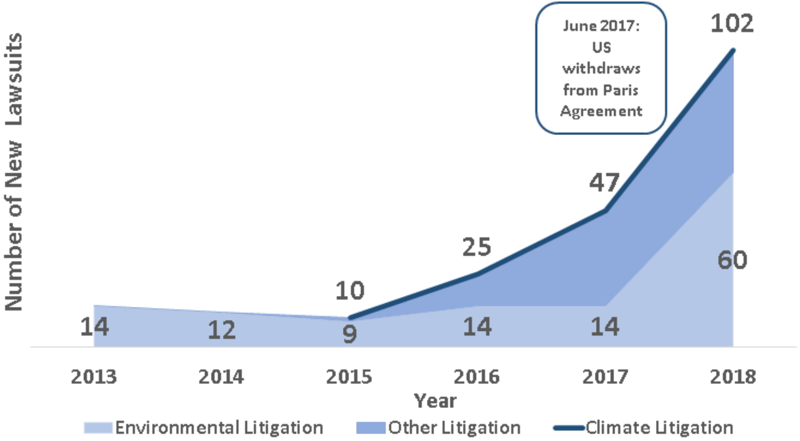
- **Climate Risks** - new business risks from climate change
  - E.g. hurricanes damaging equipment; **more lawsuits** Literature Review
- **Climate Litigation Risk**
  - Evolving Regulation: EPA can regulate GHG emissions as of 2011
  - Evolving Impact: Negative stock price reaction for poor environmental performance is increasing (Flammer, 2013)
- Lawsuit example: Car manufacturers and emissions testing
  - Fuel economy vs. emissions standards → defeat devices (Car and Driver, 2015)
  - January 4, 2016: USA v. Volkswagen
  - May 23, 2017: USA v. Fiat Chrysler

Investor Response to Litigation Risk

- Some institutional investors are aware of climate risk and are using different strategies to manage it (Krueger, Sautner and Starks, 2020)
- What is the **aggregate response of investors** to a new lawsuit?
  - Do the majority of investors know about a lawsuit?
  - Which investors know about it?
  - Do investors predominantly use exit or voice?
- Who cares?
  - Investors - informed trading and collaborative engagement
  - Firms - the investor mix and awareness affects pressure to improve environmental performance
  - Central banks - climate risk disclosure and investor's risk exposure
    - Climate change is the biggest emerging risk to the financial system - Yellen, 2021

Climate Litigation

The majority are for violating federal environmental laws, such as the Clean Air Act, the Clean Water Act, Endangered Species Act, etc.



Lawsuits by Industry Lawsuits by Company

Data Sources

Scope: U.S. public companies; 2013-2018

- **Environmental Litigation:** Audit Analytics; NOS 893 federal lawsuits including violations of Clean Air Act, Clean Water Act, National Environmental Policy Act, etc.
- **Price:** CRSP
- **Institutional Investors:** Thomson Reuters 13F Filings
  - Includes investors $>$ \$100M required to file
  - Excludes holdings $<$ 10,000 or $<$ \$200,000
- **ESG Investors:** Principles for Responsible Investment (PRI)
  - Matched investor signatories to Thomson Reuters 13F Filings
- **Engagement:** ISS Voting Analytics
  - Manually-coded environmentally-themed proposals
- **Controls:** Company fundamentals (Compustat)

Empirical Design

- I look at outcomes following a new lawsuit, including:
  - **Stock price change**
  - **Characteristics of investors buying and selling shares**
  - **Environmentally-themed shareholder proposals**
- Selection effect: defendants are larger and more profitable

  Stats: Defendant vs. Competitor Stats: Competitor vs. Others
- To address this, I also look at competitors in the same 4-digit SIC industry
  - Considered the anticipatory effect of litigation in Gande and Lewis (2009)

Hypothesis 1: No Response

No Response - **investors are not pricing in climate risk**

- Literature: Temperature and stock returns (Kumar, Xin and Zhang, 2019); drought and food companies (Hong, Li and Xu, 2019); sea level rise and house prices (Murfin and Spiegel, 2019) Literature Review

