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What do investors believe?  
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Is climate risk priced?  
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Where do we go from here?  
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Conclusion  
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# Climate Change and Asset Prices - A Review of the Literature

Olin Business School Wealth & Asset Management Research Conference

Marcus Painter

Saint Louis University

August 23, 2019



# THE WALL STREET JOURNAL.



## PG&E: The First Climate-Change Bankruptcy, Probably Not the Last

The fast fall of PG&E after California's wildfires is a jolt for companies considering the uncertain risks of a warming planet

## Credit rating agencies are concerned about climate risk



The image shows a screenshot of a Bloomberg news article. The header features the Bloomberg logo on the left and a navigation bar with links to Markets, Tech, Pursuits, Politics, Opinion, and Businessweek. The main title of the article is "Moody's Warns Cities to Address Climate Risks or Face Downgrades", displayed in a large, bold, black font against a purple and white background. Below the title, the author is listed as "By Christopher Flavelle" and the date is "November 29, 2017, 4:00 AM EST".

**Bloomberg** Markets Tech Pursuits Politics Opinion Businessweek

# Moody's Warns Cities to Address Climate Risks or Face Downgrades

By Christopher Flavelle  
November 29, 2017, 4:00 AM EST



Source: Wall Street Journal. Oct. 31 2018

## Despite the past few slides, this is not a doomsday talk

Though the overwhelming majority of climatologists believe climate change is happening and presents a great risk to society, it is still just that, a risk.

- Financial economists deal with risk all the time!
- Markets are a powerful tool for understanding and combating this risk, and a burgeoning academic literature has emerged as a result



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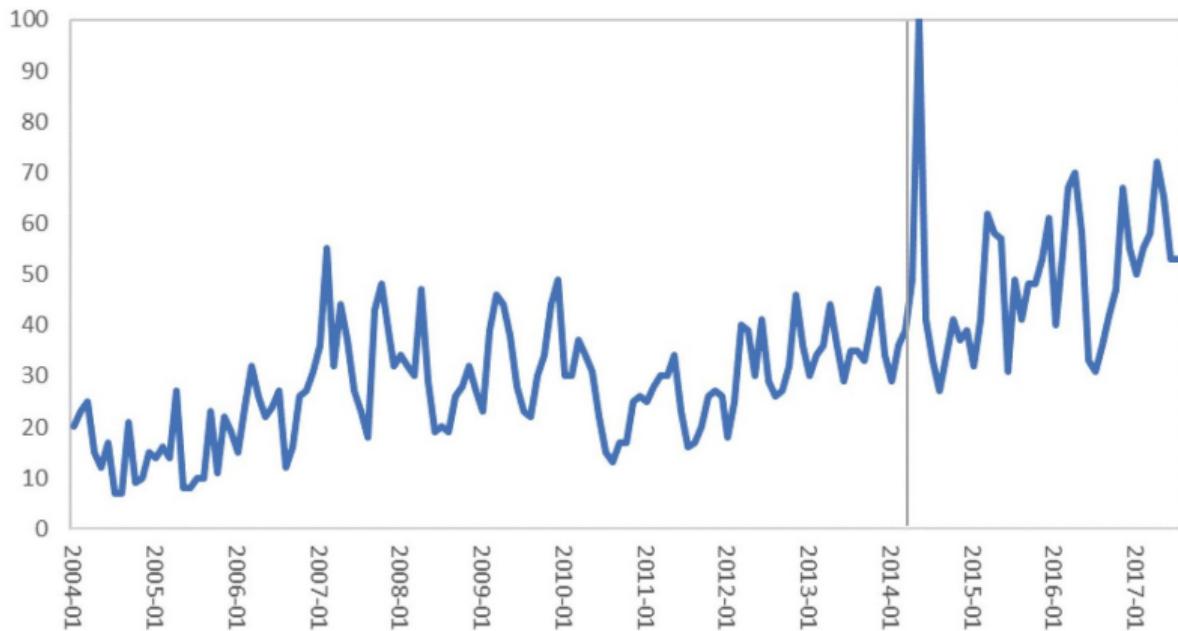
# Roadmap

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Google Search Volume for “Sea Level Rise” (Bernstein, Gustafson, and Lewis, 2019)

The vertical line indicates the release window for parts 2 and 3 of the 2013 IPCC report on climate change.

# The Importance of Climate Risks for Institutional Investors

Krueger, Sautner, and Starks,  
2019 (Note - red text indicates a  
hyperlink)

- Survey institutional investors regarding climate-risk perceptions
- 439 survey respondents

| Respondent position (N=428)      | Percentage |
|----------------------------------|------------|
| Fund/Portfolio manager           | 21%        |
| Executive/Managing director      | 18%        |
| Investment analyst/strategist    | 16%        |
| CIO                              | 11%        |
| CEO                              | 10%        |
| CFO/COO/Chairman/Other executive | 10%        |
| ESG/RI specialist                | 10%        |
| Other                            | 2%         |

| Institutional investor type (N=439) | Percentage |
|-------------------------------------|------------|
| Asset manager                       | 23%        |
| Bank                                | 22%        |
| Pension fund                        | 17%        |
| Insurance company                   | 15%        |
| Mutual fund                         | 8%         |
| Other institution                   | 15%        |

| Assets under management (N=430) | Percentage |
|---------------------------------|------------|
| Less than \$1bn                 | 19%        |
| Between \$1bn and \$20bn        | 32%        |
| Between \$20bn and \$50bn       | 23%        |
| Between \$50bn and \$100bn      | 16%        |
| More than \$100bn               | 11%        |

## Surveyed investors seem to care (a little bit) about climate change

| Panel A: Ranking of importance of investment risks (N=406) |                |                |                 |             |              |                     |
|--|----------------|----------------|-----------------|-------------|--------------|---------------------|
|  | Financial risk | Operating risk | Governance risk | Social risk | Climate risk | Other environ. risk |
| Percentage Top Risk  | 51%            | 15%            | 12%             | 11%         | 10%          | 4%                  |
| Mean Ranking   | 2.2            | 2.9            | 3.3             | 3.7         | 4.0          | 4.6                 |

| Panel B: Financial materiality and materialization of climate risks |                                 |                               |                                    |
|---|---------------------------------|-------------------------------|------------------------------------|
|   | Regulatory climate risk (N=393) | Physical climate risk (N=393) | Technological climate risk (N=393) |
| Financial materiality   |                                 |                               |                                    |
| Mean Ranking  | 2.2                             | 2.5                           | 2.2                                |

