Climate Finance: How climate change affects financial markets, and what to do about it?

Johannes Stroebel
NYU Stern & NBER

October 2021
Banco Central de Chile
Macroeconomic and Financial Implications of Climate Change

Motivation

- In addition to high humanitarian costs, climate change poses a risk to economic activity, asset values, and potentially financial stability
  - Physical Risk (e.g., rising sea levels, floods, and wildfires)
  - Transition Risk (e.g., regulation and technological change)
- Evidence that these climate risks are priced across many asset classes
  - Real estate (Giglio, Maggiori, Rao, Stroebel and Weber, 2021)
  - Equities (Engle et al, 2020; Bolton and Kacperczyk, 2020)
  - Municipal Bonds (Painter, 2020)
  - Sovereign debt? Crypto assets? Commodities?
  - Giglio, Kelly and Stroebel (2021 Annual Review of Financial Economics)

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- Larry Fink (CEO of BlackRock): "Climate Risk is Investment Risk"

REUTERS

Wall Street increasingly weighs risk from climate change

FEDS Notes

March 19, 2021

Climate Change and Financial Stability

Celso Brunetti, Benjamin Dennis, Dylan Gates, Diana Hancock, David Ignell*, Elizabeth K. Kiser, Gurubala Kotta, Anna Kovner *, Richard J. Rosen **, Nicholas K. Tabor

Corresponding authors: Diana Hancock and Elizabeth K. Kiser

NYU LEONARD N. STERN SCHOOL OF BUSINESS

Climate Finance: An Economic and Financial Approach to Climate Change

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- Important Question: Can you use financial markets to build hedge portfolios to reduce your exposure to various climate risks?

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- Few (if any) dedicated financial instruments that offer a direct and targeted hedge against specific climate risks
  - Insurance contracts: Counterparty Risks
  - Derivative contracts: Huge potential, but currently small market

Motivation

- Important Question: Can you use financial markets to build hedge portfolios to reduce your exposure to various climate risks?
- Few (if any) dedicated financial instruments that offer a direct and targeted hedge against specific climate risks
  - Insurance contracts: Counterparty Risks
  - Derivative contracts: Huge potential, but currently small market
- Alternative approach (Engle et al., 2020): Sequence of short-lived portfolios that hedge *news* about the severity of climate risks
  - This dynamic strategy replaces the idealized (and infeasible) long-dated, buy and hold derivative or insurance contract (Merton)

Motivation

To implement this strategy, you need to address two questions:

1. What news series should be your hedge target?
    - Following Engle et al. (2020), researchers constructed various climate news series based on textual analyses of newspaper coverage
    - News about physical or regulatory risk? How to measure sentiment?

Motivation

To implement this strategy, you need to address two questions:

1. What news series should be your hedge target?
   - Following Engle et al. (2020), researchers constructed various climate news series based on textual analyses of newspaper coverage
   - News about physical or regulatory risk? How to measure sentiment?
2. How do you construct the optimal hedge portfolio (i.e., portfolio that will outperform on realization of bad news about climate risk)?
   - Existing approaches to constructing hedge portfolios not work well with limited time-series data

Existing Hedge Approaches

- **Approach I:** "Narrative Approach"
  - Uses beliefs on predetermined relationships, based on factors such as business models

    > *"Solar companies will do well when there is bad news about climate change since this makes a carbon tax more likely."*

  - Direction hard to predict beyond a few obvious examples, but ideally use all assets for diversification
  - Engle et al. (2020): Systematic approach forming long-short portfolios on E-Score (or data on carbon emissions, etc.)
    - Required data usually not available or low quality
    - Scores unreliable & barely correlated across providers (Billio et al., 2020)
    - Modest hedge performance

Existing Hedge Approaches

- **Approach II:** "Mimicking Portfolio Approach"
  - Infer hedge portfolio based on past time-series relationships between news and prices
  - Project climate news series on a set of asset or portfolio returns

$$ClimateNews_t = \beta^Z \mathbf{Z}_t + e_t$$

  - Use fitted β^Z to construct portfolios, then compare next period return with next period climate news realization
  - Proposed by Lamont (2001) to hedge realizations of economic shocks such as inflation
  - **Challenge:** Curse of dimensionality; large asset space and short time series make stable out-of-sample results difficult
  - Special challenge for climate risk, which was likely not priced 10 years ago, and which does not feature very regular "news"

A Quantity-Based Approach to Constructing Climate Risk Hedge Portfolios

Georgij Alekseev
NYU Stern

Stefano Giglio
Yale & NBER

Quinn Maingi
NYU Stern

Julia Selgrad
NYU Stern

Johannes Stroebel
NYU Stern & NBER

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This Paper: Quantity-Based Hedge Approaches

- Propose new approach based on trading responses to news shocks received by some investors
  - Additional information from the cross-section of investors
  - Useful for (i) structural breaks or (ii) new risks such as climate change

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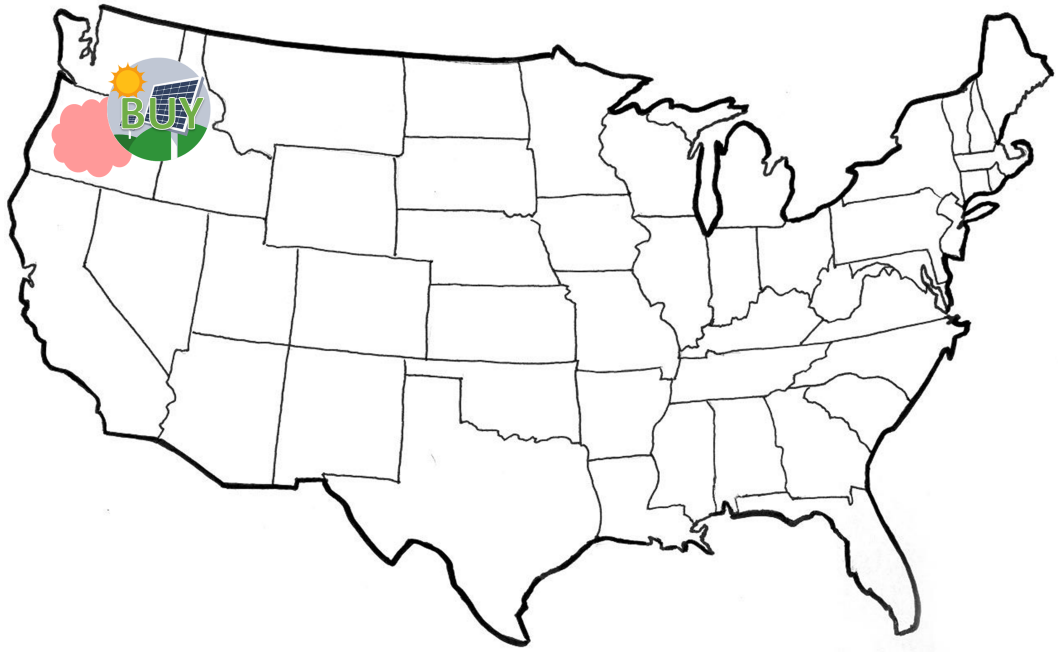

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- Suppose climate change awareness or concern increases in Oregon

This Paper: Quantity-Based Hedge Approaches

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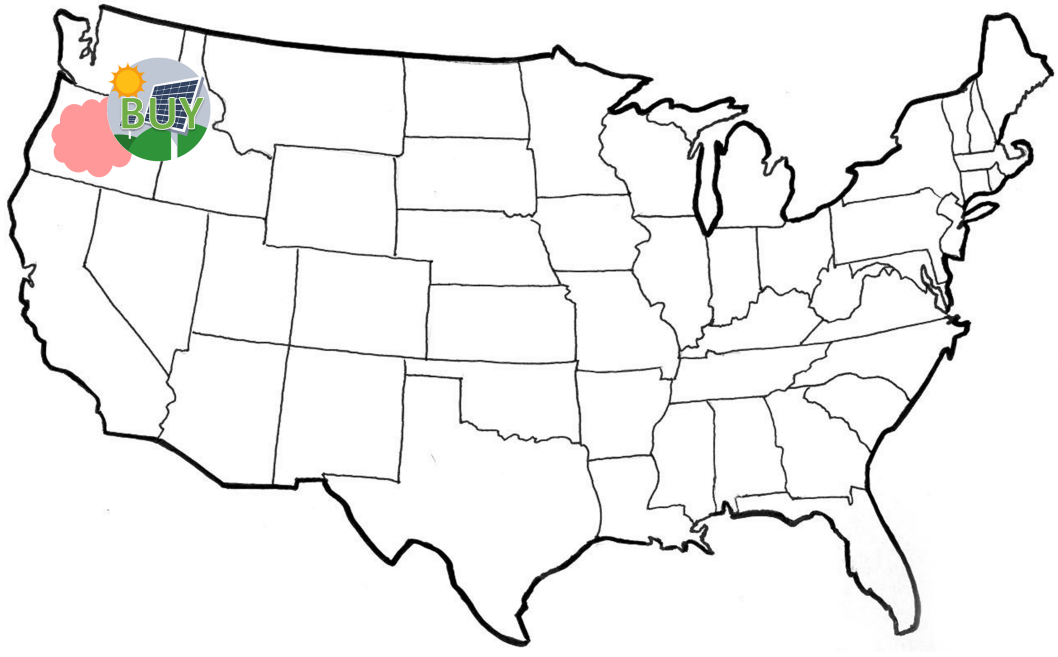

