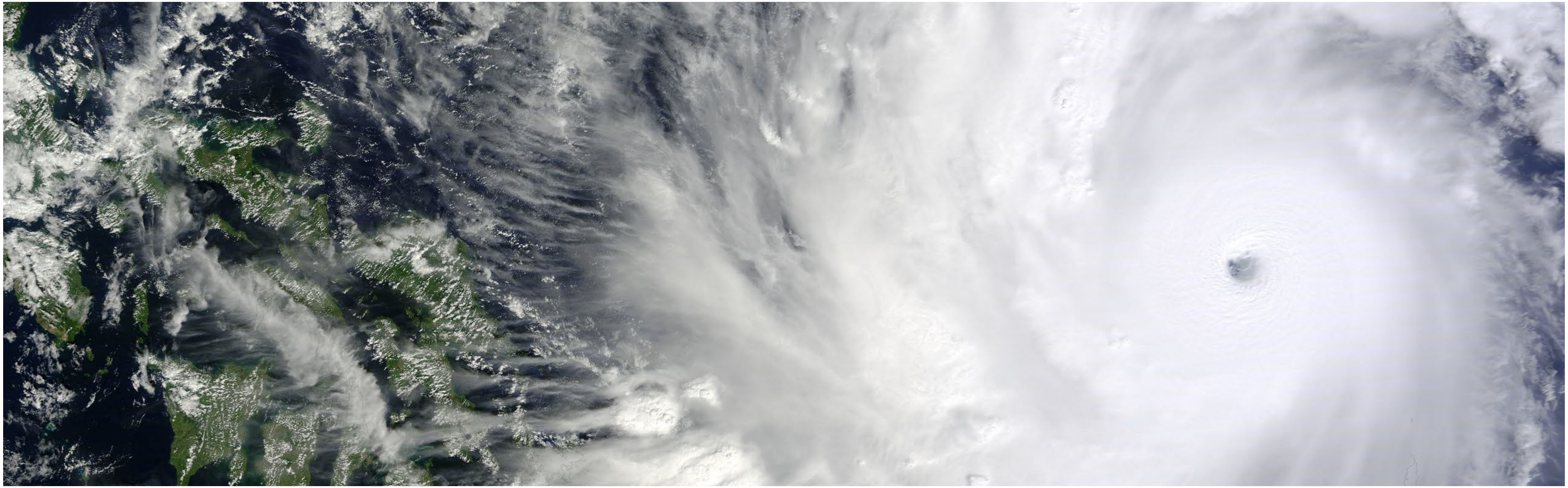


Common Factors in the Cross Section of Catastrophe Bond Returns

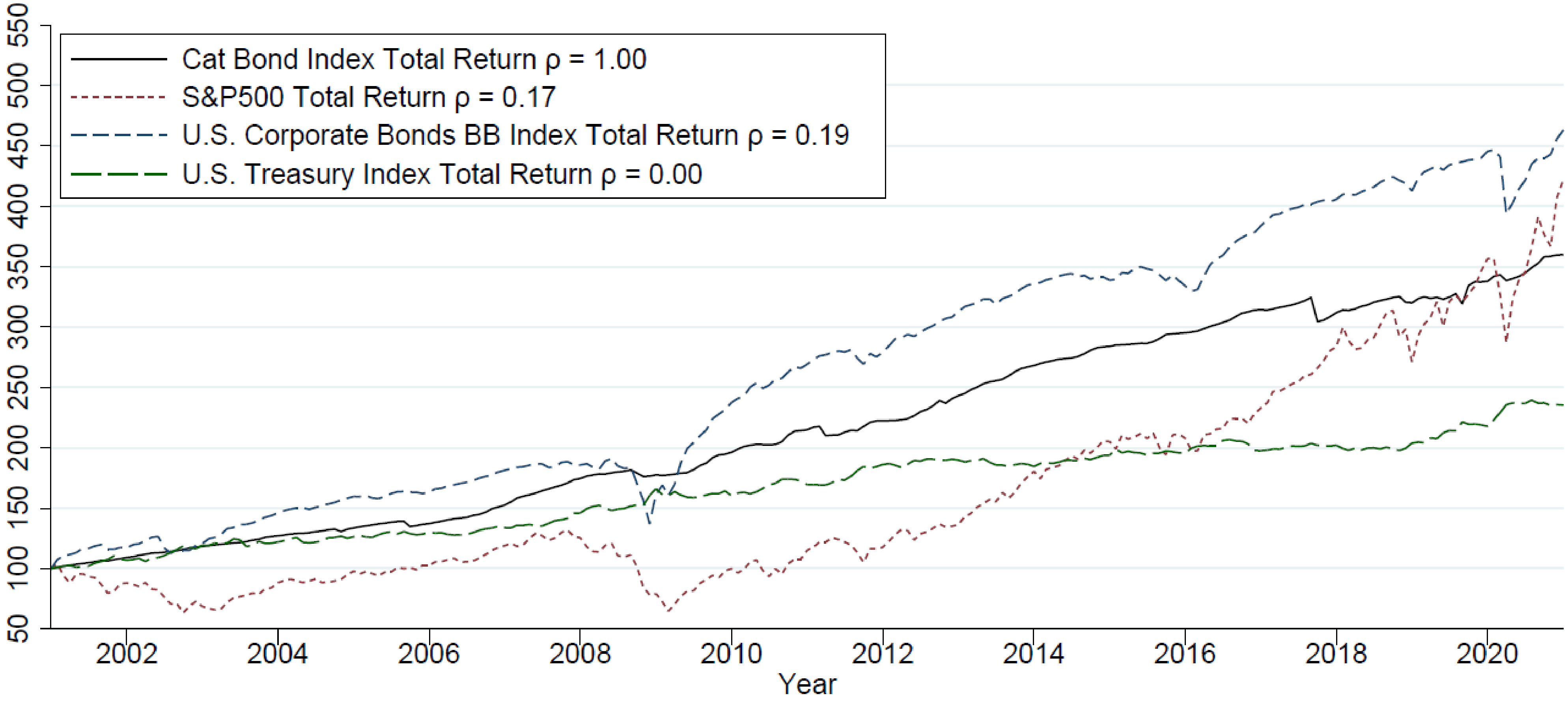
Alexander Braun, Markus Herrmann and Martin Hibbeln
CDAR Research Seminar, March 2022

