The Actuarial Profession
making financial sense of the future

OXFORD MARTIN SCHOOL

UNIVERSITY OF OXFORD

The latest issues surrounding catastrophe modelling
Peter Taylor

Janus, Cerberus, Hydra

Where Business meets Solvency II

29 March 2011

"Understanding the models, particularly their limitations and sensitivity to assumptions, is the new task we face. Many of the banking and financial institution problems and failures of the past decade can be directly tied to model failure or overly optimistic judgements in the setting of assumptions or the parameterization of a model."

Tad Montross, 2010, Chairman and CEO of GenRe in "Model Mania"

"What insurance needs, as does banking, is for seriously experienced business people to look at the firm's business plan and challenge whether it has the competence to execute it well and the risk controls to alert it in time if something goes wrong.

What we are getting instead is micromanagement of the worst sort – the FSA, through its models, trying to tell the industry how to manage itself. Board meetings in future will be all about compliance, not about trying to make a profit."

Anthony Hilton, London Evening Standard 17th September 2010

Themes – Myths and Monsters

Janus – Transitions

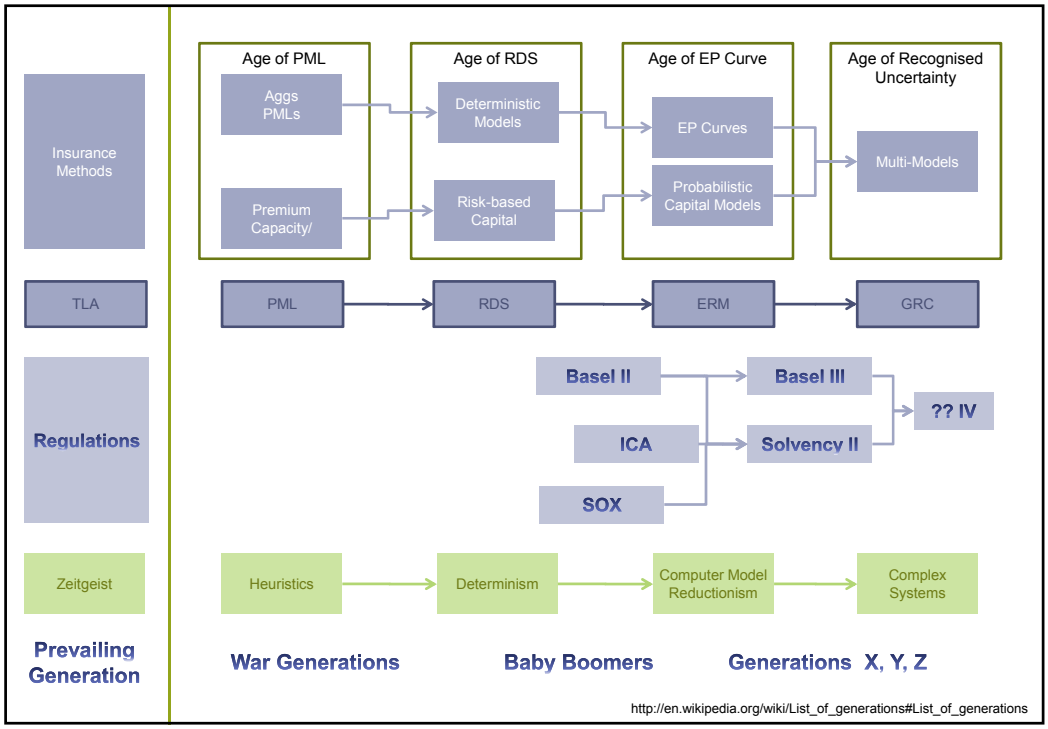
Cerberus – Lessons from the Financial Crisis

Hydra – Solvency II and Business

Transitions

Janus

- Baby Boomers
  - Control
  - Model
  - Quantify
- EP Curves
  - Primary Uncertainty
  - Secondary Uncertainty
  - Multiple Models
- VaR – the Measure of Risk