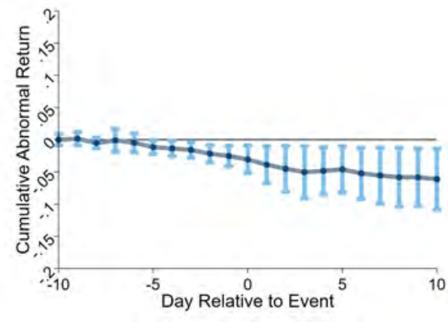
Empirical Test

Does the stock price decrease following the announcement of a new lawsuit?

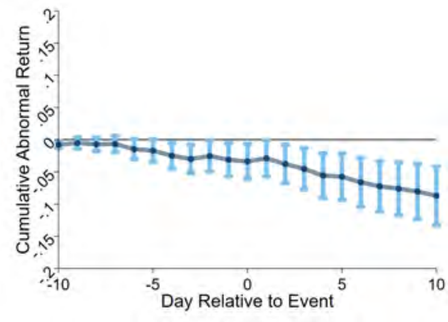
Stock Price Returns

Fama-French 3-factor event study

Defendants



Competitors



No Market Reaction → Unlikely CAR Model CAR Table Results

Hypothesis 2: Asymmetric Information

Asymmetric Information - **only some investors are aware of this risk and are selling shares to investors that are unaware**

- Literature: Hurricanes and mortgage loans (Ouazad and Kahn, 2021); temperature and stock prices (Choi, Gao and Jiang, 2019) Literature Review

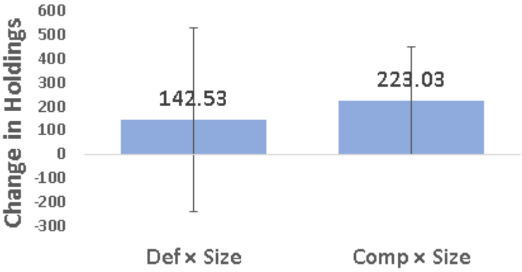
Empirical Test

Are large investors (who would have more resources to monitor litigation risk) more likely to sell company shares after increased litigation risk?

Large Institutional Investors Increase Holdings

$$\Delta Holdings_{i,m,q} = \beta^{D,Size} Def_{i,q} \times InvestorSize_{m,q} + \beta^{C,Size} Comp_{i,q} \times InvestorSize_{m,q} + \beta^{\bar{X}} \bar{X} + \alpha_j + \alpha_q + \eta_{i,m,q} \quad (1)$$

Betas



Asymmetric Information → Unlikely Holdings by Size Model

Holdings by Size Table Results

Hypothesis 3: Different Preferences

Different Preferences - as new information emerges, investors redistribute shares based on their preferences for environmental factors

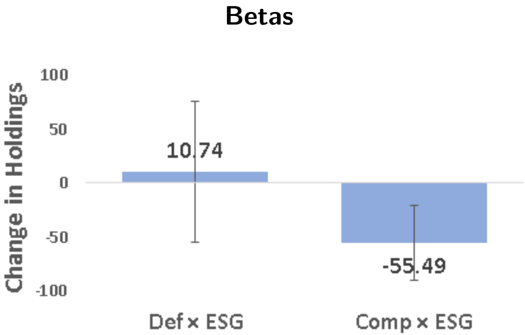
- Literature: climate risk survey (Krueger, Sautner and Starks, 2020); sea level rise and house prices (Baldauf, Garlappi and Yannelis, 2020; Bernstein, Gustafson, and Lewis 2019, Bakkensen and Barrage, 2018); policy and investor holdings (Ramelli, Wagner, Zeckhauser and Ziegler, 2019) Literature Review

Empirical Test

- Are ESG investors more likely to sell company shares after increased litigation risk?
- Are there fewer environmentally themed shareholder proposals following a lawsuit?