Graphs/Slide4.png

- Suppose climate change awareness or concern increases in Oregon
- Observe: Oregon-based investors disproportionately buy solar stocks
  - No price changes because affected investor base is small
- Still informative about what would hedge a national news shock

This Paper: Quantity-Based Hedge Approaches

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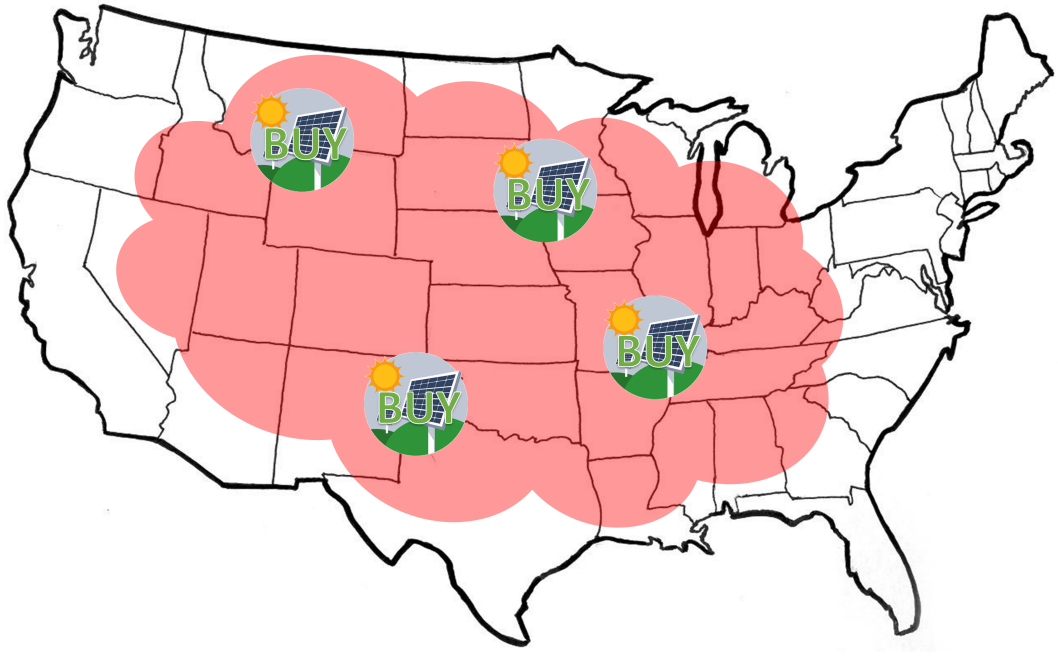

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- Now, what if we had a similar *national* shift in climate change awareness or concern (e.g., the arrival of news we want to hedge)
  - All investors now buy solar stocks $\rightarrow$ prices rise
  - Solar stocks thus hedge the national climate news series

Quantity-Based Hedge Approaches

- Comparing the quantity-based and mimicking approach:
  - National shock $\rightarrow$ price response $\propto$ demand elasticity to news
    - We have not seen many national news shocks in short time series
  - Local shock $\rightarrow$ local quantity response $\propto$ demand elasticity to news
- **Insight:** Quantity response to local news can determine demand elasticities, which are informative about the price response to global news

Quantity-Based Hedge Approaches

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- Which *industries* are disproportionately bought and sold in a given quarter by mutual fund managers located in areas with heat shocks?
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- **Finding I:** Long-short portfolios on this characteristic outperform other approaches to hedging various climate risk news series

Quantity-Based Hedge Approaches

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- Which *industries* are disproportionately bought and sold in a given quarter by mutual fund managers located in areas with heat shocks?
    - Approach expands to individual equities, other asset classes, etc.
- **Finding I:** Long-short portfolios on this characteristic outperform other approaches to hedging various climate risk news series
- **Finding II:** Approach also works well for hedging national house price and unemployment series
    - Based on insight from Kuchler and Zafar (2019) of local extrapolation

Roadmap

1. Constructing Local Heat Shocks
2. Determining Fund Industry Changes
3. Building the Hedge Portfolio
4. Choosing a Climate News Series
5. Hedge Performance
6. Conclusion

Constructing Climate Awareness / Climate News Shocks

- **Objective:** Shocks that are localized, but shift climate attention / climate beliefs of local population

Constructing Climate Awareness / Climate News Shocks

- **Objective:** Shocks that are localized, but shift climate attention / climate beliefs of local population
- Many studies show that local **heat** shocks shift climate change beliefs (Joireman et al., 2010; Li et al., 2011; Deryugina, 2013; etc.)
- Construct three local heat shocks using data from SHELDUS (Spatial Hazard Events and Losses Database) and PRISM temperature data:
  1. Injuries or fatalities.
  2. High crop indemnity payments
  3. 10-year record of 3-month-average county temperature
- First two more likely in places with extreme absolute heat, last one equally likely everywhere
- The three classes of heat shocks are only weakly correlated

Constructing Local Heat Shocks

- Question: Do our local heat shocks shift climate change awareness?
- Regress heat shock dummies on the Google search volume for "climate change" during month t in state s
- Time horizon: 2010 - 2019

$$\log(\widetilde{G_{t,s}}) = \beta_S S_{t,s} + \delta_s + \gamma_t + \epsilon_{t,s}$$

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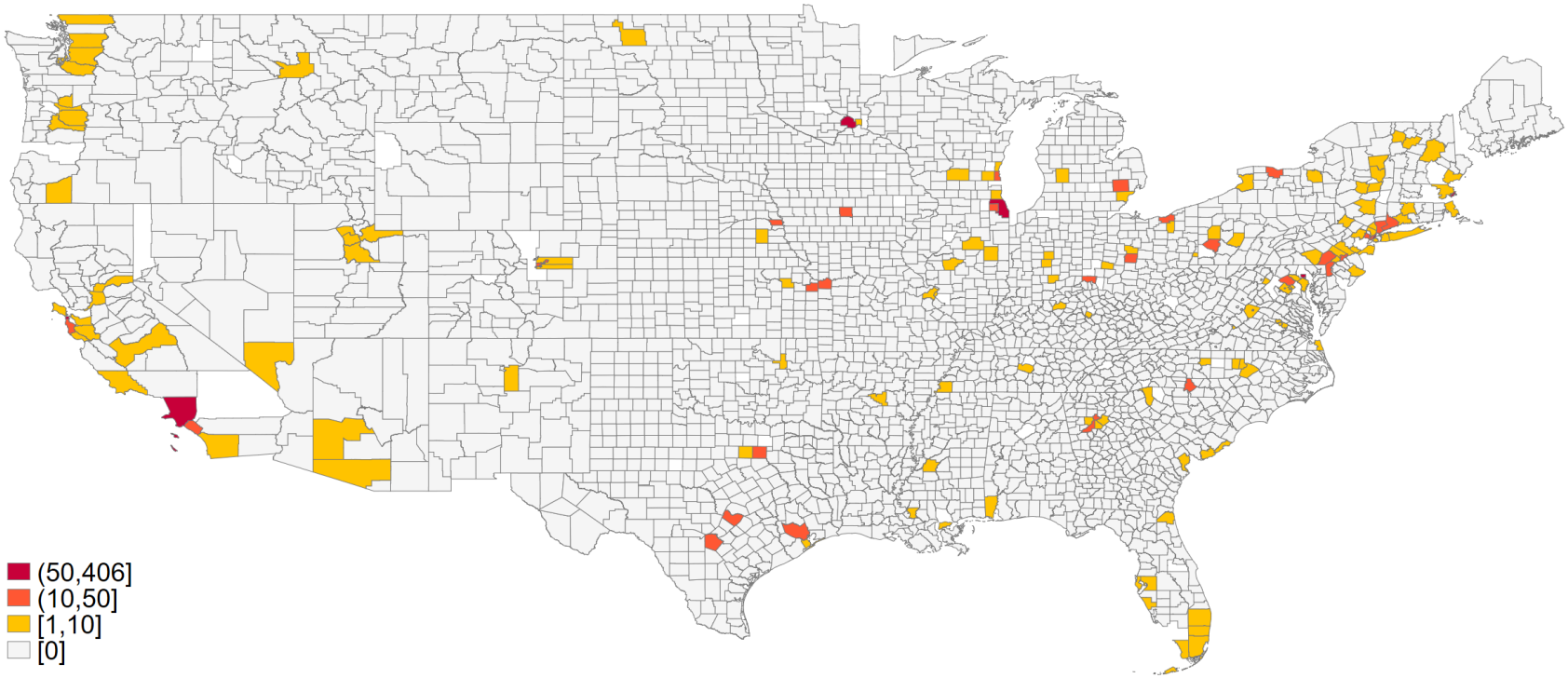
	Log(Google Search Volume)		
Heat: Fatalities/Injuries	0.05**		
	(0.03)		
Heat: High Indemnities		0.07**	
		(0.03)	
Heat: Record Temperature			0.08**
			(0.04)
R^2	0.77	0.77	0.77
State & Month FE	Y	Y	Y
N	5,506	5,506	5,506

