Hurricane Risk and Asset Prices

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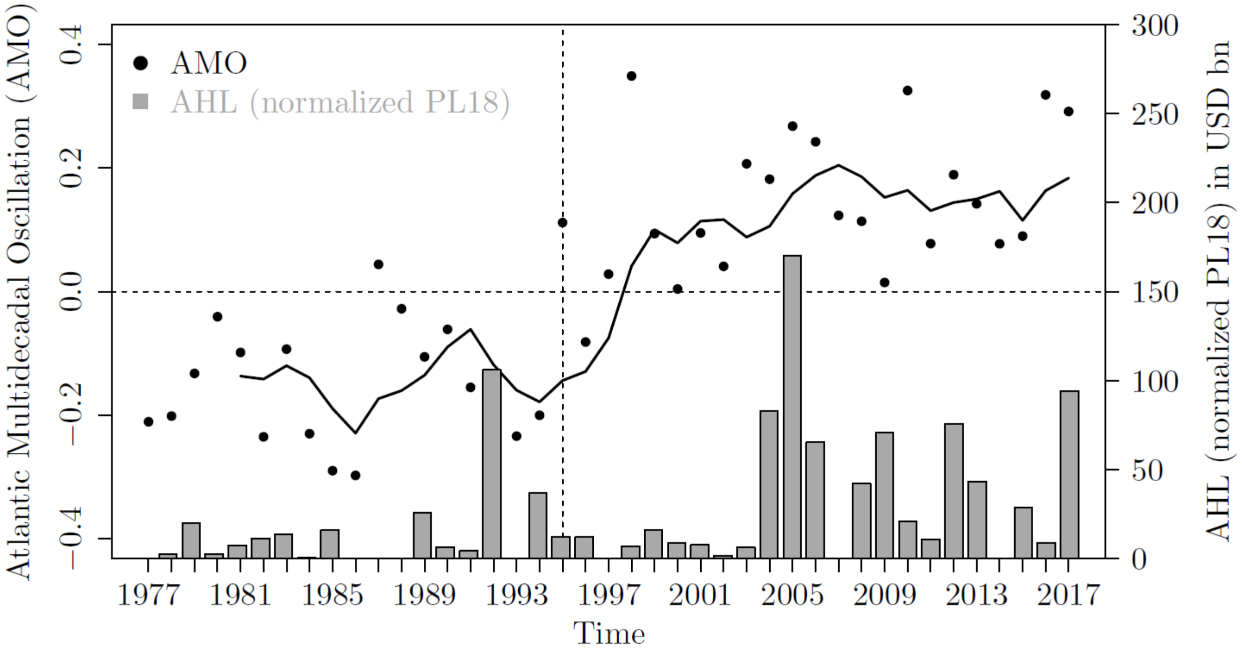
University of St.Gallen

Background and motivation

- Natural disasters are increasingly becoming an economic factor
  - ► Combined economic damages in 2017, 2018, 2019 of about USD 600 billion
- Hurricanes are the most violent type of disaster faced by US households and businesses
  - ► Account for eight of the ten costliest catastrophes in US history
- Hurricane risk has properties of a systematic risk factor
  - ► Geographically widespread, economically severe, follows clear patterns over time
- Full consumption insurance hypothesis violated
  - ► Only five percent of homeowners are insured against direct flood losses

Hurricane risk as a systematic risk factor

Stylized facts + known impact on firms



Known impact on firms:

- Management reactions (Dessaint & Matray, 2017)
- Cash flow shocks (Brown et al., 2017)
- Reallocation of capital (Cortès & Strahan, 2017)
- Credit constraints (Collier et al., 2020)

AMO warm period since 1995 / average normalized hurricane loss doubled

Contribution

- Theoretical framework rooted in consumption-based asset pricing
  - ► Predicts the existence of a hurricane risk premium since the mid 1990s
- A large range of empirical asset pricing tests confirms a hurricane risk premium
  - ► Portfolio sorts, Fama-MacBeth regressions, time series regressions etc.
- The effect is highly significant, robust and large
  - ► Zero investment portfolio NMP with an average excess return of at least 6.14% p.a.
- We provide additional insights regarding the economic mechanism
  - ► Economic hurricane risk exposure, hurricane risk across time, industry and market cap.