Investors ranked each risk on a scale of 1 (biggest risk) to 6 (smallest risk)

## How do funds manage climate risk?

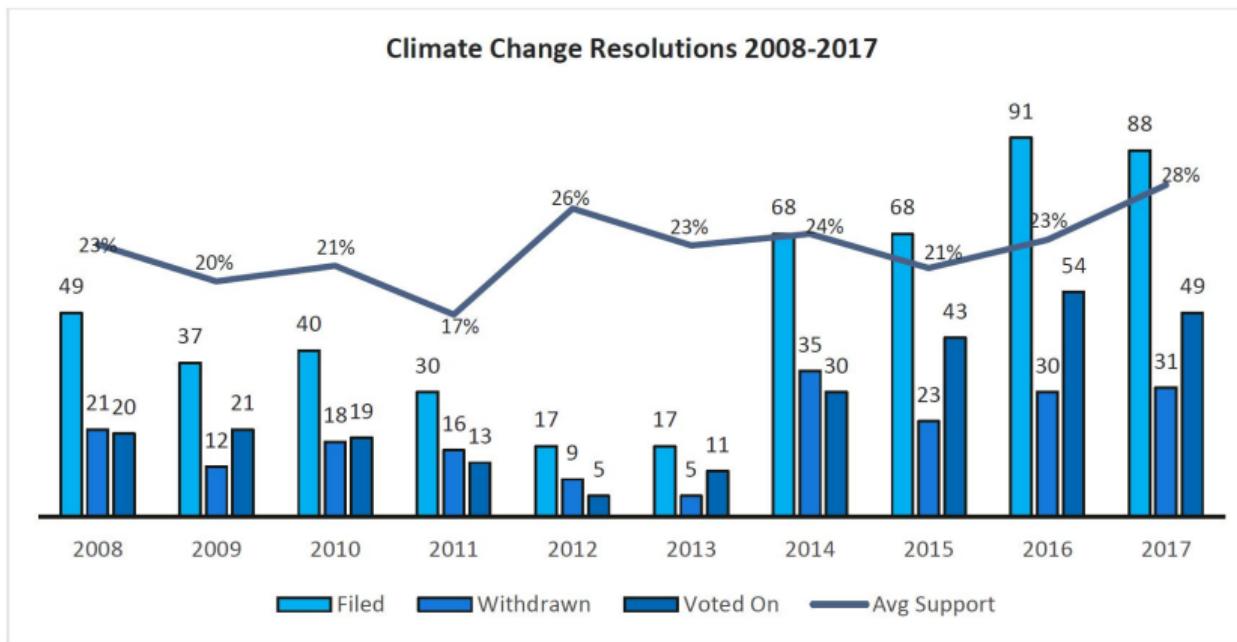
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|      |   | Percentage<br>that took<br>this measure |     |
|------|---|---|-----|
|      |   | (1)                                     | (2) |
|      | Climate-risk-management approaches taken in the past five years |   |     |
| (1)  | Analyzing carbon footprint of portfolio firms                   | 38.0%                                   | 410 |
| (2)  | Analyzing stranded asset risk                                   | 34.6%                                   | 410 |
| (3)  | General portfolio diversification                               | 33.9%                                   | 410 |
| (4)  | ESG integration   | 31.7%                                   | 410 |
| (5)  | Reducing carbon footprint of portfolio firms                    | 29.3%                                   | 410 |
| (6)  | Firm valuation models that incorporate climate risk             | 25.9%                                   | 410 |
| (7)  | Use of third-party ESG ratings                                  | 25.6%                                   | 410 |
| (8)  | Shareholder proposals   | 25.1%                                   | 410 |
| (9)  | Hedging against climate risk                                    | 24.6%                                   | 410 |
| (10) | Negative/exclusionary screening                                 | 23.7%                                   | 410 |
| (11) | Reducing stranded asset risk                                    | 22.9%                                   | 410 |
| (12) | Divestment  | 20.2%                                   | 410 |
| (13) | None  | 7.1%                                    | 410 |
| (14) | Other   | 3.7%                                    | 410 |

## How do investors vote?

Climate change has been a top ESG shareholder proposal in recent years, but few proposals win

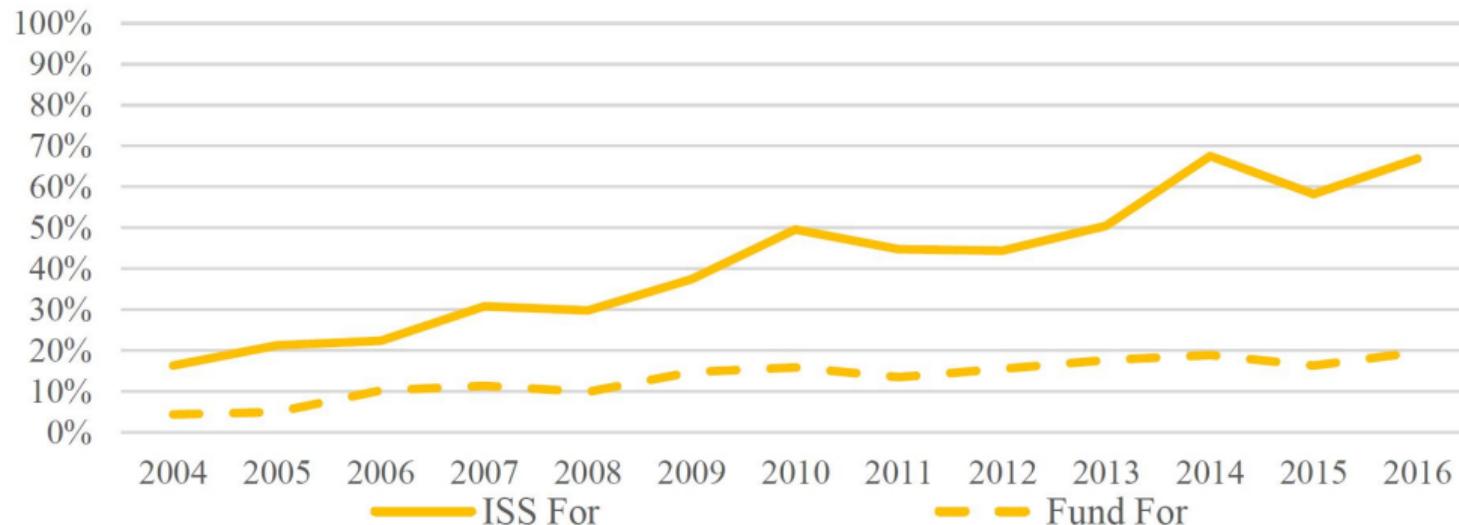


Source: ISS U.S. 2017: Proxy Season Review - Environmental & Social Issues

*“The sponsor [of the proxy] may worry that property losses will skyrocket because of weather changes. And such worries might, in fact, be warranted if we wrote ten- or twenty-year policies at fixed prices. But insurance policies are customarily written for one year and repriced annually to reflect changing exposures. Increased possibilities of loss translate promptly into increased premiums.”*

*- Berkshire Hathaway Annual Letter, 2015*





Distribution of fund votes and ISS recommendations on ES proposals over time  
- He, Kahraman, and Lowry, 2019

Failed ES proposals with higher investor support predict downside tail risk and increased likelihood of negative ES incidents.

