The Resurgence of Catastrophe Bonds and Fed's Ultra-Low Interest Rate Policy – An Analysis through Optimum Allocation in the Catastrophe Space

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Resurgence of Cat Bonds

- Cat bonds now command the fifth highest cumulative return among major global asset classes since September 2008.

- A WSJ article dated 4/23/2014 reports that “Investors embrace ‘Cat bonds’”: Issuance doubles from 2012 to 2013 while average yield halves from 9.61% to 5.22%.

Optimum Allocation in the Catastrophe Space

- Reinsurance Markets: traditional catastrophe reinsurance.
- Capital Markets: Cat bonds, collateralized reinsurance (c- reinsurance), ILWs.
- Risk limits, layers, trigger type, tenor, etc.

Why optimum allocation using Cat bonds?

Supply Side:

- reinsurer - optimally lay off exposure and extend underwriting capacity.
- Insurer - optimally diversify external hedging capital structure and minimize net hedging cost.

Demand side:

- fund manager - optimally diversify into an alternative investment with zero beta and high bond return.

Status Quo of the Catastrophe Space

- Influx of third-party capital (alternative capital) into the ILS and the c-reinsurance capacities in direct competition with traditional reinsurance during renewals,

- Repercussions: considerably lower costs of bearing catastrophe tail risks, and disruption of the traditional reinsurance market.

Contributions:

1. Modeling Optimum Allocation

- ✓ reinsurance pricing, attachment and detachment points, the reinsurer's default risk and capital/debt positions, and market interest rate risk premium,
- ✓ Cat bond spread, issuance size and trigger type and point, moral hazard and basis risk inherent in the trigger type,
- ✓ catastrophe arrival frequency and loss volatility.

2. Simulating the new normal

- Reinsurance market hard but Cat bond spreads already soften: optimum allocation dictates that the insurer ?
- The reinsurance market starts to softens?
- Both markets soften and reach equilibrium, and the insurer reverts back
- Leading to “convergence”

Convergence

- Fed’s ultra-low interest rate policy spurs Increasing alternative capital participation in the catastrophe space,

- Leading to lower catastrophe risk premiums and insurer’s leverage to dictate reinsurance coverage by issuing more Cat bonds in their optimum allocation,

- Driving reinsurance pricing down toward Cat bond pricing, leading to “convergence” of the two markets.

Academic Literatures

- Schiermeier (Nature,2011) and Emanuel (Nature,2005); Croson and Kunreuher (JRF,2000); Chang, Cheung and Krinsky (IME,1989); Froot (JFE,2001) and Froot and O’Connell (JBF,2008); Zanjani (JFE,2002); Lane and Mahul (World Bank,2008); Lee and Yu (JRI,2002); Cummins, Lalonde and Phillips (JFE,2004); Lee and Yu (IME,2007); Barrieu and Louberge (JRI,2009); Hardle and Lopez Cabrera (JRI,2010).
- Cummins and Weiss (2009) review the slow convergence of (re)insurance and capital markets
- Cummins and Trainar (2009): optimal mix is difficult.

Industry Literature

- **Fed's QEs is the under-the-scene driving force**

- **Industry: www.artemis.bm**

Findings

Don Mango at Guy Carpenter –

- capital market participation has driven the traditional reinsurers'15%+ ROE targets down towards the fixed income required returns of pension funds: ~ 400 bp spreads, and tightened the Cat bond spreads by abut 40% toward ~ 400 bp.

- $50bn of ILS will be in force by the end of 2014 and the cat bond industry is on track to break the previous 2007 issuance record of $7.2bn.

BNY Mellon predicts

- ILS in force could grow to $150bn by 2018, with the cat bond share of that total volume worth up to $50bn.

- At present, 75% of this alternative capacity is focused on US peak perils – mainly windstorm and earthquake.