Related literature

- Natural disasters and financial markets

  Bourdeau-Brien et al. (2017), Mahalingam et al. (2018), Rehse et al. (2019) …

- Economics of natural disasters

  Belasen & Polachek (2008), Stern (2008), Addoum et al. (2020) …

- Climate finance

  Ilhan et al. (2020), Krueger et al. (2020), Bolton & Kacperczyk (2021) …

- Rare disasters and asset pricing

  Rietz (1988), Barro (2006), Berkman et al. (2011), Gabaix (2012), Wachter (2013) …

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Data sets

Normalized economic losses for US hurricanes (1900−2017)

► Weinkle et al. (2018)

Monthly returns on all common stocks in the US (1963−2020)

► Center for Research in Security Prices (CRSP)

Unfiltered non-durable goods/services consumption data + annual personal income statistics

► Kroencke (2017), Bureau of Economic Analysis (BEA)

Financial statements (10-K, 10-K405, 10-KSB)

► SEC EDGAR

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Brief summary of the theory

Heterogeneous agent model in the spirit of Constantinides & Duffie (1996, JPE)

Consumption inequality hypothesis

$$E_t[\tilde{R}^e_{t+1}] = \Big(\underbrace{\rho_t\big[\Delta\tilde{c}^2_{t+1}, \Delta a\tilde{h}l_{t+1}\big]}_{=\,0\ (1995-2017)} \cdot \rho_t\big[\tilde{R}^e_{t+1}, \Delta a\tilde{h}l_{t+1}\big] + E_t[\Delta\tilde{c}^*_{t+1}\tilde{R}^{e*}_{t+1}]\Big) \cdot \alpha$$

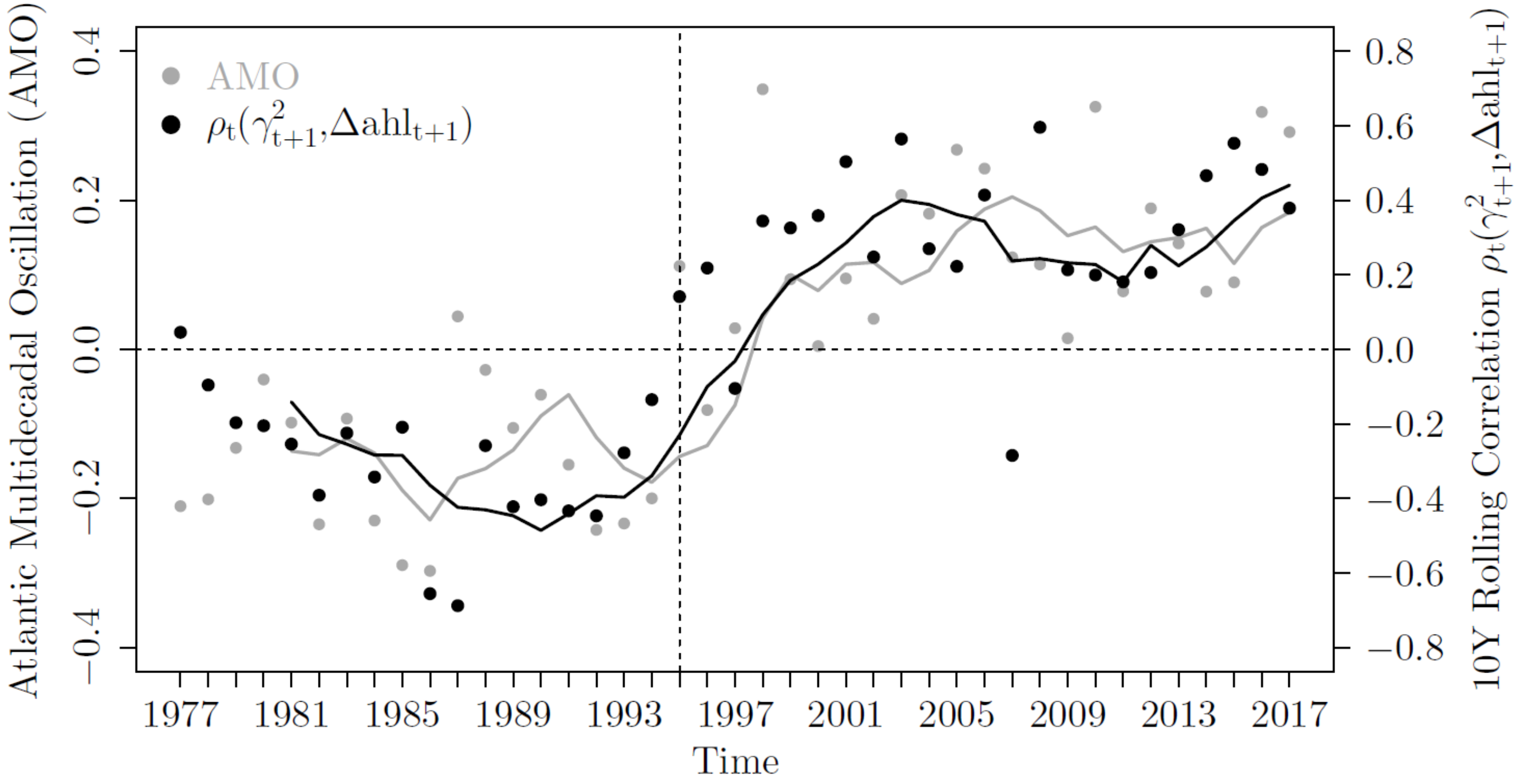
$$-\Big(\underbrace{\rho_t\big[\Delta\tilde{\gamma}^2_{t+1}, \Delta a\tilde{h}l_{t+1}\big]}_{=\,0.37^*\ (1995-2017)} \cdot \underbrace{\rho_t\big[\tilde{R}^e_{t+1}, \Delta a\tilde{h}l_{t+1}\big]}_{-?\ (1995-2017)} + E_t\underbrace{[\Delta\tilde{\gamma}^{*2}_{t+1}\tilde{R}^{e*}_{t+1}]}_{\text{orthogonal to } \Delta a\tilde{h}l_{t+1}}\Big) \cdot \alpha\frac{(\alpha+1)}{2}$$