ESG Investors Decrease Holdings

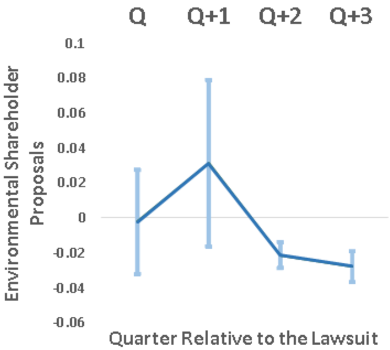
$$\Delta Holdings_{i,m,q} = \beta^{D,ESG} Def_{i,q} \times ESG_{m,q} + \beta^{C,ESG} Comp_{i,q} \times ESG_{m,q} + \beta^{\bar{X}} \bar{X} + \alpha_j + \alpha_q + \eta_{i,m,q} \quad (2)$$



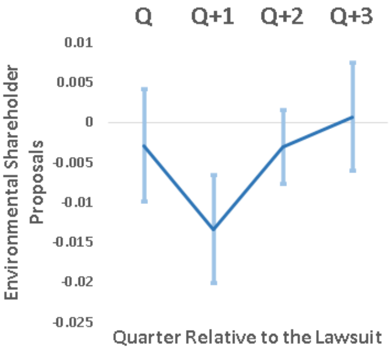
Holdings by ESG Model
Holdings by ESG Table Results

Fewer Environmental Shareholder Proposals After a Lawsuit

Defendants



Competitors



Redistributing by Preferences → Likely Shareholder Proposals Model

Shareholder Proposals Table Results

Hypothesis 4: Engagement

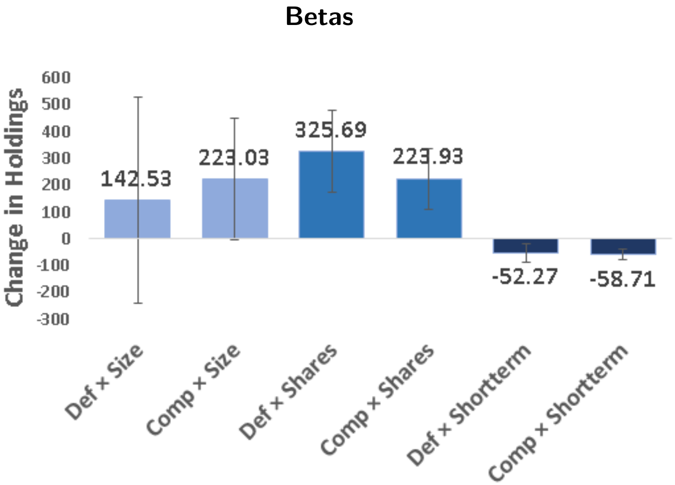
Engagement - **investors redistribute shares based on their comparative advantage to engage with the firm and manage climate risk**

- Literature: climate risk survey (Krueger, Sautner and Starks, 2020); ESG engagement and accounting performance (Dimson, Karakaș and Li, 2016), sales growth (Barko, Cremers and Renneboog, 2021) and downside risk (Hoepner, Oikonomou, Sautner and Starks, 2021); coordinated engagements (Dimson, Karakaș and Li, 2021); private equity and environmental liability risk (Bellon, 2020) Literature Review

Empirical Test

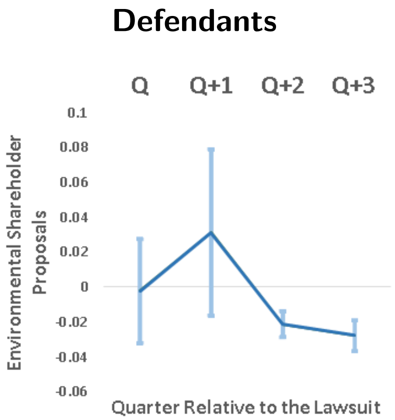
- Are large, long-term and investors with more shares in the company already more likely to increase holdings?
- Is there more engagement following an increase in litigation risk?