Determining Fund Industry Changes

- Which assets are disproportionately bought/sold by mutual fund managers exposed to heat shocks?
  - Focus here on equities, but in principle could include many other assets
  - Focus here on 24 industry portfolios (GICS 4-digit), but could do this for individual equities (sparser holdings)
- We measure industry-level holding changes in three-month intervals
  - Thomson Reuters Mutual Fund Holdings S12 database
    - Restrict to the subset of *Equity Domestic Non-Sector* funds
  - Mutual fund adviser locations parsed from SEC filings (N-SAR until 2017; N-CEN from 2018)

Determining Fund Industry Changes

- Sample characteristics:
  - 2,496 unique mutual funds, 276 unique counties
  - 25.8% in NY; 14.3% in MA; 10.3% in CA



Determining Fund Industry Changes

$$ActiveChanges^{I}_{f,t} = \left(\frac{\Delta^{Active} IndPFShare^{I}_{f,t,t-1}}{IndMarketShare^{I}_{t}} \right),$$

- $\Delta^{Active} IndPFShare^{I}_{f,t,t-1}$:
  - Active changes in portfolio share in industry I (i.e., holding prices fixed)
- Normalization by industry market share:
  - Increase in holdings of a small industry more meaningful than increase in holdings of a large industry
  - More likely to induce price changes in aggregate (our objective)

Determining Fund Industry Changes

$$ActiveChanges^{I}_{f,t} = \left(\frac{\Delta^{Active} IndPFShare^{I}_{f,t,t-1}}{IndMarketShare^{I}_{t}} \right),$$

- Interpretation: change in relative industry exposure, when holding prices constant, and scaled by relative industry size
- $ActiveChanges^{I}_{f,t} = 0 \longrightarrow$ industry I's relative weight unchanged
- $ActiveChanges^{I}_{f,t} = 1 \longrightarrow$ industry I's relative weight increased by relative industry size
  - For example, if I makes up 10% of the market, and the fund increased I from 5% to 15%, then $ActiveChanges^{I}_{f,t} = 1$

Industry Climate Quantity Betas

- Industry I's "climate quantity beta" is then determined by regressing

$$ActiveChanges^{I}_{f,t} = \beta^{I}_{t} S_{loc(f),t} + \delta^{I}_{t} + \epsilon^{I}_{f,t},$$

  where $S_{loc(f),t}$ is a local time-varying heat shock and δ^{I}_{t} captures time fixed-effects

- We re-estimate β^{I} for each month with a five-year rolling window to create a series of five-year rolling industry climate betas $\{\widehat{\beta^{I}_{t}}\}$

- The β^{I} coefficients give the portfolio weights in the hedge portfolio

- *Identifying assumption:* The only reason investors in a given county are disproportionately buying a certain industry during extreme heatwaves is because this shifts their beliefs about climate change

Industry Climate Quantity Betas

- While the shocks are almost independent sources of information, they select similar hedge portfolios
- Spearman rank correlation among climate quantity betas calculated over 2015-2019

	Fatalities/Injuries	Indemnities	Record Temperature
Heat: Fatalities/Injuries	1.00		
Heat: Indemnities	0.42	1.00	
Heat: Record Temperature	0.29	0.28	1.00

- Also similar industries selected in split samples across time, space, and funds.

Industry Climate Quantity Betas

GICS	Description	Avg.	Fatalities/Injuries	Indemnities	Record Temp.
2510	Auto & Components	0.11	0.07	0.15	0.15
4520	Tech. Hardw. & Equip.	0.09	0.05	0.21	0.06
2030	Transportation	0.06	0.02	0.13	0.08
4530	Semiconductors & Equip.	0.05	0.05	−0.01	0.12
3010	Food & Staples Retailing	0.04	0.03	0.08	0.03
5010	Communication Services	0.03	0.04	0.02	0.00
1010	Energy	0.02	0.03	0.04	−0.01
3020	Food, Bev. & Tobacco	0.02	0.01	0.07	−0.01
4020	Diversified Financials.	0.02	0.01	0.01	0.04
5510	Utilities	0.02	0.01	0.03	0.02
4010	Banks	0.02	0.04	0.01	−0.03
2010	Capital Goods	0.02	0.01	0.06	0.00
4510	Software & Services	0.00	0.01	−0.04	0.03
4030	Insurance	−0.00	−0.03	0.06	0.00
3520	Pharma., Biotech., & Life Sc.	−0.01	0.01	−0.02	−0.02
6010	Real Estate	−0.01	−0.03	0.00	−0.00
5020	Media & Entertainment	−0.02	−0.03	0.05	−0.06
3030	Household & Pers. Prod.	−0.02	0.01	−0.07	−0.03
2530	Consumer Services	−0.02	−0.06	−0.02	0.05
1510	Materials	−0.03	−0.03	−0.01	−0.03
3510	Health Care Equip. & Serv.	−0.03	−0.02	−0.07	−0.01
2550	Retailing	−0.05	−0.07	0.01	−0.05
2520	Consum. Durables & Apparel	−0.06	0.02	−0.19	−0.08
2020	Commercial & Prof. Serv.	−0.12	−0.13	−0.28	0.09

Table: Most recent (2015-2019) industry climate beta coefficients

Industry Climate Quantity Betas

- Signal is relatively robust across subsamples
  - Correlation between coefficients determined from two mutually exclusive random subsamples
  - The correlation displayed is the average from 100 independent iterations

Panel A: Random Split within Groups

	Stratified		Fully Random	
Climate Shock	Spearman	Pearson	Spearman	Pearson
Heat: Fatalities/Injuries	0.42	0.44	0.37	0.39
Heat: High Indemnities	0.24	0.29	0.22	0.29
Heat: Record Temperature	0.32	0.23	0.28	0.17

Panel B: Random Split between Groups

	Fund Split		Period Split		Location Split	
Climate Shock	Spearman	Pearson	Spearman	Pearson	Spearman	Pearson
Heat: Fatalities/Injuries	0.41	0.44	0.18	0.17	0.30	0.30
Heat: High Indemnities	0.22	0.29	0.21	0.22	0.07	0.04
Heat: Record Temperature	0.30	0.20	0.21	0.11	0.22	0.24

Building the Hedge Portfolio

- For each month t and for each type of local heat shock S, we construct the excess return of the quantity hedge portfolio as:

$$QP_{S,t} = \sum_{I} \widehat{\beta^{I}_{S,t}}(R^{I}_{t} - R^{f}_{t})$$

- R^{I}_{t} is the industry portfolio return
- R^{f}_{t} denotes the risk-free rate

Factor-loadings of hedge portfolio

Hedge Performance?