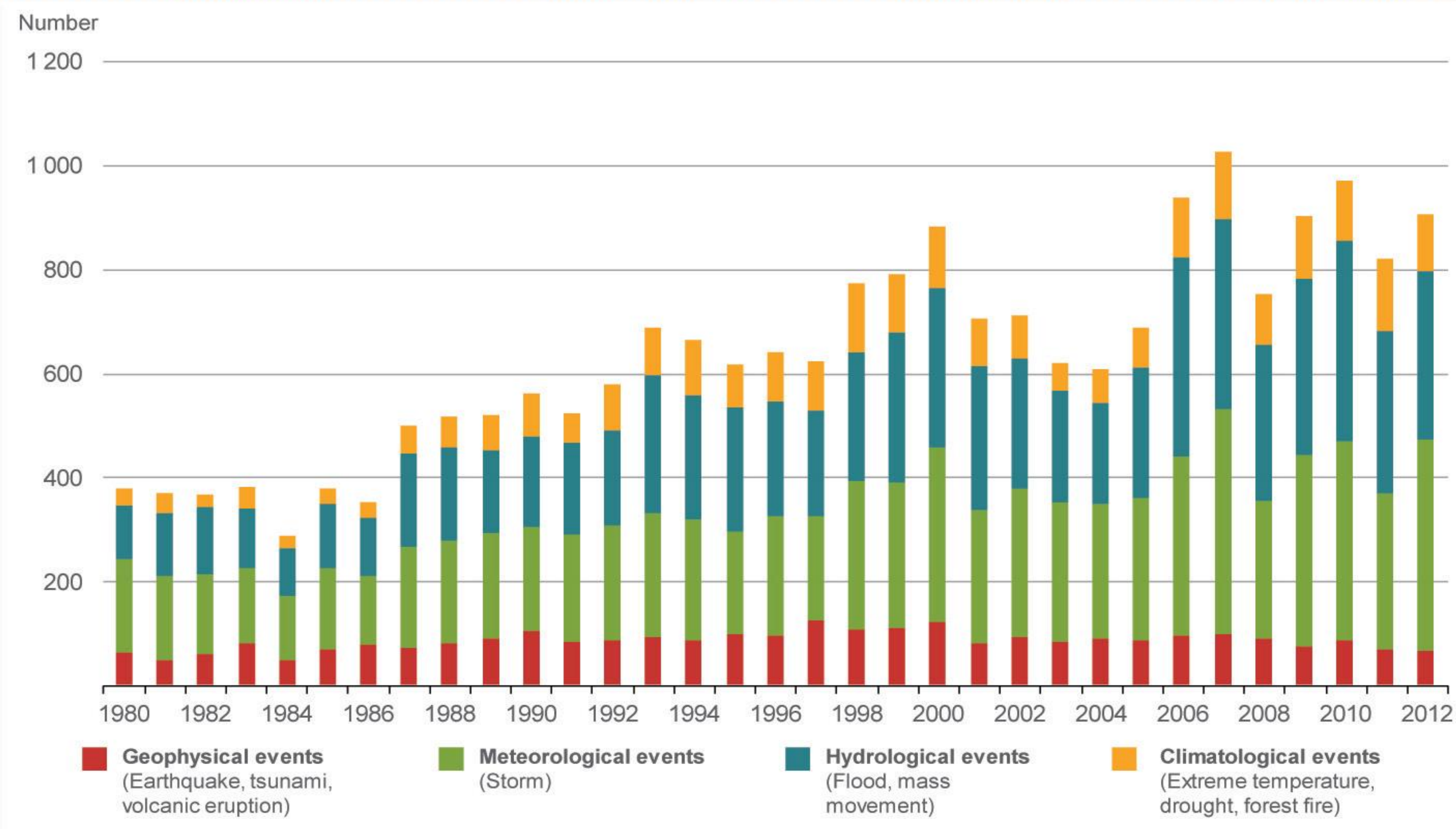
- The reduction in cost-of-capital will improve the value proposition for reinsurance; cheaper capital will enable cheaper underwriting, reductions in rates, more flexibility and may also force reinsurers to