Background and motivation

- Alternative reinsurance capital increasingly used to cover natural disaster risk
  - ► Market size close to USD 100 bn since 2018
- Rapid growth in the catastrophe bond (cat bond) segment continues
  - ► CAGR of 15% p.a. between 2016 and 2020 (overall growth of +547% since 2006)
- Empirical cat bond research has (so far) focused on coupon spreads and yields
  - ► Drivers of realized (expected) excess returns remain largely in the dark
- Classical asset pricing models fail miserably at explaining ILS returns
  - ► Can we explain differences in expected excess returns with bond characteristics?

Why is this an interesting asset class to study?

Realized returns 2001−2020



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Contribution

- First analysis of the cross section of (expected) returns in the cat bond market
  - ► Novel data set (2001−2020) provided by a large global reinsurance brokerage firm
- Propose four-factor model for excess returns on cat bonds portfolios
  - ► Explains 60% of the historical return variation (70% if adjusted for specific events)
- Factors are subjected to a wide range of established asset pricing tests
  - ► Portfolio sorts, Fama-MacBeth (1973) regressions, time series regressions
- Demonstrate good fit to expected excess returns for 24 test portfolios
  - ► Test portfolios: cat bond characteristics, random compositions, market portfolio

Main findings

- Event risk is a strong predictor of future cat bond returns
  (modeled PFL)
- Substantial impact of seasonality on realized returns
  (constructed in line with Hermann & Hibbeln, 2021)
- Downside risk, moral hazard, complexity and peak risk are not priced
  (CEL, indemnity trigger, peak dummy)
- Weak link between fixed income and cat bond markets
  (TERM and DEF significant as in Braun et al., 2019)

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Related literature

- Catastrophe bond coupon spreads (*primary market*)

  Lane (2000, ASTIN Bulletin), Galeotti et al. (2013, JRI), Braun (2016, JRI)

- Catastrophe bond yields (*secondary market*)

  Dieckmann (2009), Gürtler et al. (2016, JRI), Hermann & Hibbeln (2021, JRI)

- Catastrophe bonds realized returns

  Trottier et al. (2019, FRL), Drobetz et al. (2019, FRL), Braun et al. (2019, JBF)

- Market-consistent valuation of natural catastrophe risk

  Beer & Braun (2021)

Data sets

A) Cat bond data (from a large reinsurance broker)

- Total market from 2001−2020 (757 bonds)
- Monthly prices + structural information

► Quoted prices are highly correlated with traded prices from TRACE

B) Supplementary data

- Capital market indices and FF factors
- U.S. Treasury yield curve
- BoA ML OAS Corporate Bond Spreads
- Guy Carpenter Global P/C RoL Index