- Can these quantity portfolio returns hedge national climate news?
- How do we measure such news?
  - Different climate news indices can capture different types of climate risk
- We test performance against a range of climate news series produced in the literature
  - Measure of success: Out-of-sample correlation with news innovations
- How does our quantity-based approach perform in terms of hedging innovations in these climate news series?
  - Test period: Monthly innovations between 2015-2019
  - For data-driven approaches (quantity or mimicking portfolio): Use 5-year rolling window
  - Out of sample hedges approximate performance achievable in real time

Quantifying Climate Risk

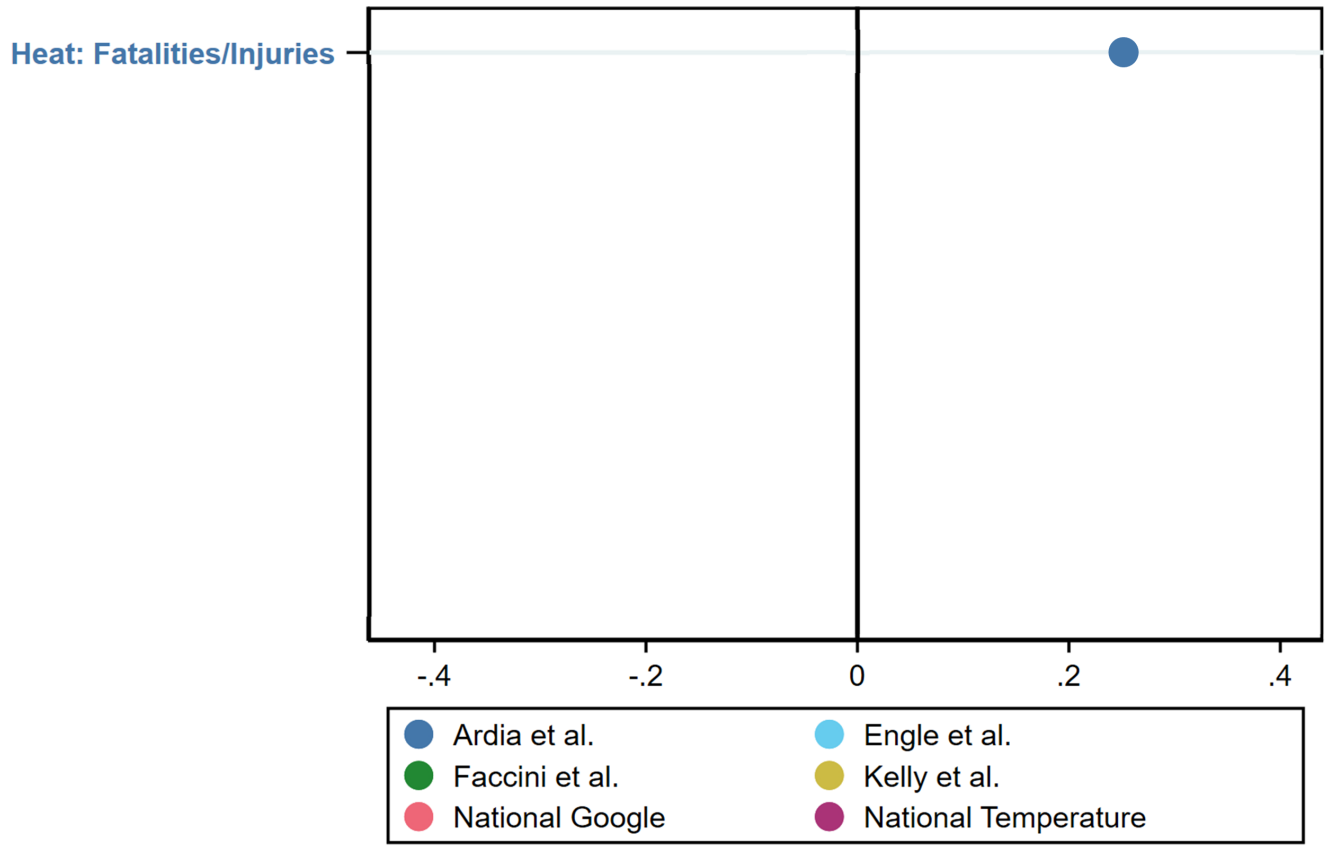
Many approaches representing a distinct mix of climate risks:

- **Engle et al. (2020):** WSJ news index (count news) and Crimson Hexagon Negative News (adds sentiment)
- **Ardia et al. (2021):** Expand on WSJ by including multiple media outlets and identifying sentiment
- **Faccini et al. (2021):** International summits, global warming, natural disasters, and narrative
- **Kelly (2021):** Machine learning signed indices for general, physical, and transitional risk
- National Google search trends
- National temperature innovations

$\rightarrow$ Moderate correlation between innovations in the various climate news measures

Hedge Performance - Main Results

Out-of-sample correlation between hedge portfolio and climate news innovation



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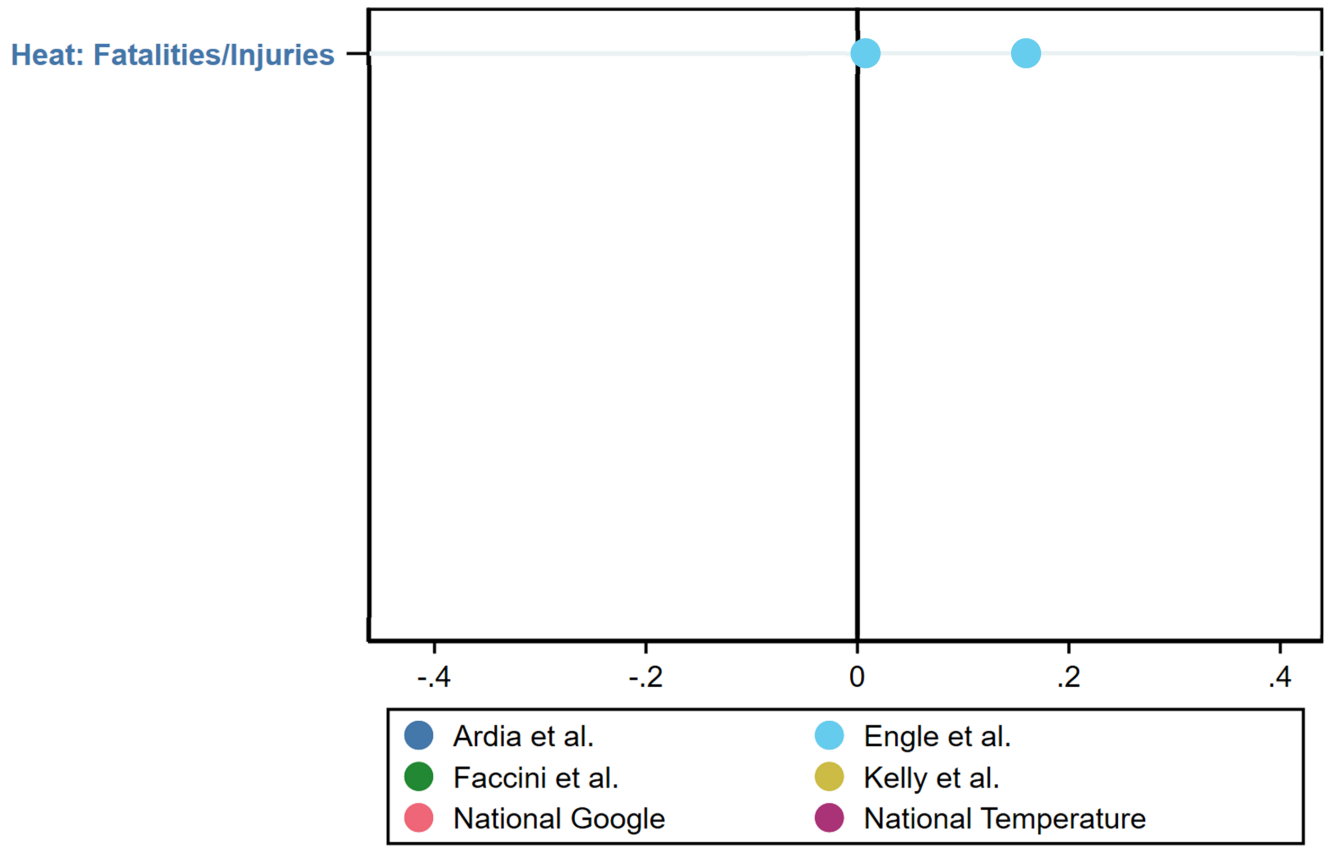

