Dissecting Climate Risks: Are they Reflected in Stock Prices?

Renato Faccini[1], Rastin Matin[2], George Skiadopoulos[3,4]

[1]Danmarks Nationalbank

[2]PFA Asset Management

[3]School of Economics and Finance, Queen Mary University of London

[4]Department of Banking and Financial Management, University of Piraeus

4rth JRC Summer School on Sustainable Finance
8 July, 2022

Motivation

- Market-wide risks from climate change are multifaceted: Physical & Transition risks

Motivation

- Market-wide risks from climate change are multifaceted: Physical & Transition risks

- **Do stock prices reflect these risks? The answer is not obvious**
  - (-) Survey studies (Krüger et al., 2020)
  - (-) Decarbonizing portfolios $\Rightarrow \uparrow$ transaction costs (Bessembinder, 2017)
  - (?) Does decarbonisation pay off? (Pedersen et al. 2020)
  - (+) Investors may be sensitive to short-term effects

Motivation

- Market-wide risks from climate change are multifaceted: Physical & Transition risks

- **Do stock prices reflect these risks? The answer is not obvious**
  - (-) Survey studies (Krüger et al., 2020)
  - (-) Decarbonizing portfolios $\Rightarrow \uparrow$ transaction costs (Bessembinder, 2017)
  - (?) Does decarbonisation pay off? (Pedersen et al. 2020)
  - (+) Investors may be sensitive to short-term effects

- **Is it physical or transition risks which are priced?**
  - **Camp #1**: *P*hysical risks are not priced $\Rightarrow$ Need for government's intervention
  - **Camp#2:** Physical risks *are not* priced & Government's intervention *is* priced, yet no need for intervention.

This paper: Contributions

1. **First time evidence** on what types of **market-wide** climate risks are reflected in U.S. stock prices

This paper: Contributions

1. **First time evidence** on what types of **market-wide** climate risks are reflected in U.S. stock prices

2. We dissect market-wide climate risks by textual analysis
   - **Novel measures** of market-wide physical & transition climate risks

This paper: Contributions

1. **First time evidence** on what types of **market-wide** climate risks are reflected in U.S. stock prices
2. We dissect market-wide climate risks by textual analysis
   - **Novel measures** of market-wide physical & transition climate risks
3. **Provide and validate** a possible explanation for the results

This paper: Contributions

1. **First time evidence** on what types of **market-wide** climate risks are reflected in U.S. stock prices
2. We dissect market-wide climate risks by textual analysis
   - **Novel measures** of market-wide physical & transition climate risks
3. **Provide and validate** a possible explanation for the results
4. **Document** which firms are the most exposed to these risks.

Dataset

- Reuters news: 1st Jan. 2000 - 31st Dec.2018
  - More than 13 million articles from Refinitiv News Archive
  - Screening & looking for "*climate change*" or "*global warming*" $\rightarrow$ $\approx$34,000 articles

Dataset

- Reuters news: 1st Jan. 2000 - 31st Dec.2018
  - More than 13 million articles from Refinitiv News Archive
  - Screening & looking for "*climate change*" or "*global warming*" $\rightarrow$ $\approx$34,000 articles
- U.S. common stocks returns & characteristics (daily data, CRSP, Compustat)
- Equity risk factors from authors' websites
- '*E*' score from Refinitiv.