embrace innovation and advance product development, all of which is positive for reinsurance buyers and also for those reinsurers that embrace change.

NatCatSERVICE

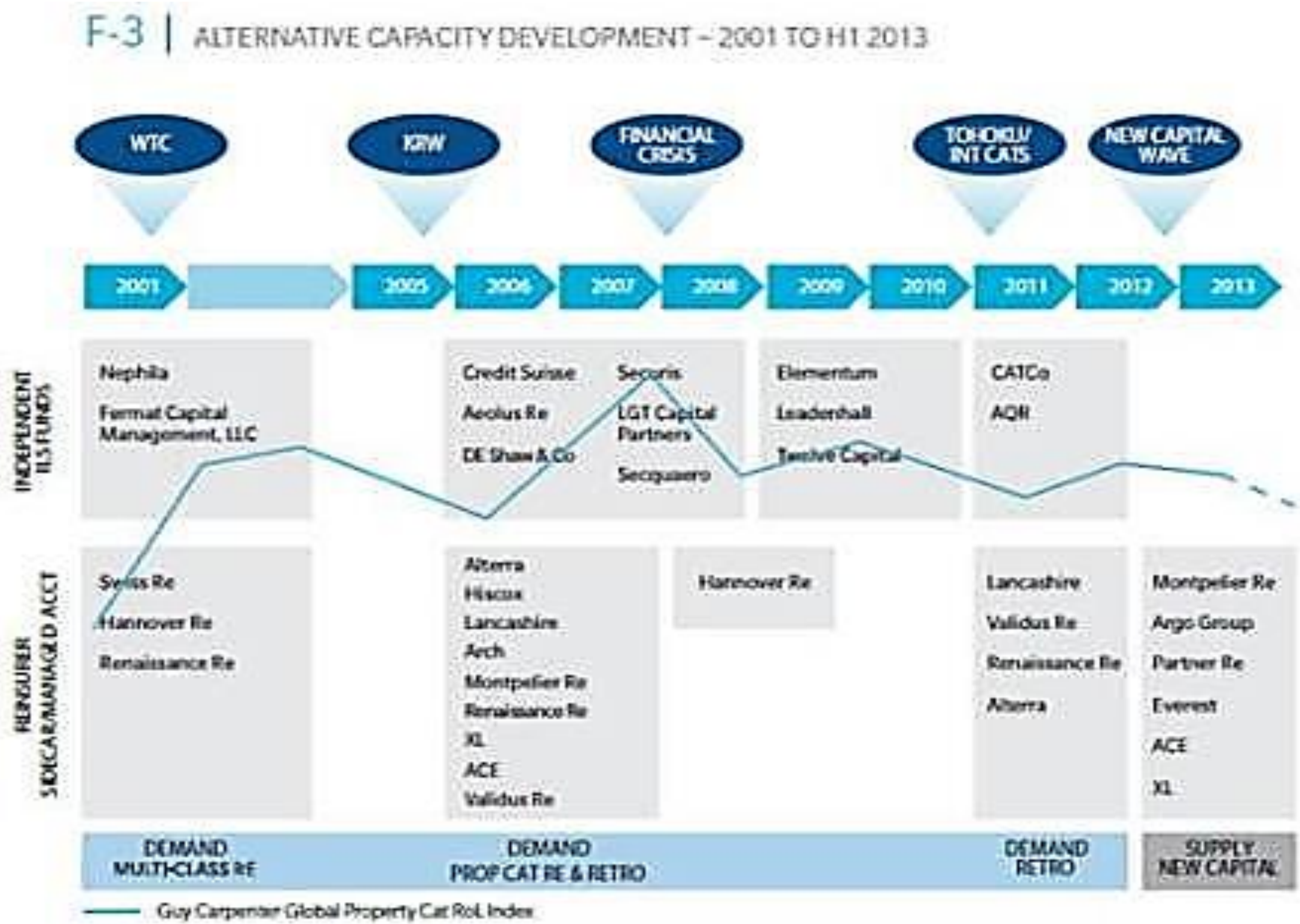
Natural catastrophes worldwide 1980 – 2012

