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Factors Affecting the Prices of Catastrophe Bonds

by Dimitris Papachristou

Introduction

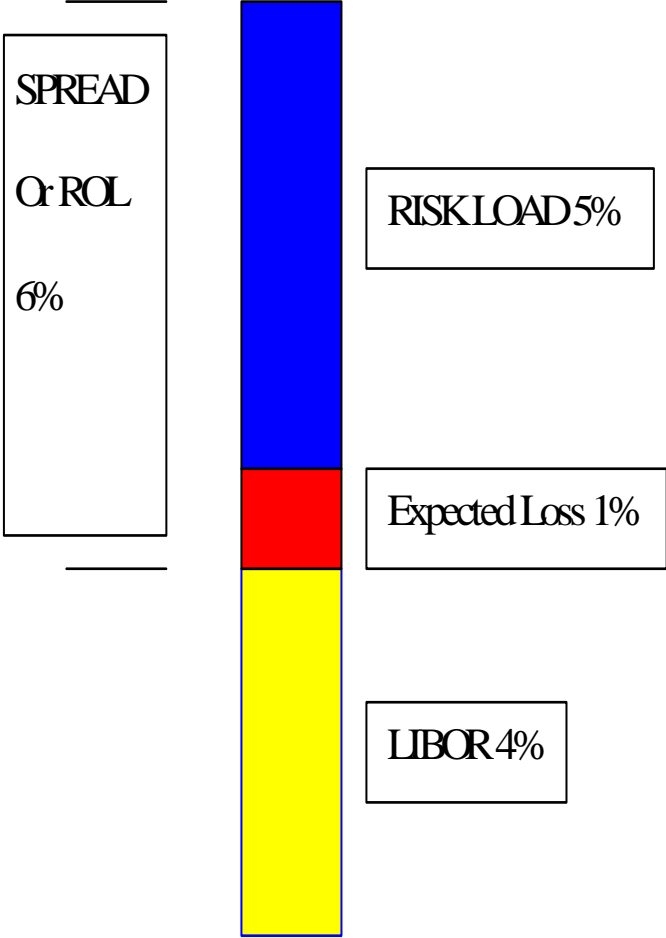
- This presentation is not about how a catastrophe (cat) bond should be priced
- This presentation is not about the prices of traded cat bonds
- It is about
 - a statistical analysis of how the market has priced the cat bonds at the time of the issue
 - the factors that have affected the prices of a bond
 - It could
 - provide a framework for analyzing and monitoring the price movements of cat bonds and reinsurance
 - Measure changes in perception of risk
- Past years' data have been analysed and the analysis is not necessarily relevant to future years
- The work was done while I was a member of the Benfield Capital Markets Team and it does not necessarily reflect the current views of AON Benfield Capital Markets team

Data

- 192 bonds issued between Jan 2003 and June 2008
- Limited amount of data
- Correlations in the data
 - May result in a not very stable model

	indemnity	Industry Index Modelled Loss	parametric	Grand Total
US Hurricane only	5	28	7	40
Multi-peril including US Hurricane	26	23	19	68
US Earthquake		16	18	34
Japanese Earthquake			10	10
European Storm, Japanese Typhoon, other	5	3	24	32
Non-Peak Territories		1	7	8
Grand Total	36	71	85	192

Spread, Risk Load, Expected Loss, Benchmark Rate



Structure of the Model

➤ What do we model?

- Spread
 - Includes expected loss which is one of the independent variables in the model (spread= expected loss + risk load)
- “Multiples” (Ratio of Spread/Expected Loss)
 - Can behave erratically
- Risk Load
 - Preferred choice

Structure of the Model

- Additive Model v Multiplicative Model
 - Multi – peril risk load is higher
 - Risk Load +1% across the board, or Risk Load * 115%?
 - Hard market
 - Risk Load +1% across the board, or Risk Load * 115%
 - Additive model could give negative values for the risk load

- One model for all bonds or more than one models?
 - One model makes use of all data, however,
 - Significant factors including Interaction terms
 - Different market cycles
 - Slightly different variances

- Two models were used
 - Including US perils
 - Non including US perils

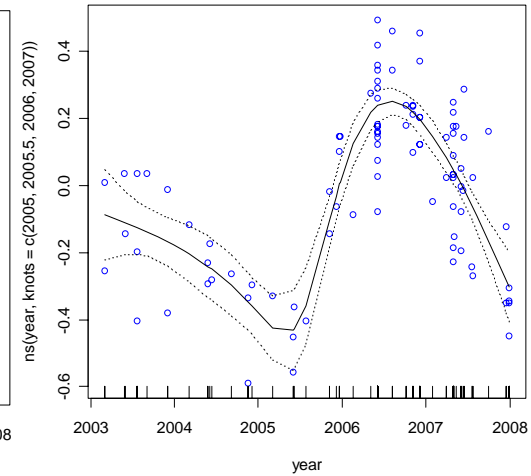
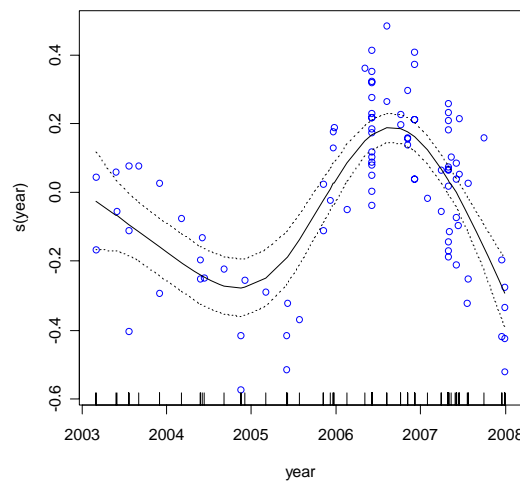
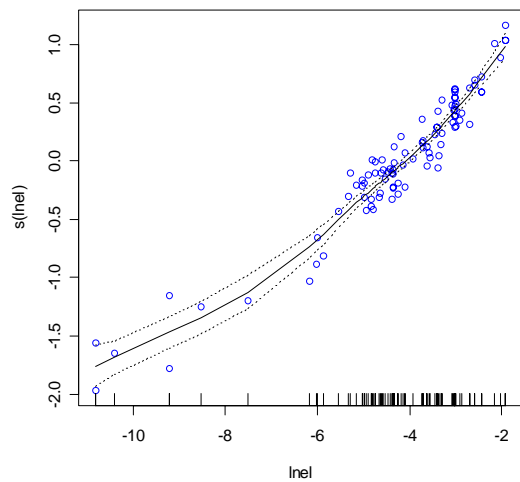
Structure of the Model