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# Is climate risk priced?

It depends!

- Type of climate risk
  - Physical (sea level rise, drought, wildfire, etc.)
  - Regulatory
  - Timing (short-term vs. long-term)
- Asset class
- Investor attention
- Investor beliefs

Open question as to what correct price is



# Does the municipal bond market price climate risk? (Painter, 2019)

The municipal bond market provides a useful setting to study this question

- Immobile
- Heterogeneity in term structure
- Heterogeneity in exposure to climate change
  - Sea level rise
  - Hallegatte et al. (2013) climate risk measure



# Counties with High Climate Risk

| City                        | County  | Mean Annual Loss (MM\$) | Climate Risk |
|-----------------------------|---|-------------------------|--------------|
| New Orleans, LA             | Orleans   | 1940                    | 1.479%       |
| Miami, FL                   | Miami Dade  | 2964                    | 0.420%       |
| Tampa/St. Petersburg, FL    | Hillsborough, Pinellas  | 948                     | 0.324%       |
| Virginia Beach, VA          | Virginia Beach  | 328                     | 0.173%       |
| Boston, MA                  | Suffolk   | 849                     | 0.149%       |
| Baltimore, MD               | Baltimore   | 299                     | 0.104%       |
| LA/Long Beach/Santa Ana, CA | Los Angeles, Orange   | 217                     | 0.097%       |
| New York, NY/ Newark,NJ     | Bronx, Kings, New York, Queens, Richmond, Essex   | 2159                    | 0.089%       |
| Providence, RI              | Providence  | 135                     | 0.083%       |
| Philadelphia, PA            | Philadelphia  | 309                     | 0.044%       |
| San Francisco/Oakland, CA   | San Francisco, Alameda  | 185                     | 0.042%       |
| Houston, TX                 | Walker, Montgomery, Liberty, Waller, Austin,<br>Harris, Chambers, Colorado, Wharton, Fort Bend,<br>Galveston, Brazoria, Matagorda | 214                     | 0.038%       |
| Seattle, WA                 | King  | 90                      | 0.023%       |
| Washington D.C.             | Washington  | 91                      | 0.016%       |
| San Diego, CA               | San Diego   | 14                      | 0.004%       |
| Portland, OR                | Multnomah   | 4                       | 0.002%       |
| San Jose, CA                | Santa Clara   | 2                       | 0.001%       |

## Long-term issuance costs are higher in counties with higher climate risk

$$Y = \beta_1 * \ln(\text{Climate Risk}) + \beta_2 * \text{Bond Controls} + \beta_4 * \text{State} \times \text{Year FE} + \epsilon \quad (1)$$

Dependent Variable = Yield + Annualized Gross Spread

|                  | Long-Term Issuances | Short-Term Issuances |
|------------------|---------------------|----------------------|
| Ln(Climate Risk) | 0.339**<br>(2.085)  | 0.093<br>(1.117)     |
| Controls         | Yes                 | Yes                  |
| State-Year FE    | Yes                 | Yes                  |

An increase of 33.9 bps represents a 7.3% increase from the mean issuance cost  
For the average bond, a 1% increase in Climate Risk is associated with a rise in total  
annualized issuance costs of \$82,682. The average county issues 26 long-term bonds in the  
sample, bringing the total burden to \$2.15 million per year.

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# Does investor attention affect whether climate risk is priced?

## Attention

- Attention is a significant factor in investing
  - stock price volatility (Andrei and Hasler, 2014)
  - short-term stock returns (Da et al., 2011; Lou, 2014)
  - reactions to earnings announcements (Hirshleifer, Lim, and Teoh, 2011)

## The Stern Review (i.e., where it all started)

- October 30, 2006
- Former World Bank Chief Economist
- One of the earliest and most thorough analyses on the economics of climate change
- Release is unlikely to change the risk profile of munis other than through increased awareness of climate change risk



# Does investor attention affect whether climate risk is priced?

## Attention

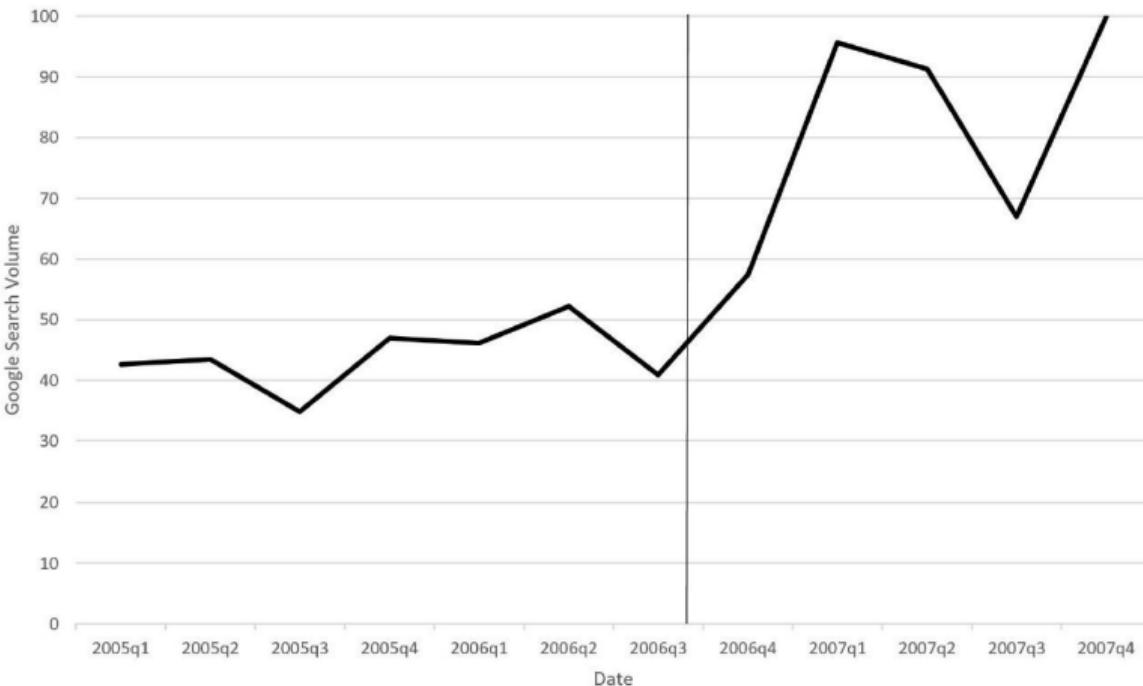
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## Climate change attention increases after the release of the Stern Review