$\Delta\tilde{c}^2_{t+1}$: log consumption growth

$\Delta a\tilde{h}l_{t+1}$: log aggregate hurricane loss growth

$\Delta\gamma^2_{t+1}$: consumption inequality (state-level cross-sectional variance of income growth per capita)

10-year rolling correlation between $\Delta\gamma_{t+1}^2$ and $\Delta a\tilde{h}l_{t+1}$



Problem: $\Delta a\widetilde{hl}_{t+1}$ only available at annual frequency

Tackle through mimicking portfolio for aggregate hurricane losses

1. Base assets: 25 FF Size and Book-to-Market Portfolios

2. Project $\Delta a\widetilde{hl}_{t+1}$ onto the set of base asset excess returns at an annual frequency:

   $\Delta a\widetilde{hl}_{t+1} = \gamma + \kappa_X' X_t + u_t$ where X_t are the base assets (t in years)

3. Normalize the estimated weights κ_X' to w_X', then apply to base assets at monthly frequency

   $MP_t^{\Delta a\widetilde{hl}} = w_X' X_t$ where $w_X' \boldsymbol{I} = 1$ (t in months)

Correlation between $\Delta a\widetilde{hl}_{t+1}$ and the mimicking portfolio $MP_t^{\Delta a\widetilde{hl}}$: 0.76 (1963−2017)

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Univariate out-of-sample portfolio sorts

