Climate change concerns and the performance of green versus brown stocks

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Seminar EFAMA, 2023

Climate change is one of the biggest challenges

Impact on firms

Physical risk: Impact today on assets from climate and weather related events

Transition risk: financial risk resulting from the process of adjustment towards a lower-carbon economy

When?

Most of these effects are in the future, but the expectation of the effect has an immediate impact on how investors see the firm value.

The importance they attach to it depends on the concerns about climate change.

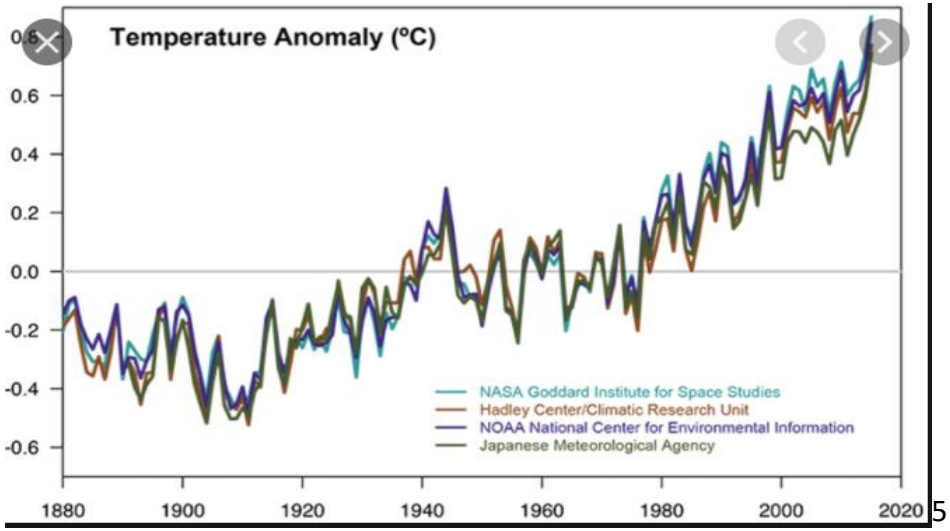
Sources of concerns

Environmental impact

Societal debate

Business impact

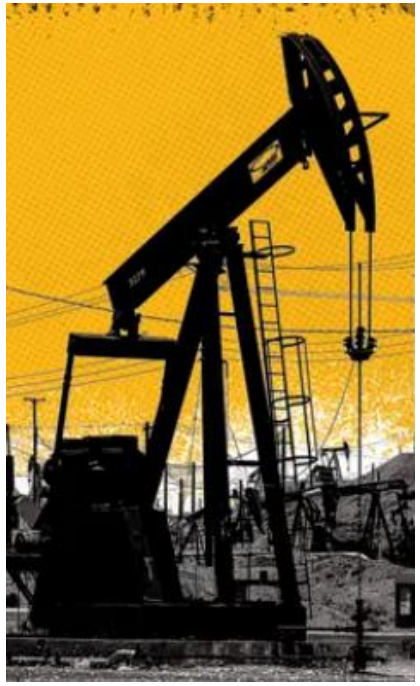
Research



Narrative of our study: impact on firm value

Event increasing media concerns about climate change

Green firms' stock price



Brown firms' stock price

Channels of price impact

$$P_t = \sum_{i=1}^{\infty} \frac{CF_{t+i}^{e}}{(1 + k_t)^i}$$

Shocks in climate change concerns affect stock valuation from two channels:

- **Change in expected cash-flow** (e.g., expectation about new regulation, consumer preferences, stranded assets, new opportunities)
- **Investors' discount factor** (risk premium + taste)

Theory

ELSEVIER

Journal of Financial Economics
Volume 142, Issue 2, November 2021, Pages 550-571

Sustainable investing in equilibrium ☆

Ľuboš Pástor [a, c, d, e], Robert F. Stambaugh [b, c], Lucian A. Taylor [b]

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Abstract

We model investing that considers environmental, social, and governance (ESG) criteria. In equilibrium, green assets have low expected returns because investors enjoy holding them and because green assets hedge climate risk. Green assets nevertheless outperform when positive shocks hit the ESG factor, which captures shifts in customers' tastes for green products and investors' tastes for green holdings. The ESG factor and the market portfolio price assets in a two-factor model. The ESG investment industry is largest when investors' ESG preferences differ most. Sustainable investing produces positive social impact by making firms greener and by shifting real investment toward green firms.

Model of Pastor et al. (2020) assumes that investors can **derive utility from owning green firms and disutility from owning brown firms**.

Model predicts that:

1. Brown firms' stocks **outperform** green firms' stocks in the **long run**.
2. Green firms' stocks **outperform** brown ones when **climate change concerns strengthen unexpectedly**

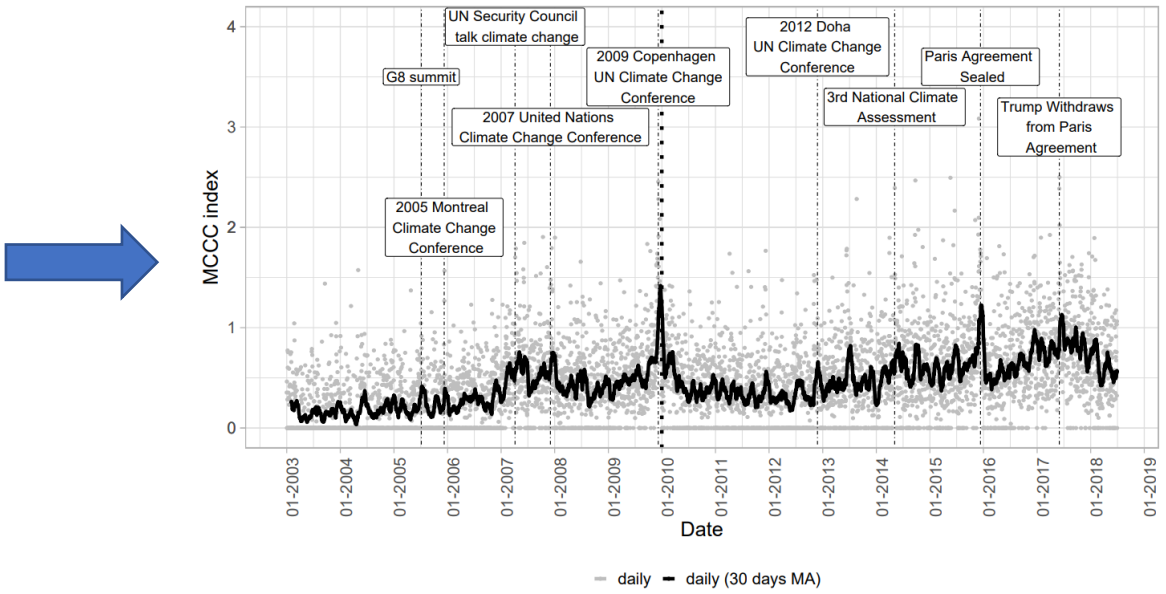
We test this hypothesis using news data

Panel A: Newswires

Source	Articles N	Articles %
Associated Press Newswires	10,061	0.07
Reuters News	9,288	0.08