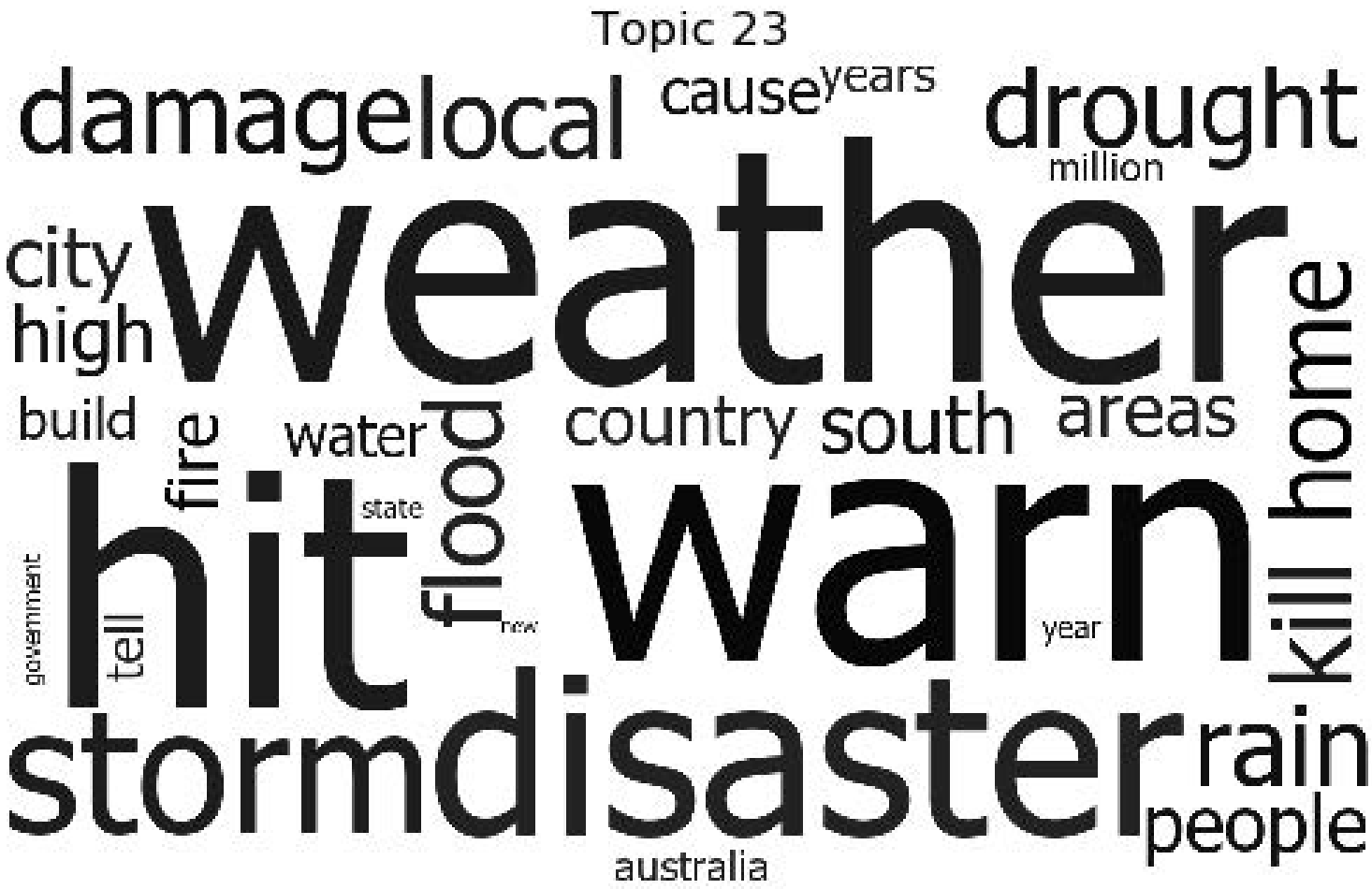
Latent Dirichlet Allocation (Blei et al. 2003)

1. Decomposes the entire textual corpus into K **topics** $(k = 1, .., K)$
   - **Topic** k: A probability distribution over unique words
2. Estimates **topic shares**: Percentage of a given article associated with the respective topic
   - **Article**: A probability distribution over topics
   - Intensity by which a topic appears in that article

- k-**risk factor value at time** t: *Intensity of news coverage of a given topic on that day*

- **We identify four topics**: Natural disasters, Global warming, International summits, U.S. climate policy.