Number of events

Munich RE

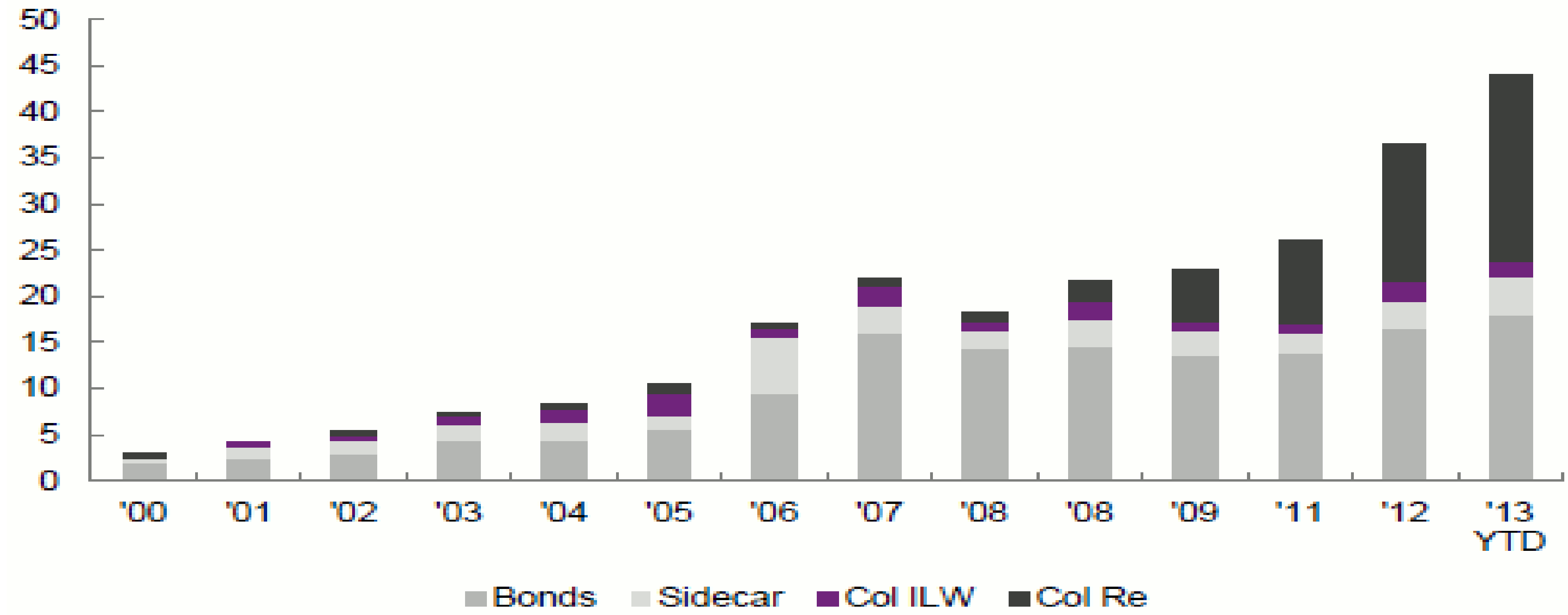


Increasing alternative capital deployment



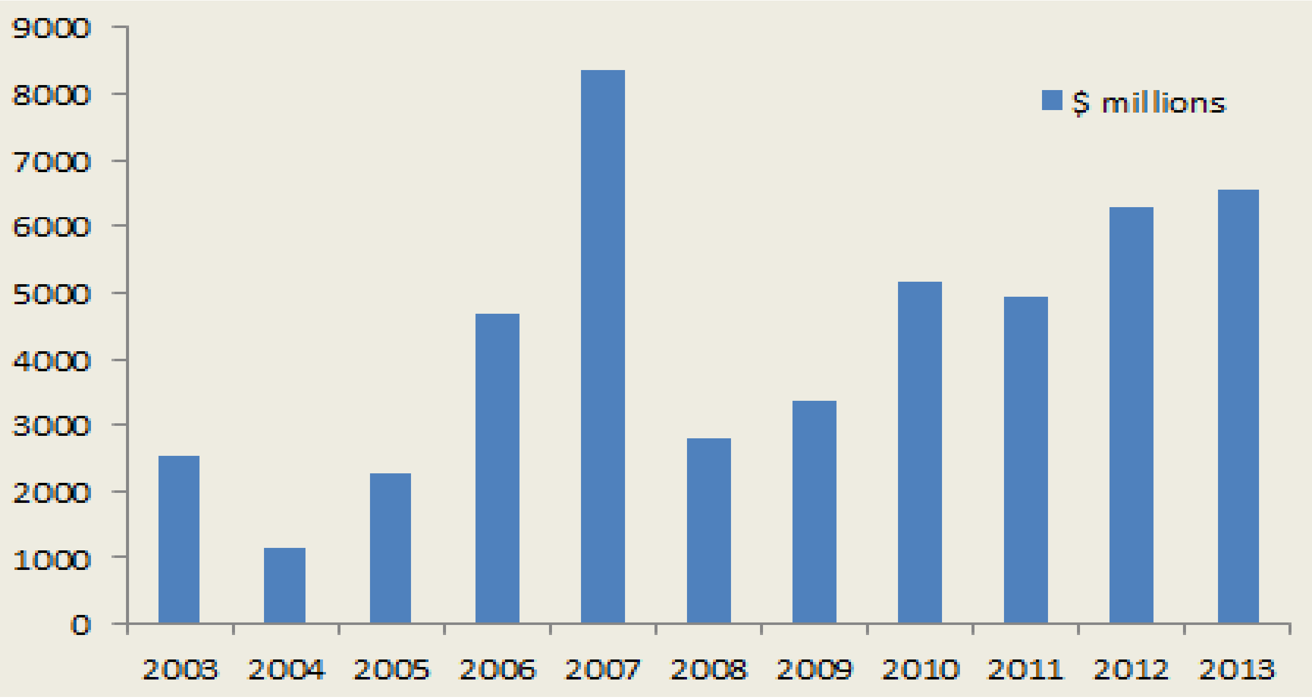
Aon Benfield reports breakdown of the current $44 billion of alternative capital which is in the reinsurance marketplace right now. They see the split as $20 billion collateralized reinsurance, $2 billion collateralized industry loss warranties (ILW's), $4 billion sidecars and $18 billion catastrophe bonds and other ILS bonds.

- 2000-13



Further Statistics: Cat bond market has recovered

- 2003-13



Insurer optimum allocation example: CEA

- Over the past 14 years, the CEA has paid $2.92 billion to reinsurers, more than 40% of its $6 billion total premium revenue, and has only collected $250,000 from reinsurers.

- With such a high hedging cost, the CEA has to charge high premium and require higher deductible, resulting in a penetration rate of only 10 -12%.

How to diversify to lower hedging costs?

- The CEA has decided to tap capital markets and completed a ground-breaking sale of $150 million earthquake CAT bonds in August 2011.

- Mr. Pomeroy: “A diverse set of risk-transfer tools will help us make earthquake insurance more affordable and more widely used.” To this date, in less than two years, the CEA has sold more than $650 million CAT Bonds, but how much more and what features are optimum?

CEA's current mix

It still has the three Embarcadero Re Cat bond issuances, from August 2011 (Embarcadero Re Ltd. (Series 2011-1)), January 2012 (Embarcadero Re Ltd. (Series 2012-1)) and July 2012 (Embarcadero Re Ltd. (Series 2012-2)) in place, which between them provide $600m of limit.

CEA's fully-collateralized reinsurance limit declined from about $340m down to about $271m after July 1st.

The traditional reinsurance protection has increased by $50m to around $1.695 billion of limit.