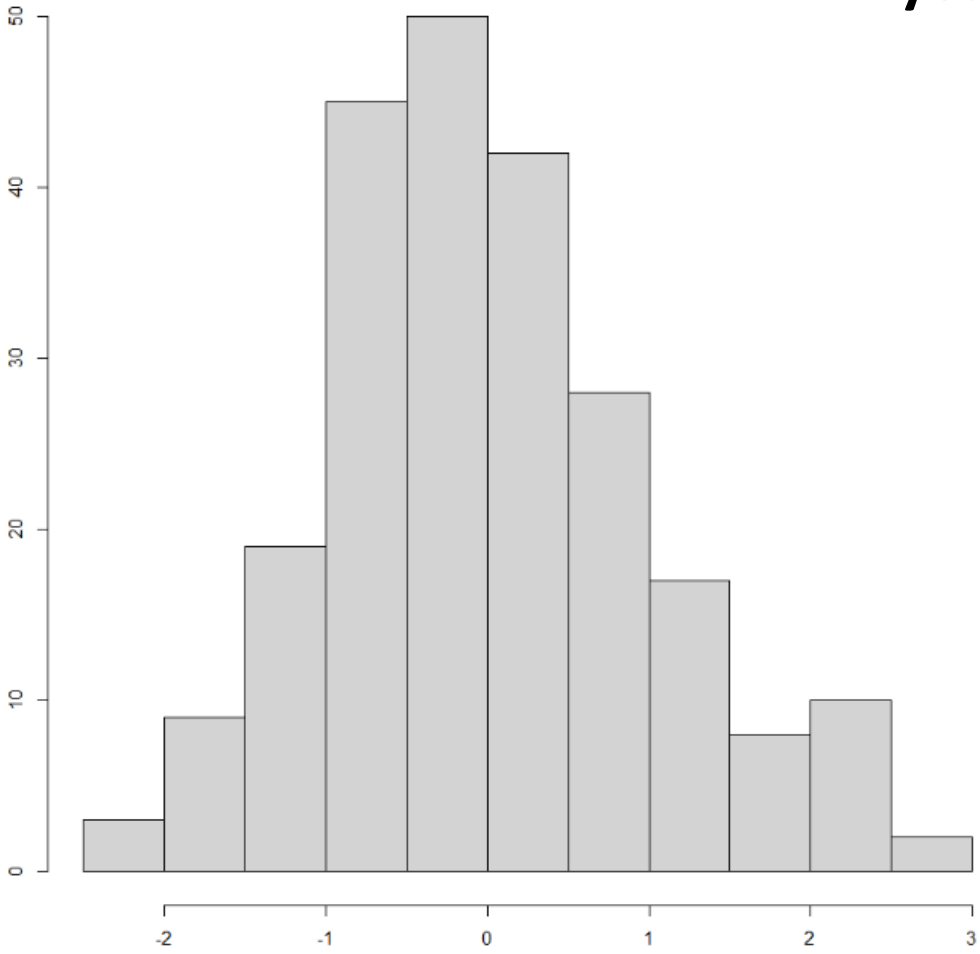
Panel B: Newspapers

Source	Articles N	Articles %
New York Times	3,472	0.25
Washington Post	2,442	0.25
Los Angeles Times	1,530	0.20
Wall Street Journal	1,412	0.26
Houston Chronicle	1,385	0.16
Chicago Tribune	482	0.03
Arizona Republic	382	0.04
USA Today	234	0.08
New York Daily News	122	0.02
New York Post	111	0.02



We test this using (standardized) GHG intensity

$$\textbf{GHG intensity} = \frac{\text{yearly } \textbf{GHG CO2 equivalent emission}}{\textbf{yearly revenue}}$$



Main take-aways for investors and managers

Green firms outperform brown firms…

… on days with unexpectedly large concerns about climate change

	GMB	Green	Brown	N
Intercept	0.068*	0.019	−0.049*	
	(0.038)	(0.019)	(0.028)	(
UMC	0.072**	0.029**	−0.042*	
	(0.031)	(0.014)	(0.023)	(

"All the News That's Fit to Print"

The New York Times

National Edition

VOL. CLXXI .... No. 59,235 SUNDAY, NOVEMBER 7, 2021 $6.00 $13.50

STRATEGIES | JEFF SOMMER

When Bad Climate News Is Good for Green Stocks

The markets respond when coverage of global warming spikes, new research suggests.

CHRISTOPHER FURLONG/GETTY IMAGES

News articles about climate change have surged during the United Nations summit in Glasgow.

IT'S NOT YET CLEAR how effective the United Nations conference underway in Glasgow will be in mitigating the most pernicious effects of global warming. But one outcome is already evident: The number of news articles about climate change is surging.

Another result of the Glasgow conference can be predicted with some confidence, too. So-called green stocks — those of companies with relatively low carbon emissions — will get a temporary boost. At the same time, brown stocks — those of companies that emit large quantities of greenhouse gases — will face a headwind.

New research indicates that the two effects are related. Three recent research papers by two groups of economists suggest that when public exposure to information about climate change spikes, investor preferences also shift, altering the performance of sectors of the stock market.

"What we've found is a story about climate change and the stock market," Lubos Pastor, a professor of finance at the University of Chicago Booth School of Business, said in an interview. "At this point, news about climate change, any news, is, at least to some extent, negative," he said, meaning that it tends to raise public concern about the planet's future. "As investors become more aware of the climate issue, they understand that regulations are coming, and that the situation will be beneficial to green firms and harmful to brown ones."

That increased public attention — and the accompanying preference of many investors for environmentally sensitive stocks — boosts the price of those stocks and hurts those of companies that are big emitters of carbon dioxide, methane and other greenhouse gases, the scholars found. They also pointed out that this investor preference for green companies has made it easier and cheaper to raise money for environmentally useful projects.

But for people who want to do well while doing good, the researchers' findings may not be entirely comforting.

For one thing, the very preference of many investors for green stocks — which creates a measurable green premium, or "greenium," that elevates their share price — implies that these shares will have lower expected returns in the future. That's just what happens in financial markets when demand for an asset soars and supply does not: Its price rises over the short run but, all else equal, it has less room for increases down the road.

"We'd say with this green preference, the market reaches a new equilibrium," said Robert F. Stambaugh, an economist at the Wharton School of the University of Pennsylvania. "By pricing green stocks higher, investors are accepting lower expected returns, whether they understand that or not."

The converse is also true. Obviously, fossil fuel stocks can still rise sharply amid an energy shortage — as they have in recent months — even if there is increasing investor preference for alternative energy companies and other green stocks. If anything, Professor Stambaugh said, by creating a premium for green stocks and shunning brown ones, environmentally conscious investors may be inadvertently raising the expected returns for brown stocks. As long as these companies still produce profits and cash flow, investors who strongly emphasize making money over environmental issues may now flock to brown stocks, judging them a relative bargain.

The core of these insights appears in "Sustainable Investing in Equilibrium," published this month in the Journal of Financial Economics and available as a working paper since December 2019. Along with Lucian Taylor, who is also a professor at Wharton, Professors Stambaugh and Pastor wrote that paper, which developed the model that explains how shifting investor preferences lead to share re-pricing and stock market shifts.

Two subsequent papers provided evidence that supports their theory.