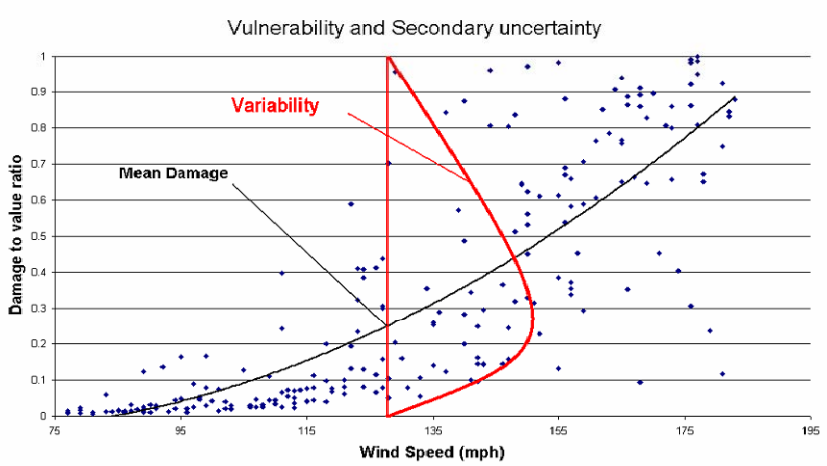


Transition Bibliography

- Useless Arithmetic - *Orin Pilkey & Linda Pilkey-Jones*
- The Science of Prediction - *David Orrell*
- The Origin of Wealth - *Eric Beinhocker*
- The Failure of Risk Management - *Douglas Hubbard*

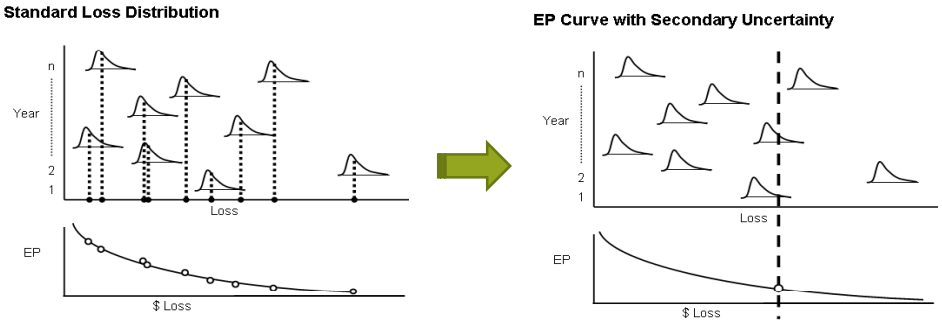
EP Curves

Secondary Uncertainty



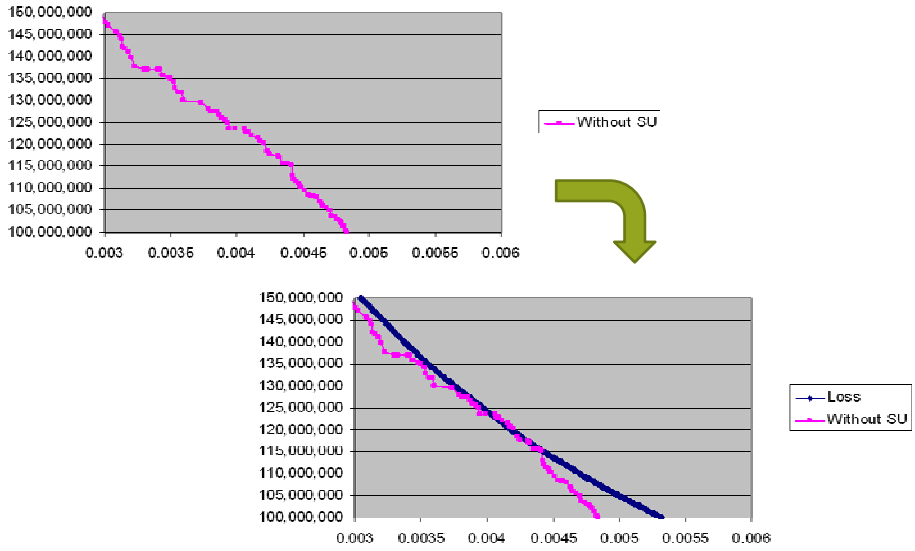
Source: Edouard von Herberstein, Master's Thesis, University of Colorado at Boulder, April 2004