Sample split in period before and after 1995

Panel a) January 1968 to December 1994

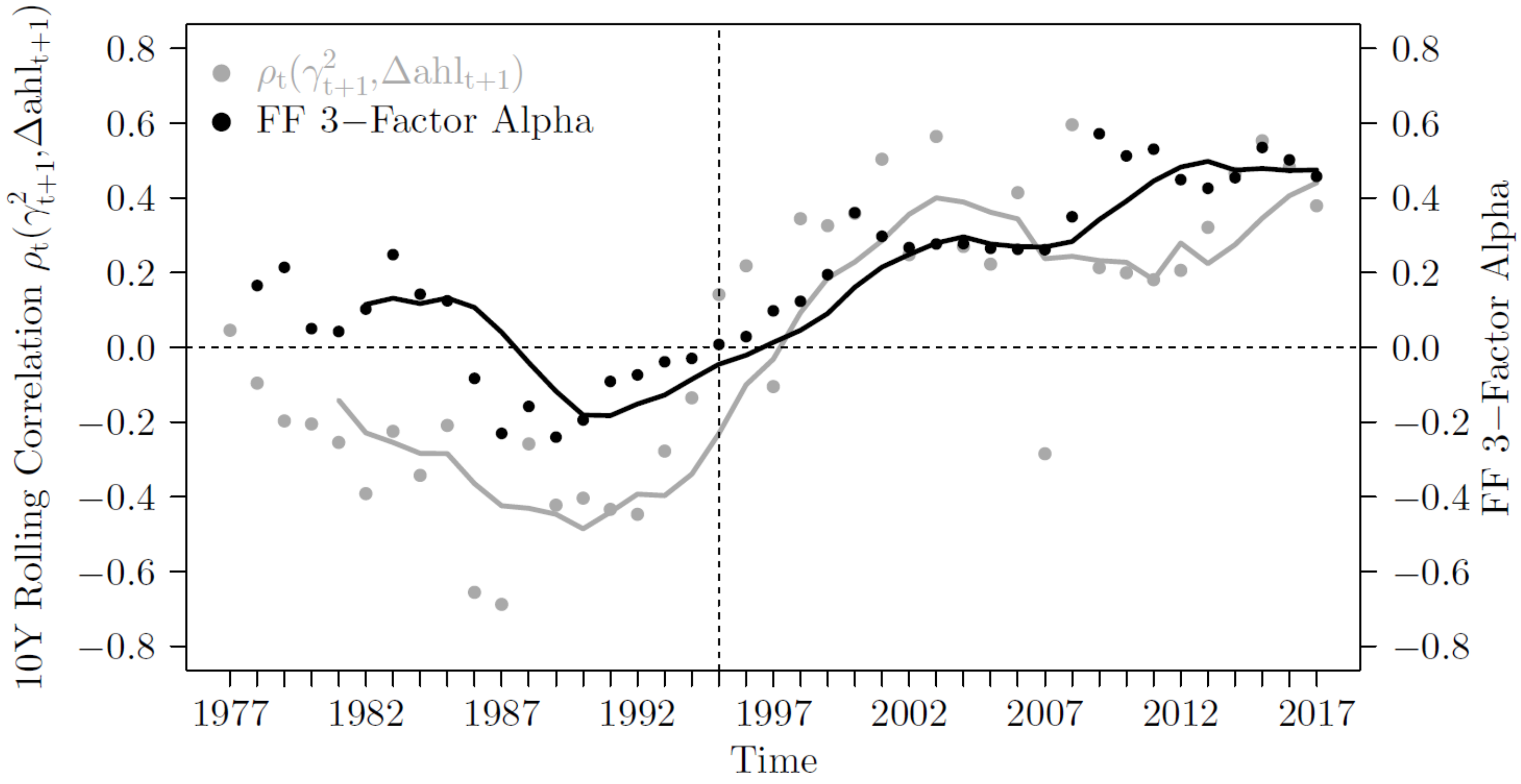
	Av. Beta	Av. Return	CAPM-Alpha	FF3-Alpha
Portfolio 1	−2.644	0.439%	0.013%	0.036%
2	−1.452	0.538%	0.153%	0.088%
3	−0.749	0.505%	0.139%	0.018%
4	−0.077	0.558%	0.204%	0.001%
Portfolio 5	+0.980	0.441%	0.031%	−0.179%
NMP (1−5)	−3.624***	0.022%	−0.019%	0.216%
t-value	(−144.69)	(0.139)	(−0.112)	(1.299)

Panel b) January 1995 to December 2020

	Av. Beta	Av. Return	CAPM-Alpha	FF3-Alpha
Portfolio 1	−2.907	1.242%	0.316%	0.250%
2	−1.367	0.985%	0.185%	0.077%
3	−0.579	0.908%	0.213%	0.113%
4	+0.138	0.837%	0.151%	0.089%
Portfolio 5	+1.422	0.496%	−0.292%	−0.262%
NMP (1−5)	−4.329***	0.746%***	0.608%**	0.512%**
t-value	(−116.11)	(3.789)	(2.832)	(2.557)

Hurricane risk premium can be documented since 1995

Time-varying FF 3-factor alpha of the zero-investment portfolio (NMP)



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Robustness checks

Beta w.r.t. the Swiss Re US Wind Cat Bond index

Panel b)	**Swiss Re US Wind Cat Bond Index January 2005 to December 2020**				
	Av. Beta	Av. Return	CAPM-Alpha	FF3-Alpha	Carhart-Alpha
Portfolio 1	−2.594	0.405%	0.642	0.481	0.469
2	−0.909	0.684%	0.043	0.063	0.062
3	0.005	0.741%	0.067	0.057	0.047
4	0.947	0.877%	0.097	0.093	0.099
Portfolio 5	2.791	1.352%	0.353	0.199	0.240
NMP (5−1)	5.385***	0.947%***	1.003***	0.785***	−0.782***
	(−27.146)	(3.809)	(3.379)	(3.390)	(3.337)

The effect is robust across different measures for hurricane losses

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Time series regressions of NMP (value-weighted) on established factors