The first, "Climate Change Concerns and the Performance of Green Versus Brown Stocks," was written by a group of economists affiliated with the National Bank of Belgium. They are David Ardia of HEC Montreal, Keven Bluteau of Université de Sherbrooke, and Kris Boudt and Koen Inghelbrecht of Ghent University.

They constructed a "Media Climate Change Concerns index" that measured the frequency and tone of climate change coverage from Jan. 1, 2010, to June 30, 2018, in The New York Times and seven other large-circulation U.S. newspapers: The Wall Street Journal, The Washington Post, The Los Angeles Times, The Chicago Tribune, USA Today, The New York Daily News and The New York Post.

The index spiked during major conferences on climate change, like the one that produced the 2015 Paris Agreement, and after major setbacks in efforts to curb global warming, like President Donald J. Trump's 2017 announcement that the United States was withdrawing from that agreement.

Some investors may flock to brown stocks, judging them a bargain.

In an interview, Professor Ardia said the researchers were working on an updated version of the index. "I think it's safe to say that the index would be spiking now, during the Glasgow conference, whatever happens there," he said.

The researchers compared their index with the returns of selected stocks, distinguishing between green and brown shares on the basis of companies' carbon intensity, as defined by their carbon emissions divided by their revenue. The researchers found that when climate coverage increased, the prices of brown stocks dropped compared with those of green stocks.

Another paper by Professors Pastor, Stambaugh and Taylor relied in part on the same Media Climate Change Concerns index, and produced similar findings. It concluded that the increased coverage of climate change contributed to a significant outperformance of green stocks over brown ones from November 2012 through December 2020. "The value-weighted portfolio of stocks in the top third of greenness outperformed the bottom third by a cumulative return difference of 174 percent," it said.

This roughly corresponds with the results of standard stock market indexes. Those that emphasize environmental factors have, for the most part, had stronger returns than the broad market in recent years. The environmentally friendly MSCI ACWI ESG Leaders index outperformed the standard MSCI ACWI index (which tracks world markets) in 10 of the 13 years through 2020, according to MSCI.

But the scholars pointed out that there's no assurance that this trend will continue, and not simply because past performance doesn't predict future outcomes, as investors are frequently warned. Their research is based on measurement of the newsworthiness of climate change. If global warming worsens, as most scientists say is likely, it's possible that people will become inured to it. When a barrage of news on any subject becomes constant, it's no longer quite as newsworthy, as any journalist knows.

"If it's a surprise, it's news, by our definition," Professor Bluteau said. "Once it's not surprising, it's no longer news." That, in turn, could affect stock returns and reduce the reward that environmentally conscious investors are receiving. Economics explains problems like this. It doesn't necessarily solve them.

Follow Jeff Sommer on Twitter: @jeffsommer

Main take-aways for investors and managers

You thus need to monitor the concerns about climate change, and more broadly ESG

… we founded a university spinoff that does this: **Sentometrics**: Transparent alerts about company involvement in ESG controversies

…. All companies: listed and non listed

…. Matches as well with the regulation (CSRD, SFDR)

Outline

1. Capturing climate change concerns
2. Testing the prediction
3. Thematic analysis

Climate change concerns

The concern that consumers, investors and policymakers have about climate change.

Latent variable.

- Could be measured using surveys. Problem: No backward analysis, low-frequency.

- Our approach: Question the news about climate change concerns by means of an index

Motivation for using media news

Availability at high-frequency: real-time + archives.

Descriptive of the events that have happened

Direct relationship to concerns by investors through two channels:

- **Agenda setting** (McCombs and Shaw (1972)): the importance that people attribute to an issue is influenced by the attention that media devote to this issue.
- **Framing** (Druckman (2004)): the way mass media report about issues influences people's attitudes and evaluations about those issues

Increased awareness and negative perception of climate change by the media will increase their concern.

Implementation

1. Choice of relevant US newspapers [those with the highest circulation]

2. Selection of relevant articles [those that discuss “Climate Change”, as tagged by Factiva, ProQuest and LexisNexis + remove articles discussing market performance]

3. Extraction of the concern about climate change expressed in the article

4. Aggregation into one number by day.

Steps 1 and 2

Panel A: Newswires	Articles	
Source	*N*	%
Associated Press Newswires	10,061	0.07
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Very high circulation US newspapers (above 500k daily).

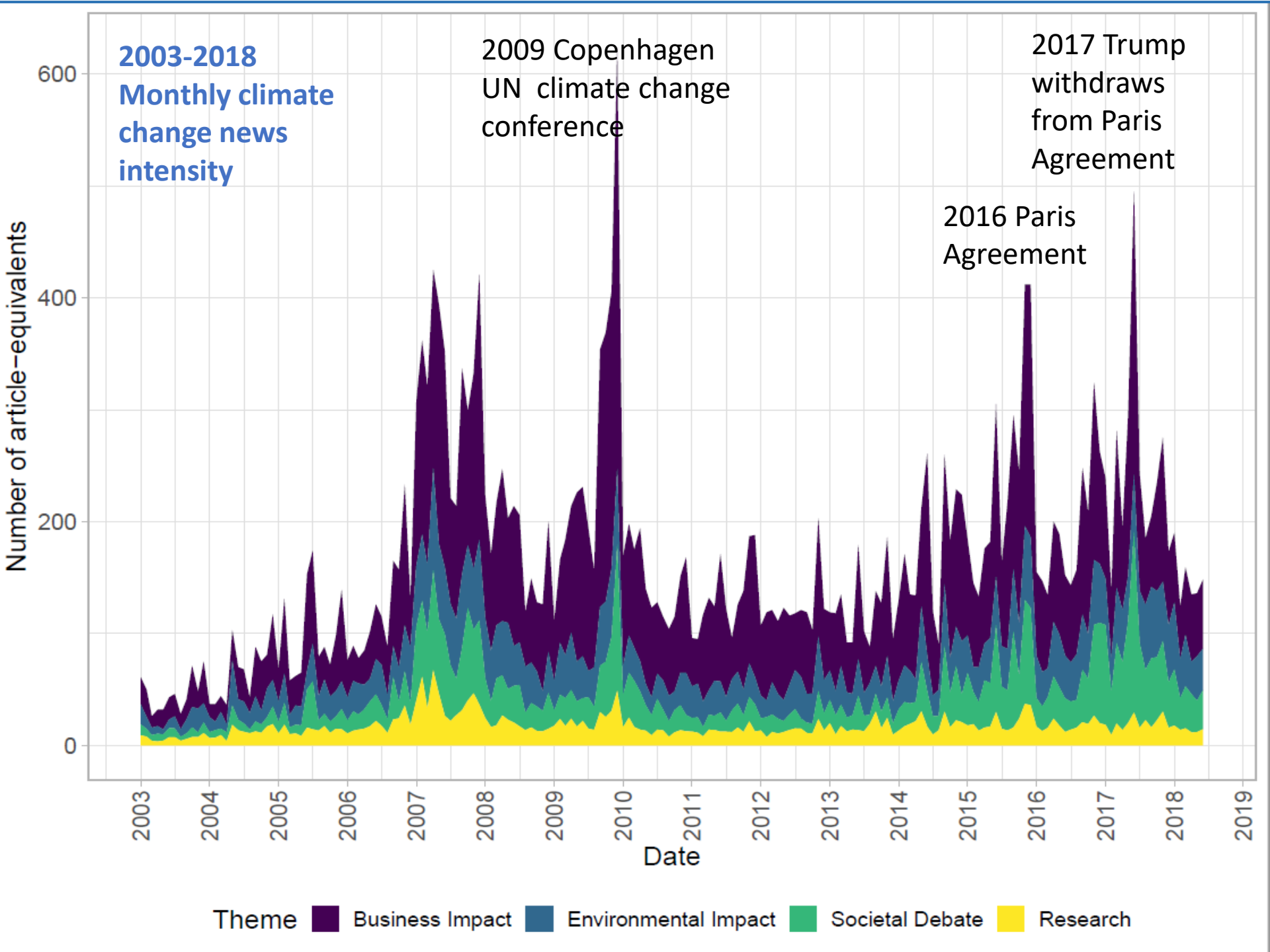
News data from January 2003 to June 2018.