Relevant cross-sectional cat bond characteristics

- Catastrophe event risk

  Reflected by EL, PFL and CEL → **Seasonality?**

- Moral hazard (cedent)

  Indemnity triggers v. other triggers

- Complexity

  Multiperil and multilocation bonds

- Peak perils v. diversifying perils

  Dominance of U.S. risks

Sources:

Braun (2016, JRI)
Gürtler et al. (2016, JRI)

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Seasonal event risk

1. Determine hazard rates λ (p.a. basis) implied by the modeled PFL
2. Transform this hazard rate into a *monthly constant* PFL (PFLC)
3. Estimate the *monthly time-varying* PFL (PFLS) that fluctuates according to the seasonal distributions of perils

	U.S. hurricanes ($\gamma_{t,us}$)	EU winter storms ($\gamma_{t,eu}$)
January	0.0%	26.0%
February	0.0%	16.5%
March	0.0%	11.5%
April	0.0%	0.0%
May	0.2%	0.0%
June	3.6%	0.0%
July	12.5%	0.0%
August	28.7%	0.0%
September	34.6%	0.0%
October	18.3%	11.0%
November	2.0%	14.0%
December	0.1%	21.0%

Note: Distributions of U.S. hurricanes and EU winter storms throughout a calendar year as modeled by AIR.

$$\underbrace{P[N(T)=0]}_{1-\text{PFL}} = \exp(-\lambda_h \Delta t) \quad (\Delta t = 1)$$

$$\text{PFLC} = 1 - \exp\left(-\lambda_h \frac{1}{12}\right)$$

$$\lambda_t = \lambda_h \cdot \gamma_t$$

$$\text{PFLS}_t = 1 - \exp(-\lambda_t)$$

$$\text{SF}_t = \frac{\text{PFLS}_t}{\text{PFLC}}$$

"seasonality amplitude factor"

Estimating seasonality for multiperil / multilocation cat bonds

1 Regress monthly yield spreads for all bonds in a category on their time-varying US and EU EL figures as well as controls

2 Compute the *peril shares* for each cat bond category (see table)

Category	Coefficients U.S.	Coefficients EU	Share of peril type U.S. hurricane	Share of peril type EU winter storm	Share of peril type Other
C_1 - SP U.S. HU (benchmark category)	2.15	-	100%	0%	0%
C_2 - SP U.S. Wind	1.42	-	66%	0%	34%
C_3 - MP U.S. HU without EU Wind	1.30	-	60%	0%	40%
C_4 - MP U.S. HU with EU Wind	0.94	0.81	44%	38%	19%
C_5 - SP EU wind	-	1.59	0%	74%	26%
C_6 - MP EU wind without U.S. HU	-	0.78	0%	36%	64%

Note: This table reports U.S. and EU seasonal coefficients of fixed effects transformation regressions of yield spreads on seasonality-adjusted EL variables strictly replicating Herrmann/Hibbeln (2021). Unreported control variables are the Guy Carpenter Global Property Catastrophe Rate-On-Line Index, the Bank of America Merrill Lynch Option-Adjusted Spread indices of various rating classes, the return of the S&P500 performance index and the time to maturity. Detailed regression results are available upon request. Additionally, this table reports the resulting estimated percentage exposure to U.S. hurricanes, EU winter storms, and other peril types, which includes other perils such as earthquakes, for the six cat bond categories.

3 monthly hazard rate for bond *i* at time *t* using perils shares for category *c*

$$\lambda_{it} = \lambda_{it,us} \cdot S_{c,us} + \lambda_{ti,eu} \cdot S_{c,eu} + \frac{\lambda_{h,i}}{12} \cdot S_{c,ns}$$