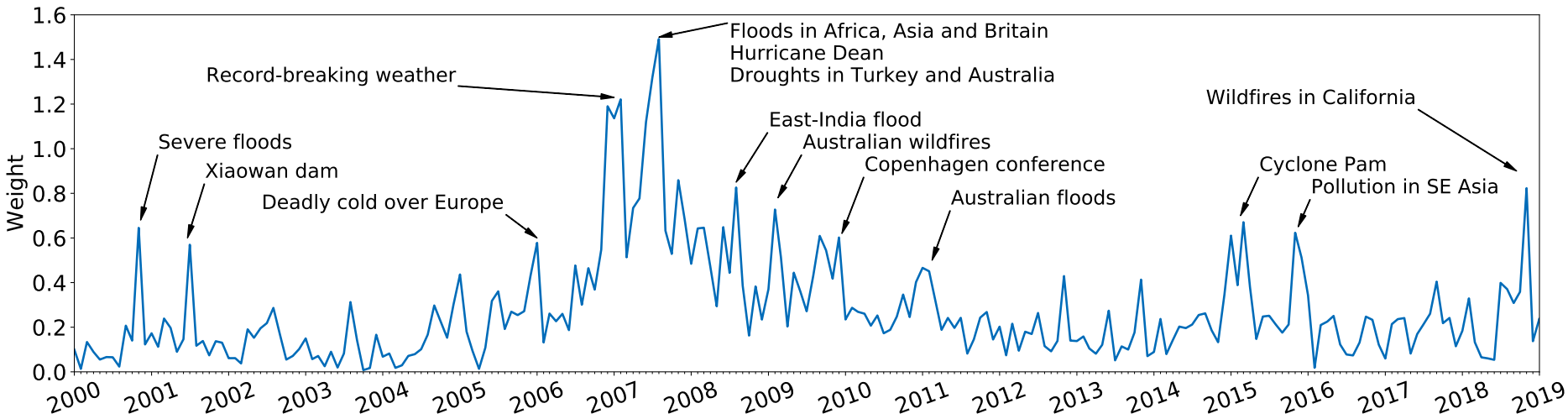
Labeling Topics: Natural disasters



Labeling Topics: U.S. climate policy I

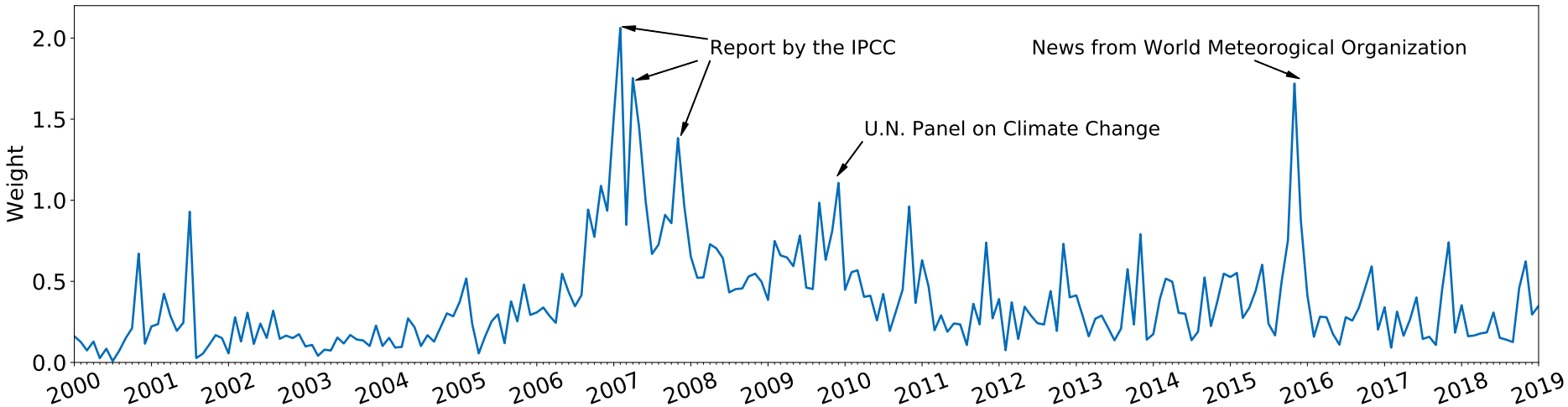
Labeling Topics: U.S. climate policy II

Natural disasters factor



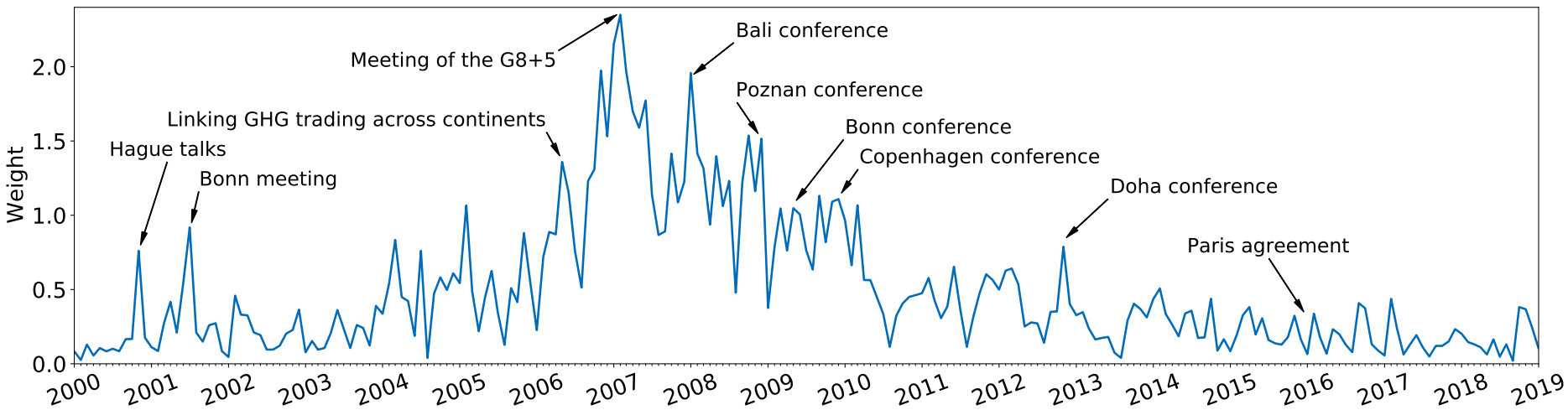
- Increases in the factor $\longrightarrow$ Bad news for the economy
- Risks which will materialize in the long-term.