Climate change tag by Factiva, LexisNexis and ProQuest.

Remove texts discussing stock market performance to mitigate reverse causality.

Panel A: Number of detected keywords used in the filters

Keyword	#	Keyword	#	Keyword	#
financial crisis	440	investment portfolio	28	share falling	2
market price	162	commodity markets	26	share fell	2
financial market	149	share prices	24	stock closed	2
green investment	144	shares fell	22	stock fall	2
green fund	141	boost investment	19	stock fell	2
capital market	127	the returns	17	stock were down	2
financial markets	118	stock index	16	market returns	1
market share	117	shares rose	15	markets closed	1
the return	113	green funds	14	share rises	1
capital markets	111	stocks fall	13	share was down	1
investment fund	108	shares fall	9	shares rises	1
stock exchange	103	drive investments	9	stock jumped	1
stock market	93	shares were down	8	stock return	1
market value	92	the performances	8	stock returns	1
market prices	84	boost investments	6	stocks indices	1
bullish	80	stocks fell	6	stocks moved	1
the performance	74	green stock	5	stocks price	1
no return	71	shares were up	5	stocks prices	1
investment funds	64	driving investments	4	stocks rally	1
stock price	60	green stocks	4	stocks rebound	1
share price	47	market shares	4		
nasdaq	46	share fall	4		
green investments	45	shares jumped	4		
drive investment	42	share rose	3		
new york stock exchange	37	shares closed	3		
stock prices	37	stock indices	3		
commodity market	37	stock rally	3		
the crash	32	stock rose	3		
bearish	31	growth stock	2		


2003-2018
Monthly climate change news intensity
2009 Copenhagen UN climate change conference
2016 Paris Agreement
2017 Trump withdraws from Paris Agreement
Number of article−equivalents
600
400
200
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Date
Theme
Business Impact
Environmental Impact
Societal Debate
Research

Step 3: News Article-Level Concerns Score

Definition of concern:

"Something that makes you feel worried"

Dictionary approach to quantifying risk of negative outcomes

Step 3: News Article-Level Concerns Score

We take a lexicon approach:

For each article:

$$\text{concern} = 100 \times \frac{\#\, risk\ words}{\#\, words} \times \frac{\#\, negative\ words}{\#\, negative\ words + \#\, positive\ words}$$

These lexicons are retrieved from the LIWC2015 software (Pennebaker et al., 2015).

https://liwc.wpengine.com/.

Example

Republicans and Democrats in congress acted responsibly in passing a billion-aid bill for victims of hurricane Sandy. Having utilities charge a few more pennies a month on electric bills for improvements to power plants that would curb manmade global warming is more prudent than having congress write big checks after each disaster pollution controls. Concern about climate change isn't treehugging. The military sees it as a threat to national security. Insurance firms track it to adjust policy rates. The dollars that congress is allocating for disaster argue for a more proactive approach. Lawmakers of both parties need to get serious finally about this environmental threat.

$$N = 105$$

$$Concern?$$

Concern Scoring Articles

Republicans and Democrats in congress acted responsibly in passing a billion-aid bill for victims of hurricane Sandy. Having utilities charge a few more pennies a month on electric bills for improvements to power plants that would curb manmade global warming is more prudent than having congress write big checks after each disaster pollution controls. Concern about climate change isn't treehugging. The military sees it as a threat to national security. Insurance firms track it to adjust policy rates. The dollars that congress is allocating for disaster argue for a more proactive approach. Lawmakers of both parties need to get serious finally about this environmental threat.

$N = 105$

$RW = 6$

Risk level

$$Concern = 100 * \frac{6}{105}$$

Concern Scoring Articles

Republicans and Democrats in congress acted responsibly in passing a billion-aid bill for victims of hurricane Sandy. Having utilities charge a few more pennies a month on electric bills for improvements to power plants that would curb manmade global warming is more prudent than having congress write big checks after each disaster pollution controls. Concern about climate change isn't treehugging. The military sees it as a threat to national security. Insurance firms track it to adjust policy rates. The dollars that congress is allocating for disaster argue for a more proactive approach. Lawmakers of both parties need to get serious finally about this environmental threat.

$N = 105$

$RW = 6$

$NW = 4$

$PW = 3$

Risk level Level of negativity

$$Concern = 100 * \frac{6}{105} * \frac{4}{4+3} = 3.26$$

Step 4: Aggregation across articles per day

Per news source s, we compute for each news source the total concern expressed for each day:

$$concerns_{t,s} = \sum_{n=1}^{N_{t,s}} concerns_{n,t,s} = N_{t,s} \times \overline{concerns}_{t,s}$$