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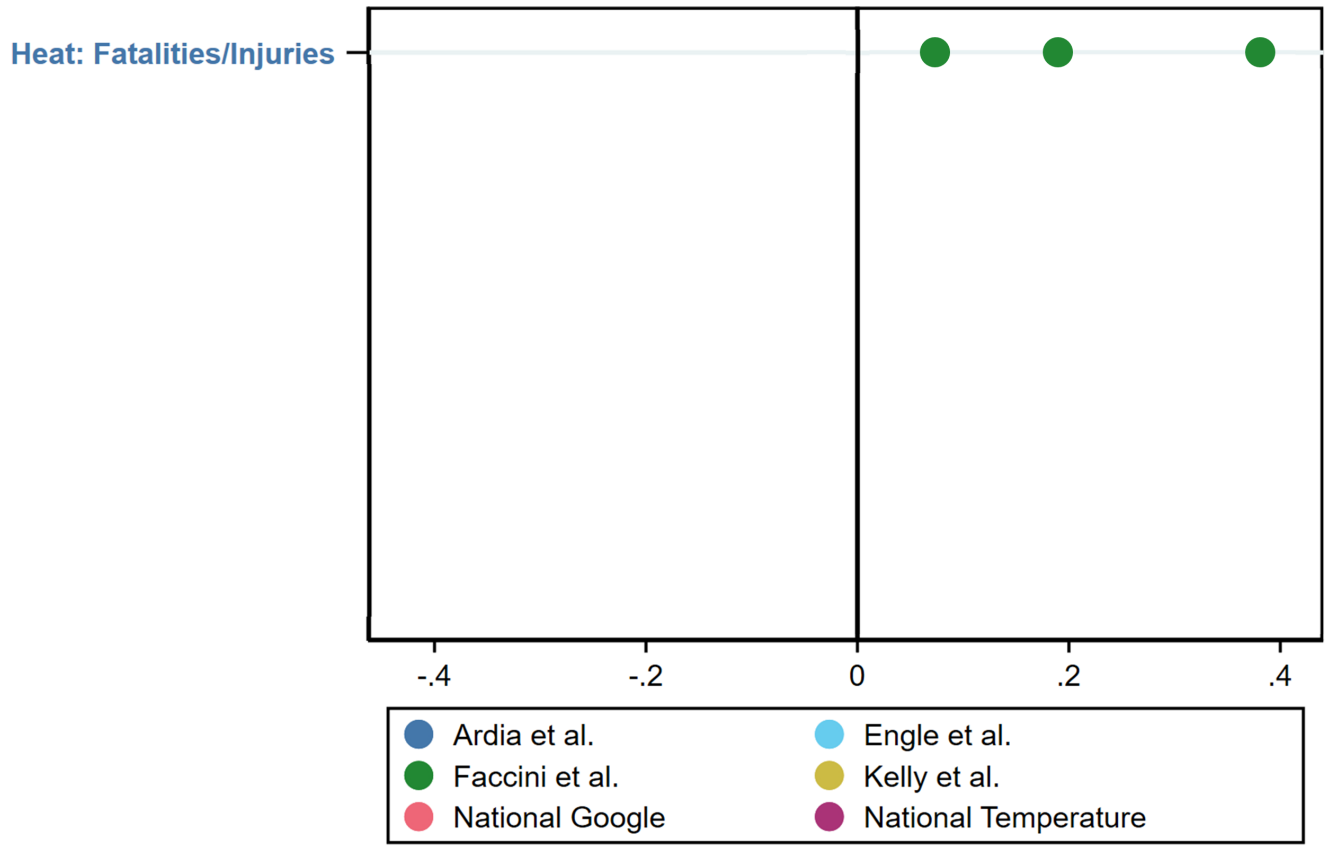

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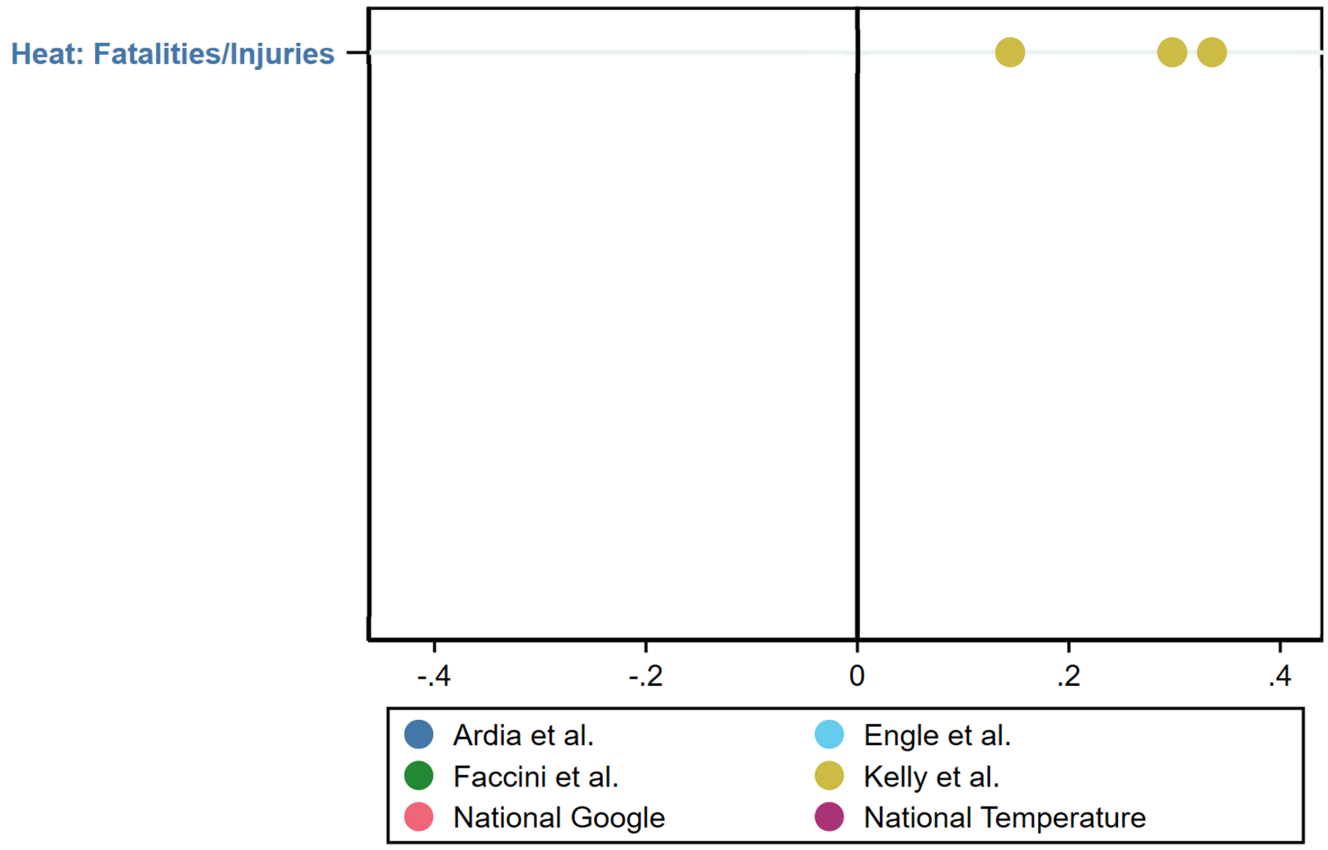

