A Machine Learning Based Anatomy of Firm-level Climate Risk Exposure

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Abstract

We construct various measures of firm-level climate risk exposure by utilizing two natural language processing techniques (LDA and word2vec) on firms' quarterly earnings conference call transcripts. The unsupervised learning method automatically generates five topics related to transition risks (i.e. Renewable, Technology, and Carbon) and physical risks(i.e. Disaster and Weather), all aligned with popular concerns about climate change. Institutional investors significantly divest from companies associated with high transition risks, even if we exclude salient industries. While most of these topics are negatively associated with firms' values, Technology has a value-increasing effect. Moreover, firms with higher disaster exposure tend to earn higher expected stock returns than those counterparts with lower exposure, suggesting that firms' disaster risk exposure significantly affects the cost of equity.

What we do

Motivation: The lack of anatomy of different aspects of climate risk exposure directly measured at the firm level.

Main contribution: Construct firm-level climate risk exposures using NLP techniques and earnings call transcripts from 2001 to 2020.

1. Apply LDA analysis on Intergovernmental Panel on Climate Change (IPCC) reports to extract keywords about climate change. This step obtains seeds automatically from the reports that have a thorough understanding of climate change and avoid human biases.
2. Use the word2vec model on entire earnings call transcripts to detect semantic relatedness between words. Collect similar words in transcripts for each seed word according to the cosine similarity between word representation vectors and form a climate change words pool with 1129 words.
3. Further apply LDA on sentences containing climate related words at the transcript level to get each transcript's loading on topics in real time.
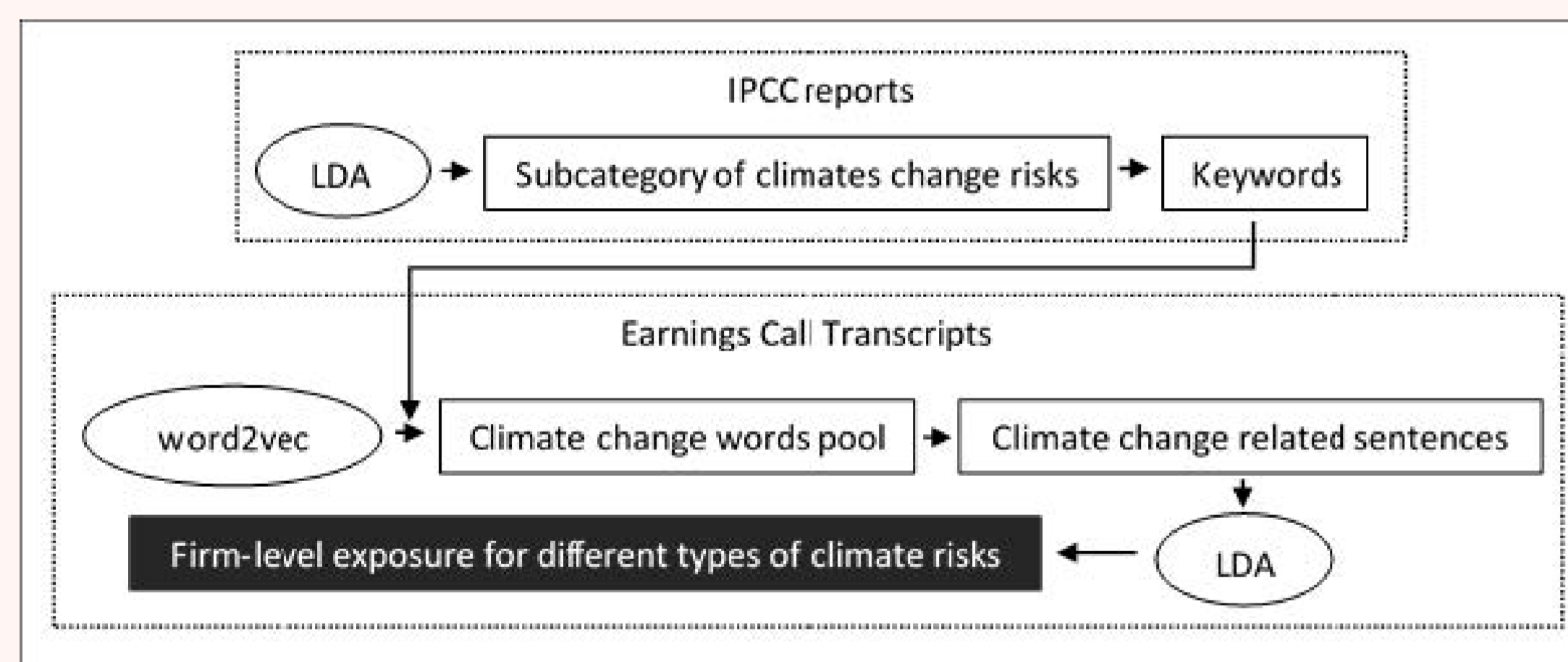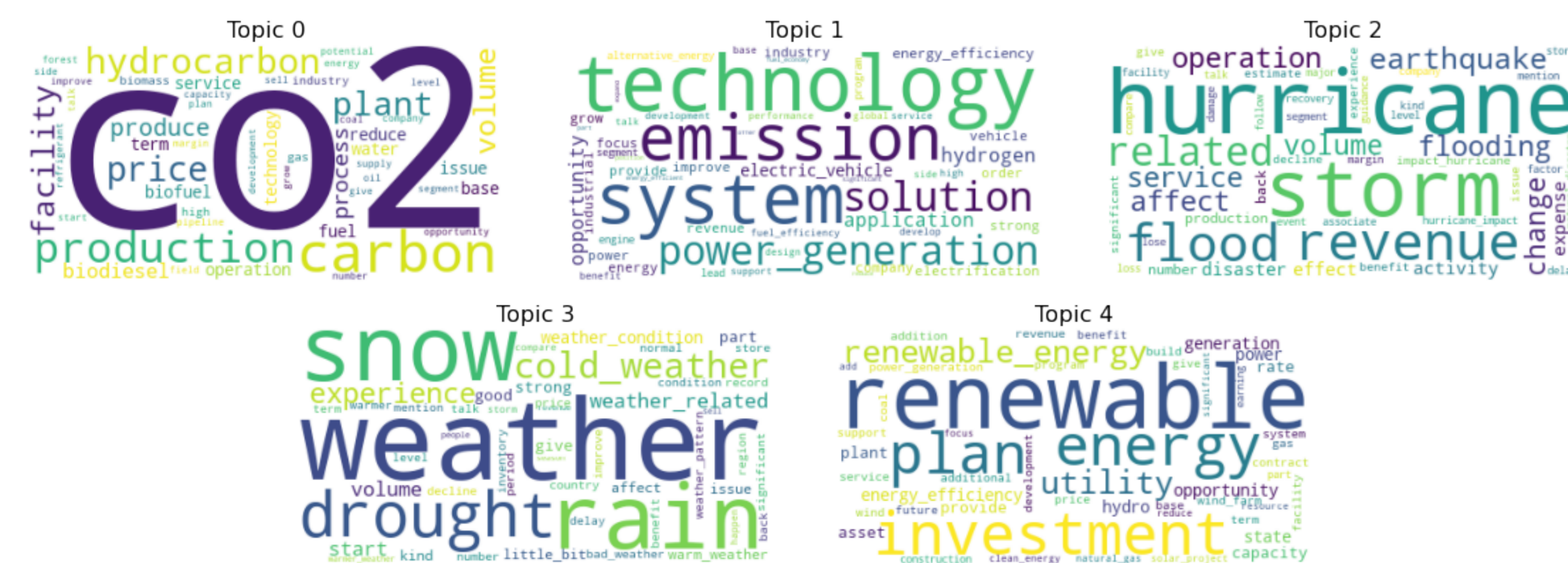