Global warming factor



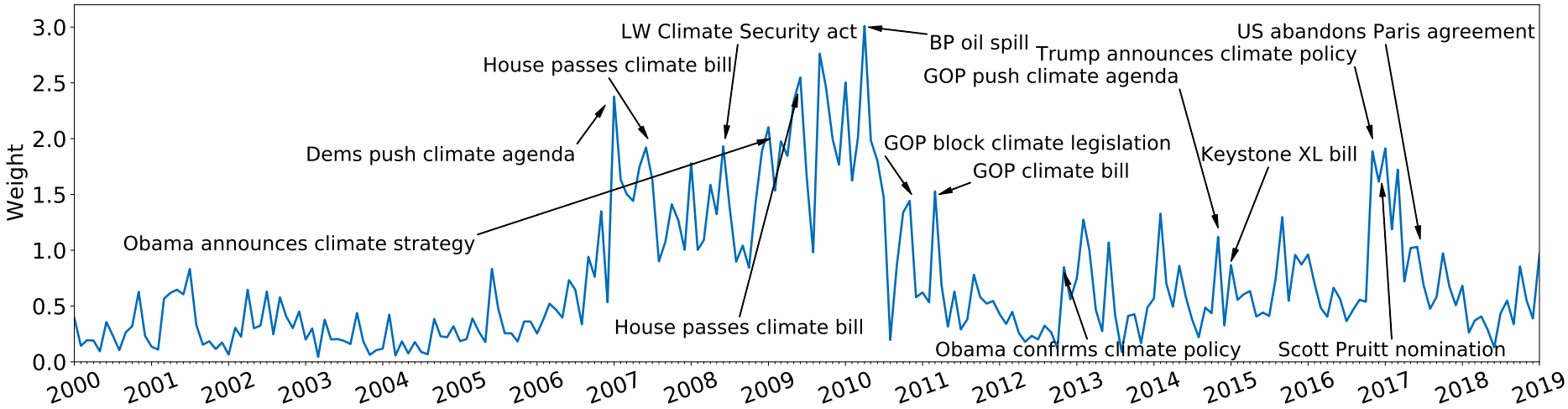
- Increases in the factor $\longrightarrow$ Bad news for the economy
- Risks which will materialize in the long-term.

International summits factor



- Increases in the factor $\longrightarrow$ Bad news for the economy
- Risks which will materialize in the long-term.

U.S. climate policy factor



- Increases $\longrightarrow$?
  - Bad or good news for the economy depending on which Party conquers the Congress
- Risks will materialize in the short-term.

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

1. We sort stocks in (decile/quintile) portfolios based on β_i

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

1. We sort stocks in (decile/quintile) portfolios based on β_i
2. Calculate monthly post-ranking portfolio returns (value-weighted)

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

1. We sort stocks in (decile/quintile) portfolios based on β_i
2. Calculate monthly post-ranking portfolio returns (value-weighted)
3. Compute spread portfolio returns

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

1. We sort stocks in (decile/quintile) portfolios based on β_i
2. Calculate monthly post-ranking portfolio returns (value-weighted)
3. Compute spread portfolio returns
4. Rolling window estimation: Repeat Steps (1 - 3) until we exhaust the sample

Asset pricing tests

- For each stock i, at each time t, we estimate the climate beta with respect to each textual factor F_t separately

$$r_{it} - r_{ft} = c_i + \beta_i F_t + \gamma_i' X_t + \varepsilon_{it} \tag{1}$$

1. We sort stocks in (decile/quintile) portfolios based on β_i
2. Calculate monthly post-ranking portfolio returns (value-weighted)
3. Compute spread portfolio returns
4. Rolling window estimation: Repeat Steps (1 - 3) until we exhaust the sample
5. Estimate alpha of spread portfolio
    - Alternative models for estimating climate beta & alpha.

Are factors priced? Jan 2000 - Dec 2018 (Deciles)

Alphas (Decile portfolios), 1st January 2000- 31st December 2018

Natural Disasters	Global Warming	Int. Summits	U.S. Climate
Panel A: Market model			
0.14	-0.0	0.12	0.96***
(0.3)	(-0.2)	(0.42)	(2.91)
Panel B: FF 3F model			
0.07	0.20	0.53*	0.65**
(0.24)	(0.67)	(1.73)	(2.34)
Panel C: FFC model			
-0.07	0.03	-0.49	0.46*
(-0.24)	(0.10)	(1.65)	(1.66)
Panel D: FF 5F model			
0.03	0.05	-0.66**	0.2***
(0.0)	(0.19)	(-2.5)	(2.75)
Panel E: FF 5F + momentum			
0.27	-0.09	-0.76***	0.61**
(0. 9)	(-0.34)	(-2.63)	(2.25)