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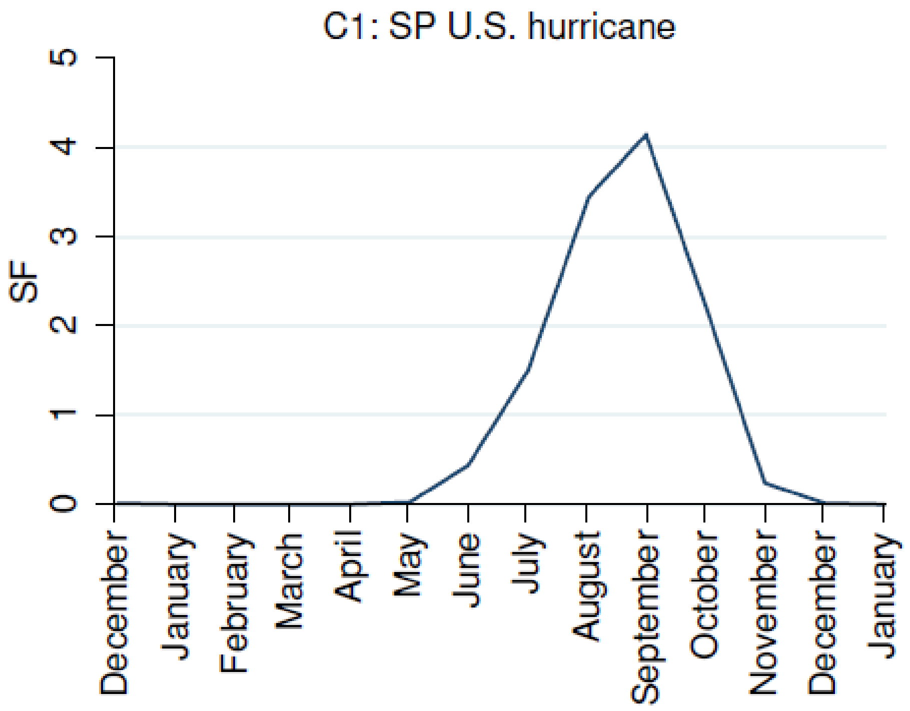
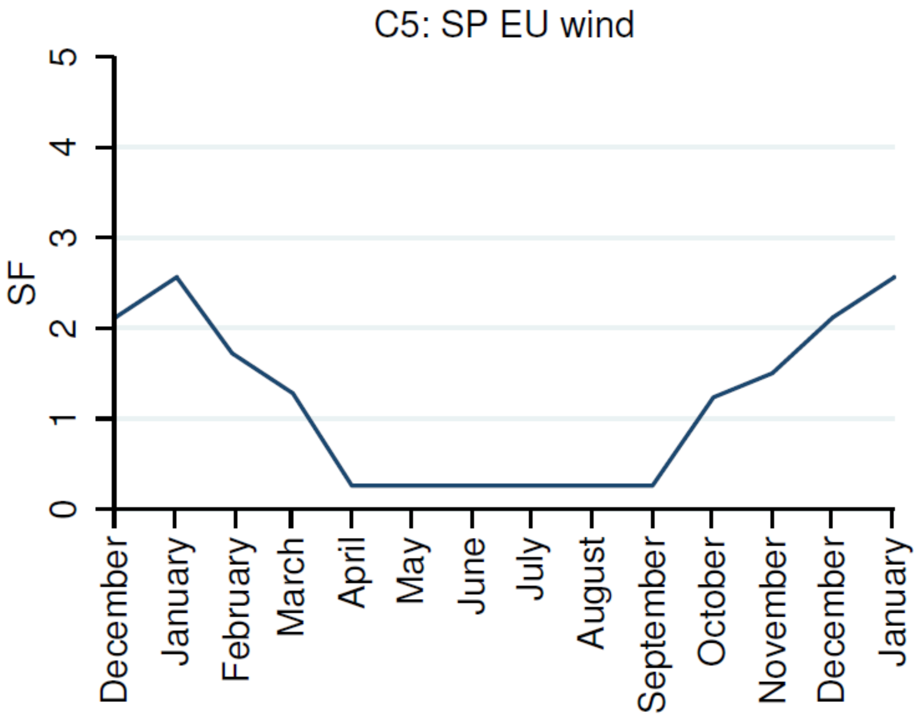
The seasonality adjustment factor SF

Two examples





Univariate portfolio sorts

Panel A	EL	PFLC	CEL	SF	Yield
P5	0.90	0.80	0.36	0.55	0.85
P4	0.55	0.46	0.53	0.50	0.54
P3	0.34	0.48	0.49	0.51	0.46
P2	0.30	0.32	0.46	0.45	0.33
P1	0.26	0.27	0.36	0.24	0.13
Difference: P5 - P1	0.64***	0.53***	0.00	0.31***	0.72***
	(.000)	(.000)	(.976)	(.000)	(.000)
Panel B	**IND**	**MP**	**ML**	**HU**	**US**
P1	0.37	0.53	0.67	0.47	0.48
P0	0.46	0.35	0.38	0.31	0.27
Difference: P1 - P0	-0.09	0.18**	0.29***	0.15*	0.20**
	(.348)	(.002)	(.000)	(.028)	(.003)