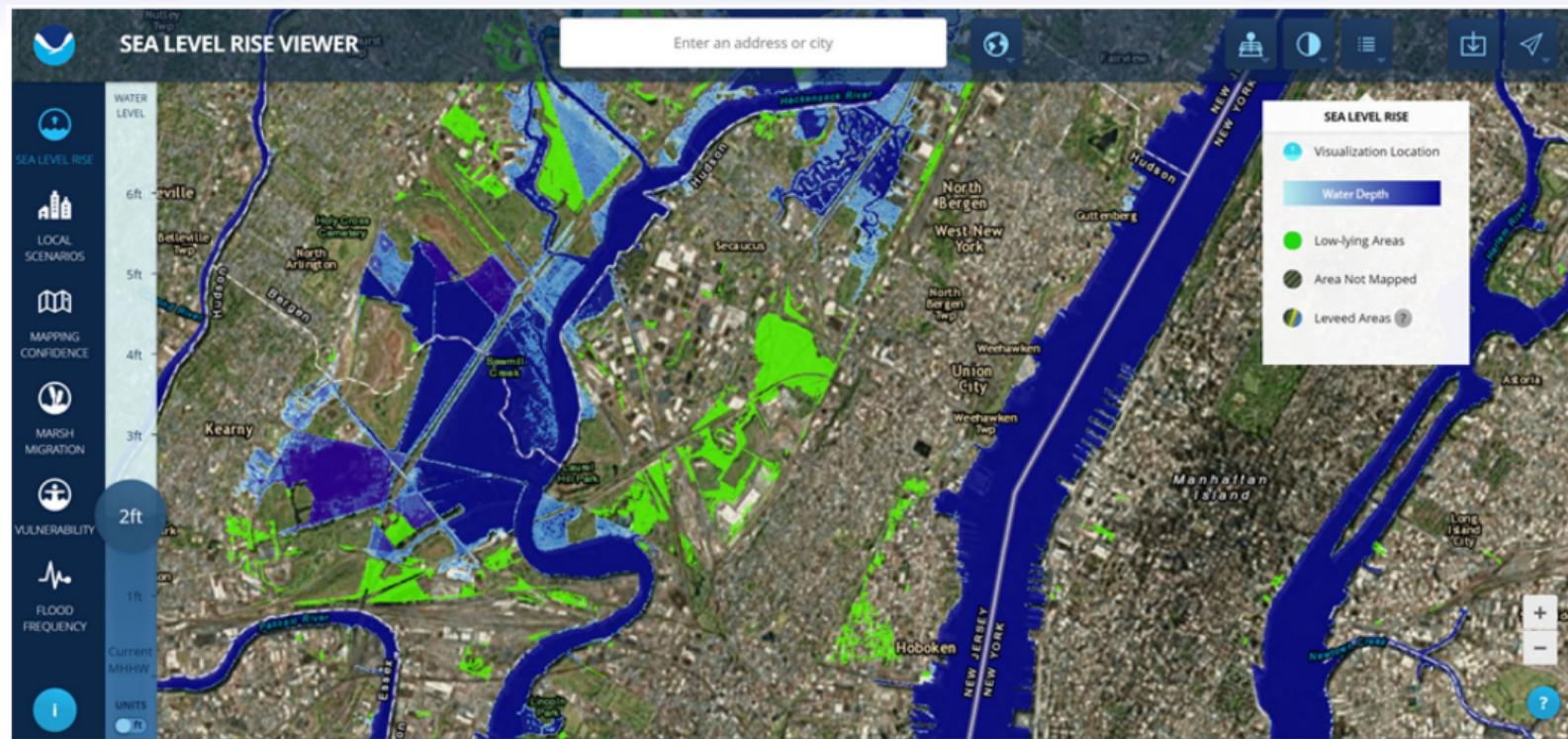
Google Search Volume for “Climate Change” around the Stern Review (Painter, 2019)

## The difference in issuance costs increases after the Stern Review



# Does the residential real estate market price climate risk?

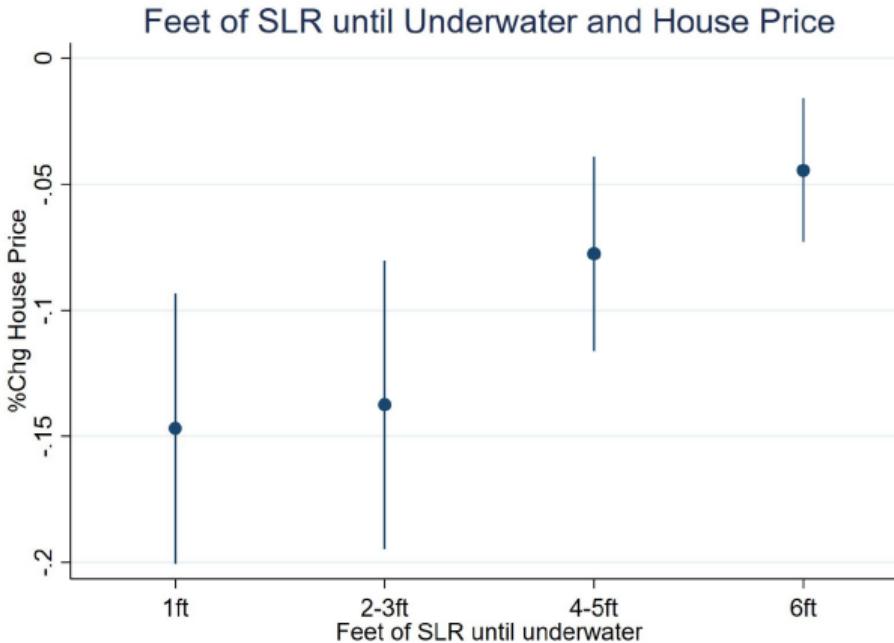
- **Murfin and Spiegel (2019)** - no
  - Measure sea level rise (SLR) risk using a continuous measure based on home's elevation and rates of subsidence/land rebound (Source - NOAA)
- **Bernstein, Gustafson, and Lewis (2019)** - yes, for sophisticated investors
  - Calculate SLR risk using dummy variables based on one foot increments (NOAA)
- **Baldauf, Garlappi, and Yannelis (2019)** - yes, if you believe in it
  - Dummy variable indicating if NOAA has designated a home at risk if seas rise six feet or more