U.S. climate policy premium: An explanation

- *Possible explanation*: **Intertemporal hedging**

U.S. climate policy premium: An explanation

- *Possible explanation*: **Intertemporal hedging**
- **Conjecture**: $\downarrow$ U.S. climate policy signals $\uparrow$ transition risks
  - $\longrightarrow$ "bad" news for the economy
  - $\longrightarrow$ deteriorates the investor's opportunity set
- *Investors would buy (short sell) stocks with negative (positive) textual climate betas*

U.S. climate policy premium: An explanation

- *Possible explanation*: **Intertemporal hedging**
- **Conjecture**: $\downarrow$ U.S. climate policy signals $\uparrow$ transition risks
  - $\longrightarrow$ "bad" news for the economy
  - $\longrightarrow$ deteriorates the investor's opportunity set
- *Investors would buy (short sell) stocks with negative (positive) textual climate betas*
- **Strategies to check proposed explanation**: Check the risk-premium's sign by ensuring that the conjecture holds

U.S. climate policy premium: An explanation

- *Possible explanation*: **Intertemporal hedging**
- **Conjecture**: $\downarrow$ U.S. climate policy signals $\uparrow$ transition risks
  - $\longrightarrow$ "bad" news for the economy
  - $\longrightarrow$ deteriorates the investor's opportunity set
- *Investors would buy (short sell) stocks with negative (positive) textual climate betas*
- **Strategies to check proposed explanation**: Check the risk-premium's sign by ensuring that the conjecture holds
  1. *Choose* an appropriate sample period (Sub-sample analysis)
  2. *Re-construct* the policy factor by marking the content of news (narrative analysis, Romer & Romer, 2010)
     - $\Rightarrow$ Know what the factor fluctuations signal.

Subsample analysis

- Post Nov 2012:
  - Lack of a majority for Democrats in the U.S. House of Representatives
  - After 2014, the Democrats also lost control of the Senate
  - Trump took over in Nov. 2016

Decile sorts on U.S. Climate		Quintile sorts on U.S. Climate	
Pre-2012	Post-2012	Pre-2012	Post-2012
		Panel A: Market model	
1.05**	0.4**	0.55	0.75***
(2.33)	(2.12)	(1.55)	(2.9)
		Panel B: FF 3F model	
0.35	0.9***	0.06	0.70***
(0.91)	(3.06)	(0.17)	(3.11)
		Panel C: FFC model	
0.17	0.97***	-0.11	0.46**
(0.46)	(3.29)	(-0.43)	(2.52)
		Panel D: FF 5F model	
0.4	1.23***	0.45*	0.59**
(1.23)	(3.2)	(1.73)	(2.15)
		Panel E: FF 5F + mom.	
0.44	0.79***	0.21	0.42**
(1.26)	(2.72)	(1.12)	(2.13)

Climate policy portfolio characteristics

	1 (L)	2	3	4	5 (H)
Panel A: Fama-French-Carhart model					
Average return	0.80*	1.03***	0.87***	0.89**	1.07***
	(1.84)	(2.88)	(2.84)	(2.60)	(2.66)
Climate beta	-0.48	-0.16	0.00	0.15	0.47
E score	35.12	40.37	41 .66	40.29	34.86
E score (change)	7.12	6.26	5.70	6.22	6.05
log(size)	6.36	6.91	7.02	6.91	6.43
N	747.00	751.00	751.00	750.00	747.00
Panel B: Fama-French five-factor model					
Average return	0.71	1.01***	0.86***	0.95***	1.10***
	(1.40)	(2.76)	(2.79)	(3.09)	(2.93)
Climate beta	-0.48	-0.16	0.00	0.16	0.48
E score	35.15	40.51	41.37	40.37	35.15
E score (change)	6.64	6.22	5.64	6.38	6.18
log(size)	6.38	6.92	7.01	6.91	6.43
N	747.00	748.00	752.00	752.00	747.00

U.S. climate policy: Construction of a narrative factor

- Select articles with a topic share on the domestic policy factor $> 40\%$ $\longrightarrow 3,500$ articles