January 1995 to December 2020										
NMP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1 MKT	0.087	0.216**	0.150*	0.054*	0.123*	0.083	0.089	0.199**	0.165***	0.139**
1 SMB	0.013	0.163**	0.152**	0.017	0.073	0.121	0.041	0.112	0.104**	0.050**
1 HML	0.233*	0.425**	0.488***	0.225*	0.354***	0.447***	0.205**	0.430***	0.136	0.187
1 MOM	−0.067	−0.108	−0.110	−0.072	−0.072	−0.109	−0.079			
2 LTD		−0.177								
3 SADKA			1.069							
4 PS				0.128**						
5 LOT					0.008					
6 SENT						0.129				
7 BAB							0.046			
8 REVS								−0.167*		
8 REVL								−0.114		
9 RMW									0.235	
9 CMA									0.118	
10 INV										0.171
10 ROE										0.047
alpha	0.695**	0.643**	0.532*	0.660***	0.579**	0.656**	0.662***	0.529**	0.505***	0.582**
t-value	(3.080)	(2.381)	(2.071)	(2.919)	(2.327)	(2.529)	(2.857)	(2.637)	(2.553)	(2.452)
R^2_{adj}	0.068	0.268	0.254	0.088	0.128	0.229	0.068	0.151	0.07	0.065

The effect withstands a comprehensive battery of established systematic factors

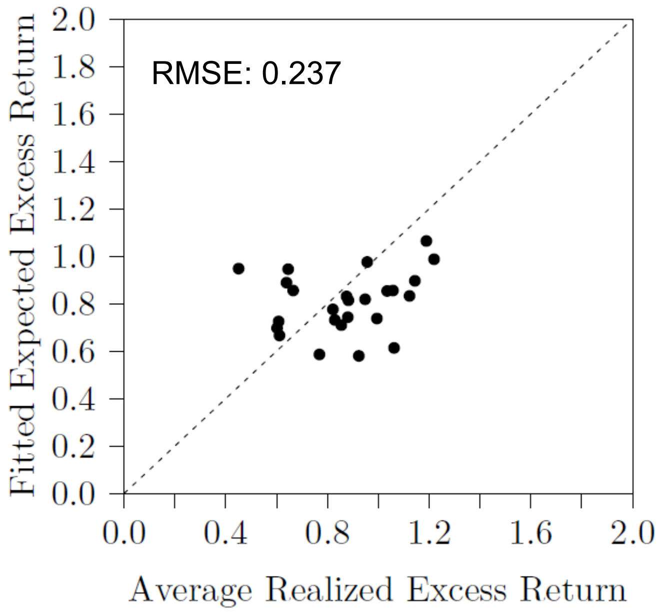
Fama & MacBeth (1973) regressions

January 1995 to December 2020

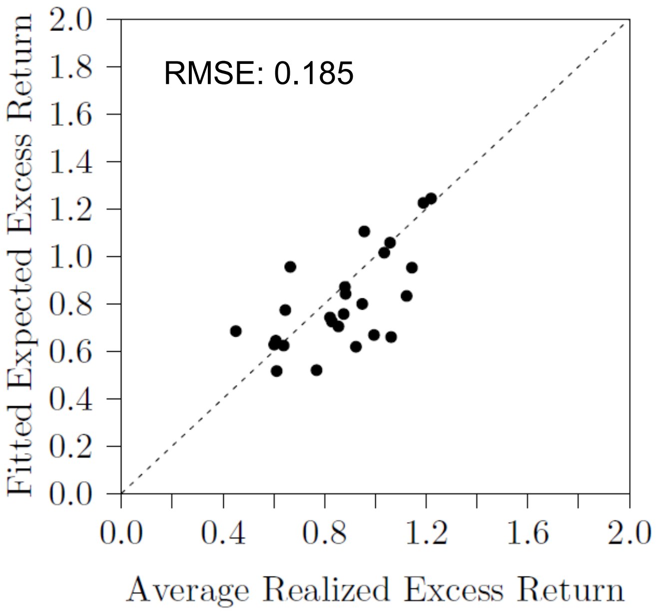
	$return_{(t+1)}$	$return_{(t+1)}$	$return_{(t+1)}$	$return_{(t+1)}$	$return_{(t+1)}$
$\beta^{\Delta \tilde{ahl}}$	−0.071**	−0.071***	−0.068***	−0.056***	−0.033*
	(−2.505)	(−2.654)	(−3.129)	(−3.017)	(−1.828)
size		−0.073	−0.106***	−0.111***	−0.119***
		(−1.349)	(−2.581)	(−2.706)	(−2.628)
idiosyncratic vol.			−0.020**	−0.014	−0.023***
			(−1.173)	(−0.773)	(−1.749)
coskewness				−0.798***	−0.639***
				(−3.538)	(−3.287)
market beta					0.219
					(1.296)
alpha	0.971***	1.837**	2.545***	2.313***	2.375***
	(2.891)	(2.012)	(4.025)	(3.793)	(3.741)

