35th ANNUAL GIRO CONVENTION
Factors Affecting the Prices of Catastrophe Bonds

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Contents

- This presentation is not about how a CAT bond should be priced
- It is about
  - how the market has priced the CAT bonds at the time of the issue
  - the factors that affect the prices of a bond
  - comparisons of prices and risk protection between different risk transfer mechanisms
- The analysis can be used in
  - Estimating prices of bonds
  - Portfolio analysis
  - Risk protection assessment
- It provides a framework for analyzing and monitoring the price movements of CAT bonds and reinsurance
  - Construct market index
  - Measure changes in perception of risk
Catastrophe bonds (1)

- Bond which pays coupon and returns capital at the end of the term if an event has NOT occurred
  - Coupon = LIBOR + Spread
- Term
  - 1 to 5 yrs – average a bit less than 3 yrs
- Size
  - from a few million $ to a few hundreds of million $
- Expected Loss
  - Usually less than 5%
  - Full analysis
- Peril
  - Multi-Peril, US Hurricane, US Earthquake, European Wind, Japanese Earthquake, Mediterranean Earthquake, etc.
Catastrophe bonds (2)

- **Trigger**
  - Indemnity
  - Index
  - Modelled Portfolio
  - Parametric
  - Combination

- **Time of Issue**
  - State of the Market

- **Other**
  - Sponsor
  - Manager
  - Shelf issue
  - etc
## Risk Transfer Mechanisms

<table>
<thead>
<tr>
<th></th>
<th>Reinsurance Retrocession</th>
<th>Catastrophe Bonds</th>
<th>ILWs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coverage</strong></td>
<td>All Perils, All Territories</td>
<td>Mainly Property Catastrophe</td>
<td>Mainly Natural Catastrophe</td>
</tr>
<tr>
<td><strong>Trigger</strong></td>
<td>Generally Indemnity</td>
<td>Indemnity, Index, Modelled, Parametric, Combination</td>
<td>Industry Loss</td>
</tr>
<tr>
<td><strong>Reinstatements</strong></td>
<td>Usually Available</td>
<td>Usually 1 Limit</td>
<td>Usually 1 Limit</td>
</tr>
<tr>
<td><strong>Expected Loss</strong></td>
<td>Available at most levels</td>
<td>Majority have Expected Loss &lt;5%</td>
<td>Usually up to 20%</td>
</tr>
<tr>
<td><strong>Data/Modelling</strong></td>
<td>Falls mainly on reinsurer</td>
<td>Extensive external assessment</td>
<td>Limited, Tailored Trigger</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Counter Party Risk, Could be fully Collateralised</td>
<td>Fully Collateralised</td>
<td>Counter Party Risk, Could be fully Collateralised</td>
</tr>
<tr>
<td><strong>Seller</strong></td>
<td>Reinsurer, Side Cars, Funds</td>
<td>ILS investors, Funds</td>
<td>Reinsurer, Side Cars, Funds</td>
</tr>
</tbody>
</table>

- **ILW**s: Catastrophe Bonds, Reinsurance, Retrocession.
Spread, Risk Load, Expected Loss, Benchmark Rate

- Spread or ROL 6%
- Risk Load 5%
- Expected Loss 1%
- LIBOR 4%
Statistical Analysis

✓ Allows us to quantify differences between the spreads of different types of bonds
✓ Helps to separate the effect of the different factors
✓ People are not very good at separating random effects from a real trend. They can be easily “fooled by randomness”
✓ Gives estimates about the errors in our estimates
✗ Subjective choice of model
✗ Trends may be hidden in randomness (“fooled by trends”)
✗ Limited amount of data
Data

- 192 bonds issued between Jan 2003 and June 2008
- Limited amount of data
- Correlations in the data

<table>
<thead>
<tr>
<th></th>
<th>Indemnity</th>
<th>Industry Index</th>
<th>Modelled Loss</th>
<th>Parametric</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Hurricane only</td>
<td>5</td>
<td>28</td>
<td>7</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Multi-peril including US Hurricane</td>
<td>26</td>
<td>23</td>
<td>19</td>
<td></td>
<td>68</td>
</tr>
<tr>
<td>US Earthquake</td>
<td></td>
<td>16</td>
<td>18</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Japanese Earthquake</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>European Storm, Japanese Typhoon, other</td>
<td>5</td>
<td>3</td>
<td>24</td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>Non-Peak Territories</td>
<td></td>
<td>1</td>
<td>7</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>36</strong></td>
<td><strong>71</strong></td>
<td><strong>85</strong></td>
<td><strong>85</strong></td>
<td><strong>192</strong></td>
</tr>
</tbody>
</table>
Data

- Retrocession data covering 2007 and 2008 renewals, representing around 40% the market
- Reinsurance data covering all perils US for 2006, 2007 and 2008 – around 600 contracts
- Reinsurance/Retro contracts have been included only if risks had been modelled
  - Allowance for proportional and per risk
Structure of the Model

- **What do we model?**
  - Spread
  - Ratio (Spread/Expected Loss)
  - Risk Load

- **Asymptotic behaviour**
  - Unsafe to extrapolate
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%?
- Linear Model: Constant Variance
  - Transformation
  - General Linear Model
  - Generalised Linear Model
- One model for all bonds or more than one models?
  - Trial and Error
    - Significant Factors including Interaction Terms
    - Error Term (Distribution and Variance)
Structure of the Model