Note: This table reports mean returns for univariate portfolio sorts. For Panel A, P5 represents the mean returns for the portfolios with the highest values for the respective variable, P1 contains the lowest variable values. For Panel B, P1 contains the portfolio were the respective dummy variable has the value 1, P0 contains the dummy variable value 0. To assess the potential impact of the respective variables on returns, we determine the difference in mean returns between P5 and P1, or P1 and P0, respectively. p-values in parentheses were determined with Newey & West (1987) standard errors with four lags. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

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Fama & MacBeth (1973) regressions for event risk variables

Intercept	EL	PFLC	CEL	adj. R^2
.262***	1.498***			0.186
(0.000)	(0.000)			
.103		1.12***	.002	0.192
(.51)		(0.000)	(.247)	
.264***		1.108***		0.184
(0.000)		(0.000)		

Note: 240 cross-sectional regressions of one-month ahead cat bond returns on explanatory event risk variables. p-values in parentheses were determined with Newey & West (1987) standard errors with four lags. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

Fama & MacBeth (1973) regressions for further potential factors

	Intercept	PFLC	SF	IND	MP	ML	HU	US	Maturity	Size	adj. R^2
(1)	.133	1.088***							.007	.021	0.217
	(.413)	(0.000)							(.826)	(.523)	
(2)	–.146	1.085***	.257***						0	.025	0.274
	(.407)	(0.000)	(0.000)						(.992)	(.466)	
(3)	.287*	1.058***		–.145+					.008	.009	0.23
	(.029)	(0.000)		(.089)					(.803)	(.787)	
(4)	.045	1.019***			.167**				0	.028	0.228
	(.795)	(0.000)			(.004)				(.992)	(.396)	
(5)	.158	1.002***				.168**			.006	.014	0.229
	(.338)	(0.000)				(.003)			(.849)	(.668)	
(6)	.037	1.073***					.098		.001	.029	0.258
	(.834)	(0.000)					(.125)		(.984)	(.413)	
(7)	.013	1.066***						.124*	.009	.026	0.244
	(.936)	(0.000)						(.044)	(.78)	(.442)	
(8)	–.169	.989***	.36***	–.128+	.117	–.015	.051	.065	–.008	.013	0.325
	(.328)	(0.000)	(0.000)	(.094)	(.12)	(.834)	(.749)	(.374)	(.803)	(.697)	

Explaining the market with a cat bond factor model

	(1)	(2)	(3)	(4)	(5)
F_PFLC	0.242**	0.225**	-0.016		
	(0.001)	(0.004)	(0.897)		
F_SF		0.253***	0.180***	0.183***	0.183***
		(0.000)	(0.000)	(0.000)	(0.000)
F_PFLS			0.282*	0.269***	0.267***
			(0.016)	(0.000)	(0.000)
TERM					0.062**
					(0.008)
DEF					0.066**
					(0.005)
Constant	0.298***	0.227***	0.206***	0.205***	0.160***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Observations	240	240	240	240	240
R^2	0.279	0.447	0.565	0.565	0.601
Adjusted R^2	0.276	0.443	0.560	0.561	0.594

Note: This table reports time-series regressions of the monthly excess returns of the cat bond market index on different factor models. All factor returns are generated using long-short portfolios. The factors TERM and DEF are taken from Fama & French (1993). p-values in parentheses are based on Newey & West (1987) standard errors with four lags. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

Benchmarking with the FF (1993) and FF (2015) models

	(1)	FF(1993) (2)	FF(2015) (3)	(4)	(5)
F_SF	0.183***			0.182***	0.183***
	(0.000)			(0.000)	(0.000)
F_PFLS	0.267***			0.268***	0.268***
	(0.000)			(0.000)	(0.000)
TERM	0.062**	0.062		0.088***	0.087***
	(0.008)	(0.208)		(0.000)	(0.001)
DEF	0.066**	0.043		0.034+	0.031
	(0.005)	(0.123)		(0.094)	(0.103)
Mkt-RF		0.029**	0.045**	0.029**	0.030**
		(0.008)	(0.001)	(0.005)	(0.007)
SMB		-0.008	0.001	0.001	0.003
		(0.725)	(0.978)	(0.944)	(0.833)
HML		0.021	0.014	0.021*	0.025
		(0.409)	(0.596)	(0.046)	(0.125)
RMW			0.038+		0.010
			(0.056)		(0.522)
CMA			0.005		-0.016
			(0.811)		(0.512)
Constant	0.160***	0.376***	0.386***	0.151**	0.150**
	(0.001)	(0.000)	(0.000)	(0.002)	(0.002)
Observations	240	240	240	240	240
R^2	0.601	0.059	0.050	0.618	0.619
Adjusted R^2	0.594	0.039	0.030	0.607	0.604