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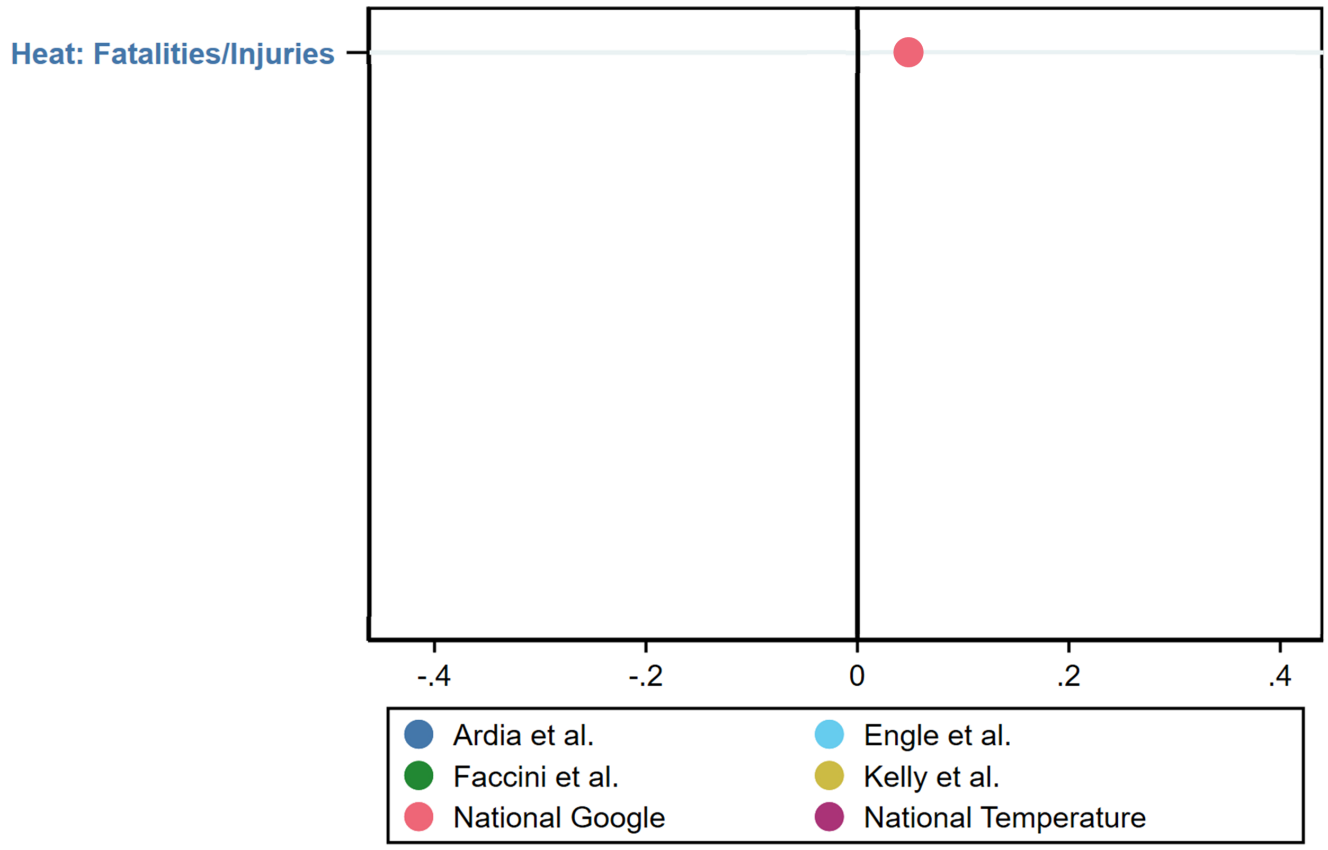

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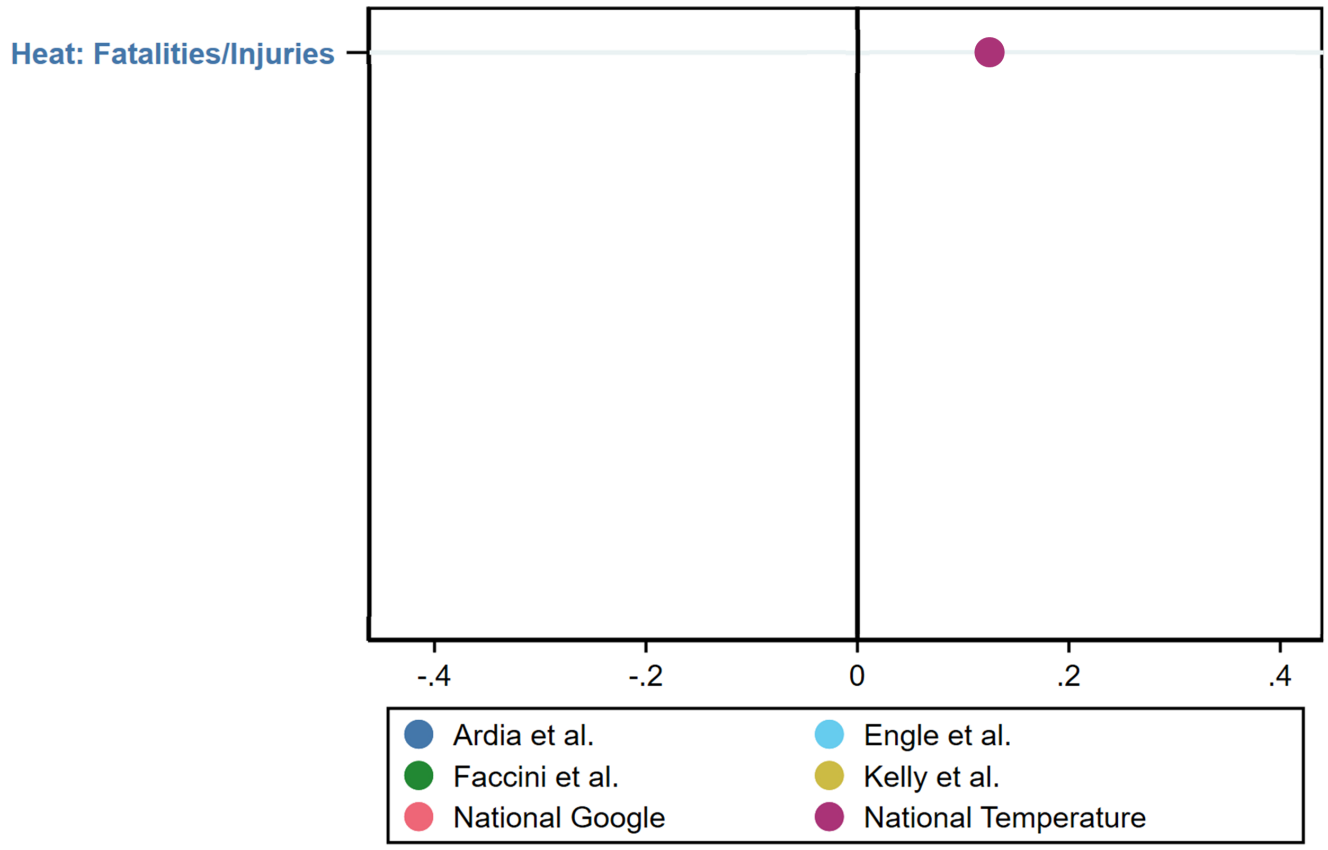

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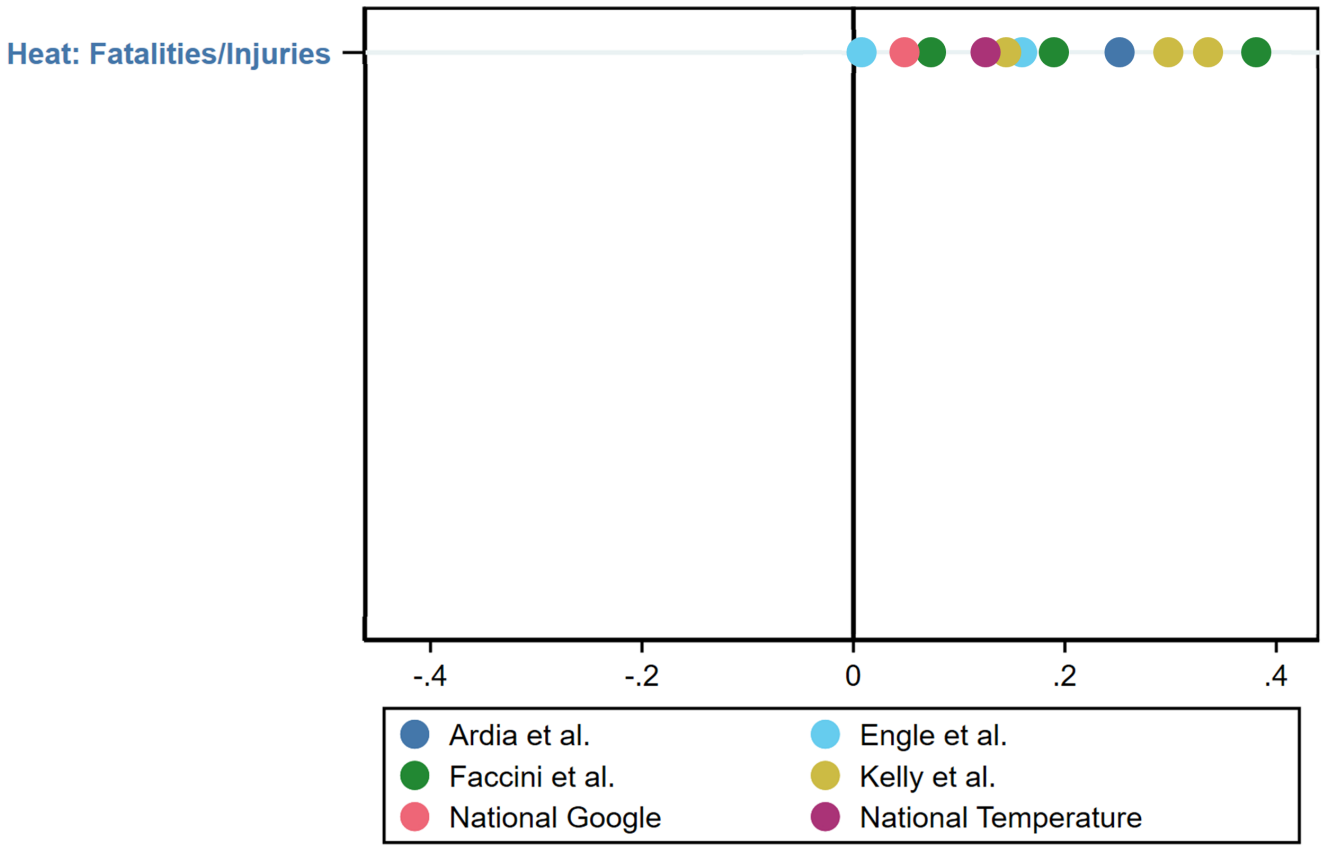