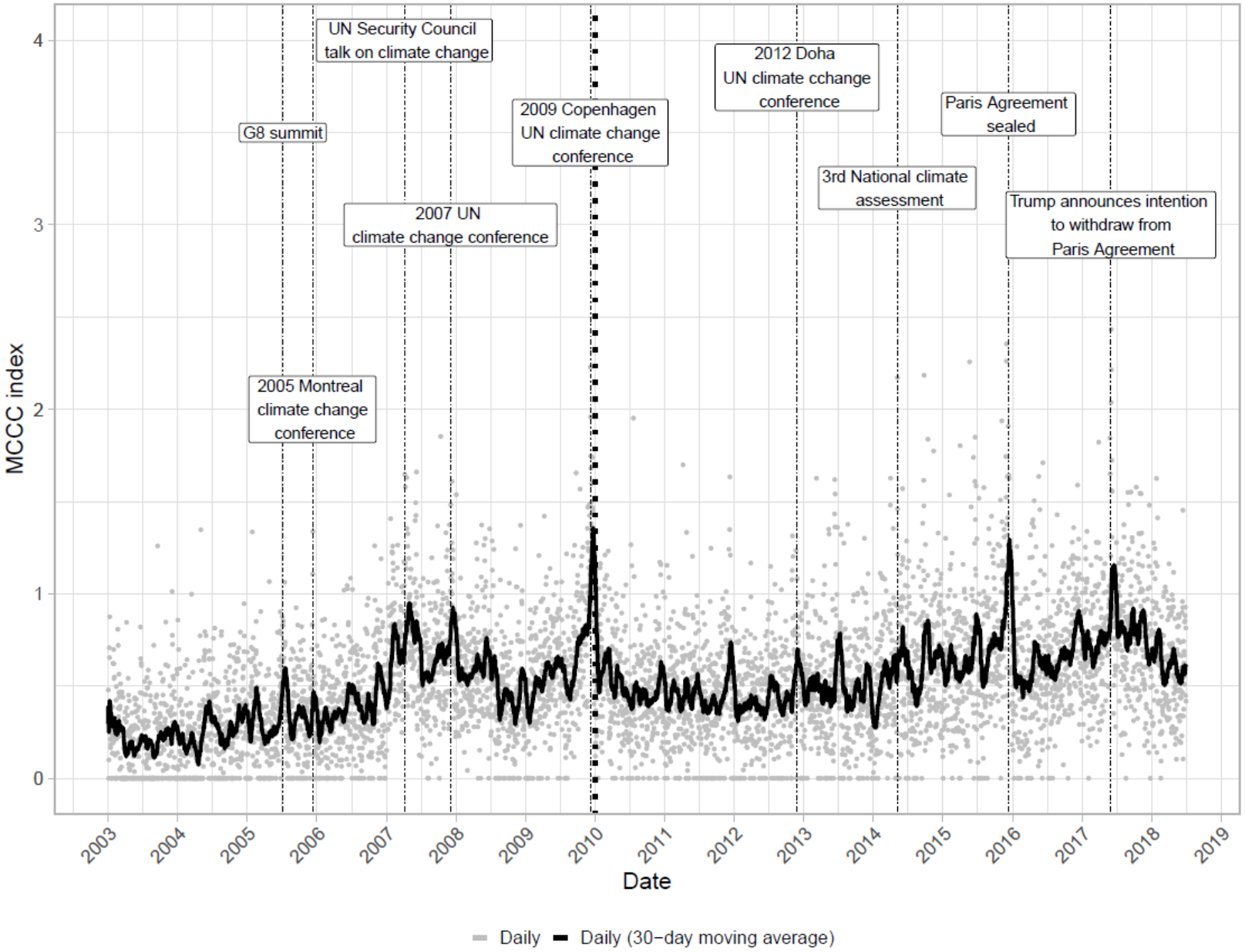
(reach x intensity)

Step 4: Aggregation across newspapers

We then obtain the media climate change concern by taking the average across the different news sources standardized concerns

$$MCCC_t = \frac{1}{S}\sum_{s=1}^{S}\frac{concerns_{t,s}}{\sigma_s}$$

Media Climate Change Concerns Index



Unexpected component of MCCC

Expected changes in concerns about climate change should **already be priced** (i.e., prices should not move on expected events).

Thus, we need to extract the **unexpected** part of our index.

Unexpected component of MCCC

Expected changes in concerns about climate change should **already be priced** (i.e., prices should not move on expected events).

Thus, we need to extract the **unexpected** part of our index.

We use the prediction error from an **ARX(1) model** to get a proxy of unexpected changes in climate change concerns for each day.

Expectation

$$UMC_t = MCCC_t - \left(\hat{\alpha} + \hat{\rho} MCCC_{t-1} + \widehat{\gamma}' X_t\right)$$

UMC will be our state variable

ARX to remove confounding effects

The variables are:

1. *MKT*: the daily excess market return;
2. *HML*: the daily high-minus-low factor of Fama and French (1992);
3. *SMB*: the daily small-minus-big factor of Fama and French (1992);
4. *CMA*: the daily conservative-minus-aggressive factor of Fama and French (2015);
5. *RMW*: the daily robust-minus-weak factor of Fama and French (2015);
6. *MOM*: the daily momentum factor of Carhart (1997);
7. *WTI*: the daily crude oil return (West Texas Intermediate crude oil price, DCOILWTICO);
8. *NG*: the daily natural gas return (Henry hub natural gas spot price, DHHNGSP);
9. *PROP*: the daily propane return (Mont Belvieu Texas price, DPROPANEMBTX);
10. *EPU*: the daily U.S. economic policy uncertainty index of Baker, Bloom, and Davis (2016);
11. *VIX*: the daily CBEO volatility index;
12. *TED*: the daily TED spread;
13. *TERM*: the daily term factor of Fung and Hsieh (2004);
14. *DFLT*: the daily default factors of Fung and Hsieh (2004);
15. *FTS*: the daily flight-to-safety index of Baele et al. (2020);
16. *GB*: the daily returns of a green bonds' portfolio;
17. *GMB*: the daily return of the green-minus-brown stocks' portfolio (25-75th percentile).

Outline

1. Capturing climate change concerns
2. **Testing the prediction**
3. Thematic analysis

Universe and Greenness

We focus on **S**&P 500 firms for the period 2010-2018.

We use their GHG intensity of the previous year to make green (lowest 25%) and brown (highest 25%) portfolios.

Portfolios are equally-weighted.

Universe and Greenness

For each portfolio, we have a daily return series, which we regress on the unexpected climate change concern index and control variables:

$$r_{G,t} = c_G + \beta_G UMC_t + controls + \epsilon_{G,t}$$

$$r_{B,t} = c_B + \beta_B UMC_t + controls + \epsilon_{B,t}$$

$$r_{G,t} - r_{B,t} = c_{GMB} + \beta_{GMB} UMC_t + controls + \epsilon_{GMB,t}$$

Prediction from Pastor et al. (2020): $\beta_G > 0$, $\beta_B < 0$, and $\beta_{GMB} > 0$

	GMB	Green	Brown
Intercept	0.068*	0.019	−0.049*
	(0.038)	(0.019)	(0.028)
UMC	0.072**	0.029**	−0.042*
	(0.031)	(0.014)	(0.023)
MKT	0.127***	1.1***	0.973***
	(0.016)	(0.008)	(0.013)
HML	0.112***	0.178***	0.066***
	(0.036)	(0.018)	(0.024)
SMB	0.071***	0.016	−0.055***
	(0.026)	(0.011)	(0.02)
CMA	−0.462***	−0.08***	0.382***
	(0.048)	(0.028)	(0.035)
RMW	−0.296***	−0.122***	0.174***
	(0.04)	(0.019)	(0.031)
MOM	0.078***	−0.088***	−0.165***
	(0.023)	(0.011)	(0.017)
WTI	−8.458***	−2.956***	5.502***
	(0.695)	(0.336)	(0.51)
NG	−0.361	−0.065	0.296
	(0.27)	(0.113)	(0.208)
PROP	−1.252***	−0.404	0.848**
	(0.482)	(0.251)	(0.351)
EPU	0.013	−0.005	−0.018
	(0.019)	(0.009)	(0.013)
VIX	−0.003	0.001	0.004***
	(0.002)	(0.001)	(0.001)
TED	−0.063	−0.069*	−0.006
	(0.081)	(0.041)	(0.062)
TERM	3.324***	1.122***	−2.202***
	(0.366)	(0.164)	(0.273)
DFLT	0.291	0.146	−0.145
	(0.211)	(0.103)	(0.159)
FTS	0.078	−0.044	−0.122
	(0.125)	(0.057)	(0.097)

$\beta_G > 0$

$\beta_B < 0$

$\beta_{GMB} > 0$

$|\beta_G| > |\beta_G|$

Robustness to controls used and cutoff

Panel A: 25-75th percentiles

	UMC exposure		
	GMB	Green	Brown
CTRL-1	0.085**	0.03*	−0.056*
	(0.038)	(0.015)	(0.029)
CTRL-3	0.086**	0.03**	−0.056**
	(0.036)	(0.015)	(0.026)
CTRL-6	0.081**	0.031**	−0.05**
	(0.034)	(0.015)	(0.024)
CTRL-15	0.072**	0.029**	−0.042*
	(0.031)	(0.014)	(0.023)