➤ Linear Model

- A priori choice of structure by the user

➤ Smoothers

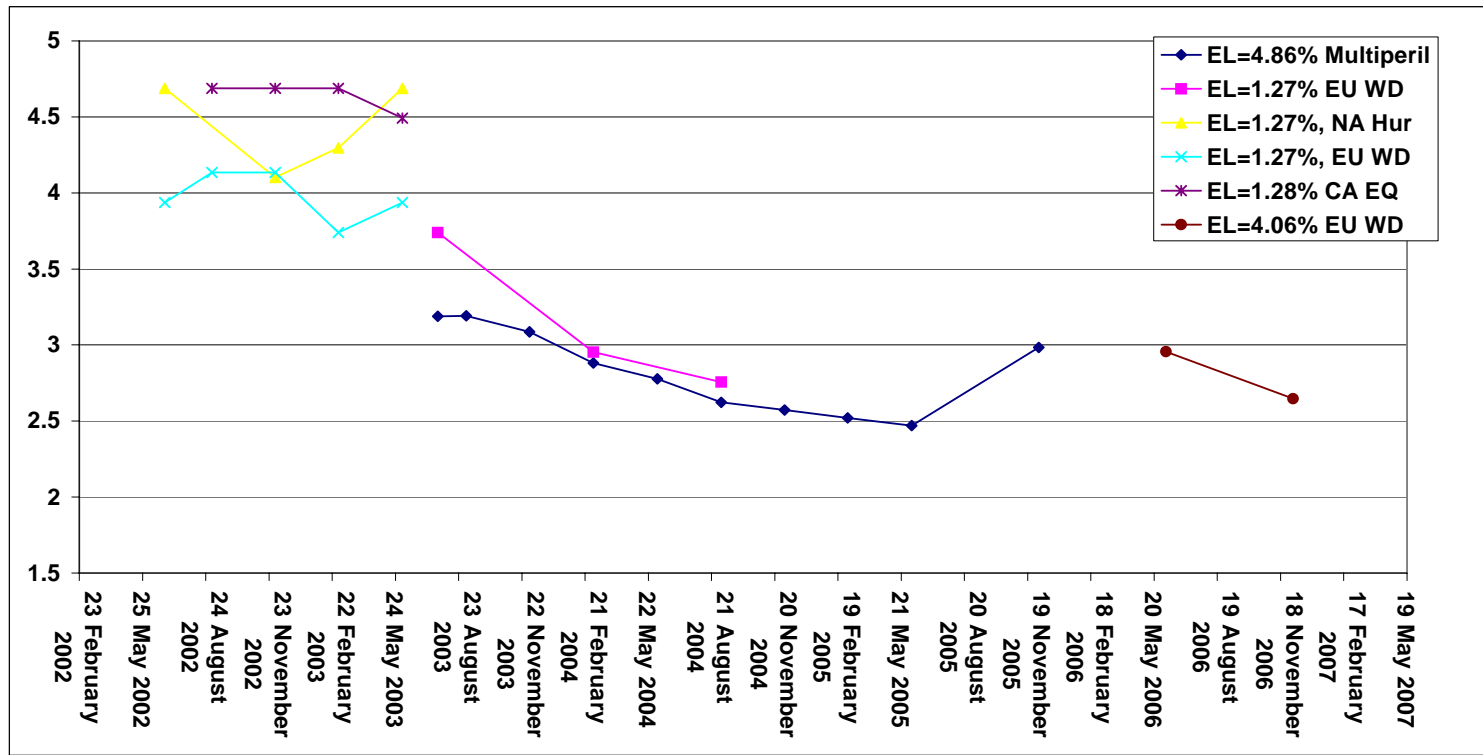
- Data show the relation between dependent and independent variables
- Choice of smoother and degrees of freedom



Individual Cat Bonds with Similar Features

➤ To examine changes over time, someone could analyse cat bonds with very similar features

- + Eliminates effect of other factors
- Different Expected Losses
- Different Perils and Triggers
- Random Effects



