By Force of Nature: The Cat Bond Market & Katrina

Stephan Dieckmann

Arizona State University

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Rare Event Risk

- A catastrophe bond is a unique investment vehicle to gain exposure to rare event risk.
- Rare event risk describes risk stemming from *earthquakes*, *windstorms*, *mortality*, *terrorism*, and *war*.
- A mega-catastrophe has a skewed law of motion as compared to “normal” economic risk.
- The average cat bond is linked to rare events occurring every 49 years, and has a conditional expected loss of 78%.

Research Questions

Empirically ...

- For what risks does a cat bond investor get rewarded?
- Is a risk premium assessed for the occurrence of a catastrophe, as well as its uncertain impact?
- Is there a race between indemnity versus non-indemnity triggers?

Moving to the modeling stage ...

- Can cat bond spreads be explained by an equilibrium model in the presence of a small amount of systematic risk, while linking observed prices to economic primitives?

Stylized Facts

- Cat bond spreads equal between 2 and 3 times expected losses.
- The term structure is moderately upward sloping.
- Investors require approximately 100 bp for facing an indemnity trigger.
- A risk premium appears to exist for the occurrence of a loss, as well as the severity of its impact.
- One observes an increase in spreads between 15% and 20% at Katrina, an effect that is stronger for non-windstorm catastrophes.

Empirical Exercise

- 61 cat bonds observed in the secondary market in 2005 and 2006; spreads are measured with respect to the swap level.
- 33 subject to wind, and 28 to non-wind perils; 13 subject to indemnity, and 48 to non-indemnity (mainly parametric) triggers.
- Results from a multiple regression analysis with explanatory variables including: expl = expected loss, loss gc = conditional expected loss, pfl = probability of a first loss, indem = presence of indemnity trigger, amount (in millions), age (in months), ttm (in months).

Cat Bonds Spreads in Levels

	(1)	(2)	(3)	(4)	(5)	(6)
intercept	86.14	42.02	-33.28	2.65	2.66	2.48
	6.92	1.45	-0.95	25.70	23.40	18.51
expl	2.54	2.58	2.57			
	64.11	23.74	27.99			
ln(loss gc)				0.33	0.69	0.60
				1.12	2.41	2.54
ln(pfl)				0.69	0.70	0.69
				38.56	41.77	33.81
indem		121.94	103.58		0.20	0.16
		2.15	3.02		2.31	1.86
amount		-0.11	0.00		0.00	0.00
		-0.36	-0.01		-0.18	0.06
age		-0.71	0.03		-0.01	0.00
		-0.72	0.08		-4.22	-2.56
ttm		1.97	2.38		0.01	0.01
		1.45	2.35		1.75	2.22

Katrina Effect

	(1)	(4)
expl	2.21	2.35
	33.72	25.33
expl * (1-wind)	0.68	
	2.44	
expl * (1-wind) * (1-indem)		0.09
		0.51
expl * post kat	0.49	0.42
	6.44	6.86
expl * post kat * (1-wind)	0.86	
	1.76	
expl * post kat * (1-wind) * (1-indem)		-0.02
		-0.08
indem	81.39	104.62
	2.73	3.31
ttm	1.70	2.30
	1.97	2.12

Choice of Preferences

- The Campbell and Cochrane (1999) model has been successful in explaining several market phenomena.
- Why not explore more standard preferences, or uncertainty aversion as in Liu, Pan and Wang (2005)?
- Why not utilize other models that can generate countercyclical risk premiums, Dieckmann and Gallmeyer (2005), and derive time-series implications to generate a Katrina effect?
- Abstract from market frictions as in Froot (2001).