EP Curve with Secondary Uncertainty



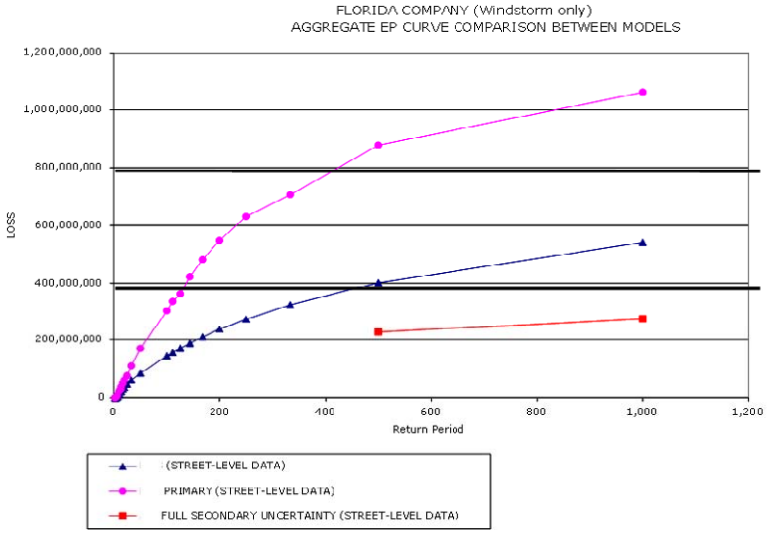
Source: AIR

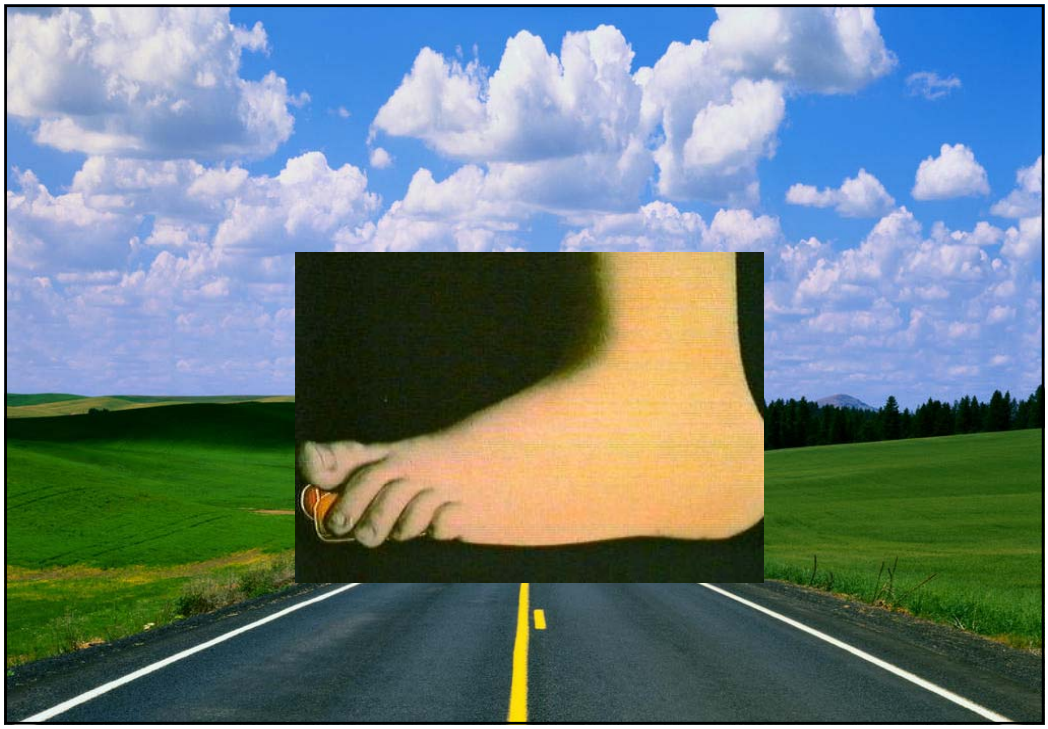
Applying Secondary Uncertainty

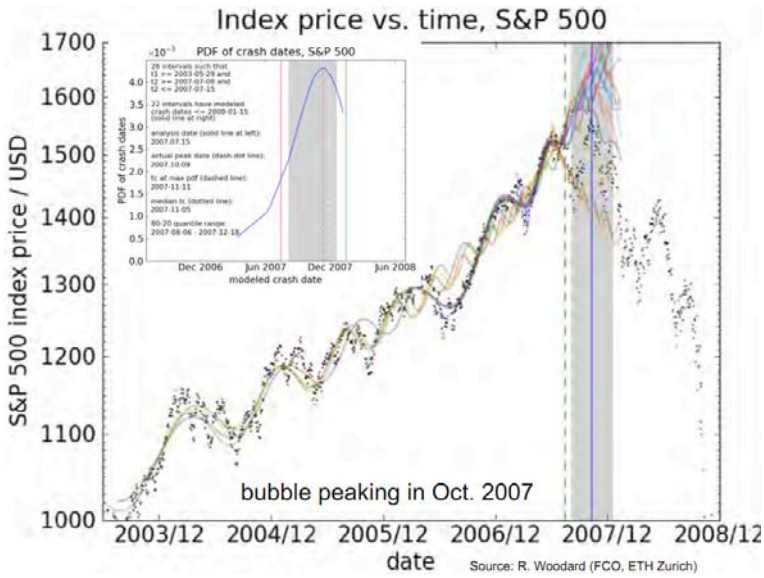


Multiple Models

Model Comparison – Different Models







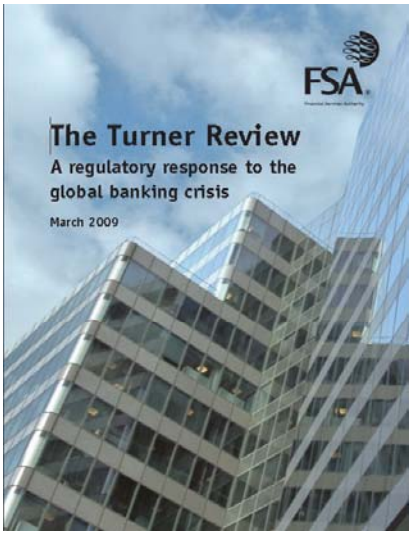
The Financial Crisis

Cerberus

- Finance - what went wrong?
- The Hidden dimensions of Risk
- Recognising Uncertainty

What went wrong?

Turner Review Conclusions



MODELLING PROBLEMS

- Short observation periods
- Non-normal distributions
- Systemic versus idiosyncratic risk (Correlated behaviour)
- Non-independence of future events (The past not a guide to the future)

Basel II and the idiot brother of Insurance

- **Framing errors**: over-reliance on data sets, often artificial, that did not include a sufficient range of outcomes
- **Model risk**: over-simplistic model and risk distribution assumptions
- **Parameter risk**: insufficient consideration of error due to lack of calibration of models
- **Behavioural risk**: anyone pointing out model failings would have been shouted-down - it would have stopped a lot of lucrative business and things were “different this time”