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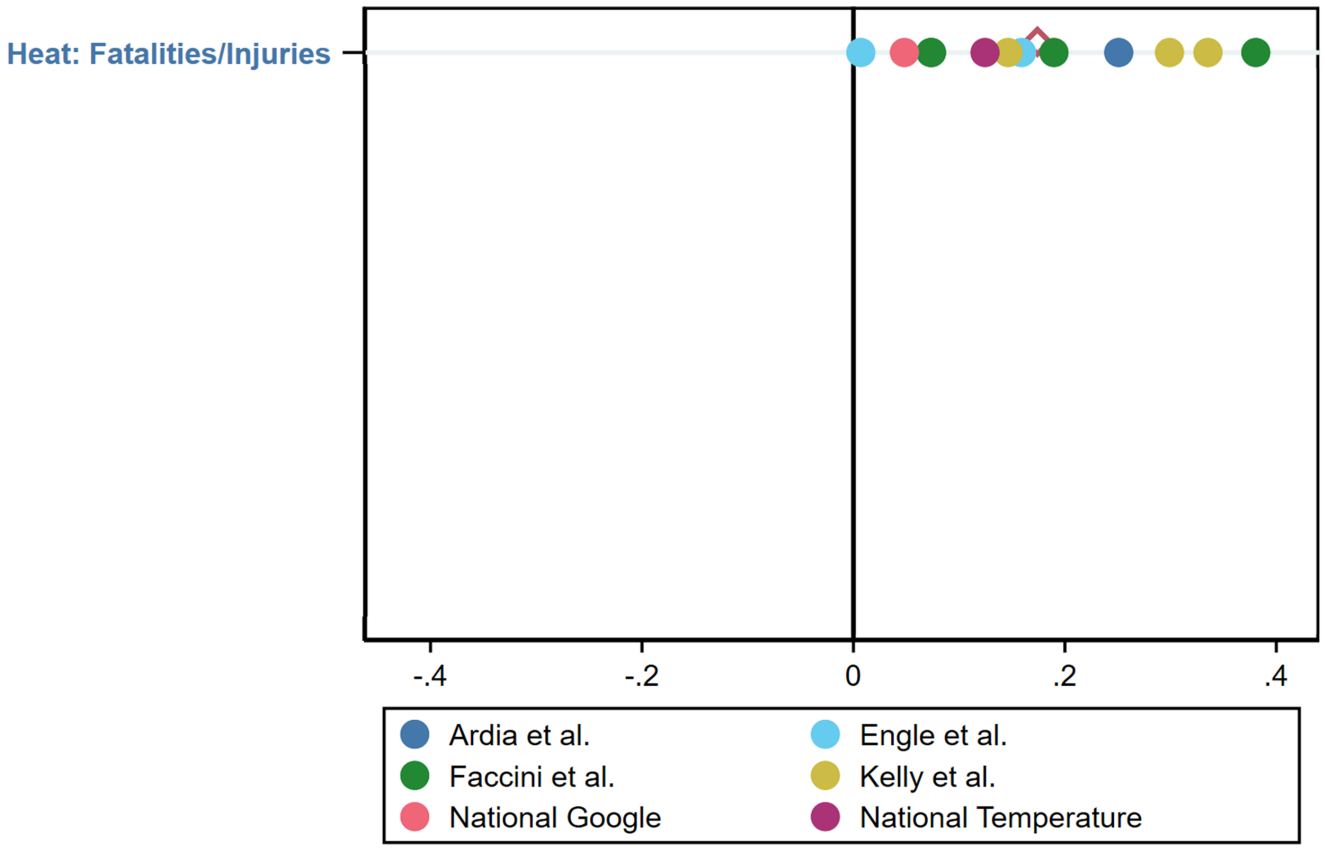

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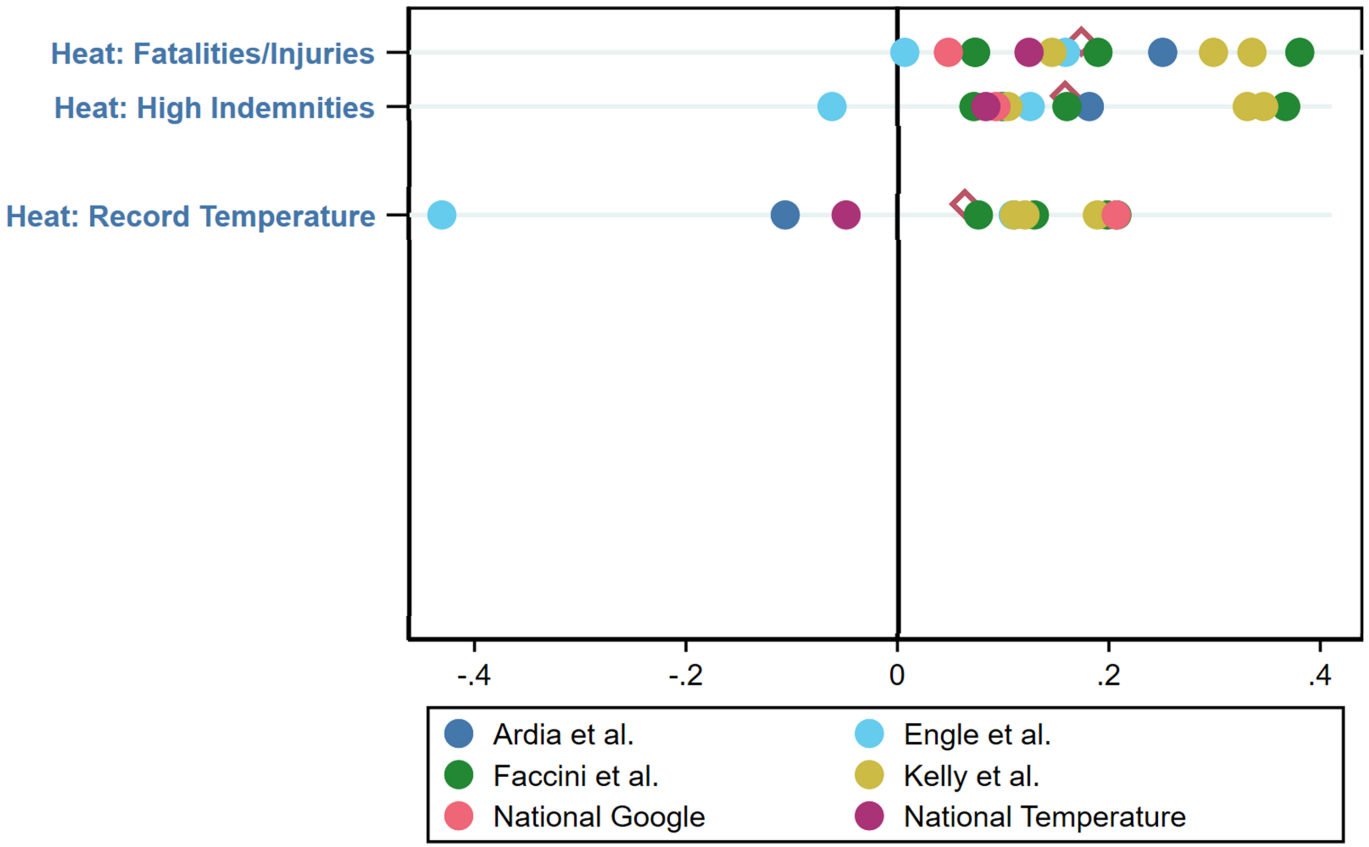

Robust to various specifications.