Economic Primitives

- An economy populated by an educated and informed representative investor who owns a firm and maximizes

$$E\left[\int_0^\infty e^{-\rho t}\frac{(C_t - X_t)^{1-\gamma}}{1-\gamma}dt\right],$$

- given an exogenous income process

$$\frac{dC_t}{C_{t-}} = \mu_c dt + \sigma_c dW_t + \kappa_{c1} dN(\lambda_1) + \kappa_{c2} dN(\lambda_2),$$

- faces normal economic risk and two sources of cat risk,
- determines the surplus consumption ratio, $s_t = \ln(\frac{C_t - X_t}{C_t})$,

$$ds_t = \phi(\widehat{s} - s_t) + \theta_t \sigma_c dW_t + \kappa_{t,s1} dN(\lambda_1) + \kappa_{t,s2} dN(\lambda_2).$$

Solution

- The pricing kernel is given by

$$\frac{d\xi_t}{\xi_{t-}} = [\ldots]dt - \eta dB + \sum_{i=1}^{2} \left(\frac{\lambda_i^Q}{\lambda_i} - 1 \right) dN(\lambda_i).$$

- The market price of normal economic risk,

$$\eta = \gamma \sigma_c (\theta_t + 1)$$

and the market prices of catastrophe risk,

$$\lambda_i^Q = \lambda_i (\kappa_{ci} + 1)^{-\gamma} e^{-\gamma \kappa_{t,si}}$$

are endogenously determined, almost in closed form. The dynamic nature of the equilibrium is characterized by the surplus consumption ratio.

Assumptions

Three key assumptions to determine the process for s_t:

- A constant riskless interest rate.
- A pre-determined habit level *at* the steady-state of s.
- A pre-determined habit level *in close proximity* to the steady-state of s.
- The calibrated model has a fixed amount of total economic risk, and uses expected loss figures as reported to the investor.

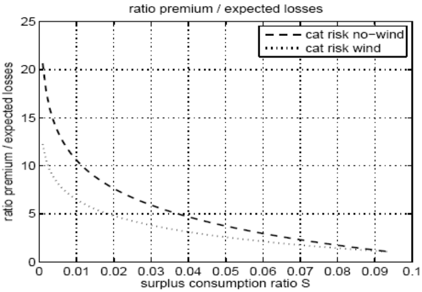
Calibration

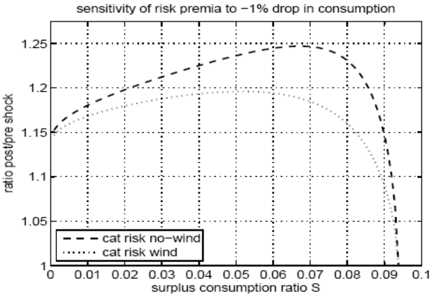
- While calibrating the model to pre-Katrina levels, do plausible values emerge?

parameters	scenario A	scenario B
patience	0.0543	0.0703
phi	0.13	0.13
gamma	2	2
growth rate	0.0189	0.0189
sigma	0.0070	0.0109
lambda no-wind	0.0108	0.0108
kappa no-wind	**-0.0445**	**-0.0250**
lambda wind	0.0279	0.0279
kappa wind	**-0.0390**	**-0.0190**

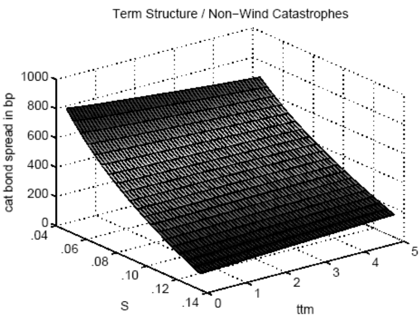
- To generate a post-Katrina effect, perturbation of -1% in the income process.

Market Prices of Cat Risk





Term Structure of Cat Spreads



Conclusion

- For each peril, calibrate a term structure and determine a relative pricing scheme in an equilibrium model with habit formation preferences.
- Calibration implies 88% of total economic risk is normal economic risk, and 12% is rare event risk.
- Suppose a reinsurance company has exposure to multiple cat risks, then the model predicts an increase in the cost of capital between 15% and 20% at Katrina, an effect that is stronger for non-windstorm catastrophes.
- Can this be applied to catastrophes like terrorism or war?