The effect is not explained by firm characteristics

Actual versus predicted average excess returns



(c) FF Three-Factor Model + Momentum



(d) FF Three-Factor Model + Momentum + NMP

Adding NMP to the FF3 + Momentum model improves the fit in the cross section

Exploring the economic mechanism

1. Geographic versus economic hurricane risk exposure
2. Hurricane risk over time
3. Hurricane risk across industries
4. Hurricane risk across market capitalizations

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Geographic vs. economic hurricane exposure (I)

Sample split based on textual analysis of financial reports (2000−2017, keyword: “hurricane loss”)

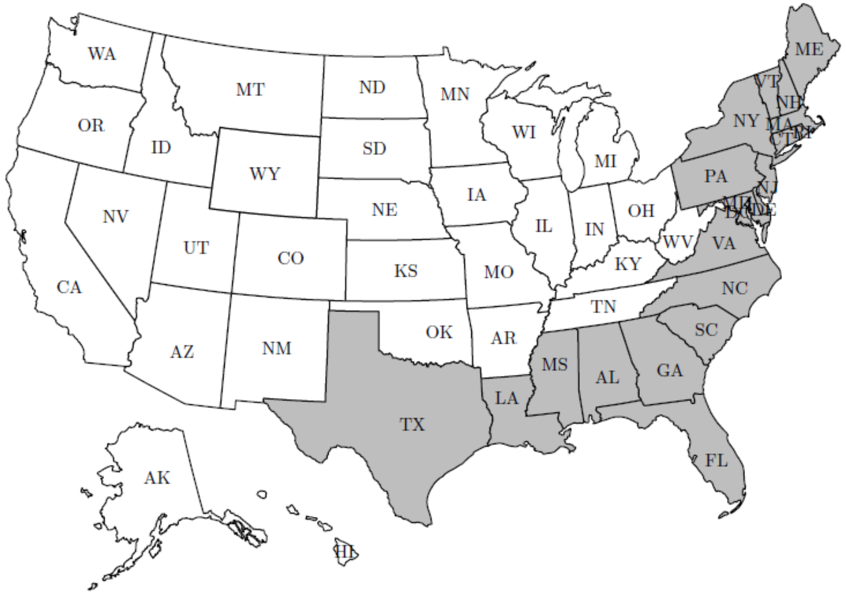
Panel a): Headquarters with Hurricanes		
	Av. Beta	Av. Return
Portfolio 1	−3.116	1.367%
2	−1.455	1.084%
3	−0.611	0.917%
4	+0.164	0.787%
Portfolio 5	+1.524	0.489%
NMP (1−5)	−4.639***	0.878%**
t-value	(−126.29)	(4.203)

Panel b): Headquarters without Hurricanes		
	Av. Beta	Av. Return
Portfolio 1	−2.311	0.955%
2	−0.959	1.004%
3	−0.317	0.835%
4	+0.319	0.792%
Portfolio 5	+1.537	0.693%
NMP (1−5)	−3.847***	0.261%
t-value	(−160.79)	(1.109)

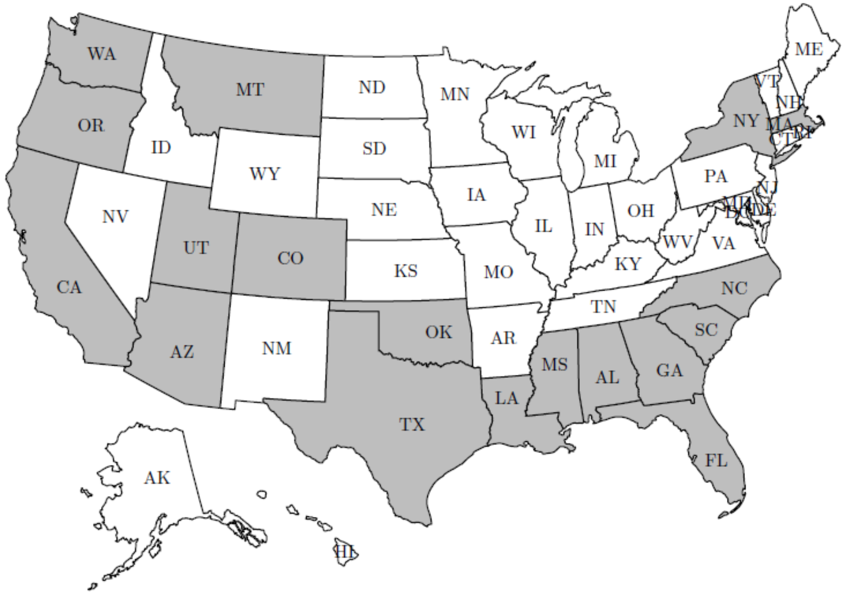
No risk premium for states in which headquartered firms did not mention hurricane losses