Comparison to Existing Hedging Strategies

- **Narrative portfolios:** First principles; beliefs of how climate change risk affects company returns
  - Long PBD:US (Invesco Global Clean Energy ETF)
  - Short XLE:US (Energy Select SDPR Fund ETF)
  - Short stranded assets portfolio $0.3XLE + 0.7KOL - SPY$
  - Long-Short Sustainalytics E-Score portfolio
    - Position is defined as Sustainalytics percentile minus 50

Hedge Performance - Main Results

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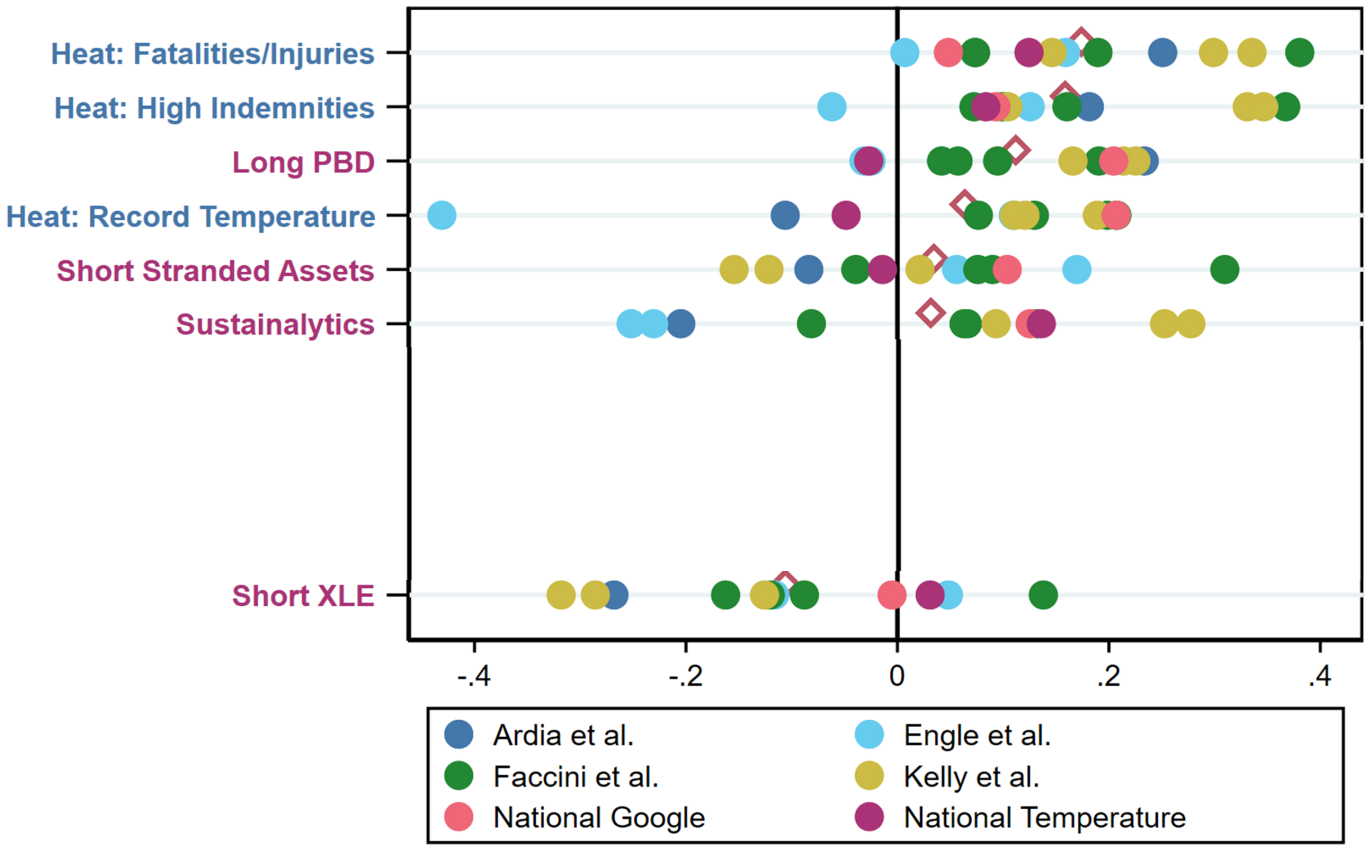

Comparison to Existing Hedging Strategies

- **Mimicking portfolio:** Data driven; regress each news series on base asset returns (five-year rolling window)
  - Projection on SPY
  - Projection on market, size, and value
  - Projection on PBD, XLE, market, size, and value
  - Projection on all industry portfolios
  - Lasso projection on all industry portfolios

Hedge Performance - Main Results

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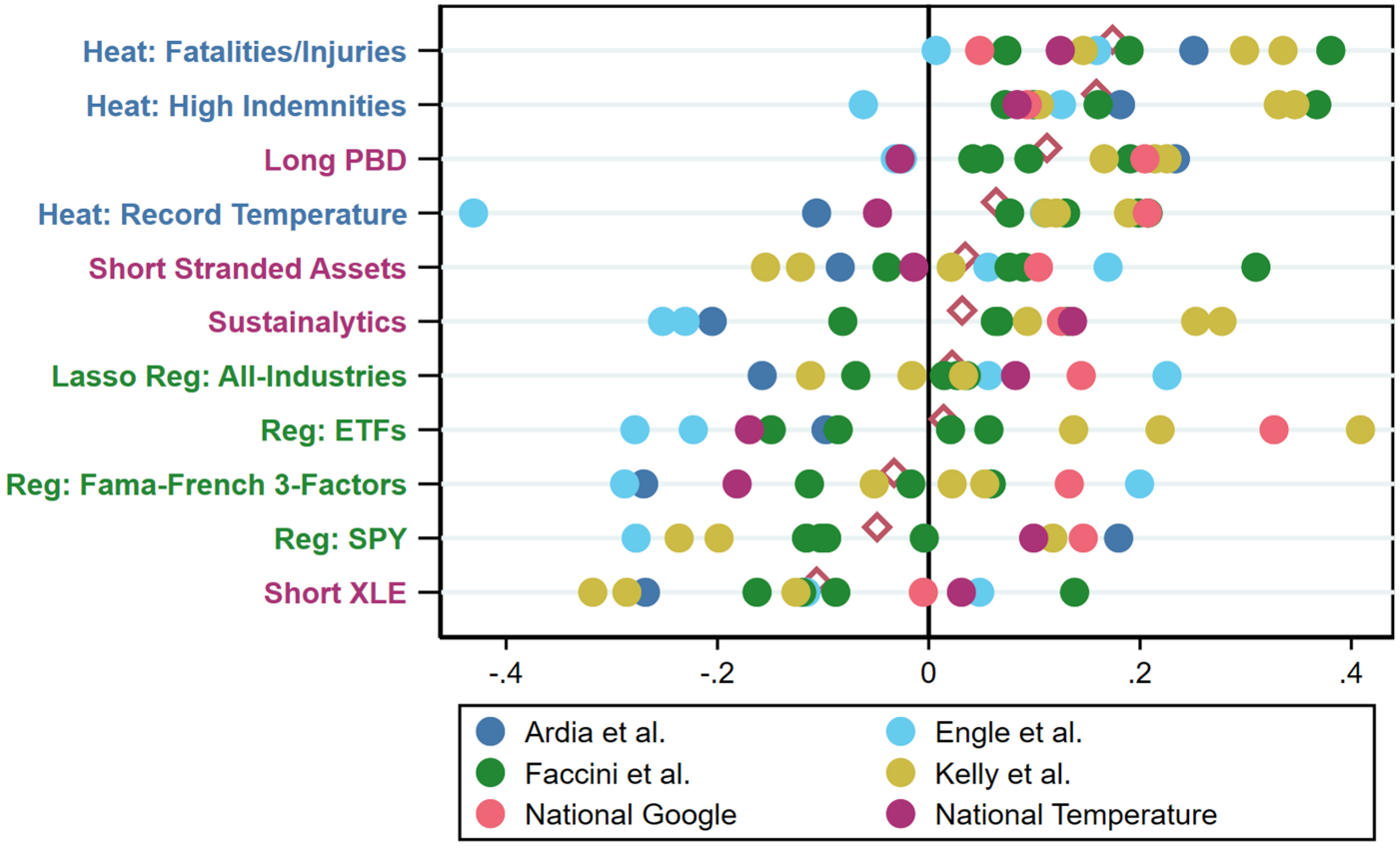

All coefficients in a table.

Conclusion

- Propose new approach based on trading responses to news shocks received by some investors
  - Additional information from the cross-section of investors
  - Useful for (i) structural breaks or (ii) new risks such as climate change
- **Finding I:** Long-short portfolios on this characteristic outperform other approaches to hedging a variety of climate risk news series
- **Finding II:** Approach also works well for hedging national house price and unemployment series
- Climate Finance is an exciting new research field; lots of work to be done!