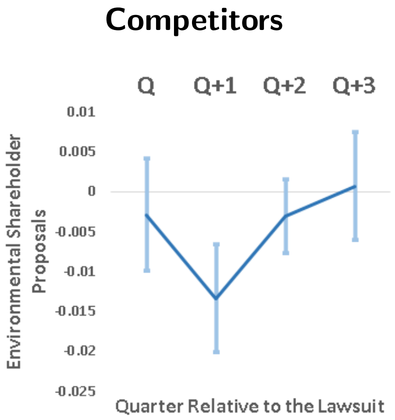
Large, Long-term and Investors with More Shares Previously Are More Likely to Increase Holdings



Holdings by Size Model
Holdings by Size Table Results

Fewer Environmental Shareholder Proposals After a Lawsuit





Engagement → Less Likely Shareholder Proposals Model Shareholder Proposals Table Results

Overall, Exit Strategy Dominates For Risk Management

Hypotheses: More Details

1. **No Response (NR)** - no market reaction to risk
   - **Unlikely:** Stock price decrease following a lawsuit
2. **Asymmetric Information (AI)** - asymmetric information among investors
   - **Unlikely:** Large investors increase holdings
3. **Preferences (P)** - eco-conscious investors sell shares
   - **Very likely:** ESG investors exit firms and there is less environmental engagement
4. **Engagement (E)** - different comparative advantage of engagement
   - **Less likely:** Large, long-term investors increase holdings but there is less public environmental engagement following a lawsuit

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Literature Review

Climate risk matters to investors; possible mispricing (Krueger et al., 2020)

- **No Response** - drought and food company stocks (Hong et al., 2019); sea level rise and house prices (Murfin and Spiegel, 2019); temperature and stock returns (Kumar et al., 2019)
- **Asymmetric Information** - temperature and stock prices (Choi et al., 2019); mortgage securitization (Ouazad and Kahn, 2019)
- **Preferences** - sea level rise and house prices (Baldauf et al., 2019; Bernstein et al., 2018, Bakkensen and Barrage, 2018); policy and investor holdings (Ramelli et al., 2019)

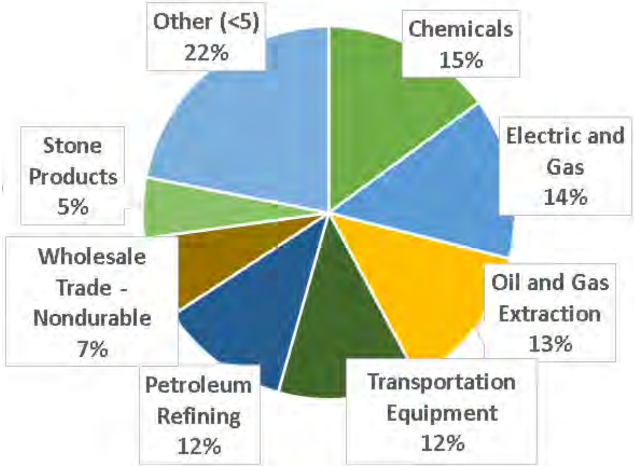
Environmental Litigation Risk

- Event study with data from 1980-2000 (Karpoff et al., 2005)
- Firm-specific and time-varying

This Paper: Institutional investor response to environmental litigation risk

Back

Lawsuits by Industry



Back

Lawsuits by Company

	Frequency	Percent
3M CO	7	5.69
EXXON MOBIL CORP	4	3.25
CHEMOURS CO	3	2.44
MARATHON OIL CORP	3	2.44
UNITED STATES STEEL CORP	3	2.44
APACHE CORP	2	1.63
BRISTOL MYERS SQUIBB CO	2	1.63
CASELLA WASTE SYSTEMS INC	2	1.63
CHEVRON CORP NEW	2	1.63
CONOCOPHILLIPS	2	1.63
EASTMAN CHEMICAL CO	2	1.63
F M C CORP	2	1.63
HESS CORP	2	1.63
MARATHON PETROLEUM CORP	2	1.63
N L INDUSTRIES INC	2	1.63
NAVISTAR INTERNATIONAL CORP	2	1.63
PHILLIPS 66	2	1.63
PLAINS ALL AMERN PIPELINE L P	2	1.63
PLAINS G P HOLDINGS LP	2	1.63
PORTLAND GENERAL ELECTRIC CO	2	1.63
REPUBLIC SERVICES INC	2	1.63
TEXTRON INC	2	1.63
UNION PACIFIC CORP	2	1.63
OTHER (< 2)	67	54.47
TOTAL	123	100.00

Back

Are defendant firms comparable to other firms?