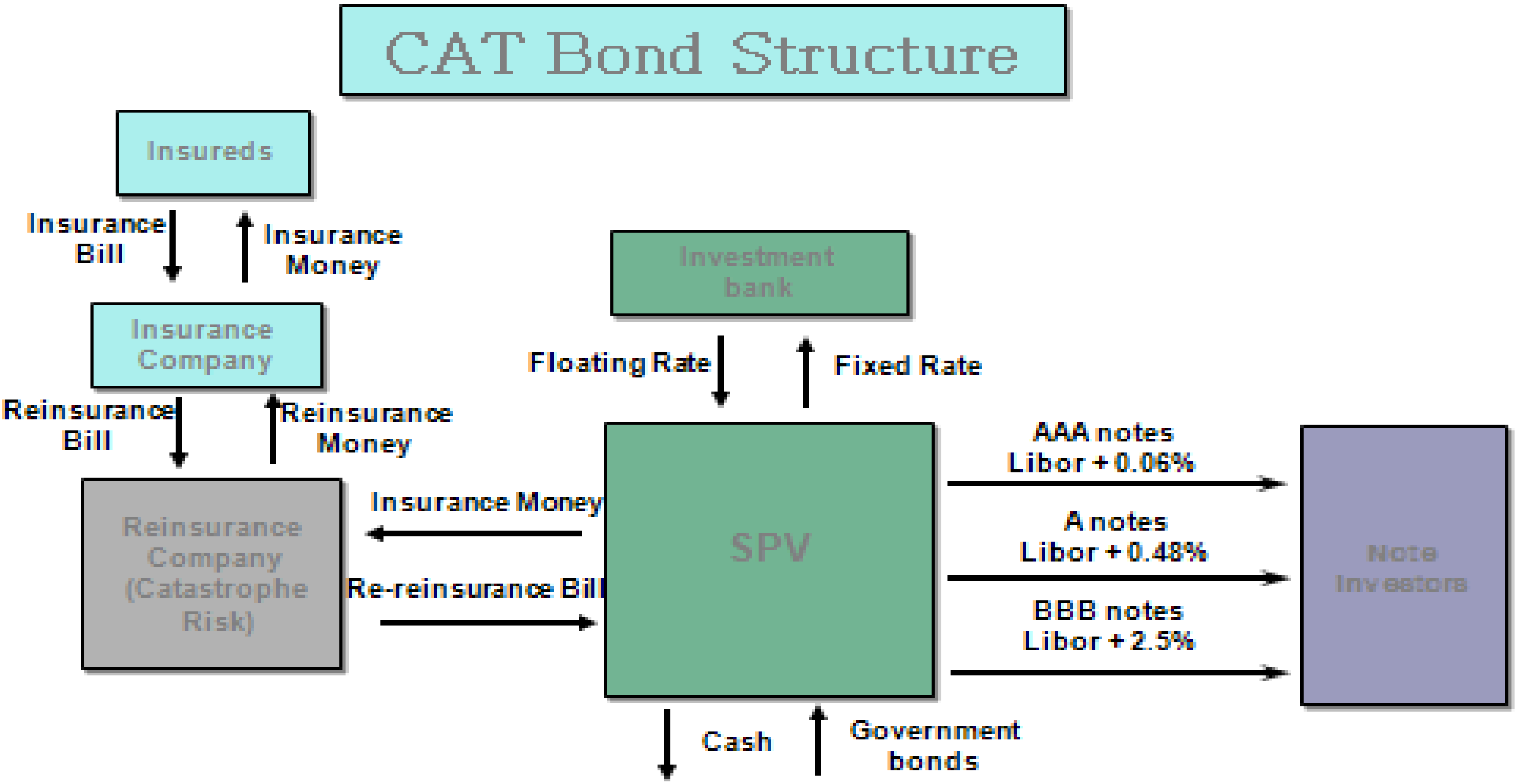
Also at the mid-year renewals, the CEA has roughly doubled the amount of reinsurance limit backed with letters of credit, from around $ 101m to roughly $206m. The changes in the program at mid-year also saw the use of parental guarantees in the CEA's reinsurance program decrease by about half.

Mexico Fund's (FONDEN) optimum allocation

Issued 160 million Cat bond in 2006 as a hedge against a 450 million reinsurance contract against earthquake risk. In this arrangement, the reinsurer EFR (European Financial Reinsurance and a subsidiary of SRC), retained 290 million of the reinsurance exposure and issued a 160 million Cat bond through a SPV. In other words, the mix is 64 % in the default-risky traditional reinsurance and 36% in the default-free Cat bond.

Modeling Methodology

CAT Bonds



How to mix a reinsurance product with a capital market product?

Reinsurer’s Position: Short – Long Mix

Insurer’s Position: Long – Long Mix

Parity Relation

- By issuing Cat bonds, (re)insurers actually enter into a long position in retro-reinsurance with the SPV, free from default and interest rate risk under a parity relationship - the reinsurance premium paid tied to "the bond premium plus the TRS negative spread".

- The cost of the re-reinsurance equals to the cost of Cat bond issuance.

How to model CEA's optimum allocation using an systems integration approach?

- Model counter-party one - default-risky reinsurer
- Model earthquake(RMS) /hurricane (AIR) to calibrate the loss process, or using implied triple from Cat bond prices
- Model counter-party two – the SPV, to position CEA's external hedging capital structure as a net option spread
- Model CEA's total hedging need in a risk-return optimization framework, given exposures
- Model optimum allocation: maximize the NPV of the option spread w.r.t. the reinsurance and Cat bond parameters

Module one:
Model the default-risky Reinsurer

1) We employ Merton's (1974, 1977) structural approach to as applied in Duan and Yu (2005) and Lee and Yu (2007) to an reinsurer to couch the asset, liability, interest rates, and Cat loss dynamics.

2) In a risk-neutralized framework, we endogenize default by linking the valuation of financial claims to a firm's balance sheet.