U.S. climate policy: Construction of a narrative factor

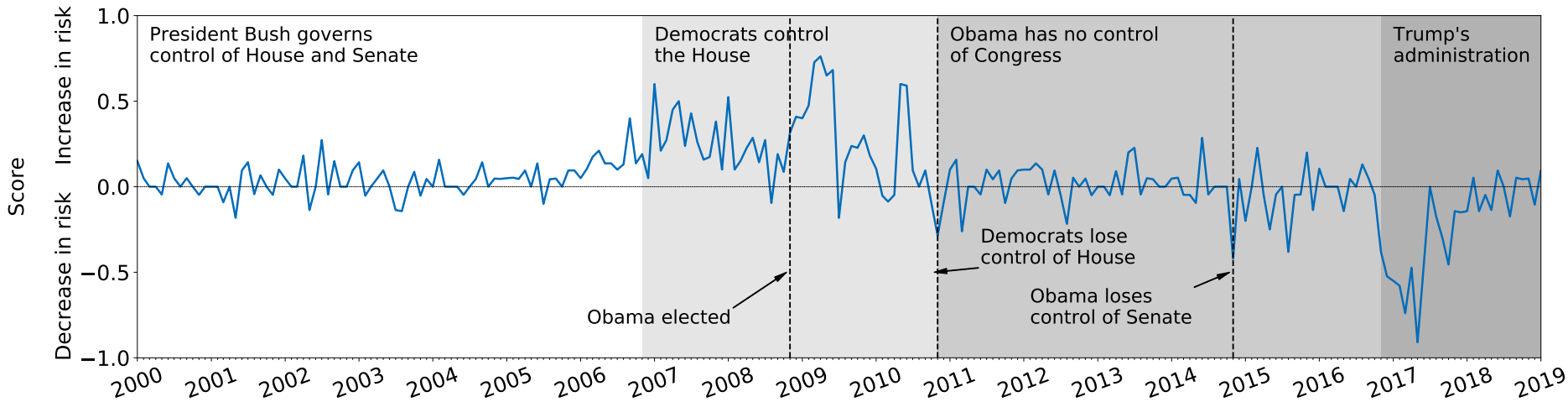
- Select articles with a topic share on the domestic policy factor $> 40\%$ $\longrightarrow 3,500$ articles
- Read each article and mark it with
  - $+1$, if it signals an increase in transition risks,
  - -1, if it signals a decrease in transition risks,
  - 0, if its content is mixed

U.S. climate policy: Construction of a narrative factor

- Select articles with a topic share on the domestic policy factor $> 40\%$ $\longrightarrow 3,500$ articles
- Read each article and mark it with
  - $+1$, if it signals an increase in transition risks,
  - -1, if it signals a decrease in transition risks,
  - 0, if its content is mixed
- **Narrative factor value at time** t: Sum of the marks given to the articles over day t.

U.S. climate policy narrative factor

Sign of the risk premium under hedging hypothesis



- By construction, decreases in the factor signal good news for the economy
- $\Rightarrow$ **Risk premium of the U.S. climate policy narrative factor**: It should be negative under the hedging argument.

Asset pricing tests: Narrative factor (Decile)

2000-2018	2000-2012	2012-2018
Panel A: Market model		
-0.64*	-0.52	-1.01**
(-1.86)	(-1.13)	(-2.43)
Panel B: FF 3F model		
-1.03***	0.77**	-1.39***
(-3.56)	(-2.37)	(-4.30)
Panel C: FFC model		
-0.85***	-0.59*	-1.37***
(-2.76)	(-1.66)	(-3.61)
Panel D: FF 5F model		
-0.65**	-0.62	-0.84***
(-1.97)	(-1.43)	(-2.97)
Panel E: FF 5F + momentum		
-0.31	0.00	-0.93***
(-1.07)	(0.00)	(-3.40)

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era
- **Implications**:
  1. It is the government's intervention and not physical risks

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era
- **Implications**:
  1. It is the government's intervention and not physical risks
  2. Climate policy risks have started to be priced only recently

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era
- **Implications**:
  1. It is the government's intervention and not physical risks
  2. Climate policy risks have started to be priced only recently
  3. Investors reward firms which improve their environmental profile

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era
- **Implications**:
  1. It is the government's intervention and not physical risks
  2. Climate policy risks have started to be priced only recently
  3. Investors reward firms which improve their environmental profile
  4. Results are consistent with both camps

Conclusions

1. We dissect market-wide climate risk in its multiple sources
2. Examine whether these are priced in U.S. stocks
3. Provide & validate an explanation: Intertemporal hedging

- **Results**:
  - We identify four market-wide textual factors with a clear interpretation
  - Only U.S. climate policy is priced
  - This evidence is driven by the post-2012 era
- **Implications**:
  1. It is the government's intervention and not physical risks
  2. Climate policy risks have started to be priced only recently
  3. Investors reward firms which improve their environmental profile
  4. Results are consistent with both camps
- **Future research:** Why are not **all** risks priced? Investors' short-termism and/or lack of information, or not systemic.

Thank you for your attention and time !