	Ever Sued		Never Sued		Difference in Means	
	Mean	S.D.	Mean	S.D.	t-stat	
Assets	28,092	36,310	5,346	16,099	-30.60	***
Book Leverage	0.63	0.20	0.52	0.29	-8.43	***
Log(Sale)	8.86	1.62	6.11	2.43	-26.12	***
Market-to-Book Ratio	1.04	0.89	2.05	2.68	8.34	***
Profitability	0.11	0.09	0.00	0.30	-8.14	***
Tangibility	0.41	0.27	0.25	0.25	-15.15	***
Cash Flow Volatility	0.04	0.05	0.09	0.16	7.45	***
Intangible Assets	0.17	0.17	0.19	0.21	1.82	*
Firm-Year Observations	536		19,126			

- Defendant firms are larger and more profitable Back

Summary Statistics - Competitors vs. Others

Are competitor firms comparable to other firms?

	Ever Sued		Never Sued		Difference in Means	
	Mean	S.D.	Mean	S.D.	t-stat	
Assets	8,171	20,475	4,552	14,538	-12.90	***
Book Leverage	0.51	0.30	0.52	0.29	1.53	
Log(Sale)	6.26	2.55	6.06	2.39	-4.59	***
Market-to-Book Ratio	1.87	2.50	2.11	2.73	5.01	***
Profitability	-0.02	0.33	0.01	0.30	4.30	***
Tangibility	0.34	0.29	0.22	0.23	-28.88	***
Cash Flow Volatility	0.12	0.18	0.09	0.15	-10.77	***
Intangible Assets	0.13	0.18	0.20	0.22	20.54	***
N	4,199		14,927			

- Competitor firms are more comparable but still significantly larger

Back

Price Response: Empirical Strategy

Event Study:

- Three-Factor Fama French
  - Controls for: market return; size of firm; and book-to-market value
- Significance: Normalize t-statistics with historical stock price standard deviation (Boehmer et al., 1991)

Also look at competitors

- **Advantage:** Get around selection effect of litigation and increase sample size (Gande and Lewis, 2009; Arena and Julio, 2015)
- **Plausible:** Volkswagen emission scandal: decrease in competitor sales (Bachmann et al., 2019) and market values (Barth et al., 2019)

Back

Negative Reaction For Defendant and Peer Firms

Window (Days Relative to Event)	Defendant CARs		Competitor CARs	
Before	-1.90%	***	-2.22%	**
$[-10, -2]$	(-2.97)		(-2.18)	
During	-1.67%		0.36%	
$[-1, +1]$	(-1.50)		(0.76)	
After	-1.67%	*	-5.80%	***
$[+2, +10]$	(-1.84)		(-4.84)	
N	123		2,145	

- Test statistics normalized with firm-level standard errors (Boehmer et al., 1991)

Back

Institutional Investors by Size: Empirical Strategy

$$\Delta Holdings_{i,m,q} = \beta^{D,Size} Def_{i,q} \times InvestorSize_{m,q} + \beta^{C,Size} Comp_{i,q} \times InvestorSize_{m,q} + \beta^{\bar{X}} \bar{X} + \alpha_j + \alpha_q + \eta_{i,m,q} \quad (3)$$

$\Delta Holdings_{i,m,q}$ - Change in holdings of firm, i, by manager, m, in quarter, q