Panel B: 10-90th percentiles

	UMC exposure		
	GMB	Green	Brown
CTRL-1	0.113**	0.039	−0.074*
	(0.056)	(0.026)	(0.039)
CTRL-3	0.113**	0.038	−0.075**
	(0.051)	(0.025)	(0.037)
CTRL-6	0.111**	0.04	−0.071*
	(0.052)	(0.025)	(0.037)
CTRL-15	0.116**	0.041*	−0.075**
	(0.05)	(0.024)	(0.037)

Panel C: 40-60th percentiles

	UMC exposure		
	GMB	Green	Brown
CTRL-1	0.061**	0.023*	−0.038*
	(0.029)	(0.013)	(0.023)
CTRL-3	0.061**	0.023*	−0.038*
	(0.028)	(0.013)	(0.021)
CTRL-6	0.057**	0.025**	−0.032*
	(0.028)	(0.012)	(0.019)
CTRL-15	0.05**	0.023*	−0.027
	(0.025)	(0.012)	(0.018)

The panel of stock returns

The portfolio analysis captures an average effect of green versus brown stocks.

Stocks differ in terms of their carbon footprint, as measured by their greenhouse gas emission intensity.

Heterogeneity: We expect that the impact of climate change concerns on firm value depends on the GHG emission.

A simple model for firm value

A simple model for firm value:

$$V_{i,t} = V_{i,t-1} \exp\left(c + \left(\beta + \beta_{lGHG} lGHG_{i,t}\right) UMC_t\right)$$

with $\beta_{lGHG} < 0$ such that the more polluting the firm is, the more it loses equity value on days with increased climate change concern (cashflow effect + discount rate)

Note if UMC_t=0, then only a drift in firm value.

We expect $\beta_{lGHG} < 0$

From firm value to returns

A simple model for firm value:

$$V_{i,t} = V_{i,t-1} \exp\left(c + \left(\beta + \beta_{lGHG} lGHG_{i,t}\right) UMC_t\right)$$

with $\beta_{lGHG} < 0$

The corresponding regression model is obtained by taking logs and adding controls and error terms:

$$r_{i,t} = \ln\left(V_{i,t}\right) - \ln\left(V_{i,t-1}\right) = c + \left(\beta + \beta_{lGHG} lGHG_{i,t}\right) UMC_t + controls + \epsilon_{i,t}$$

with $\beta_{lGHG} < 0$ such that the more polluting the firm is, the more it loses equity value on days with increased climate change concern (cashflow effect + discount rate)

β_{lGHG} in the panel of stock returns

	$lGHG$	UMC	$lGHG \times UMC$
CTRL-1	0.005^{*}	-0.006	-0.027^{***}
	(0.003)	(0.004)	(0.005)
CTRL-3	0.004	-0.008^{**}	-0.024^{***}
	(0.003)	(0.004)	(0.005)
CTRL-6	0.005	-0.005	-0.023^{***}
	(0.003)	(0.004)	(0.005)
CTRL-15	0.007^{**}	-0.002	-0.021^{***}
	(0.003)	(0.004)	(0.005)

Non-Disclosure

Several firms do not disclose GHG emissions data.

Are they exposed to unexpected changes in climate change concerns?

We use the industry average at each point in time to estimate the GHG intensity level of non-disclosing firms.

Findings: No significant deviation compared to firms that disclose. **They are still exposed to unexpected change in climate change concerns.**

Outline

1. Capturing climate change concerns.
2. Empirical results.
3. **Thematic analysis.**

Concern about climate change

We have used one index

Climate change concerns cover different themes

More granularity by making a UMC index for each theme

RQ1: Which themes?

RQ2: Does it impact the performance of green and brown stocks?

RQ3: Is it a cashflow or discount effect?

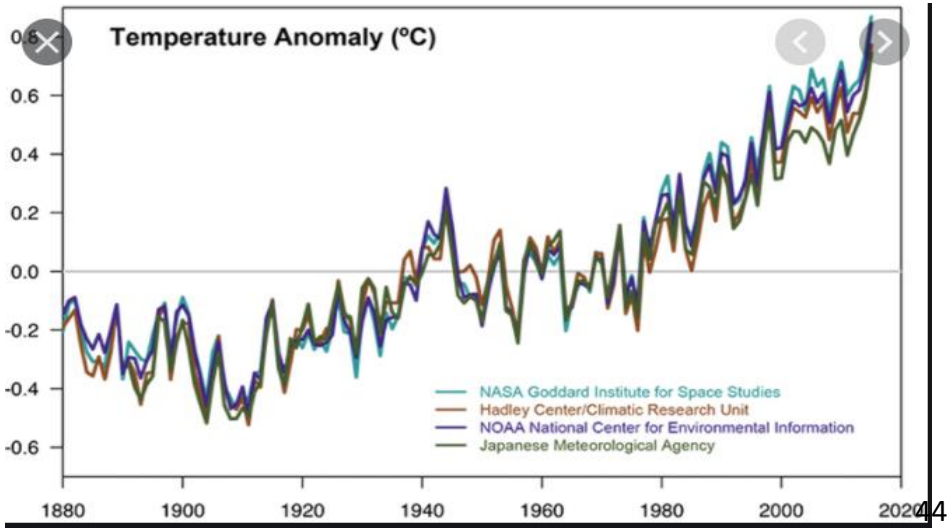
Expected Topics of Discussion

Environmental impact

Societal debate

Business impact

Research



Topic model

A **topic model** is textual analysis method for discovering in an unsupervised way the "topics" that occur in a collection of documents.

Each document is a mixture of subjects and each subject is described as a set of words with given probabilities.

We use the **Correlated Topic Model** of Blei et al. (2006), which allows for correlation between topics and gives more coherent (and interpretable) topics.