3) Allocation: A reinsurer sells Cat event-linked XOL reinsurance policies to the CEA and in the same time sponsors and sets up a SPV to issue tailor-made Cat bonds in varying size, tenor, trigger, and event structure in capital markets as a "pure play" to lay off exposure – a Short-Long option combination to net off exposure

The net payoff structure as a net call spread

$$PO_{R,T} = \begin{cases} M - A & \text{if } C_T \geq M \text{ and } V_T + \delta \geq L_T + M - A, \\ C_T - A & \text{if } M > C_T \geqq K \text{ and } V_T + \delta \geq L_T + C_T - A, \\ \left(\dfrac{V_T}{L_T + M - A}\right)(M - A) & \text{if } C_T \geq M \text{ and } V_T + \delta < L_T + M - A, \\ \left(\dfrac{V_T}{L_T + C_T - A}\right)(C_T - A) & \text{if } M > C_T \geqq K \text{ and } V_T + \delta < L_T + C_T - A, \\ C_T - A & \text{if } K > C_T \geq A \text{ and } V_T \geq L_T + C_T - A, \\ \left(\dfrac{V_T}{L_T + C_T - A}\right)(C_T - A) & \text{if } K > C_T \geq A \text{ and } V_T < L_T + C_T - A, \\ 0 & \text{otherwise} \end{cases}$$

- When C_T is larger than the reinsurance cap *M* and the reinsurer's total asset inclusive of payment from the SPV (δ_T) is larger than total liability inclusive of the reinsurance obligation *M-A*, the payoff is *M-A with no default*.

- When the reinsurer's total asset inclusive of payment from the SPV (δ_T) is smaller than total liability inclusive of the reinsurance obligation *M-A*, the reinsurer will default, and the payoff to the insurer now is only $\left(\frac{V_T+\delta_T}{L_T+M-A}\right)(M-A)$.

The reinsurer's optimum allocation

- Position: A Short Default-Risky XOL Option Spread + A long Default-Free Re-Reinsurance Binary Spread

- Optimization: Maximization of the NPV of the position to determine optimum allocation and the sell-side reference XOL price:

$$Max_{\ F,K}\left(uPV_{R,0} - \ d\Delta_0\right)$$

PV of cat bond issuance cost

$$\Delta_0 = E_0^Q[e^{-\int_0^T r_s\, ds} \times PO_{B,T}] - E_0^Q[e^{-\int_0^T r_s\, ds} \times PO_{Cat,T}],$$

U: mark up on the reinsurance price

Reinsurance pricing:15%+ ROE targets down towards the fixed income required returns of pension funds: ~ 400 bp spreads.

Cat bond spreads down about 40% to ~ 400 bp.

d: make up on the cat bond spread

How to estimate *u* and *d*?

- Reinsurance pricing database – GARP
- Cat bond secondary-market spread data base – Lane Financial

Table 1. Parameter Definitions and Base Values

Asset parameters		
V	(Re)insurer's assets	V/L=1.1 (or 1.3, 1.5)
μ_V	Drift due to credit risk	Irreverent
ϕ_V	Interest rate elasticity of asset	(-7), 0
σ_v	Volatility of credit risk	5%
$W_{V,t}$	Wiener process for credit shock	
Liability parameters		
L	(Re)insurer's liabilities	100
μ_L	Drift due to credit risk	Irreverent
ϕ_L	Interest rate elasticity of liability	(-3), 0
σ_L	Volatility of credit risk	2%
$W_{L,t}$	Wiener process for credit shock	
Interest rate parameters		
r	Initial instantaneous interest rate	2%
κ	Magnitude of mean-reverting force	0.2
m	Long-run mean of interest rate	5%
ν	Volatility of interest rate	10%
λ_r	Market price of interest rate risk	0
Z	Wiener process for credit shock	
Catastrophe loss parameters		
λ	Catastrophe intensity	0.5 (or 1, 2)
μ_C	Mean of the logarithm of CAT losses for the insurer	2
σ_C	Standard deviation of the logarithm of CAT losses for the insurer	0.5 (or 1, 2)
$N(t)$	Poisson process for the occurrence of catastrophes	
Other parameters		
K	Trigger levels	10~ 70
F	Face Value of Cat Bond	0~ 90
A	Attachment level of a reinsurance contract	10
M	Cap level of loss paid by a reinsurance contract	70
R	Total Risk Capital	150
T		3 years

We choose the base case parameters λ=0.5, μ_C=2, σ_C=0.5, ϕ_L=-3,ϕ_V=-3, the mark-up u=0.4,d=0.05, coverage(M,A) = (70,10), to find the Optimum(Max,F_R,K_R) = (2.100952,33,37). That is the reinsurer's optimum allocation for coverage (70,10) is to issue Cat bond (33,37),

	F=0	F=10	F=20	F=30	F=33	F=40	F=50	F=70	F=130
K=10	2.087526	1.932766	1.877060	1.863365	1.862492	1.857624	1.854605	1.853341	1.853165
K=20	2.087526	2.028887	2.015934	2.017540	2.018853	2.017095	2.016101	2.015704	2.015655
K=30	2.087526	2.071641	2.073988	2.080890	2.083019	2.082470	2.082200	2.082025	2.082024
K=35	2.087526	2.081200	2.086854	2.095014	2.097367	2.097076	2.096904	2.096808	2.096808
K=36	2.087526	2.082596	2.088742	2.096910	2.099281	2.099033	2.098869	2.098784	2.098784
K=37	2.087526	2.083707	2.090223	2.098559	2.100952	2.100736	2.100580	2.100505	2.100505
K=38	2.087526	2.084407	2.090845	2.098751	2.100943	2.100752	2.100606	2.100541	2.100541
K=39	2.087526	2.083934	2.088725	2.095366	2.097582	2.097412	2.097275	2.097219	2.097219
K=40	2.087526	2.082846	2.085836	2.090647	2.092453	2.092302	2.092174	2.092126	2.092126
K=50	2.087526	2.084507	2.083513	2.083642	2.084678	2.084600	2.084553	2.084551	2.084551
K=60	2.087526	2.086532	2.086262	2.086333	2.086529	2.086498	2.086496	2.086496	2.086496
K=70	2.087526	2.087256	2.087128	2.087280	2.087278	2.087278	2.087278	2.087278	2.087278

The optimum coverage across combinations of (M,A) is (90,10) with optimum Cat bond issuance (F,K) = (52,37).