Geographic vs. economic hurricane exposure (II)

Illustration of the spatial profile



(a) Hurricane Landfalls (1815-2012)



(b) Economic Hurricane Exposure Map

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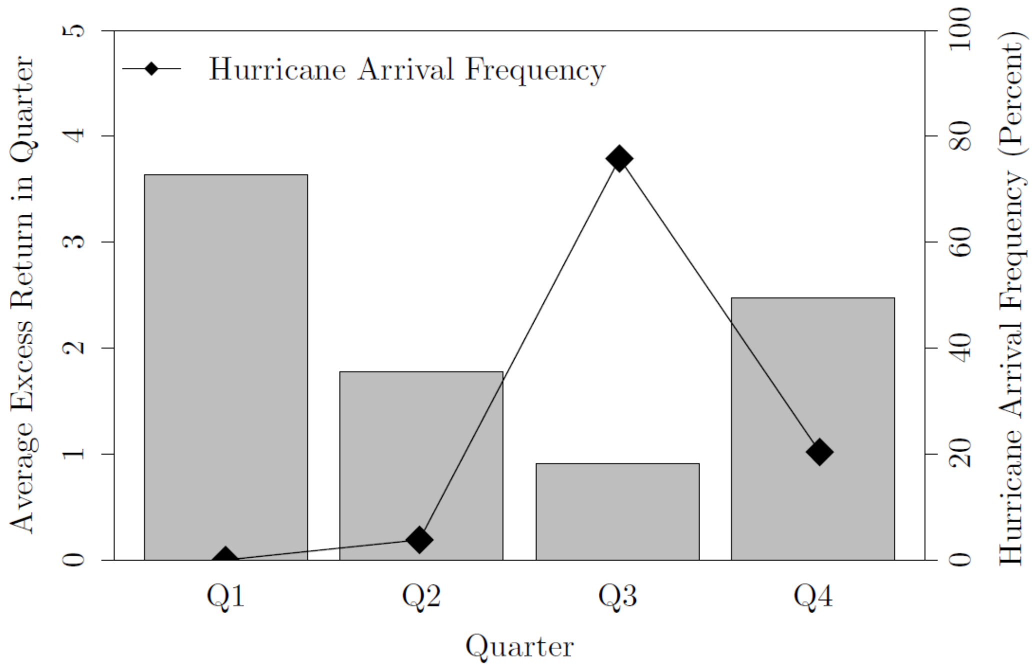
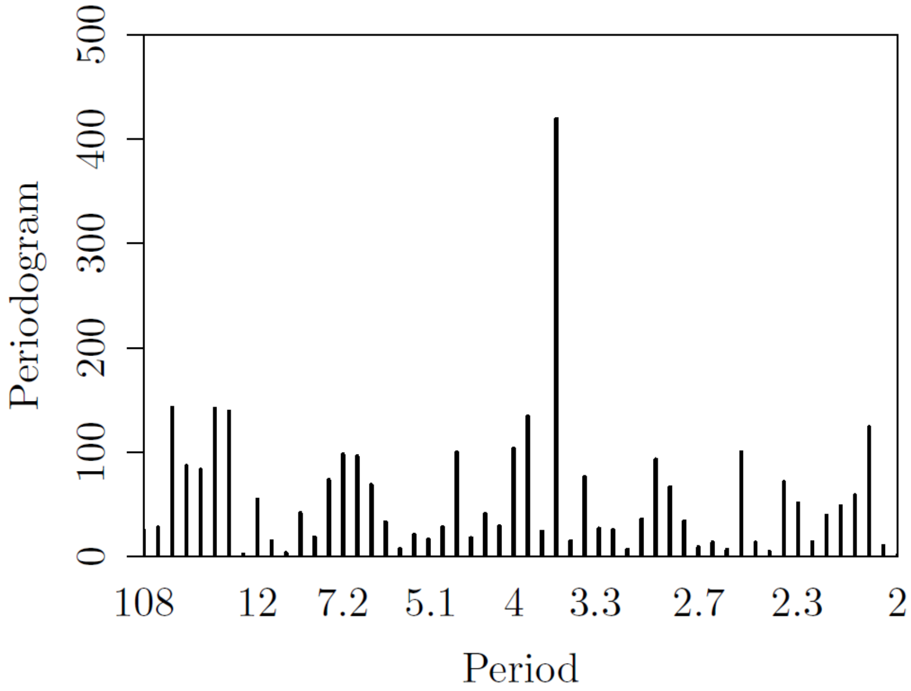
Hurricane risk over time (I)