Note: This table reports time-series regressions of the monthly excess returns of the cat bond market index on different benchmark factor models. These factor models are the Fama-French (1993) five-factor (Mkt-RF, SMB, HML, TERM, DEF) and the Fama-French (2015) five-factor model (Mkt-RF, SMB, HML, RMW, CMA). All factor returns are generated using long-short portfolios or directly taken from the Kenneth R. French data library. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

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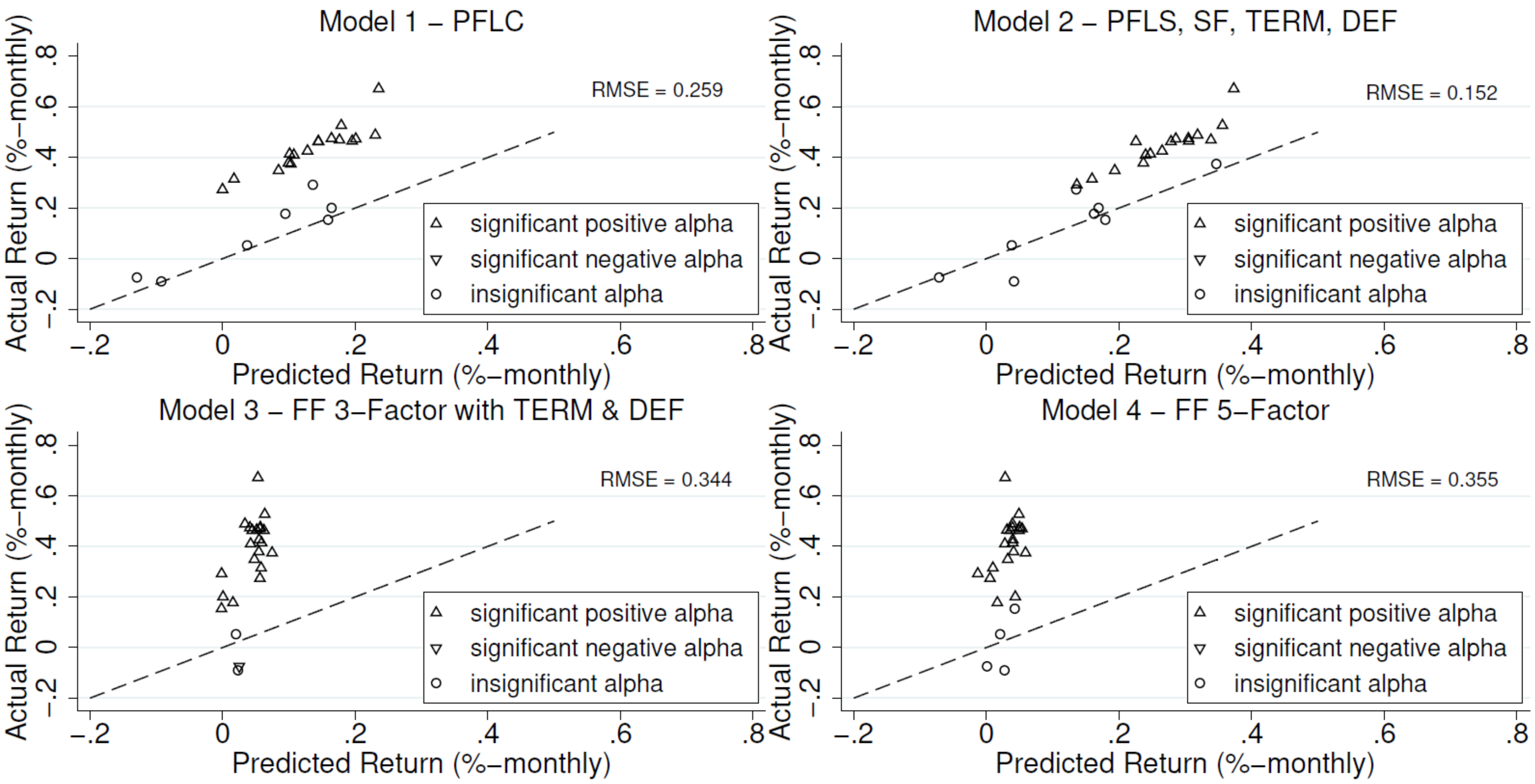
Actual versus model-predicted average excess returns