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3795964

gskiado@unipi.gr, g.skiadopoulos@qmul.ac.uk

Related literature

Related literature

1. **Climate Finance empirical literature** (Giglio et al., 2021a)
   - **Real estate**: Bernstein et al. (2019), Baldauf et al. (2020), Giglio et al. (2021b)
   - **Bonds:** Painter (2020), Seltzer et al. (2020), Goldsmith-Pinkham et al. (2021), Duan et al. (2021)
   - **Options**: Ilhan et al. (2021), Cao et al. (2021)
   - **Stocks**: Oesteich and Tsiakas (2015), Bansal et al. (2017), Hong et al. (2019), Görgen et al. (2019), Bolton & Kacperczyk (2021a, b), Hsu et al. (2021), Pastor et al. (2021)

Related literature

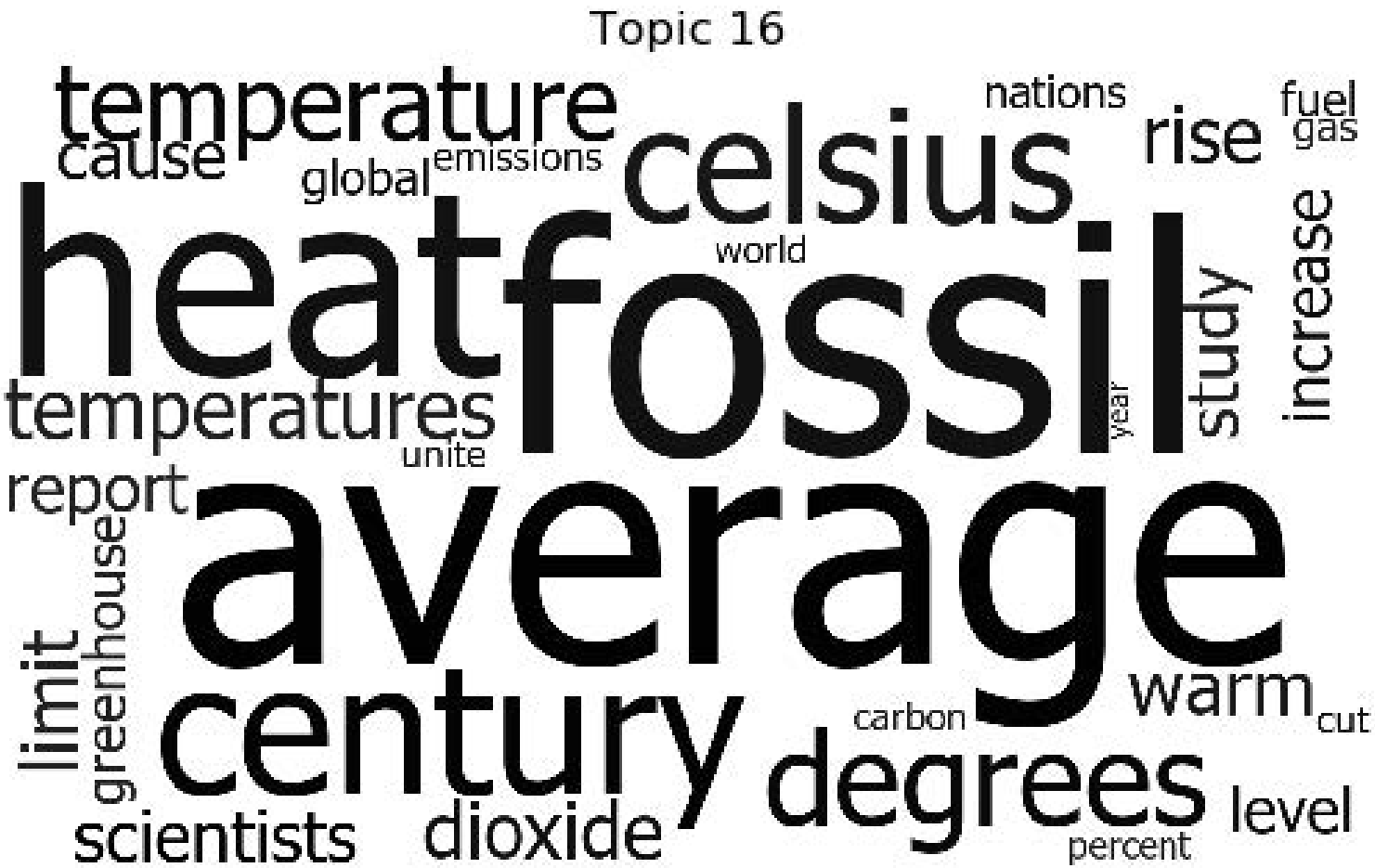
1. **Climate Finance empirical literature** (Giglio et al., 2021a)
   - **Real estate**: Bernstein et al. (2019), Baldauf et al. (2020), Giglio et al. (2021b)
   - **Bonds:** Painter (2020), Seltzer et al. (2020), Goldsmith-Pinkham et al. (2021), Duan et al. (2021)
   - **Options**: Ilhan et al. (2021), Cao et al. (2021)
   - **Stocks**: Oesteich and Tsiakas (2015), Bansal et al. (2017), Hong et al. (2019), Görgen et al. (2019), Bolton & Kacperczyk (2021a, b), Hsu et al. (2021), Pastor et al. (2021)