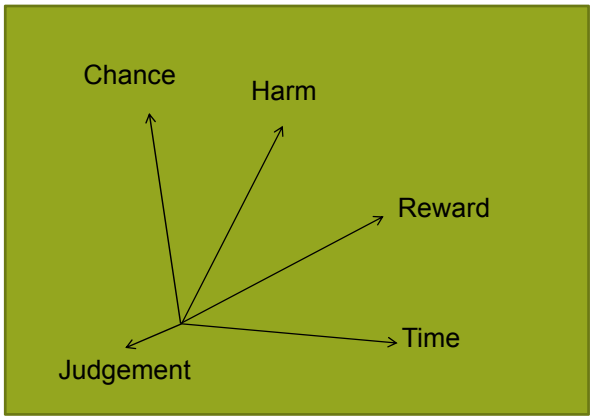
The Hidden Dimensions of Risk

Dimensions of Risk Decisions

- Harm
- Chance
- Time

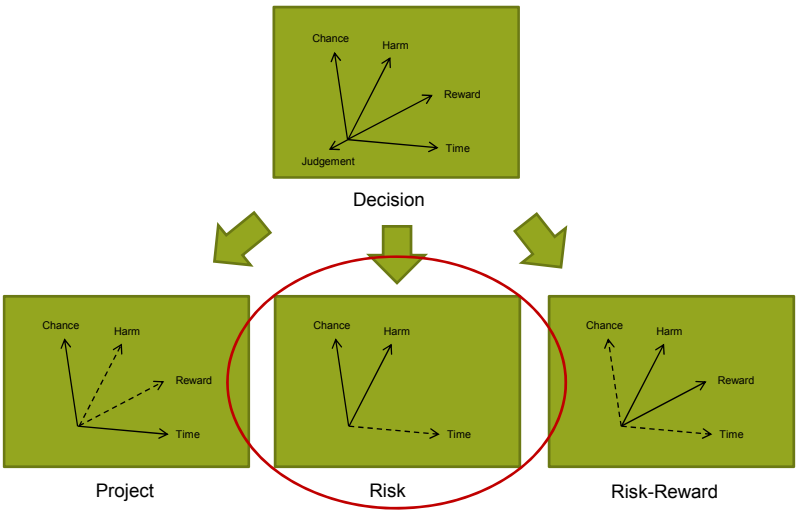
plus

- Reward
- Judgement



Source: **The Mismeasure of Risk** ,The Handbook of Risk Theory, Springer 2011

2D Projections

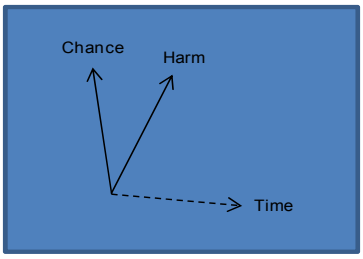


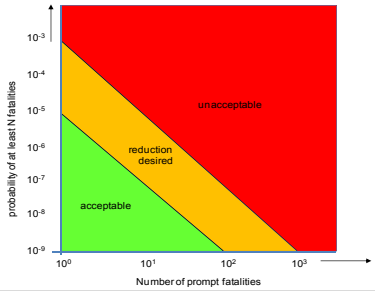
Risk

- Harm
- Chance
- Time

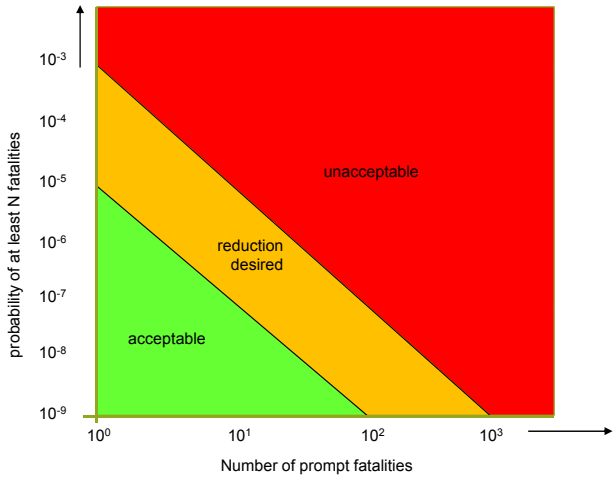
plus

- Measures





The Dutch Group Risk Criteria



Source: Probabilistic Risk Analysis, Bedford and Cooke, CUP, 2001

Tackling Model Risk

Tackling Model Risk – Round 1

- On the Quantitative Definition of Risk
- Stress Tests
- Evidence
- Model Comparison
- Independent Estimates