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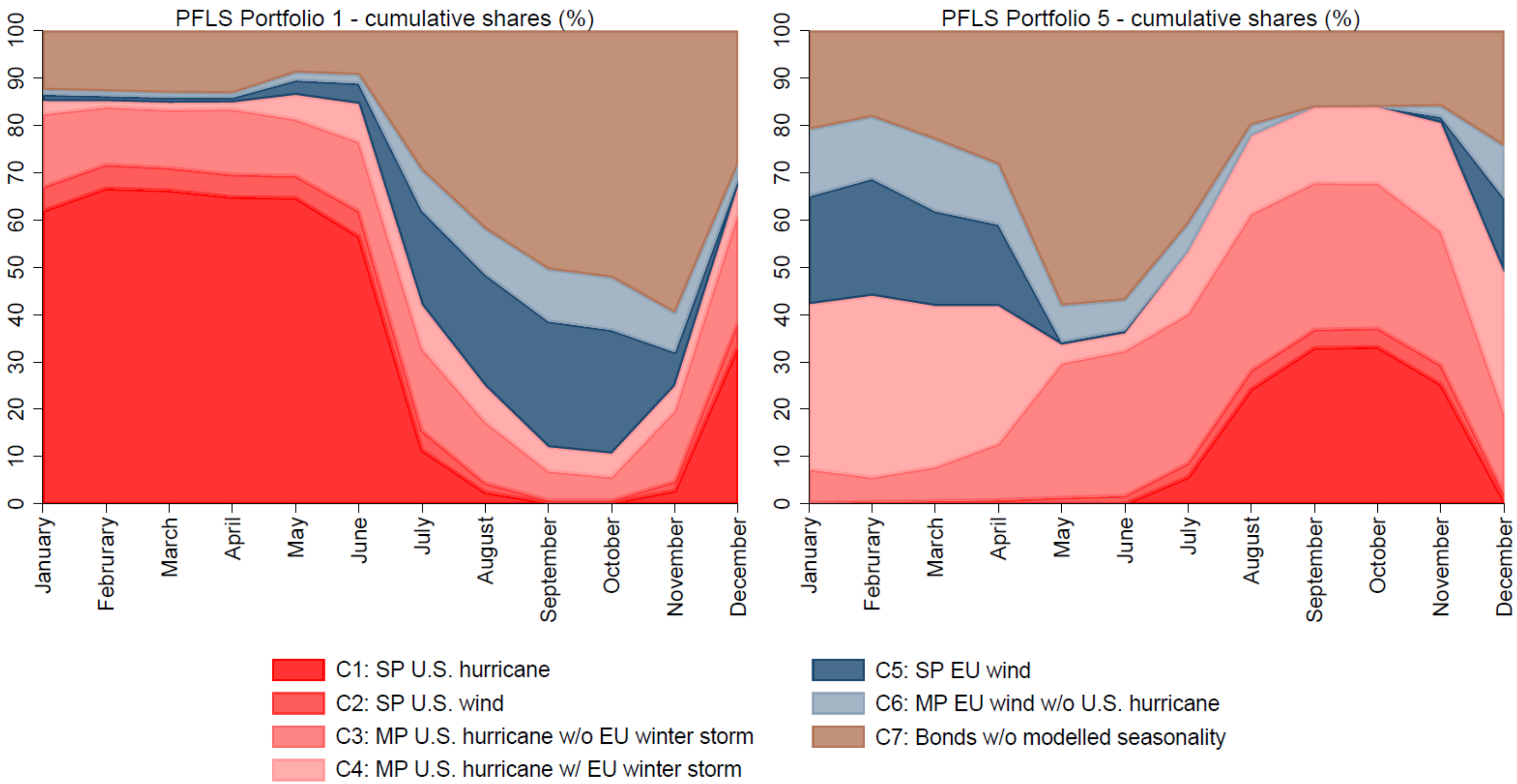
Explaining the cat bond market with long-only factor portfolios