2. **Textual analysis in finance** (Gentzkow et al., 2019)
   - *Market-wide climate factors*: Engle et al. (2020), Huynh and Xia (2020), Alekseev et al. (2021)
   - *Firm-specific climate factors*: Kölbel et al. (2020), Li et al. (2020) and Sautner et al. (2020, 2021)

Related literature

1. **Climate Finance empirical literature** (Giglio et al., 2021a)
   - **Real estate**: Bernstein et al. (2019), Baldauf et al. (2020), Giglio et al. (2021b)
   - **Bonds:** Painter (2020), Seltzer et al. (2020), Goldsmith-Pinkham et al. (2021), Duan et al. (2021)
   - **Options**: Ilhan et al. (2021), Cao et al. (2021)
   - **Stocks**: Oesteich and Tsiakas (2015), Bansal et al. (2017), Hong et al. (2019), Görgen et al. (2019), Bolton & Kacperczyk (2021a, b), Hsu et al. (2021), Pastor et al. (2021)
2. **Textual analysis in finance** (Gentzkow et al., 2019)
   - *Market-wide climate factors*: Engle et al. (2020), Huynh and Xia (2020), Alekseev et al. (2021)
   - *Firm-specific climate factors*: Kölbel et al. (2020), Li et al. (2020) and Sautner et al. (2020, 2021)
3. **Construction of accurate ESG ratings** (Berg et al., 2020).

Labeling Topics: Global warming



Labeling Topics: International summits

Topics: Correlations

	U.S. Climate policy	Int'l summits	Global warming	Natural disasters	mktrf	hml	smb	rmw	cma	umd
U.S. Climate policy	1.00	0.30	0.27	0.18	-0.02	-0.02	0.01	0.02	-0.02	-0.00
Int'l summits	0.30	1.00	0.31	0.24	-0.01	0.01	0.00	0.02	-0.01	-0.00
Global warming	0.27	0.31	1.00	0.34	-0.01	-0.01	-0.01	0.02	-0.01	0.01
Natural disasters	0.18	0.24	0.34	1.00	-0.02	-0.03	-0.02	0.02	-0.01	0.04
mktrf	-0.02	-0.01	-0.01	-0.02	1.00	0.06	0.12	-0.44	-0.28	-0.30
hml	0.02	0.01	-0.01	-0.03	0.06	1.00	-0.18	0.06	0.45	-0.33
smb	0.01	0.00	-0.01	-0.02	0.12	-0.18	1.00	-0.35	-0.05	0.13
rmw	0.02	0.02	0.02	0.02	-0.44	0.06	-0.35	1.00	0.26	0.17
cma	-0.02	-0.01	-0.01	-0.01	-0.28	0.45	-0.05	0.26	1.00	0.11
umd	-0.00	-0.00	0.01	0.04	-0.30	-0.33	0.13	0.17	0.11	1.00

1. Low correlations $\Rightarrow$ LDA has successfully dissected climate risks
2. Why the low correlations? Long-term vs. Short-term effects.

Asset pricing tests: Narrative factor (Quintile)

2000-2018	2000-2012	2012-2018
Panel A: Market model		
-0.23	-0.01	-0.71
(-0.77)	(-0.02)	(-1.52)
Panel B: FF 3F model		
-0.58***	-0.20	-1.05***
(-2.64)	(-0.78)	(-3.67)
Panel C: FFC model		
-0.48**	-0.24	-0.93***
(-2.30)	(-1.05)	(-2.86)
Panel D: FF 5F model		
-0.39*	-0.16	-0.69**
(-1.89)	(-0.62)	(-2.53)
Panel E: FF 5F + momentum		
-0.26	-0.05	-0.60**
(-1.20)	(-0.19)	(-2.08)

Do climate policy factors conflate EPU / Political risks?

- Conditional bivariate sorts (Bali et al., 2017)
- Control variables: EPU (Baker et al., 2016), Political risk (Hassan et al., 2019)

First control variable:	EPU	PRisk
Panel A: Market model		
Textual	0.6**	0.71**
	(2.09)	(2.44)
Narrative	-0.65	-0.17
	(-1.55)	(-0.38)
Panel B: FF 3F model		
Textual	0.63**	0.7***
	(2.54)	(2.84)
Narrative	-0.96***	-0.84***
	(-3.78)	(-2.75)
Panel C: FFC model		
Textual	0.43***	0.42**
	(3.06)	(2.2)
Narrative	-0.89***	-0.65**
	(-2.68)	(-2.14)
Panel D: FF 5F model		
Textual	0.56**	0.46*
	(2.31)	(1.76)
Narrative	-0.53**	-0.46**
	(-2.45)	(-2.17)
Panel E: FF 5F + momentum		
Textual	0.43**	0.54***
	(2.58)	(3.06)
Narrative	-0.69***	-0.57**