Model Chosen

➤ Current Model Choice

- two “power” models for two groups of territories
- with smoothing functions

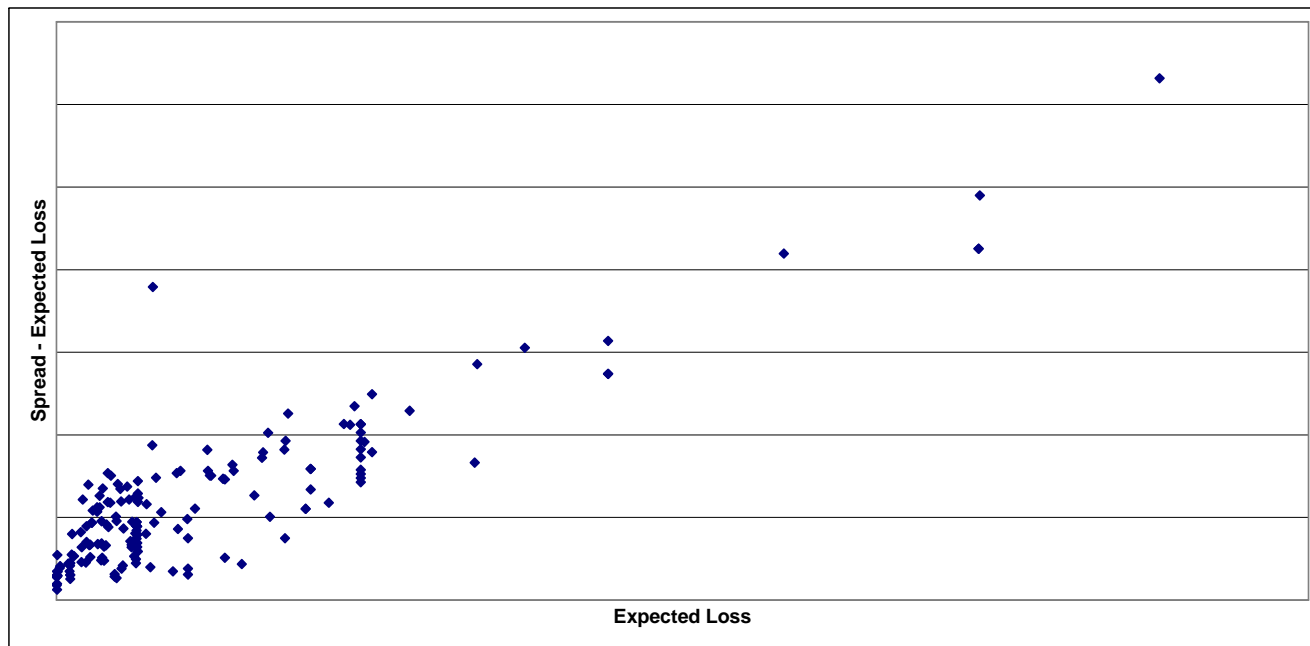
$$\text{Log}(RL_i) = f_1(\log(EL_i)) + f_2(\text{time}_i) + \text{Peril} / \text{Territory}_i + \text{Trigger}_i + \varepsilon_i$$

where RL_i is the risk load, EL_i the expected loss, the f s are smoothing functions, the Peril/Territory and Trigger are factor variables and the ε_i s are i.i.d. $N(0, \sigma^2)$ random variables

- Normality improves

Main Driver of Risk Load: Expected Loss

- Relation of risk load and expected loss looks at first linear, but actually a straight line does not fit the data well, especially at lower values of expected loss
- Piece-wise linear model was better, but maybe not very satisfactory
- Smoothing Spline was used
- Asymptotic behaviour



Main Driver of Risk Load: Expected Loss

➤ Expected Loss

- It is an annualised rate
- Different models may come up with different estimates

➤ Alternative Factors

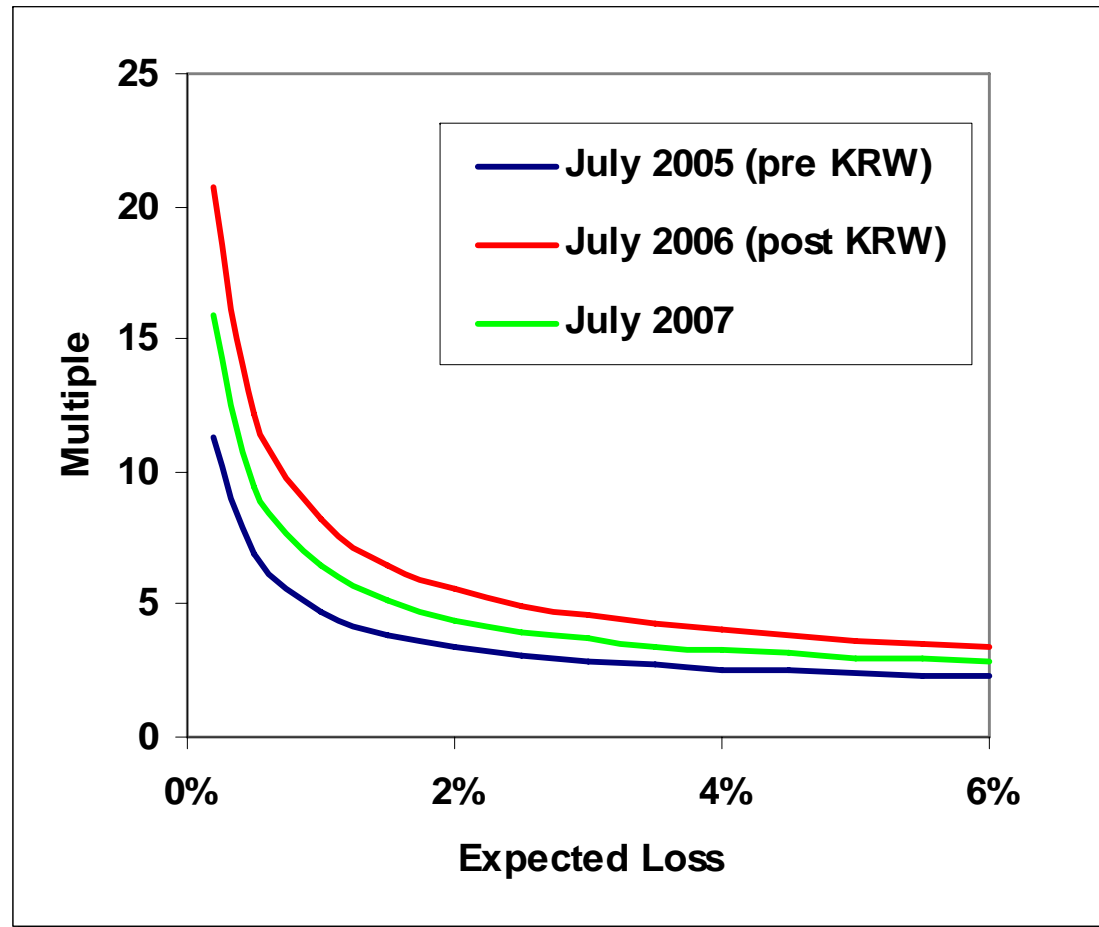
- Probability of Loss and Conditional Expected Loss
- Rating Agencies rate
- But statistically not as good as expected loss