- NOAA Database - NYC, NY. Light blue area indicates areas that will be inundated following a 2 foot increase in SLR

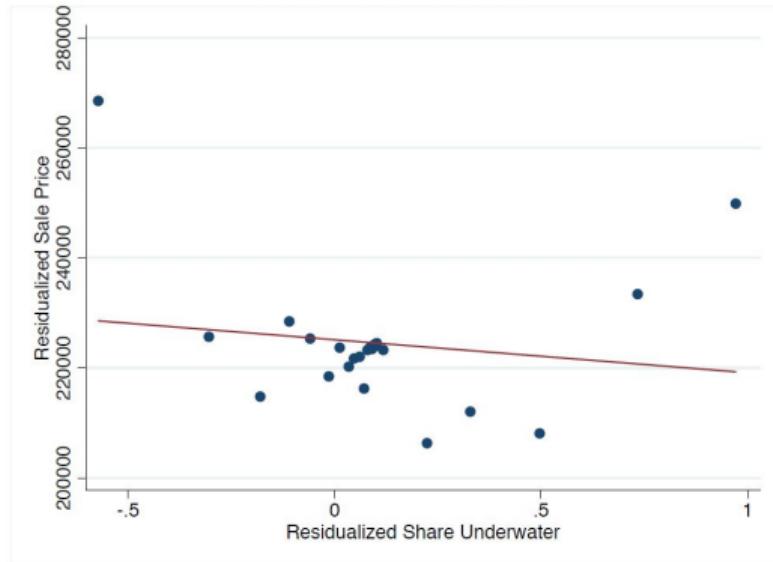
# Murfin and Spiegel (2019) - null result

| ln(Price)  | Full Sample<br>(1)   | Shoreline Sample<br>(2) | Shoreline Sample<br>(3) | Excl. flood zone<br>(4) | Excl. flood zone<br>(5) | 2015-2017<br>(6)     |
|--|----------------------|-------------------------|-------------------------|-------------------------|-------------------------|----------------------|
| ln(Elevation over MHHW)  | -0.003<br>(0.003)    | -0.004<br>(0.008)       | 0.002<br>(0.005)        | 0.002<br>(0.013)        | 0.013<br>(0.010)        | -0.004<br>(0.009)    |
| ln(Elevation over MHHW) x local RSLR trend   |                      | 0.000<br>(0.003)        |                         | 0.000<br>(0.005)        | -0.004<br>(0.003)       | 0.001<br>(0.003)     |
| Relative local SLR trend   | -                    | -                       | -                       | -                       | -                       | -                    |
| ln(sq. feet)   | 0.566***<br>(0.006)  | 0.566***<br>(0.006)     | 0.571***<br>(0.009)     | 0.571***<br>(0.009)     | 0.548***<br>(0.006)     | 0.529***<br>(0.008)  |
| ln(land sq. ft)  | 0.116***<br>(0.003)  | 0.116***<br>(0.003)     | 0.123***<br>(0.005)     | 0.123***<br>(0.005)     | 0.121***<br>(0.003)     | 0.117***<br>(0.003)  |
| ln(distance to coast)  | -0.117***<br>(0.004) | -0.117***<br>(0.004)    | -0.132***<br>(0.004)    | -0.132***<br>(0.004)    | -0.105***<br>(0.005)    | -0.113***<br>(0.004) |
| Beachfront   | 0.160***<br>(0.017)  | 0.160***<br>(0.017)     | 0.102***<br>(0.016)     | 0.102***<br>(0.016)     | 0.299***<br>(0.020)     | 0.171***<br>(0.017)  |
| Other Controls: Bed, Bath, Age, Flood Zone, Mobile<br>Year, Census Tract Fixed Effects | YES<br>YES           | YES<br>YES              | YES<br>YES              | YES<br>YES              | YES<br>YES              | YES<br>YES           |
| Observations   | 4,292,176            | 4,292,176               | 813,794                 | 813,794                 | 3,858,372               | 2,096,230            |
| R-squared  | 0.564                | 0.564                   | 0.605                   | 0.605                   | 0.583                   | 0.608                |

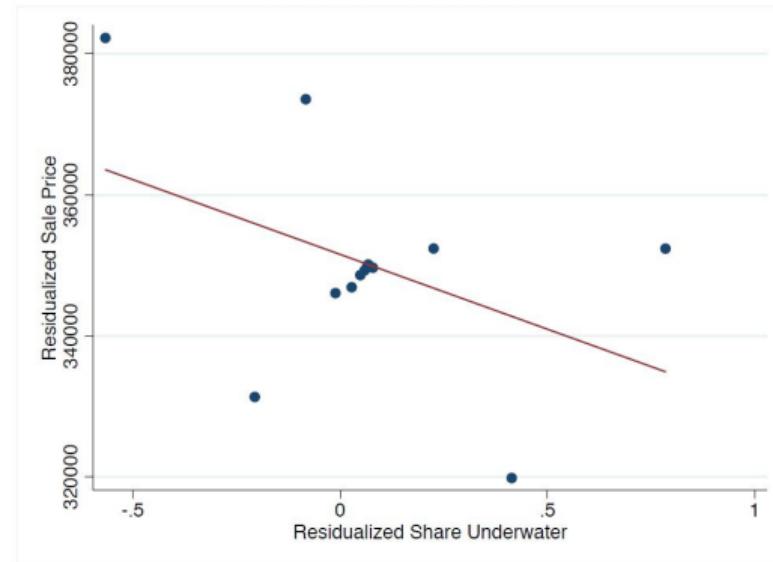


- Bernstein, Gustafson, and Lewis (2019). Includes fixed effects for zip code x time x distance-to-coast bin x Elevation Bin x owner occupied property and non-local buyer x condominium x total bedrooms. This difference is driven by **non-owner occupied homes**.