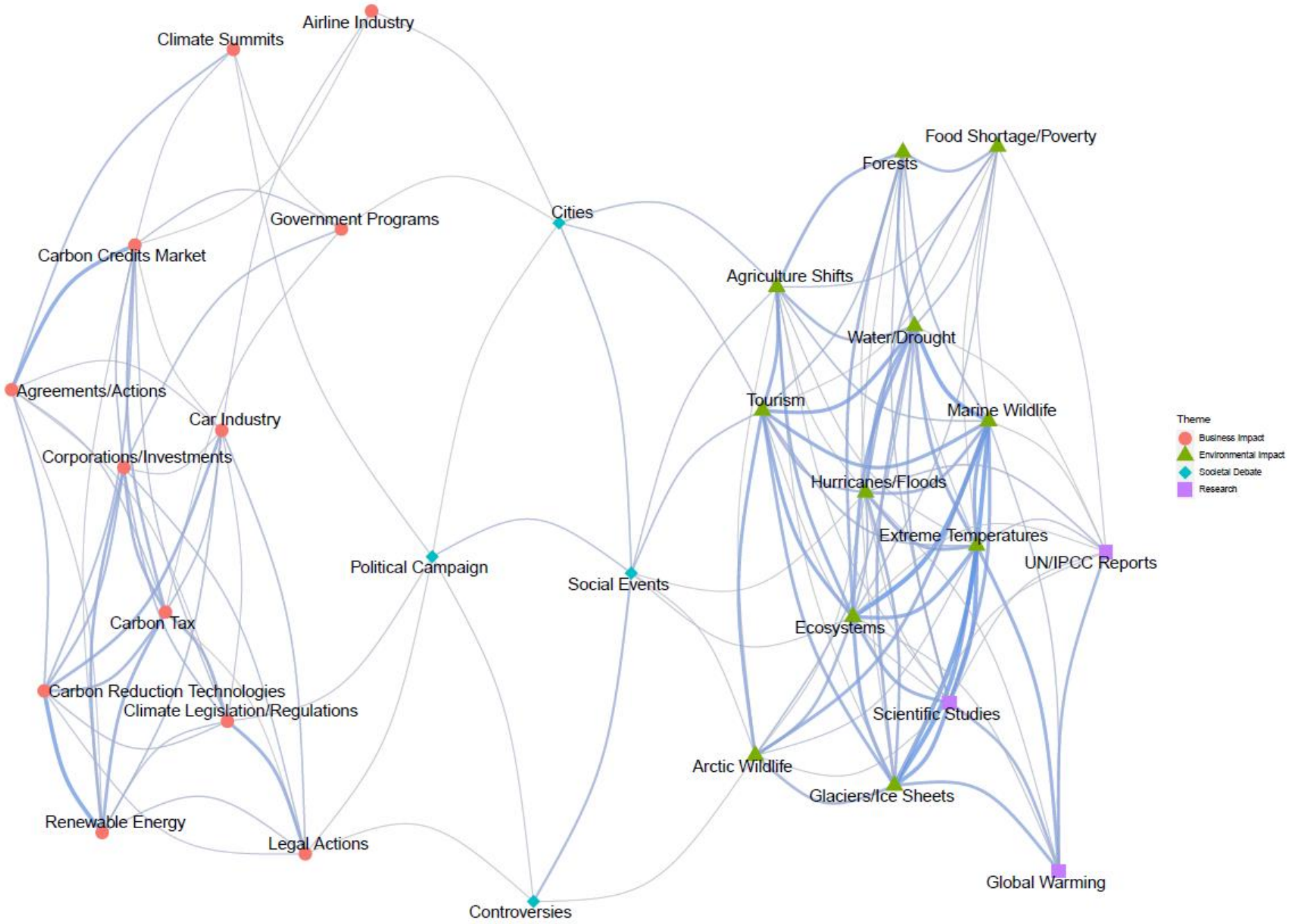
Theme 1: "Business Impact"	
Topic	Top ten keywords in terms of probability
Climate Summits	agreement, country, climate change, nation, world, talk, deal, meeting, develop country, summit
Agreements/Actions	percent, emission, level, target, greenhouse gas emission, goal, country, government, greenhouse gas, year
Climate Legislation/Regulations	bill, state, cap, legislation, vote, lawmaker, measure, program, global warming, year
Legal Actions	state, administration, rule, regulation, agency, plan, court, decision, law, case
Renewable Energy	oil, energy, natural gas, gas, pipeline, fossil fuel, renewable energy, wind, nuclear power, world
Carbon Reduction Technologies	coal, plant, power plant, electricity, carbon dioxide, technology, power, utility, gas, year
Carbon Credits Market	market, price, scheme, government, credit, euro, tonne, carbon, year, permit
Carbon Tax	cost, tax, carbon, energy, price, policy, fuel, carbon tax, biofuel, economy
Government Programs	project, money, fund, program, year, development, government, budget, funding, plan
Corporations/Investments	company, business, climate change, investor, group, investment, firm, industry, risk, chief executive
Car Industry	car, vehicle, standard, methane, gas, year, fuel, industry, automaker, carbon dioxide
Airline Industry	airline, flight, ship, emission, aviation, plane, air, pollution, shipping, aircraft
Theme 2: "Environmental Impact"	
Topic	Top ten keywords in terms of probability
Extreme Temperatures	year, record, weather, temperature, winter, day, summer, climate change, heat, global warming
Food Shortage/Poverty	climate change, people, crop, country, farmer, world, food, woman, agriculture, foundation
Hurricanes/Floods	flood, storm, hurricane, climate change, sea level, island, disaster, damage, flooding, risk
Glaciers/Ice Sheets	ice, glacier, year, scientist, foot, ice sheet, mile, melting, sea ice, satellite
Ecosystems	species, animal, plant, bird, disease, climate change, population, year, habitat, extinction
Forests	tree, forests, forest, fire, land, deforestation, carbon, acre, area, soil
Water/Drought	water, state, region, river, rivers, drink, year, lake, area, dam
Tourism	site, town, day, mountain, year, snow, mile, park, foot, people
Arctic Wildlife	polar bear, sea ice, bear, seal, ice, habitat, species, wildlife, year, population
Marine Wildlife	fish, water, sea, oceans, ocean, scientist, coral, alga, year, reef
Agriculture Shifts	food, farm, year, wine, plant, meat, production, farmer, coffee, cow
Theme 3: "Societal Debate"	
Topic	Top ten keywords in terms of probability
Political Campaign	climate change, issue, leader, president, campaign, election, party, country, speech, policy
Social Events	people, world, time, life, climate change, child, year, student, book, global warming
Controversies	climate change, science, global warming, scientist, climate, issue, question, evidence, research, document
Cities	city, people, building, home, energy, light, resident, community, mayor, group
Theme 4: "Research"	
Topic	Top ten keywords in terms of probability
Global Warming	degree, global warming, warming, world, scientist, year, carbon dioxide, atmosphere, greenhouse gas, century
UN/IPCC Reports	report, climate change, risk, impact, global warming, panel, effect, government, world, study
Scientific Studies	study, research, scientist, researcher, data, atmosphere, researchers, climate, effect, model