➤ Minimum Risk Loads

- Liquidity Premium
- Expenses
- Threshold by corporate bonds?

Modelled multi-peril including US hurricane multiples

➤ Risk load was modelled, but here results are presented as multiples

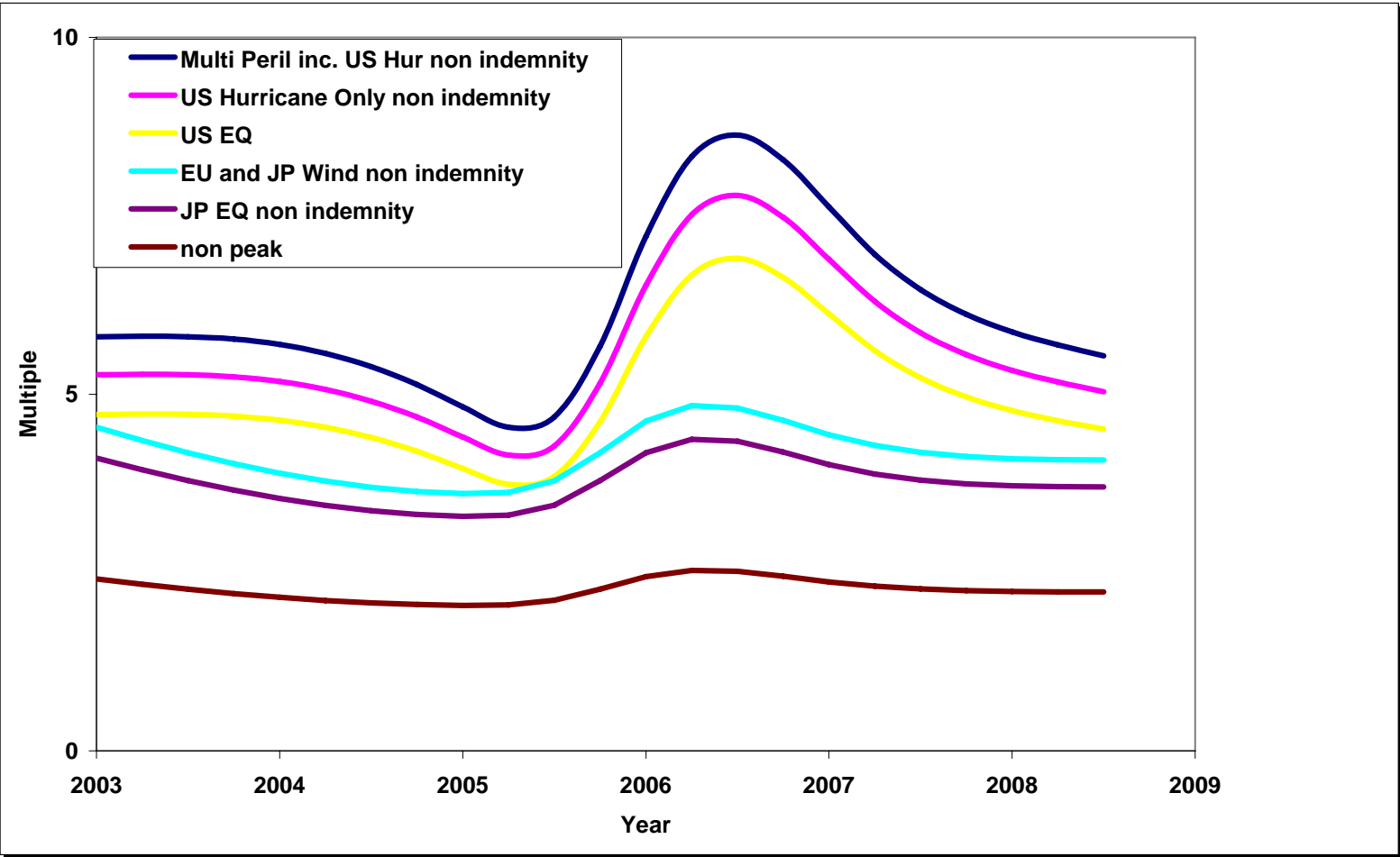


Factors Affecting Risk Load

Date of Issue

- Novelty premium in early years
- Levels v. smoothers
 - Smoothers
 - Data show trends
 - Changes maybe discontinuous
 - Could use levels, e.g. “hard”, “soft”, “other”
 - Choice somewhat arbitrary
 - Average over period
- Market Cycle
 - 2005 Hurricanes
 - Cycle has been more pronounced for bonds including US perils
 - “Payback” for reinsurers
- Updates of Vendor Models