yielding a

- Revised EP Curve

On the Quantitative Definition of Risk

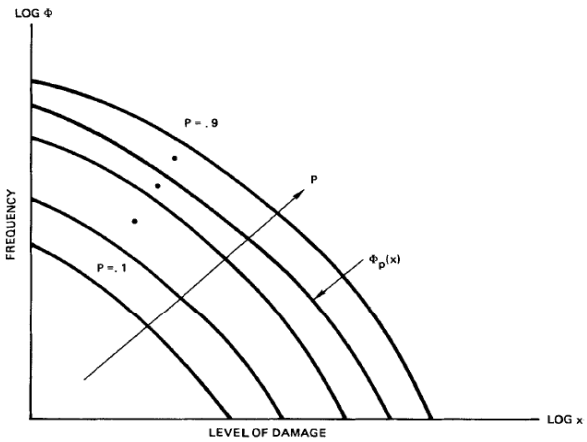
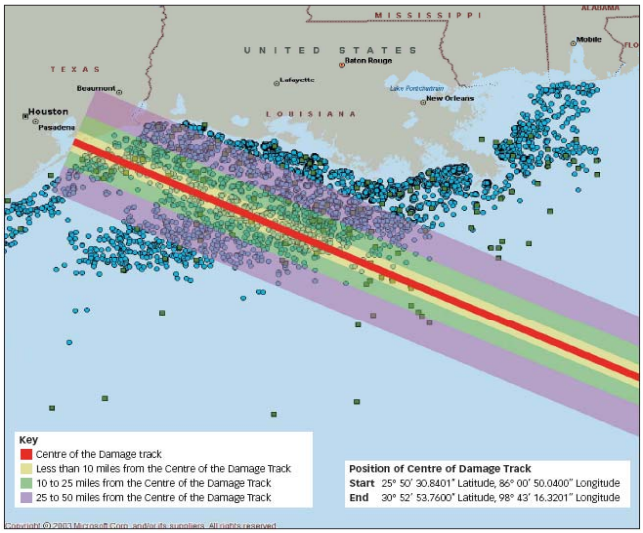


Fig. 7. Risk curve in probability of frequency format.

Source: Kaplan and Garrick, Risk Analysis Vol 1 No 1 1981

Scenario Tests



Source: **Lloyd's RDS**

Evidence

Table 1: **Number of Atlantic Hurricanes**

			Near Term Predictions		
	Long-Term Average	Actual	AIR	EQECAT	RMS
2006	5.9	5	8.4	8.0	8.4
2007	5.9	6	6.6	6.0	6.4
2008	5.9	8	6.8	8.1	8.4
2009	5.9	3	6.8	8.1	7.6
Total	23.6	22	28.8	32.2	32.8

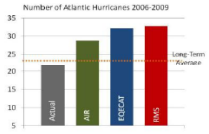


Table 2: **Number of U.S. Landfalling Hurricanes**

			Near Term Predictions		
	Long-Term Average	Actual	AIR	EQECAT	RMS
2006	1.7	0	2.4	2.3	2.4
2007	1.7	1	2.0	2.3	2.4
2008	1.7	3	2.0	2.3	2.4
2009	1.7	0	2.0	2.3	2.2
Total	6.8	4	8.4	9.2	9.4

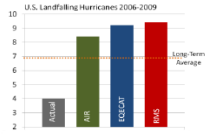
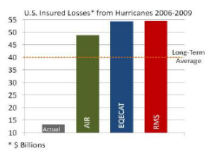


Table 3: **U.S. Insured Losses from Hurricanes ($ Billions)**

			Near Term Predictions		
	Long-Term Average	Actual	AIR	EQECAT	RMS
2006	10	0	14.0	13.6	14.0
2007	10	0	11.6	13.5	14.0
2008	10	13.3	11.6	13.7	14.0
2009	10	0	11.6	13.7	12.6
Total	40	13.3	48.8	54.5	54.6



Source: **2006 - 2010 Loss Model "Near-Term" Predictions**
Karen Clark & Company, "Near Term Hurricane Models Performance Update " January 2010

More Evidence

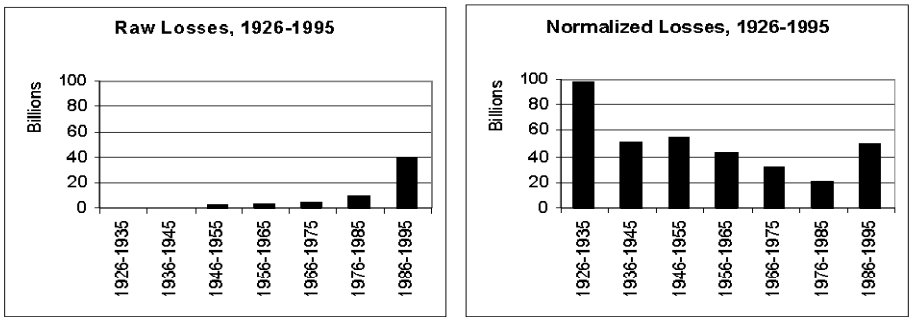


Figure 1: Raw loss data shows a rapid increase in hurricane losses in recent decades. However, the normalized record shows that losses in recent years have been near the long term average, and that normalized losses from 1926-1935 were significantly worse than from 1986-1995.