Visual identification of seasonality in the NMP series





(smoothed series)

Visual diagnostics (including ACF and PACF) of NMP match with hurricane season

Hurricane risk over time (II)

Statistical evidence of seasonality in the (smoothed) NMP series

→ ARIMA(1,0,2)(1,0,0)$_4$

Panel a) TS Regression	coeff.	p-val. (NW)	sig.	**Panel b) SARIMA (smooth NMP)**	coeff.	p-val. (NW)	sig.
Intercept	1.0300	0.2784		AR(1)	0.2532	0.0105	**
Q2	−1.8547	0.1879		MA(1)	0.9350	0.0000	***
Q3	−2.7255	0.0321	**	MA(2)	1.0000	0.0000	***
Q4	−1.1560	0.3505		SAR(1)	0.3542	0.0004	***
df	75			df	98		
Year FE	Yes			AIC	4.1450		
BP	39.8430	0.0683	*	BIC	4.2737		
LB(3)	11.7330	0.0084	***	LB(3)	1.1184	0.7726	

NMP particularly driven by the peak of the hurricane season in Q3

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Hurricane risk across industries

Sortings by industry (SIC division) subsample

Panel b)	Finance, Insurance and Real Estate			Construction		
	Av. Beta	Av. Exc. Return	Carhart-Alpha	Av. Beta	Av. Exc. Return	Carhart-Alpha
Portfolio 1	−2.156	1.175	0.301	−3.096	1.975	0.715
2	−0.985	0.942	0.146	−1.754	1.471	0.433
3	−0.424	0.813	0.033	−0.937	1.297	0.295
4	0.093	0.892	0.148	−0.207	0.688	−0.174
Portfolio 5	0.971	0.663	-0.116	0.903	0.691	−0.109
NMP (1-5)	3.126	0.512	0.417*	3.999	1.284	0.825*
t-value	81.721	2.545	1.756	63.757	2.521	1.657

Effect found for four out of six industry divisions − plausible business impact

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Hurricane risk across market capitalizations

Double sortings (by size and by hurricane risk)

Panel a) No Winsorization

Market Cap.	Low	2	3	4	High
Portfolio 1	0.67	0.96	1.19	1.22	1.06
2	1.06	1.12	1.14	1.03	0.88
3	0.92	0.83	0.95	0.88	0.85
4	0.77	0.99	0.88	0.82	0.60
Portfolio 5	0.61	0.65	0.45	0.64	0.61
NMP (1–5)	0.06	0.31	0.74*	0.59**	0.45**
t-value	0.24	1.55	3.49	3.05	2.07

Panel b) Winsorization

Market Cap.	Low	2	3	4	High
Portfolio 1	0.67	0.92	1.13	1.31	1.18
2	1.02	1.13	1.15	0.98	0.96
3	0.93	0.84	0.98	0.87	0.89
4	0.77	0.94	0.91	0.78	0.88
Portfolio 5	0.63	0.62	0.47	0.62	0.68
NMP (1–5)	0.04	0.30	0.66***	0.69***	0.50***
t-value	0.15	1.53	3.04	3.61	2.77

Effect driven by the largest 60% of firms

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Conclusion and implications

- Hurricane risk has been a systematic risk factor since 1995
  - ► Paper presents theory + evidence for a hurricane risk premium
- Novel transmission channel for economic impact of extreme weather events
  - ► Natural disaster risks no longer completely independent from financial risks
- Higher cost of equity for exposed firms (also higher cost of insurance)
  - ► Impact on future business decisions
- The impact of hurricane risk can be expected to rise further in the future
  - ► Climate change and economic integration

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Examples how hurricanes affect the financial performance of companies

"Hurricane Harvey and Hurricane Irma - During the quarter ended September 30, 2017, a significant number of our properties in Houston and Jacksonville incurred storm related damages from Hurricane Harvey and Hurricane Irma. We have estimated the extent of our asset impairments, damages and repairs to the properties to be approximately $2.8 million and have reduced our carrying values of our homes by that amount."

Reven Housing REIT Inc, 2017-12-31, Headquarter in California

"The higher 2005 average price per Mcf resulted largely from the extreme hurricane season that occurred in late 2005, putting Gulf of Mexico production out of service and increasing the price for natural gas from other areas of the country being used to fill demand."

Teton Energy Corporation, 2008-03-13, Headquarter in Colorado