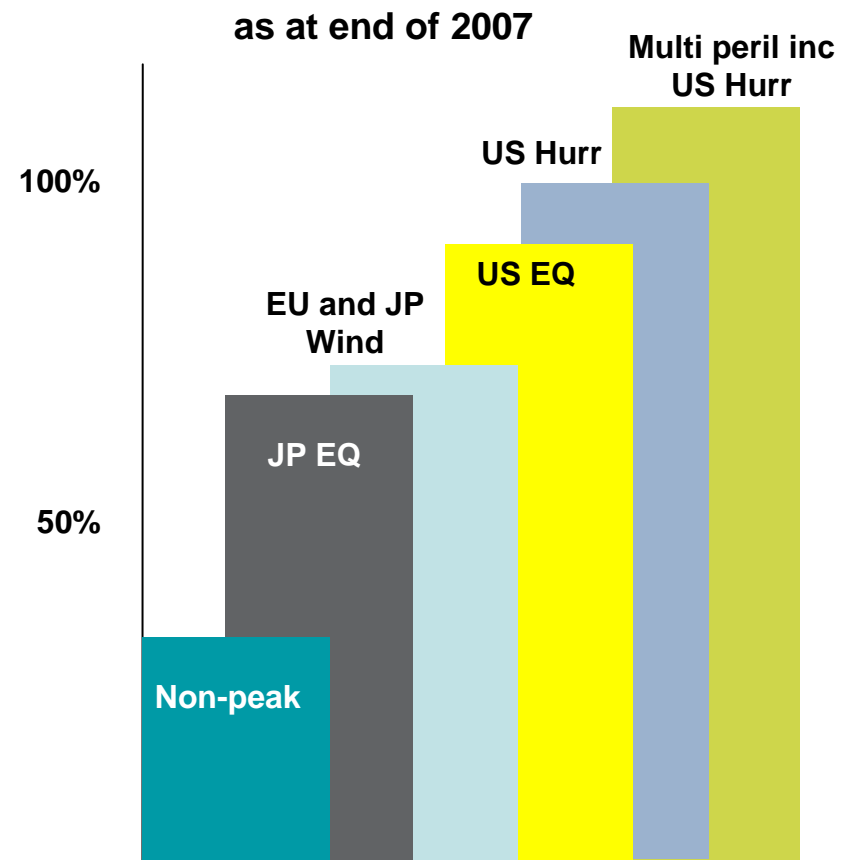
Modelled Multiples for Cat Bonds for Different Perils/Territories (EL=1%)



Factors Affecting Risk Load Perils/Territory Cat Bonds

- The exact difference varies with the market cycle
 - E.g. US EQ around the same level as European Wind before Katrina, but higher after

Approximate Relative Risk Load by Peril



Factors affecting Risk Load Perils/Territory and Trigger

➤ Relation between Peril and Trigger

- More parametric bonds for non peak perils
- Statistical model attempts to separate effect of Peril and Trigger

➤ Perils including US Hurricane

- Risk Load for indemnity bonds around 5 -10% higher than for other types of trigger
 - Limited data
 - Large percentage of indemnity bonds issued by established insurers. Market familiarity and comfort with these bond issues
- Risk Load for Parametric bonds a bit lower than that for index/modelled portfolio, but not statistically significant
 - Market perception about better quality of data and vendor models for the US

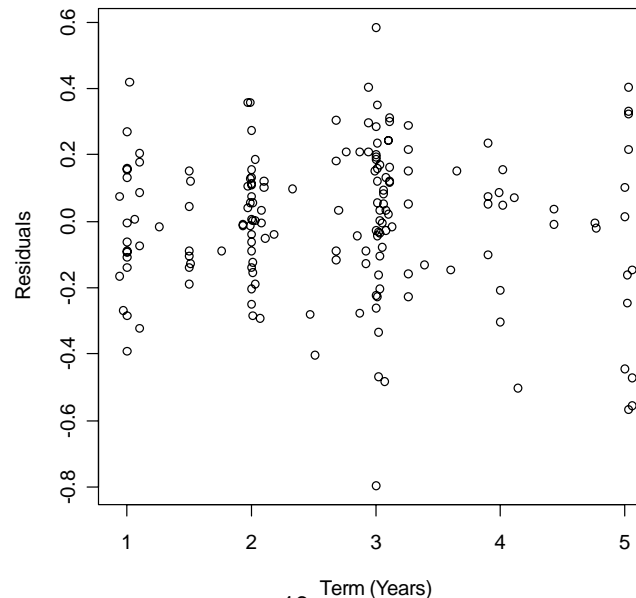
➤ Perils not including US Hurricane

- Hardly any indemnity bonds
- Risk Load for parametric triggers 10-15% lower than for other triggers

Some Comments on Other Features of Cat Bonds

➤ Term of the Bond

- A bond with longer term is subject to greater uncertainties
 - E.g. changes in risk, but use of the same vendor model (“model risk”)
- Higher Risk Load may be expected
- Market cycle and changes in the level of confidence in the vendor models may have had some influence
- Statistically not a significant factor
- This is not to say that the term (uncertainty and future rates expectations) do not have an effect on the price of the bond.