	(1)	(2)	(3)	(4)	(5)	(6)
F_SF	0.183***					
	(0.000)					
F_PFLS	0.267***					
	(0.000)					
R_SF_P5		0.286***				
		(0.000)				
R_PFLS_P5		0.225***				
		(0.000)				
R_SF_P4			0.246***			
			(0.000)			
R_PFLS_P4			0.372***			
			(0.000)			
R_SF_P3				0.333***		
				(0.000)		
R_PFLS_P3				0.310***		
				(0.000)		
R_SF_P2					0.310***	
					(0.000)	
R_PFLS_P2					0.509***	
					(0.000)	
R_SF_P1						0.772**
						(0.002)
R_PFLS_P1						0.114
						(0.656)
TERM	0.062**	0.034*	0.024	0.033	0.029	-0.016
	(0.008)	(0.024)	(0.206)	(0.253)	(0.367)	(0.719)
DEF	0.066**	0.042**	0.029*	0.022*	0.024	0.027+
	(0.005)	(0.002)	(0.040)	(0.046)	(0.147)	(0.050)
Constant	0.160***	-0.014	0.020	0.050	0.010	0.104+
	(0.001)	(0.711)	(0.747)	(0.199)	(0.839)	(0.069)
Observations	240	240	240	240	240	240
R^2	0.601	0.802	0.824	0.779	0.703	0.439
Adjusted R^2	0.594	0.798	0.821	0.775	0.698	0.430

Note: Model (1) uses long-short portfolios. Models (2)−(6) instead use the returns of the five sorted quintile portfolios for the factors F_SF and F_PFLS. R_P5 contains the returns of the portfolio with the highest values for SF and PFLS. R_P1 contains the returns of the portfolio with the lowest values for SF and PFLS. The factors TERM and DEF are taken from Fama & French (1993). p-values in parentheses were determined with Newey & West (1987) standard errors with four lags. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

Composition of the long only portfolios



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Robustness of the four-factor model for different time periods

	(1)	(2)	(3)	(4)
	2001-2005	2006-2010	2011-2015	2016-2020
F_SF	0.265***	-0.050	-0.247	0.162***
	(0.000)	(0.762)	(0.285)	(0.000)
F_PFLS	0.088	0.307**	0.627**	0.264***
	(0.341)	(0.009)	(0.005)	(0.000)
TERM	0.008	0.122*	0.124*	0.050
	(0.712)	(0.011)	(0.012)	(0.439)
DEF	0.027	0.059+	0.008	0.178***
	(0.345)	(0.066)	(0.913)	(0.000)
Constant	0.294***	0.223	0.232+	0.051
	(0.000)	(0.192)	(0.073)	(0.306)
Observations	60	60	60	60
R^2	0.678	0.374	0.524	0.819
Adjusted R^2	0.655	0.328	0.489	0.806

Note: This table reports time-series regressions of the monthly excess returns of the cat bond market index on different factor models. These factor models are the Fama-French (1993) five-factor (Mkt-RF, SMB, HML, TERM, DEF) and the Fama-French (2015) five-factor model (Mkt-RF, SMB, HML, RMW, CMA). All factor returns are generated using long-short portfolios or directly taken from the Kenneth R. French data library. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

Cat bond returns in downside scenarios

	(1)	(2)	(3)
F_SF	0.183***		0.193**
	(0.000)		(0.006)
F_PFLS	0.267***		0.170*
	(0.000)		(0.011)
TERM	0.062**		0.037+
	(0.008)		(0.095)
DEF	0.066**		0.045*
	(0.005)		(0.015)
Katrina		-3.918***	-0.945
		(0.000)	(0.335)
Lehman		-2.078***	-1.101***
		(0.000)	(0.000)
Tohoku		-4.051***	-3.188***
		(0.000)	(0.000)
Irma/Maria		-6.728***	-3.232*
		(0.000)	(0.033)
California wildfires		-0.226***	-0.113*
		(0.000)	(0.025)
Michael		-2.163***	-1.395***
		(0.000)	(0.000)
Covid-19		-2.048***	-1.704***
		(0.000)	(0.000)
Constant	0.160***	0.515***	0.281***
	(0.001)	(0.000)	(0.000)
Observations	240	240	240
R^2	0.601	0.498	0.700
Adjusted R^2	0.594	0.482	0.686

Note: This table reports time-series regressions of the monthly excess returns of the cat bond market index on the four-factor cat bond model. In addition, several event variables are introduced. All factor returns are generated using long-short portfolios. The factors TERM and DEF are taken from Fama & French (1993). p-values in parentheses are based on Newey & West (1987) standard errors with four lags. The symbols +, *, ** and *** indicate statistical significance at the 10%, 5%, 1% and 0.1% levels, respectively.

Outlook

- The four-factor model fills an important gap
  - Benchmarking and cost of capital of ILS asset managers
- Unexplained alpha of 0.16% per month (1.92% p.a.) on the market portfolio remains
  - Frictions or further factors?
- Liquidity risk not captured by the model but a likely factor
  - TRACE data currently too thin
- Link between stock market and cat bond market
  - Evidence from both asset classes calls for future analysis

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