## Below Median



## Above Median



- Baldauf, Garlappi, and Yannelis (2019). Demeaned home prices and demeaned flood projections, split at the median based on belief of whether climate change is happening (**Yale climate change survey**).

# Does the stock market price climate risks?

Markets under react to climate induced droughts (Hong, Li, and Xu, 2019)

- A long-term trend towards drought for a country forecasts relatively poor profit growth and stock returns for companies in the food industry
- A cross-country long-short strategy earns a 4-factor alpha of 0.58% per month

Markets under react to a stock's sensitivity to temperature shocks (Kumar, Xin, and Zhang, 2019)

$$r_{i,t} - r_{f,t} = \alpha_i + \beta_i(r_{mkt,t} - r_{f,t}) + \theta_i \text{TempAnomaly}_t + \epsilon_{i,t} \quad (2)$$

- TempAnomaly is the difference between the current temperature at time t and the average temperature over the past 30 years in the same month.
- A long-short strategy based on climate sensitivity earns a risk-adjusted 3.6% alpha per year

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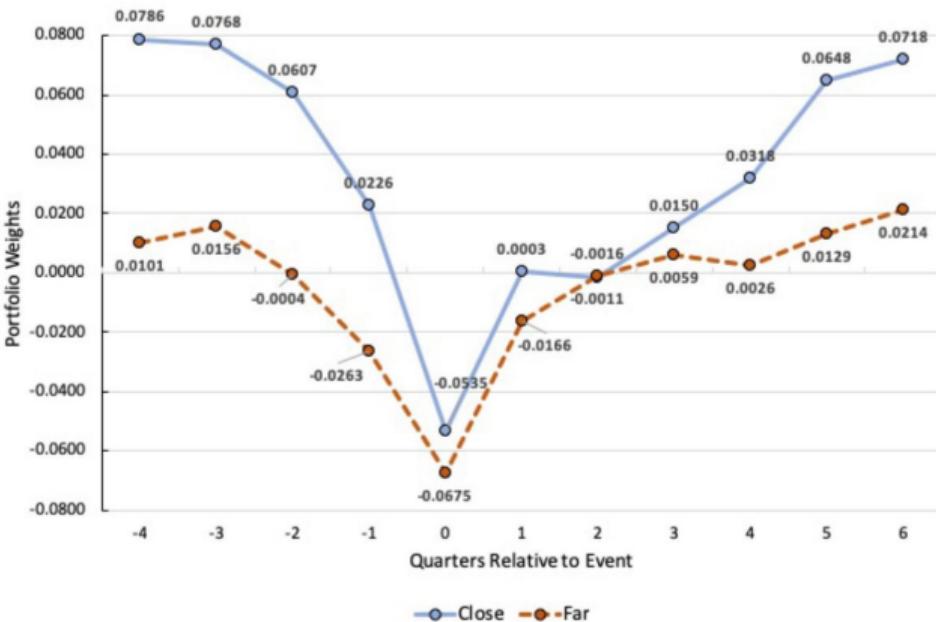
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## Fund managers may overreact to climate risks

Alok, Kumar, and Wermers (2019)

- Managers within a major disaster region underweight disaster-zone stocks to a much greater degree than distant managers
- "In the two years following a climatic disaster, the underweighted portfolio by funds in proximity of the disaster zone outperforms the overweighted portion of the portfolio by about 16%"



Trends demeaned by county, year, disaster quarter and fund

## Market pricing summary

### Everything is backwards!

- Markets recognize long-term climate risk but mis-estimate short-term climate risk
- Climate change is priced in municipal bond and real estate markets, but not in stock market

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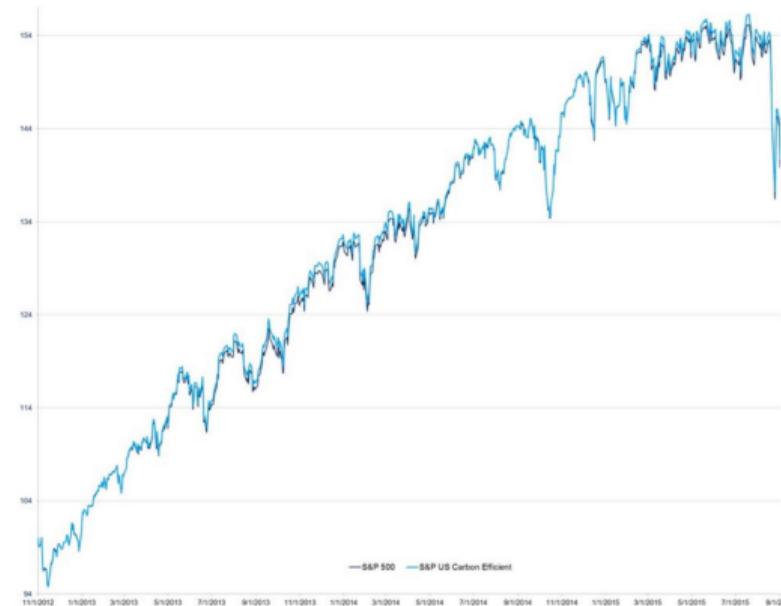
## Proposed solutions

- Hedging
- Green bonds
- Government intervention (and firm response)
- Rating agencies

# Hedging climate risk

Andersson, Bolton, and Samama, 2016

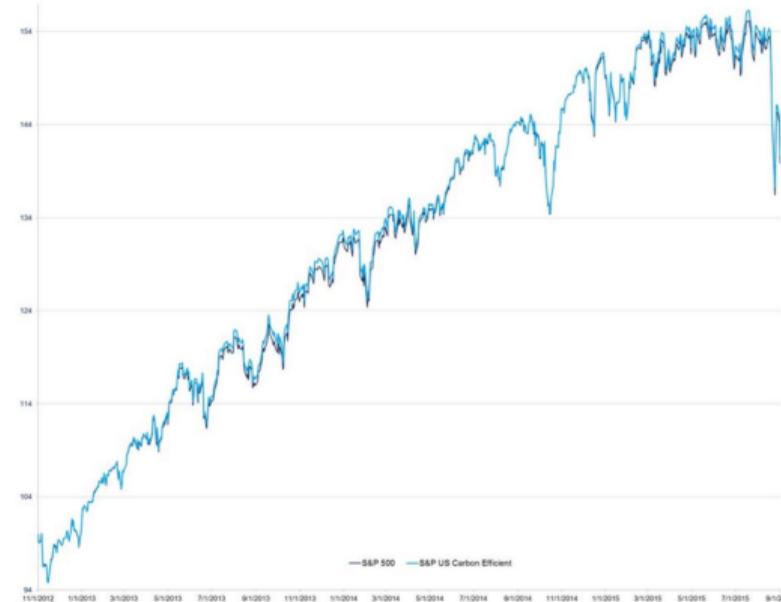
- Simply divesting all stocks with high carbon footprint risks underperforming the benchmark for a long time
- Carbon risk is asymmetrically concentrated in a few firms
- Optimization problem: excluding worst performers in terms of carbon intensity and reweighting the remaining stocks in the green portfolio so as to minimize tracking error
- As long as carbon risk stays unpriced by the market, the two indices will generate similar returns
- Carbon free index should outperform when carbon risk becomes priced