Some Comments on Other Features of Cat Bonds

➤ Size of the bond

- Higher size may require more investors bidding the price up
- Not a statistically significant factor

➤ 1st or 2nd Event

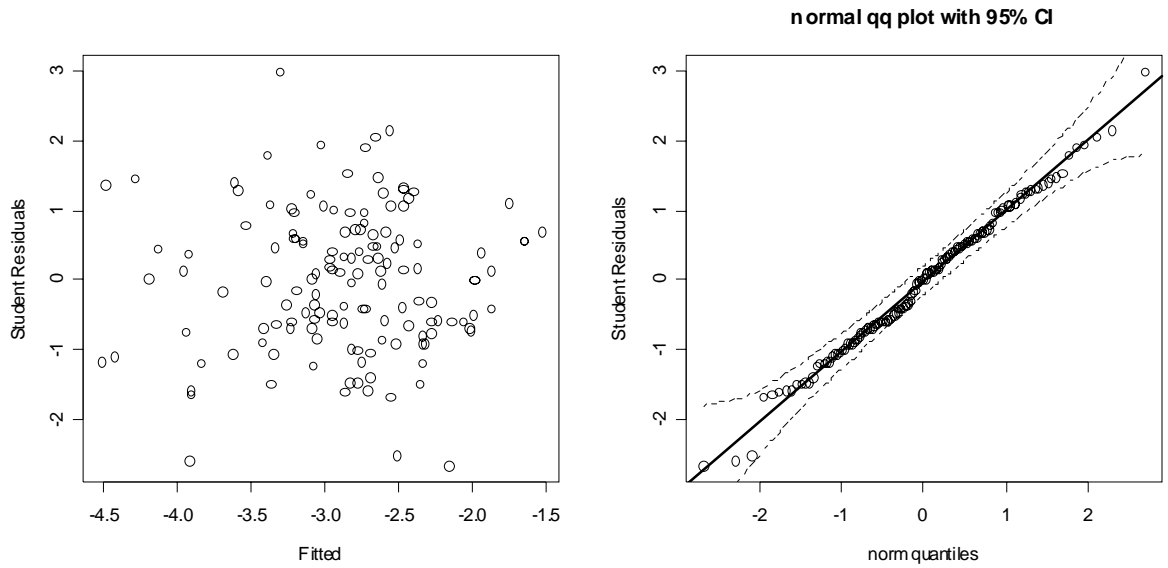
- Cat Bonds: Not a significant effect
- Retrocession: 2nd event (back up) covers seem to have higher risk loads other things being equal
 - May reflect scepticism of underwriters about accuracy of natural hazards models for 2nd event
 - Prevailing market conditions after first event

Some Comments on Other Features of Cat Bonds

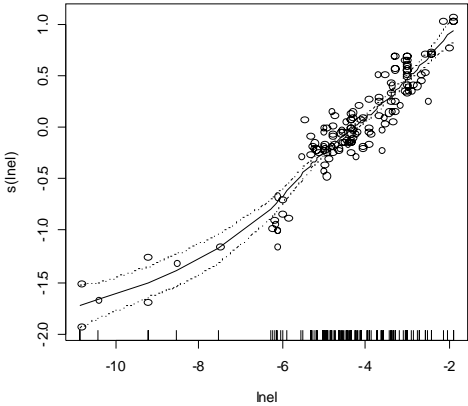
- Time of issue within a year
- Sponsor/Manager/Model
- Shelf Issue
- Retro/Reinsurance/Insurance
- Extension period
- Spreads on corporate bonds

Statistics of US Model

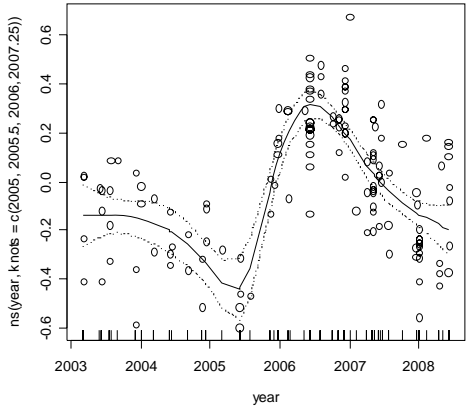
added term	Residual df	Residual Deviance	Difference in df	Difference in Deviance	P(> Chi)
Intercept	141	53.845			
s(log(EL))	137	11.137	4	42.708	0.0000%
ns(year)	132	5.931	5	5.206	0.0000%
Peril/Territory	130	4.251	2	1.680	0.0000%
Trigger	129	4.155	1	0.097	8.3000%



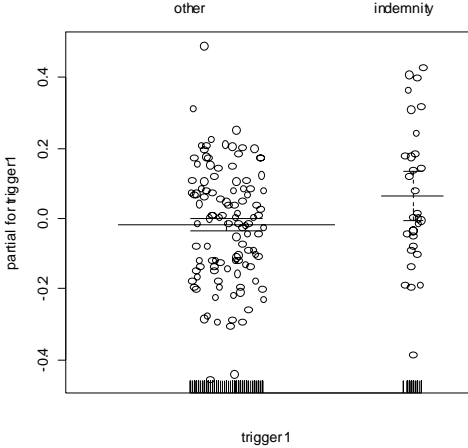
Statistics of US Model – Partial Residuals



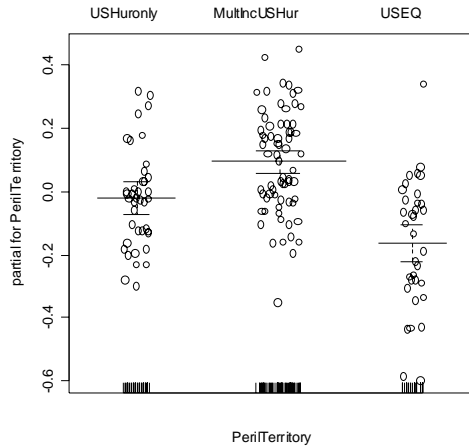
(a) Log(EL)