Figure 1. NLP Procedure

Figure 2. Word cloud for topics in transcripts

What we find

Our procedure automatically generates five topics and Figure 1 shows their word clouds. According to the distribution of the words, three of the topics depict transition risks, which start to increase in the early 2000s and have a peak immediately after Copenhagen Summit, and two belong to physical risks, whose peaks correspond to well-known extreme weather events.
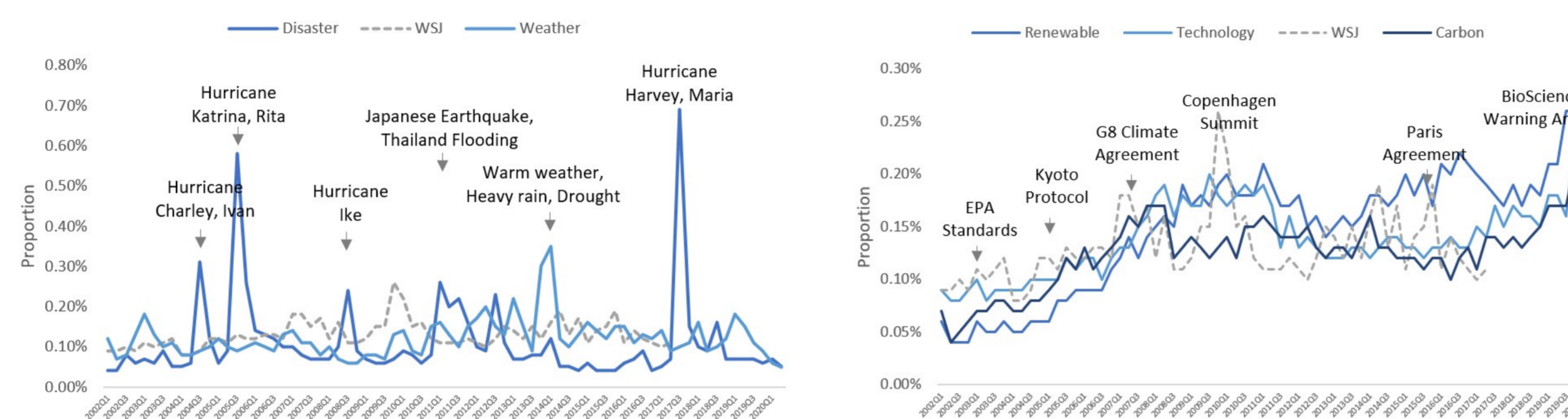

Figure 3. Mean value across firms over time

We label the five topics as:

- **Disaster:** The most common discussion is about the negative impact of a specific natural disaster. Some firms mention general disaster concerns due to their business sensitivities. Industry concentration: construction, utilities and transportation.
- **Weather:** This topic pays more attention to abnormal weather patterns like extreme cold/warm/dry conditions, which are more likely to have a chronic impact. Industry: agriculture, metal mining, and retail.
- **Technology:** This topic often talks about advanced technology on emission control that helps firms in the transportation, industrial and mining markets to meet mandated emissions standards. Industry: electrical equipment, and automobiles and trucks.
- **Renewable:** It focuses on firms' goal or commitment on renewable investments (e.g. wind farm, solar energy) and coal-to-gas conversion. These firms are often the main target for regulation to limit emissions. Industry: utilities, coal and construction.
- **Carbon:** Topic Carbon centers on regulations or firms' efforts on constraining carbon footprints (e.g. carbon capture, carbon tax, phase-out of refrigerants). Industry: chemicals, agriculture, and coal.

Validation

- Topics Disaster and Weather are positively associated with realized hazard dummy.
- Firms with high E score and underlying categories' scores tend to discuss transition related topics more.