Max							
Coverage	M=60	M=65	M=70	M=75	M=80	M=85	M=90
A=10	2.09445	2.09879	2.10095	2.10221	2.10286	2.10342	2.10374
A=15	1.32104	1.32546	1.32766	1.32893	1.32957	1.33014	1.33043
A=20	0.80600	0.81049	0.81274	0.81400	0.81465	0.81521	0.81550
A=25	0.47884	0.48335	0.48564	0.48690	0.48755	0.48811	0.48837
A=30	0.27942	0.28366	0.28597	0.28723	0.28788	0.28844	0.28871
F_R							
Coverage	M=60	M=65	M=70	M=75	M=80	M=85	M=90
A=10	23	28	33	38	43	48	52
A=15	18	23	28	33	38	43	47
A=20	13	18	23	28	33	38	42
A=25	8	13	18	23	28	33	37
A=30	0	8	13	18	23	28	32
K_R							
Coverage	M=60	M=65	M=70	M=75	M=80	M=85	M=90
A=10	38	38	37	38	38	38	37
A=15	43	43	43	43	43	43	42
A=20	48	48	48	48	48	48	47
A=25	55	53	53	53	53	53	52
A=30	60	60	58	58	58	58	57

Module Two: Modeling Earthquake in California to endogenize the loss process

- Geological survey is carried out: historical frequency and magnitude of past earthquakes are evaluated

- Structural survey is carried out: evaluation of the structural integrity of the buildings in the area of interest

- Stochastic earthquake model is developed to produce hazard maps and calibrate loss process

Stochastic Earthquake Model

- model earthquake generation stochastic process
- model shock diffusion stochastic process from the source to the building site
- model the dependent severity of ground shaking at the site
- model damage to the building as a function of the building integrity and compute corresponding losses on a replacement cost basis

The Loss Process

- the aggregate earthquake loss is modeled as a compound Poisson process as follows:
-