(b) Time(Year)

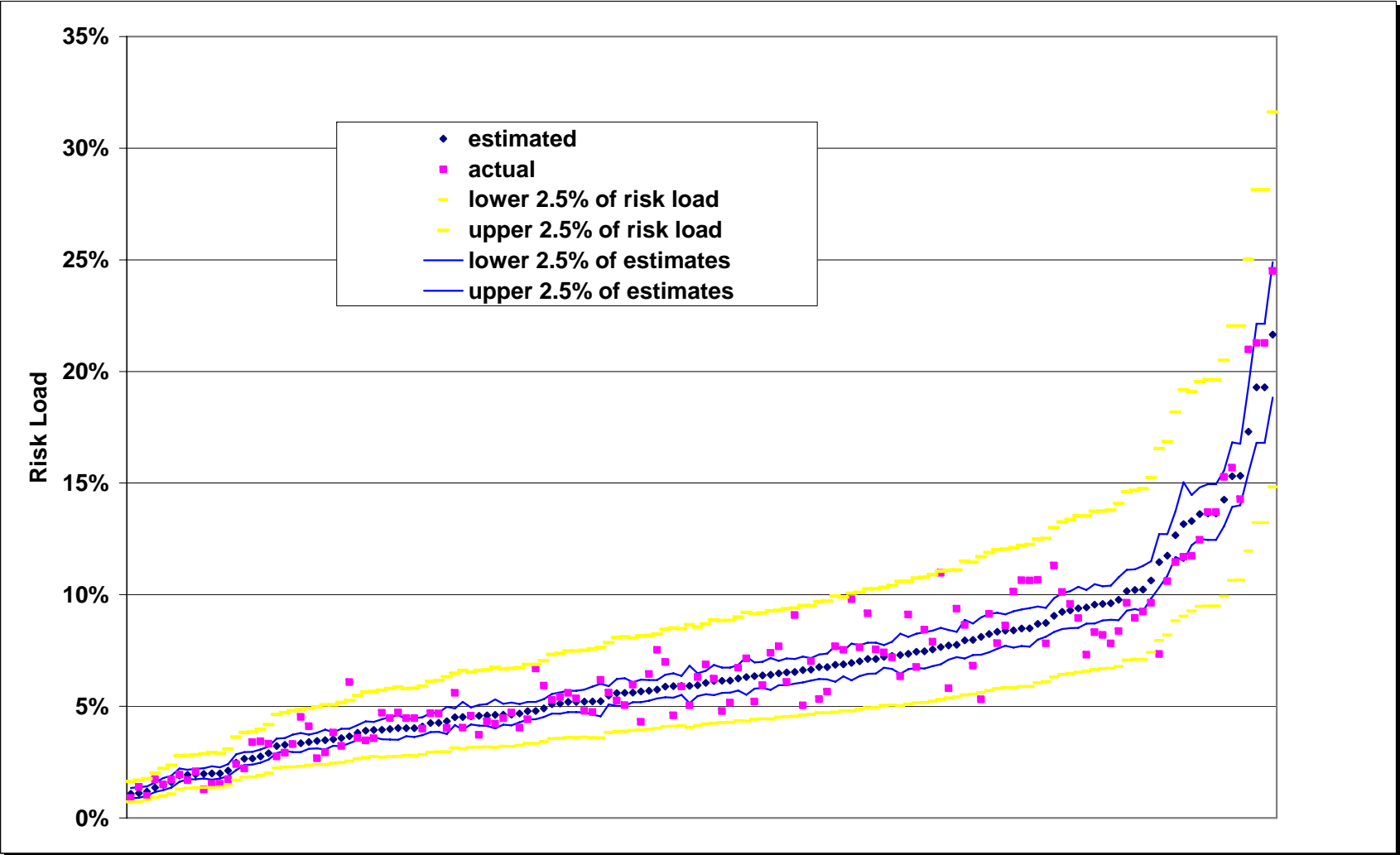


(c) Trigger



(d) Peril/Territory

US Model Actual v. Fitted Risk Loads



Comparisons Cat Bonds v Retro

➤ Direct comparisons not straightforward

- Two different products

➤ Some issues

- Cat bonds mixture of retro and reinsurance
- Data quality of retro portfolios
- Un-modelled risks in retro book?
- Treatment of expenses
- Bonds fully collateralised