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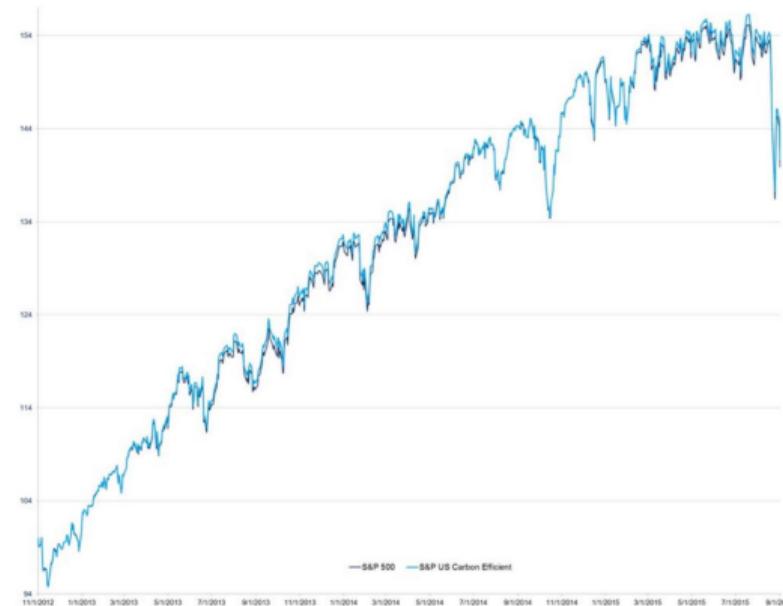
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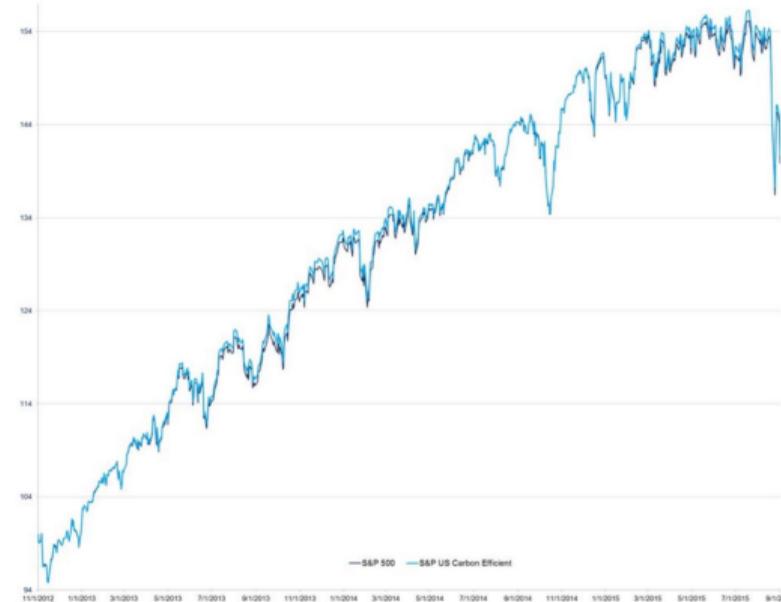
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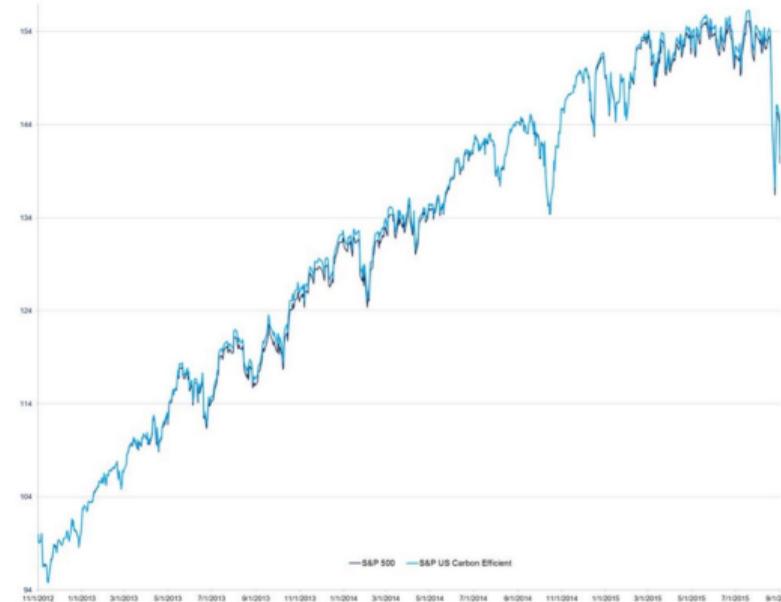
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## Green bonds (Baker, Bergstresser, Serafeim, and Wurgler, 2019)

- “Bonds whose proceeds are used for environmentally sensitive purposes”
- First bond issued in 2007 by the European Investment Bank
  - No universally recognized system for granting “green” status
  - External certifications exist through the Climate Bond Initiative, among others
- Baker et al study green US municipal bonds, their characteristics, and their pricing

## What is a green bond?

- Bloomberg's definition: "all issuers must commit to deploying 100% of bond proceeds for environmental sustainability-oriented activities in order for their bond to be identified as a labeled green bond"
- Examples include renewable energy, green infrastructure, clean transportation, sustainable water management, pollution control, climate change adaptation, etc.
- Most popular uses for green munis include public power, mass transit, education, and water and sewer projects