	Physical risks			Transition risks		
Variables	Disaster	Weather	Variables	Carbon	Renewable	Technology
Real disaster	0.11**	-0.02	E score	0.24***	0.20***	0.300***
	(2.50)	(-1.30)		(3.43)	(2.93)	(4.44)
Hurricane	0.76***	-0.05	Emission	0.31***	0.10	0.13**
	(2.88)	(-1.68)		(4.60)	(1.53)	(2.24)
Flood	0.07*	-0.02	Innovation	0.28***	0.36***	0.55***
	(1.79)	(-1.37)		(3.06)	(4.12)	(7.90)
Drought	-0.03	0.17***	Resource	0.10	0.07	0.14***
	(-0.18)	(3.48)		(1.64)	(0.95)	(2.68)
Control	Yes	Yes		Yes	Yes	Yes
Industry FE	No	No		Yes	Yes	Yes
YearQtr FE	Yes	Yes		Yes	Yes	Yes

Implications of climate risk exposure

- Topics Disaster and Weather hurt sales growth.
- Firms with higher exposure to topic Carbon are likely to have larger sales growth, investment rate, and employment growth.
- Institutions ownership is negatively related to Carbon and Renewable, while mutual funds tend to invest in firms with high exposure to Technology.

				Inst. Own.			
Variables	Sales growth	I/K	Emp growth	All	Salient ind.	Ex. salient	MFO
Technology	0.44**	0.02	0.03	-0.19	0.18	-0.58**	1.03*
Carbon	0.77***	0.14***	0.42***	-1.33***	-0.64**	-1.25***	0.14
Weather	-0.22**	0.02	0.12	0.44	-0.31	0.85***	0.11
Disaster	-0.22**	0.07**	-0.32***	-0.05	-0.3	0.11	-0.04
Renewable	-0.08	0.03	0.30**	-2.42***	-1.80**	-0.86**	-0.99*
State&YQ FE	No	No	No	Yes	Yes	Yes	Yes
Industry&YQ FE	Yes	Yes	Yes	No	No	No	No

Firm valuations

- Topic Technology is positively correlated to firm value, especially for firms with low institutional ownership.
- Carbon and Renewable are negatively associated with firm value in recent ten years.
- Disaster has a value decreasing effect. This effect becomes insignificant in recent years, which may be because firms learned how to cope with natural disasters.

	log(Tobin's Q)						
Variables	All	2002-2010	2011-2020	IO_Low	IO_High	Salient	Ex. salient
Technology	1.42***	2.15***	0.92**	1.93***	0.36	2.42***	0.98*
	(3.32)	(3.49)	(1.99)	(3.81)	(0.64)	(3.81)	(1.80)
Carbon	-0.77**	0.33	-1.48***	-0.87*	-0.53	0.57	-1.64***
	(-1.96)	(0.76)	(-3.02)	(-1.72)	(-1.08)	(0.92)	(-3.28)
Weather	0.74*	0.62	0.82*	0.78	0.28	0.1	1.03**
	(1.90)	(1.62)	(1.70)	(1.58)	(0.57)	(0.17)	(2.11)
Disaster	-0.56***	-0.91***	-0.31	-0.52*	-0.54**	-0.57*	-0.52**
	(-2.63)	(-3.16)	(-1.20)	(-1.68)	(-2.28)	(-1.70)	(-1.99)
Renewable	-1.55***	-0.37	-1.98***	-1.61***	-1.51***	-1.10***	-2.18***
	(-4.70)	(-0.60)	(-5.39)	(-4.47)	(-2.59)	(-2.81)	(-3.86)
IndYear&YQ FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Salient industries include Agriculture, Chemicals, Electrical elements, Automobiles and Trucks, Coal, and Petroleum and Natural Gas.

Pricing of topic Disaster

A long-short portfolio based on the topic Disaster generates a positive return of 5% per annum, which cannot be explained by common risk factors and other firm characteristics. This positive Disaster-return relation has a one-year delay and the slow recovering behavior could be caused by slow learning speed about the disaster risk.

	Disaster							
	L	M	H	H-L	L	M	H	H-L
	Panel A: FF5				Panel B: HXZ5			
α	-0.38**	-0.04	0.15	0.53***	-0.10	0.07	0.27*	0.37**
t-stat	(-2.00)	(-0.31)	(0.81)	(3.19)	(-0.65)	(0.54)	(1.93)	(2.48)

Table 1. Asset pricing factor test for topic Disaster