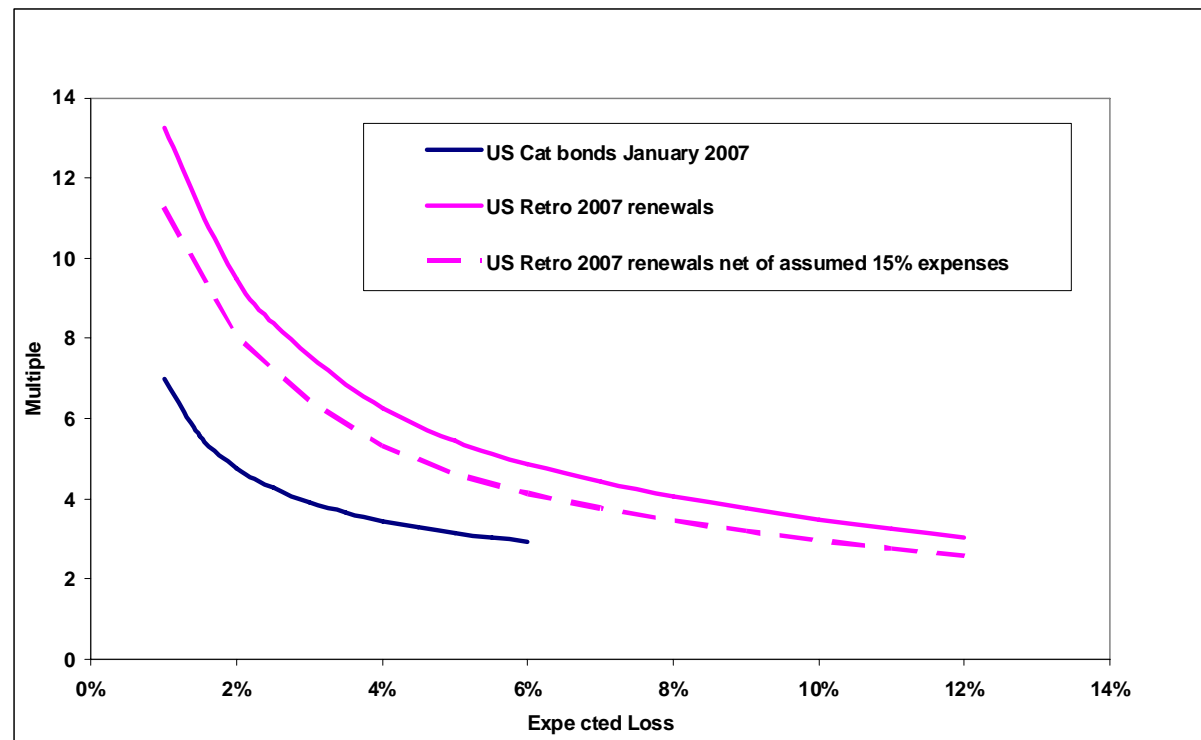
➤ Retro v Cat Bonds

- Risk loads seem to be higher
- Indemnity retro triggers may not be possible to place easily in cat bond markets
- Reinstatement generally available for retro

➤ Reinsurance risk loads closer (lower) to those for bonds

Modelled US Hurricane Multiples January 2007

- Retrocession data covering 2007 and 2008 renewals, representing around 40% the market
- Reinsurance/Retro contracts have been included only if risks had been modelled
 - Allowance for proportional and per risk



Some Common Pricing Methods

➤ Standard Deviation

$$\text{Premium} = E[X] + a \cdot \text{st.dev}$$

➤ Maximum Loss

➤ Esscher Principle

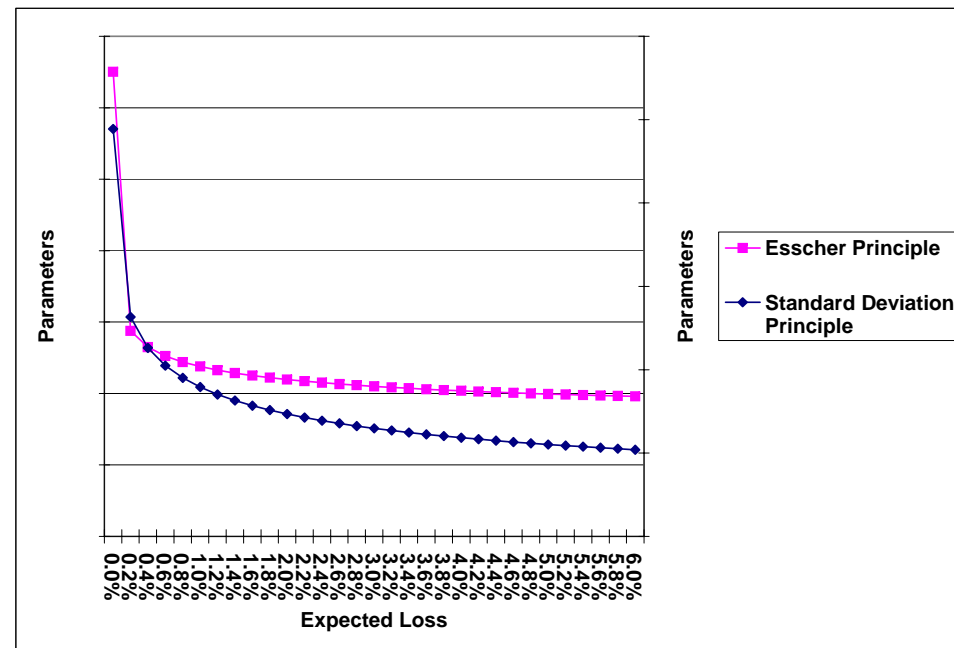
$$\text{Premium} = \frac{E[Xe^{aX}]}{E[e^{aX}]}$$

➤ Proportional Hazards

➤ etc

Approximate Implied Parameters of Standard Methods from Market Prices

- Implied parameters are not constant over the range of expected loss
- Market demands higher premium for lower expected losses
 - Parameter uncertainty?
 - Price discrimination?



The End

- Statistical Modelling provides a good formal framework for analysing market prices
- Data collection and data limitations
- Main drivers
 - Expected Loss
 - also reflecting volatility
 - Peril
 - mainly reflecting correlation with the rest of the portfolio
 - Time of Issue
 - mainly reflecting state of the market, perceptions about risk
 - Trigger
 - basis risk, quality of data
 - Other
- Prices for different risk transfer mechanisms
 - Differences in coverage

Acknowledgments

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