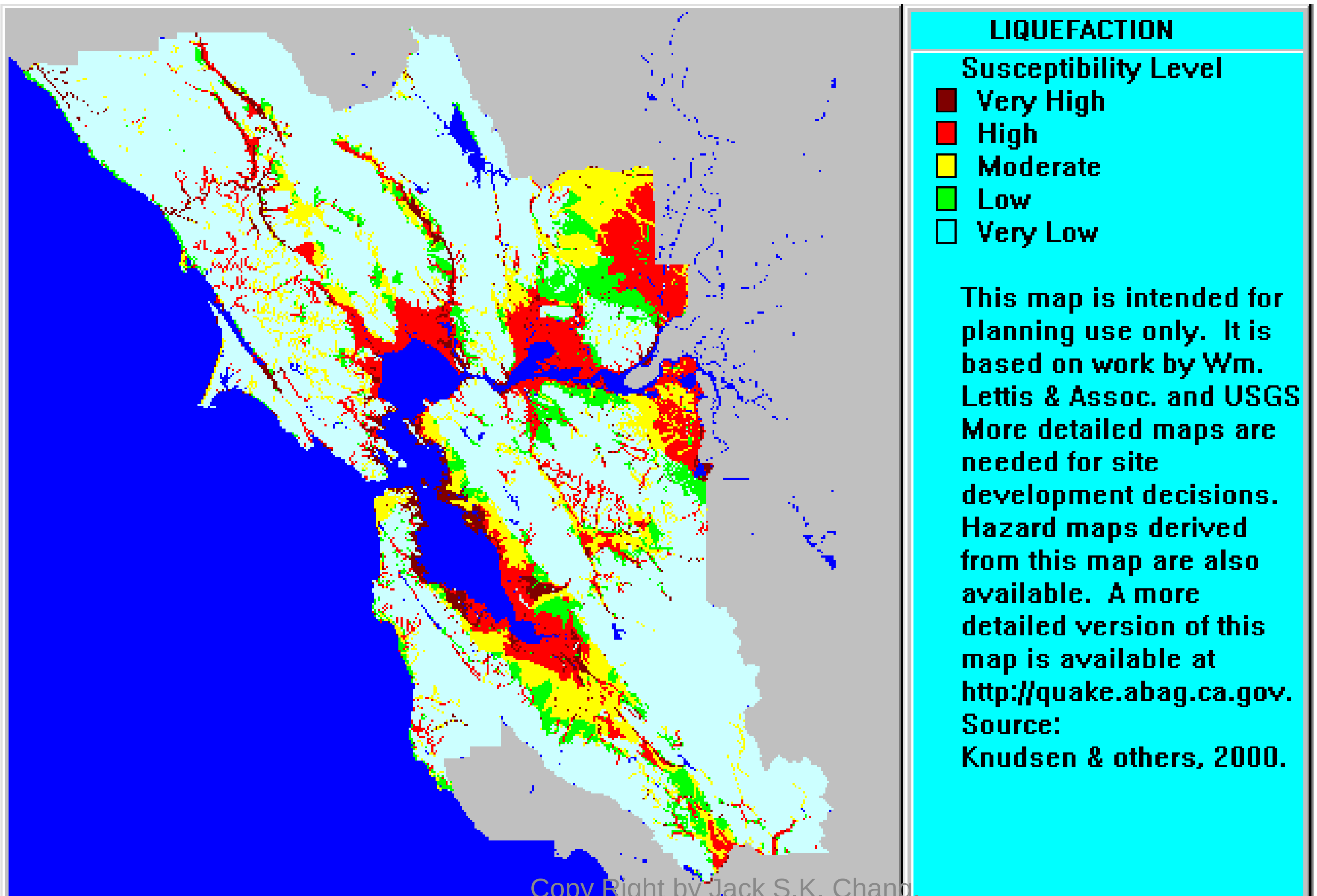
$$C_t = \sum_{j=1}^{N(t)} c_t$$

- Calibration? Using all data – historic and market

A forward-looking market-consensus approach

- Pricing
- Forecasting
- optimum allocation

Hazard Map Example



Module Four:

Model External Hedging Capital Structure

- The CEA has a long position in the traditional XOL reinsurance as a call spread and a long position in the SPV reinsurance as a binary call, i.e. a long-long position of a net call spread
- What is the optimum total?
- What is the optimum allocation?

CEA's Total Hedging Need

- Chang, Chang and Wen (JRI, 2014)

  "OPTIMUM HURRICANE FUTURES HEDGE IN A WARMING ENVIRONMENT: A RISK–RETURN JUMP-DIFFUSION APPROACH"

  – a three-factor formula involving optimum jump hedge, diffusion hedge, and cost of hedging ratios.

Module Five:
CEA's Constrained Optimization

- Minimize the total hedging cost w.r.t. four reinsurance and cat bond parameters s.t. the total hedging capital constraint

- This minimum value underpins the buy-side maximum reinsurance premium

$$Min_{\ M,A,K} \left((1+u)PV_{R,0} + (1+d)\Delta_{I0}\right)$$
$$\text{s.t.}\, M - A + \ F_I = R.$$

We let u=[0,0.4], d=[0,0.05], K_l = A, and set the total required external hedging capital R=80. When u=0.4 and d=0.05, the optimum allocation (Min,M,A,F_l,K_l) = (1.73904,60,30,50,30) i.e. purchase reinsurance coverage (60,30) and issue Cat bond (50,30), with a mix of (30,50). When market softens? (Min,M,A,F_l,K_l) = (1.42324,80,30,30,30), i.e. a mix of (50,30).

u=0.4,d=0.05					
Coverage	M=60	M=65	M=70	M=75	M=80
A=10	12.68857	12.50621	12.17674	11.63300	10.74934
A=15	8.08177	8.03535	7.92784	7.73049	7.40975
A=20	4.96457	4.95992	4.92900	4.86493	4.75000
A=25	2.96594	2.97738	2.97289	2.95475	2.91403
A=30	1.73904	1.75557	1.76121	1.75915	1.74789

u=0.1,d=0.05					
Coverage	M=60	M=65	M=70	M=75	M=80
A=10	11.10572	10.92270	10.59731	10.05688	9.17712
A=15	7.08440	7.03403	6.92604	6.73124	6.41270
A=20	4.35666	4.34806	4.31513	4.25088	4.13707
A=25	2.60532	2.61280	2.60631	2.58710	2.54647
A=30	1.52935	1.54192	1.54555	1.54243	1.53061

u=0,d=0					
Coverage	M=60	M=65	M=70	M=75	M=80
A=10	10.32563	10.15122	9.84197	9.32781	8.49055
A=15	6.58874	6.54013	6.43722	6.25209	5.94907
A=20	4.05271	4.04389	4.01221	3.95099	3.84278
A=25	2.42401	2.43051	2.42401	2.40555	2.36687
A=30	1.42324	1.43458	1.43772	1.43458	1.42323

Fund Manager’s optimum allocation

- Since Cat bonds are zero-beta investments, given the bond allocation (1-2 % for pension funds) the NPV of the investment in the mix when the pricing of SPY is at equilibrium is simply $d\Delta_0$, so the fund manager simply try to maximize the benefit of wide spreads available in a thin market across all Cat bond offers to earn the highest bond return possible per risk profile. That is to maximize the NPV of the mix with respect to *d*, *F*, and *K* across all available Cat bond purchases as

$$Max_{\,d,F,K}\,(d\Delta_0),$$

where the Cat bond that offers the most benefit will be purchased.

Further Analyses

- Impact of the reinsurance underwriting cycle – more Cat bond in a hard market,
- Impact of risks-on due to QEs – more collateralized alternative investments but less after tapering,
- Impact of reinsurer default – more Cat bond with higher default probability
- Impact of larger basis risk – less Cat bonds
- Impact of larger catastrophe risk: more Cat bonds with increasingly lower trigger level

Empirical Test

Thank You & Q/A