- Linear Model
  - A priory choice of structure by the user
- Smoothers
  - Data show the relation between dependent and independent variables
  - Choice of smoother and degrees of freedom
Fit of the model for US and Multi-territory perils

- Current Model Choice
  - two power models for two groups of territories
  - with smoothing functions

![Student Residuals plot](image)

- normal qq plot with 95% CI

![Student Residuals quantiles](image)
Individual Cat Bonds with Similar Features

- Useful, but maybe not necessarily the best way
  - Different Expected Losses
  - Different Perils and Triggers
  - Random Effects

<table>
<thead>
<tr>
<th>Date</th>
<th>EL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 February 2002</td>
<td>4.86</td>
</tr>
<tr>
<td>25 May 2002</td>
<td>1.27</td>
</tr>
<tr>
<td>24 August 2002</td>
<td>1.27</td>
</tr>
<tr>
<td>23 November 2002</td>
<td>1.28</td>
</tr>
<tr>
<td>22 February 2003</td>
<td>4.06</td>
</tr>
</tbody>
</table>
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
  - Statistically not as good as expected loss

- It does not seem to be a simple linear relation between risk load and expected loss

- **Minimum Risk Loads**
  - Liquidity Premium
  - Expenses
  - Threshold by corporate bonds?
Modelled US Hurricane Multiples
January 2007

- US Cat bonds January 2007
- US Retro 2007 renewals
- US reinsurance 2007 renewals
- US reinsurance 2007 renewals net of assumed 15% expenses
- US Retro 2007 renewals net of assumed 15% expenses
Comparisons
Cat Bonds v Retro/Reinsurance

- Direct comparisons not straightforward
- 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 to those for bonds
Factors Affecting Risk Load
Date of Issue

- Date of Issue
- Novelty premium in early years
- Market Cycle
  - 2005 Hurricanes
  - Cycle has been more pronounced for bonds including US perils
  - Cycle has been less pronounced for non US perils
  - “Payback” for reinsurers
- Updates of Vendor Models
- Risk loads seem to be levelling off.
  - However, there is significant price volatility.
  - More issues required to draw firmer conclusions
Modelled Multiples for Cat Bonds for Different Perils/Territories (EL=1%)
Factors Affecting Risk Load
Perils/Territory

- Peril/Territory statistically more significant factor than Trigger
  - The exact difference varies with the market cycle
    • E.g. US EQ around the same level as European Wind before Katrina, but higher after
  - Correlation of perils with the rest of the portfolio
Factors Affecting Risk Load Perils/Territory
Cat Bonds

Approximate Relative Risk Load by Peril
as at end of 2007

- Non-peak
- JP EQ
- EU and JP Wind
- US EQ
- US Hurr
- Multi peril inc

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Factors affecting Risk Load Perils/Territory Retrocession

![Graph showing expected loss vs multiple for different categories of 2008 renewals. The graph compares 'WW and US 2008 renewals' and 'other 2008 renewals'. The multiple decreases as the expected loss increases.]

- The graph compares 'WW and US 2008 renewals' and 'other 2008 renewals'.
- The multiple decreases as the expected loss increases.

[The Actuarial Profession logo: making financial sense of the future]
Factors affecting Risk Load
Perils and Trigger

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

- Limited data
  - Very few indemnity bonds not covering perils including US Hurricane.
  - Reputation of sponsor
Factors affecting Risk Load 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 such as USAA, Chubb, etc. 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 15-20% lower than for other triggers
US Industry Loss Warranty (ILW)

- ILWs pay if industry losses (usually based on index) is in excess of certain nominal amount
  - Contrast with cat bond comparisons based on expected loss
- Vendor model estimations of expected loss changed over time
  - Need to adjust for this
- ILW spreads seem to have been lower than those of Cat bonds
- Spreads got closer to those for cat bonds during the hard market following Katrina
US Industry Loss Warranty (ILW)

US Hurricane only

Year

Spread

2004 2005 2006 2007 2008 2009

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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
  - Higher Risk Load may be expected
  - Statistically not a significant factor
  - Changes in level of confidence in the vendor models may have had some influence
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

- **Time of issue within a year**
  - Seasonality of some natural perils
  - May have psychological effect on investors
  - Not a statistically significant factor
  - There is seasonality in the prices in the second market, but here we consider prices at issue

- **Sponsor/Manager/Model**
- **Shelf Issue**
- **Retro/Reinsurance/Insurance**
Some Comments on Other Features of Cat Bonds

- Extension period
- Spreads on corporate bonds
- 1\textsuperscript{st} or 2\textsuperscript{nd} Event
  - Cat Bonds: Not a significant effect
  - Retrocession: 2\textsuperscript{nd} 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 2\textsuperscript{nd} event
    - Prevailing market conditions after first event
Some Common Pricing Methods

- **Standard Deviation**
  \[ \text{Premium} = E[X] + a \cdot \text{st.dev} \]

- **Maximum Loss**
- **Esscher Principle**
  \[ \text{Premium} = \frac{E[X e^{aX}]}{E[e^{aX}]} \]

- **Proportional Hazards**
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?

![Graph showing parameters varying with expected loss](image)
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
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