$Def_{i,q}$ - Dummy for whether firm, i, is a defendant in quarter, q
$Comp_{i,q}$ - Dummy for whether a competitor of firm, i, is a defendant in quarter, q
$InvestorSize_{m,q}$ - Holdings of manager, m, in the previous quarter
$\bar{X}$ - Vector of controls: Assets, leverage, log(sales), market-to-book ratio, profitability, tangibility, cash flow volatility and intangible assets, investor type, ESG flag, turnover, and the shares held of firm, i, in the previous quarter
α_j, α_q - Industry and Quarterly FEs Back

Large Investors Increase Holdings; Small Investors Sell

	Holdings Change	Holdings Change	Holdings Change	Holdings Change
Defendant	-40.74***	-29.03	-40.35**	-22.27
	(-2.61)	(-1.59)	(-2.56)	(-1.47)
Defendant×LaggedShares	0.20***	0.33***	0.33***	0.33***
	(7.49)	(4.14)	(4.14)	(4.14)
Defendant×Turnover	-48.85***	-51.73***	-48.66***	-52.27***
	(-3.22)	(-3.10)	(-2.87)	(-3.04)
Defendant×InvestorSize	271.27	142.96	146.41	142.53
	(1.53)	(0.73)	(0.74)	(0.72)
Defendant×ESG	-19.01	8.15	10.41	10.74
	(-0.48)	(0.24)	(0.31)	(0.32)
Competitors	-36.45***	-45.21***	-51.21***	-43.16***
	(-5.42)	(-4.91)	(-7.97)	(-6.58)
Competitors×LaggedShares	0.22***	0.22***	0.22***	0.22***
	(4.06)	(3.92)	(3.91)	(3.90)
Competitors×Turnover	-54.55***	-56.35***	-57.13***	-58.71***
	(-5.51)	(-5.21)	(-5.34)	(-5.44)
Competitor×InvestorSize	244.86**	223.83*	222.29*	223.03*
	(2.20)	(1.94)	(1.93)	(1.93)
Competitor×ESG	-52.23***	-55.85***	-56.27***	-55.49***
	(-3.12)	(-3.14)	(-3.16)	(-3.12)
Controls	No	Yes	Yes	Yes
Industry FEs	No	No	Yes	Yes
Quarterly FEs	No	No	No	Yes
N	8,519,455	7,776,391	7,776,391	7,776,391

Back

Institutional Investors by ESG: Empirical Strategy

$$\Delta Holdings_{i,m,q} = \beta^{D,ESG} Def_{i,q} \times ESG_m + \beta^{C,ESG} Comp_{i,q} \times ESG_m + \beta^{\bar{X}} \bar{X} + \alpha_j + \alpha_q + \eta_{i,m,q} \quad (4)$$

$\Delta Holdings_{i,m,q}$ - Change in holdings of firm, i, by manager, m, in quarter, q

$Def_{i,q}$ - Dummy for whether firm, i, is a defendant in quarter, q
$Comp_{i,q}$ - Dummy for whether a competitor of firm, i, is a defendant in quarter, q
ESG_m - Dummy for if manager, m, is an ESG investor
$\bar{X}$ - Vector of controls: Assets, leverage, log(sales), market-to-book ratio, profitability, tangibility, cash flow volatility and intangible assets; and investor type
α_j, α_q - Industry and Quarterly FEs Back