## Green bond issuances

| <b>Year</b>        | <i>Green</i>        |                       | <i>Ordinary</i> |               |
|--------------------|---------------------|-----------------------|-----------------|---------------|
|                    | <b>Unique Bonds</b> | <b>Unique Issuers</b> | <b>\$ (M)</b>   | <b>\$ (M)</b> |
| Panel A. Municipal |                     |                       |                 |               |
| 2010               | 116                 | 32                    | 466             | 255,000       |
| 2011               | 97                  | 34                    | 137             | 180,000       |
| 2012               | 106                 | 24                    | 180             | 261,000       |
| 2013               | 78                  | 15                    | 261             | 224,000       |
| 2014               | 309                 | 22                    | 2,130           | 244,000       |
| 2015               | 593                 | 38                    | 2,940           | 309,000       |
| 2016               | 784                 | 39                    | 6,530           | 353,000       |
| Total              | 2,083               | 204                   | 12,644          | 1,826,000     |

- Baker et al (2019)

## Do green bonds sell at a discount or premium?

- A premium!
  - In their multivariate regression model, Baker et al find green bonds are issued at after-tax yields around five to seven basis points lower than those of ordinary bonds.
  - Bonds with a CBI certification have even lower yields
- Why? When some investors have an additional nonpecuniary preference for a security, they bid up its price
  - Consistent with this prediction, green bonds have more concentrated ownership, particularly for those with low market values and low risk
- What does this imply? The green bond premium is unlikely to last as the size of the market increases

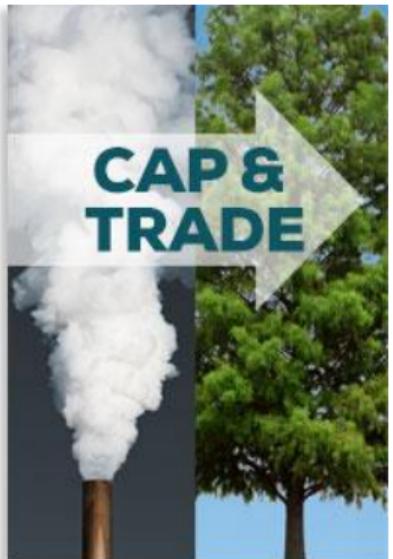
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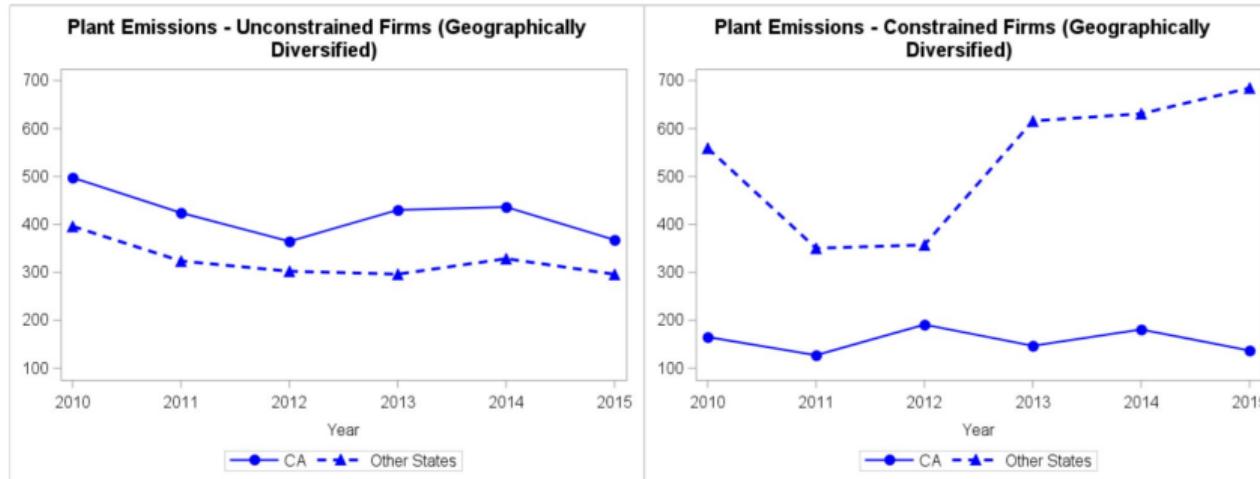
## Real effects of climate policy - California's cap and trade program



Bartram, Hou, and Kim, 2019

- Cap-and-trade rule is based on an allocation of capped allowances with specific year vintages and the market trading of those allowances
- Firms are required to pay off their plants emissions using these and additional allowances they may buy via market transactions, according to a vintage specific schedule laid out by the program.
- So what's the problem? This only affects plants in California!

## Results of California's cap and trade program



- Financially constrained firms reduce emissions by 35% in CA plants relative to plants in other states, but increase emissions in their non-CA plants by 29% more than firms without CA presence
- Compared to unconstrained firms, constrained firms are less likely to invest in plants in CA, and more likely to invest in plants in other states
- Constrained firms increase their total emissions by as much as 19%

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## Do investors account for credit ratings in the muni market?



The image shows a screenshot of a Bloomberg news article. The header features the Bloomberg logo and navigation links for Markets, Tech, Pursuits, Politics, Opinion, and Businessweek. The main title of the article is "Moody's Warns Cities to Address Climate Risks or Face Downgrades", written in large, bold, black capital letters. Below the title, the author is listed as "By Christopher Flavelle" and the date as "November 29, 2017, 4:00 AM EST".

*"Higher rated sovereigns tend to be less susceptible to climate change risks... In contrast, sovereigns with a greater reliance on agriculture, lower incomes, weaker infrastructure quality, and smaller fiscal capacity exhibit greater susceptibility to the physical effects of climate change."*

## Issuance costs are only higher for long-term bonds with poor credit ratings

| Credit Rating:   | Long-Term          |                  | Short-Term       |                  |
|------------------|--------------------|------------------|------------------|------------------|
|                  | < AA-              | ≥ AA-            | < AA-            | ≥ AA-            |
| Ln(Climate Risk) | 0.527**<br>(2.041) | 0.141<br>(0.686) | 0.107<br>(0.878) | 0.091<br>(0.634) |
| Controls         | Yes                | Yes              | Yes              | Yes              |
| State-Year FE    | Yes                | Yes              | Yes              | Yes              |

Painter (2019)

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Painter (2019)

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# Roadmap

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Conclusion

## Conclusion

- Institutional investors have growing concerns toward climate risk
- Markets generally react to long-term climate risk but mis-estimate short-term climate risk
  - Research also consistently finds markets are getting better at pricing climate change over time
- It is early days in finding solutions to climate change, but policies need to internalize potential externalities and factor in the market's potential to recognize climate risk
- Other references
  - RFS Climate Finance Conference program
  - Columbia University Center on Energy Policy climate report and lit review