TRANSITION RISK

PHYSICAL RISK

TRANSITION RISK

PHYSICAL RISK


Airline Industry
Climate Summits
Government Programs
Cities
Carbon Credits Market
Food Shortage/Poverty
Forests
Agriculture Shifts
Water/Drought
Agreements/Actions
Tourism
Marine Wildlife
Car Industry
Corporations/Investments
Hurricanes/Floods
Extreme Temperatures
UN/IPCC Reports
Political Campaign
Social Events
Carbon Tax
Ecosystems
Carbon Reduction Technologies
Climate Legislation/Regulations
Scientific Studies
Arctic Wildlife
Glaciers/Ice Sheets
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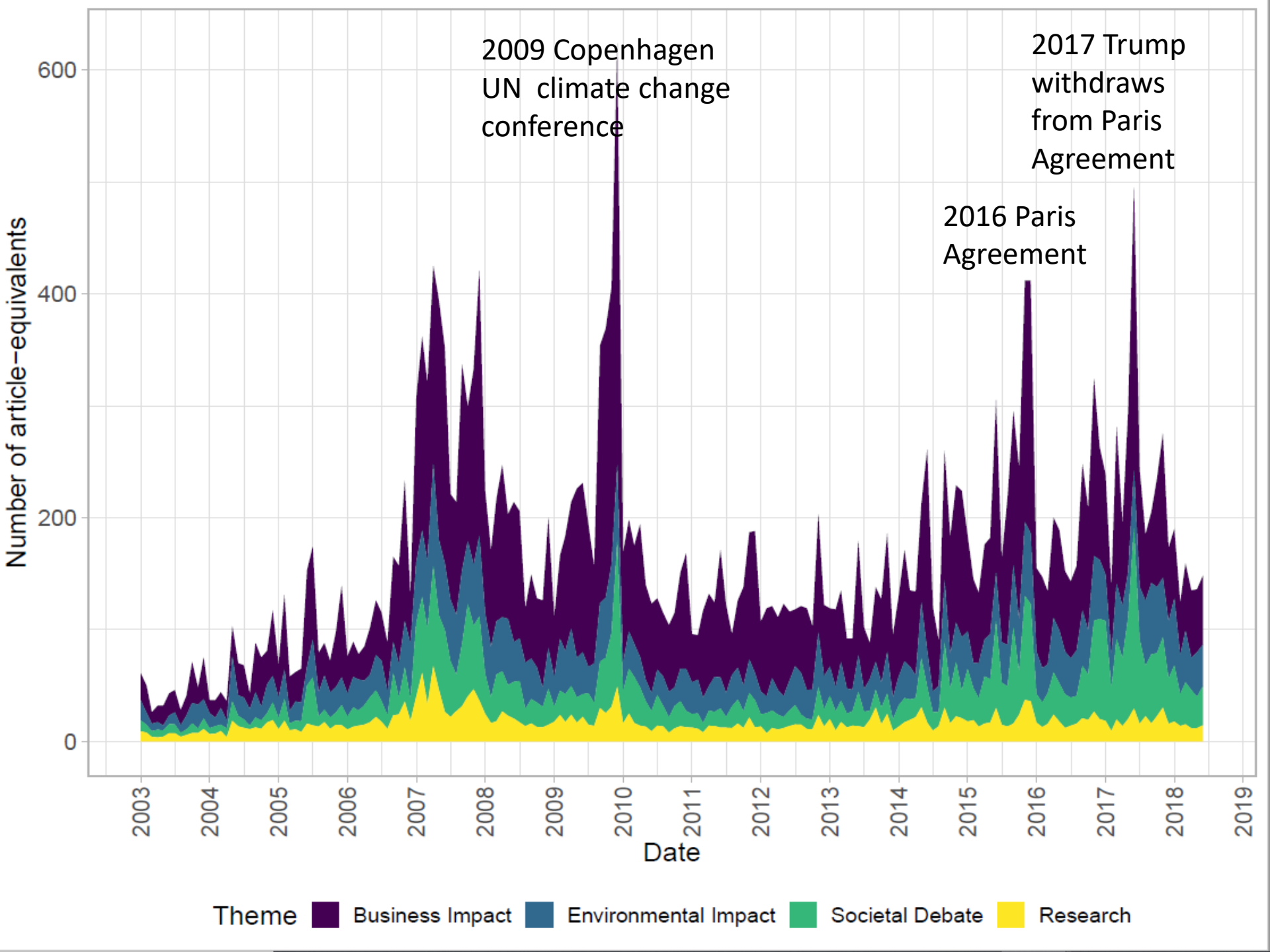
Legal Actions
Global Warming
Controversies
Theme
Business Impact
Environmental Impact
Societal Debate
Research


2009 Copenhagen UN climate change conference
2017 Trump withdraws from Paris Agreement
2016 Paris Agreement
Number of article−equivalents
600
400
200
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Date
Theme
Business Impact
Environmental Impact
Societal Debate
Research

Aggregation to thematic concerns

Per article, we know

- The concern
- The thematic probability

- Thematic climate change concerns index is then obtained by averaging across their product:

thematic probability x concern

They capture different concerns

Panel A: Unconditional correlations				
	BI	EI	SD	R
Aggregate	0.85	0.79	0.82	0.81
BI		0.47	0.66	0.57
EI			0.51	0.73
SD				0.58
Panel B: Correlations when aggregate UMC is high				
	BI	EI	SD	R
Aggregate	0.58	0.41	0.53	0.54
BI		−0.25	0.34	0.04
EI			−0.22	0.37
SD				0.03

	$lGHG$	UMC_k	$lGHG \times UMC_k$
Theme 1: "Business Impact"	0.007^{**}	0.006	-0.028^{***}
Climate Summits	0.006^{**}	-0.002	-0.028^{***}
Agreements/Actions	0.006^{**}	-0.001	-0.021^{***}
Climate Legislation/Regulations	0.006^{*}	0.006	-0.026^{***}
Legal Actions	0.007^{**}	0.005	-0.013^{***}
Renewable Energy	0.007^{**}	0.001	-0.02^{***}
Carbon Reduction Technologies	0.006^{**}	0.01^{***}	-0.015^{***}
Carbon Credits Market	0.006^{**}	-0.002	-0.018^{***}
Carbon Tax	0.006^{*}	0.011^{***}	-0.014^{***}
Government Programs	0.007^{**}	-0.002	-0.019^{***}
Corporations/Investments	0.006^{**}	-0.003	-0.015^{***}
Car Industry	0.006^{*}	0.002	-0.001
Airline Industry	0.006^{*}	0.013^{***}	-0.012^{***}
Theme 2: "Environmental Impact"	0.006^{*}	-0.008^{*}	-0.005
Extreme Temperatures	0.006^{*}	-0.007^{**}	0.003
Food Shortage/Poverty	0.006^{*}	-0.007^{*}	0.001
Hurricanes/Floods	0.006^{**}	-0.006^{*}	-0.01^{***}
Glaciers/Ice Sheets	0.006^{*}	-0.011^{***}	-0.016^{***}
Ecosystems	0.006^{*}	-0.004	0.004
Forests	0.006^{*}	0.005	-0.006
Water/Drought	0.006^{**}	-0.002	-0.01^{**}
Tourism	0.006^{**}	0.002	-0.025^{***}
Arctic Wildlife	0.006^{*}	-0.007	-0.002
Marine Wildlife	0.006^{*}	0.015^{***}	0.001
Agriculture Shifts	0.005^{*}	-0.006	0.012^{**}

	$lGHG$	UMC_k	$lGHG \times UMC_k$
Theme 3: "Societal Debate"	0.007^{**}	0.005	-0.023^{***}
Political Campaign	0.007^{**}	0.00	-0.024^{***}
Social Events	0.006^{*}	0.007^{*}	-0.01^{**}
Controversies	0.007^{**}	-0.003	-0.022^{***}
Cities	0.006^{**}	0.01^{***}	-0.014^{***}
Theme 4: "Research"	0.006^{*}	-0.011^{***}	-0.01^{*}
Global Warming	0.006^{*}	-0.007	-0.014^{**}
UN/IPCC Reports	0.006^{*}	-0.015^{***}	-0.009^{*}
Scientific Studies	0.006^{*}	-0.005	-0.002

Conclusion

Motivation: While greenness of firms is only slowly varying, the concerns about climate change can be rapidly varying. This can have substantial price impact.

- Empirical result is new: Possible thanks to the MCCC and UMC index
- Confirms theory by Pastor, Stambaugh and Taylor (2021)
- Result is robust: portfolio approach, panel approach
- Impact depends on the carbon footprint of the firm and theme (main impact from transition risk)

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