ESG Investors Decrease Holding

	Holdings Change	Holdings Change	Holdings Change	Holdings Change
Defendant	-40.74***	-29.03	-40.35**	-22.27
	(-2.61)	(-1.59)	(-2.56)	(-1.47)
Defendant×LaggedShares	0.20***	0.33***	0.33***	0.33***
	(7.49)	(4.14)	(4.14)	(4.14)
Defendant×Turnover	-48.85***	-51.73***	-48.66***	-52.27***
	(-3.22)	(-3.10)	(-2.87)	(-3.04)
Defendant×InvestorSize	271.27	142.96	146.41	142.53
	(1.53)	(0.73)	(0.74)	(0.72)
Defendant×ESG	-19.01	8.15	10.41	10.74
	(-0.48)	(0.24)	(0.31)	(0.32)
Competitors	-36.45***	-45.21***	-51.21***	-43.16***
	(-5.42)	(-4.91)	(-7.97)	(-6.58)
Competitors×LaggedShares	0.22***	0.22***	0.22***	0.22***
	(4.06)	(3.92)	(3.91)	(3.90)
Competitors×Turnover	-54.55***	-56.35***	-57.13***	-58.71***
	(-5.51)	(-5.21)	(-5.34)	(-5.44)
Competitor×InvestorSize	244.86**	223.83*	222.29*	223.03*
	(2.20)	(1.94)	(1.93)	(1.93)
Competitor×ESG	-52.23***	-55.85***	-56.27***	-55.49***
	(-3.12)	(-3.14)	(-3.16)	(-3.12)
Controls	No	Yes	Yes	Yes
Industry FEs	No	No	Yes	Yes
Quarterly FEs	No	No	No	Yes
N	8,519,455	7,776,391	7,776,391	7,776,391

- Dependent variable: Change in holdings (1,000 shares) Back

Shareholder Engagement: Empirical Strategy

$$Engage_{i,q} = \Sigma_{s=-2}^{3} \beta^{d,s} Def_{i,q-s} + \Sigma_{s=-2}^{3} \beta^{c,s} Comp_{i,q-s} + \beta^{\bar{X}} \bar{X} + \alpha_j + \alpha_q + \epsilon_{i,q} \quad (5)$$

$Engage_{i,q}$ - Dummy for environmental shareholder proposal

$Def_{i,q}$ - Dummy for whether firm, i, is a defendant in quarter, q
$Comp_{i,q}$ - Dummy for whether a competitor of firm, i, is sued in quarter, q
$\bar{X}$ - Vector of controls: Assets, leverage, log(sales), market-to-book ratio, profitability, tangibility, cash flow volatility and intangible assets
α_j, α_q - Industry and Quarterly FEs Back

Fewer Shareholder Proposals Afterwards

Defendant	Q	0.01	-0.00	-0.00	-0.00
		(0.66)	(-0.01)	(-0.05)	(-0.16)
Defendant	Q+1	0.06**	0.04	0.04	0.03
		(2.24)	(1.55)	(1.49)	(1.28)
Defendant	Q+2	-0.00	-0.02***	-0.03***	-0.02***
		(-0.16)	(-7.14)	(-6.42)	(-5.62)
Defendant	Q+3	-0.01***	-0.02***	-0.03***	-0.03***
		(-5.88)	(-6.96)	(-6.26)	(-6.26)
Competitor	Q	0.01**	0.01	0.00	-0.00
		(2.05)	(1.36)	(0.08)	(-0.80)
Competitor	Q+1	0.00	-0.00*	-0.01***	-0.01***
		(0.25)	(-1.65)	(-3.41)	(-3.94)
Competitor	Q+2	0.00*	0.00	-0.01***	-0.00
		(1.91)	(0.31)	(-2.69)	(-1.34)
Competitor	Q+3	0.02***	0.01**	0.00	0.00
		(3.38)	(2.19)	(0.26)	(0.21)
Controls		No	Yes	Yes	Yes
Industry FEs		No	No	Yes	Yes
Quarterly FEs		No	No	No	Yes
N		53,866	48,670	48,670	48,670

- Dependent variable: Environmental shareholder proposal [0,1] Back

Market Response Scenarios

1. **No Response (NR)** - No market reaction to risk
2. **Asymmetric Information (AI)** - Informed investors offloading risky assets to uninformed investors
3. **Preferences (P)** - Environmentally-conscious investors hold environmentally-conscious firm stocks and vice versa
4. **Engagement (E)** - Comparative advantage to engagement - high-skilled investors buy assets from low-skilled investors
   - Financial motivation to engagement: Dyck et al. (2019); Flammer (2015); Krueger et al. (2020)

Back to Conclusion

CLIMATE ADAPTATION RESEARCH SYMPOSIUM

MEASURING & REDUCING SOCIETAL IMPACTS

Thanks for tuning in!

UCLA Luskin Center for Innovation