Source: **Evaluation of Catastrophe Models Using a Normalized Historical Record 1999**
Roger A. Pielke, Jr., Christopher W. Landsea, Rade T. Musulin, and Mary Downton

More Evidence

Hurricane Isabel (2003)

Company	*Modelled*	*Actual*	*Multiple*
A	*0.47*	*3.30*	*6.9*
B	*1.44*	*7.30*	*5.1*
C	*2.36*	*15.00*	*6.4*
D	*0.31*	*2.25*	*7.1*
E	*0.11*	*0.30*	*2.6*
F	*1.20*	*2.30*	*1.9*
G	*2.54*	*10.00*	*3.9*
H	*3.32*	*12.00*	*3.6*
I	*1.55*	*5.70*	*3.7*

More Evidence

Katrina Loss Estimate Development

	RMS Industry	*AIR Industry*
Pre-Event Est (no flood)	**$10-25bn** (30/08)	**$12-26bn** (29/08)
August Close (no flood)	**$20-35bn** (09/09)	**$18-25bn** (30/08)
Lloyd's Pick (inc flood)	**$40-60bn** (13/09)	**$42-61bn** (27/09)
Sept Close	**$40-60bn** (27/09)	**$42-61bn** (27/09)
Oct 9th	**$40-60bn** (27/09)	**$42-61bn** (27/09)

Actual insurance industry loss (Swiss Re figure) $66bn

Model Comparison

2008 Industry Florida Hurricane

Annual Aggregate Loss Costs

	Mean	Std. Dev.	Min	Max
RMS 7.0	$ 2,609	$ 2,483	$ 24	$ 140,716
RMS 6.0	$ 1,724	$ 1,637	$ 18	$ 85,798
AIR 9.5	$ 2,510	$ 2,785	$ 32	$ 134,544
EQECAT 3.1	$ 3,030	$ 3,888	$ 2	$ 176,318

Source: **A Comparison of Hurricane Loss Models, *Journal of Insurance Issues,*** Cole, Macpherson, McCullough

More Model Comparison

1999-2001 Survey of 180 cat layers

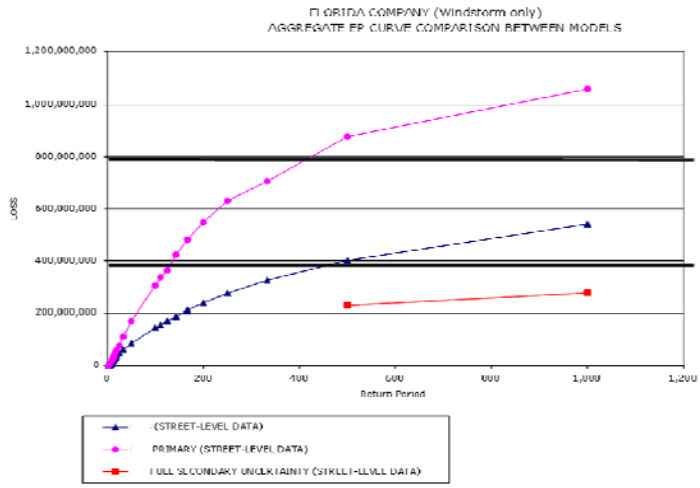
Expected Loss variability between models

Gulf (Texas – W Florida):	50%
Nationwide or **Worldwide**:	30-40% (mostly due to Florida)
NE Risks:	Factor of 3
New Madrid:	Factor of 10
FF Cal Quake:	Thought to be > factor of 10

Florida convergence considered possibly due to Florida Commission on Hurricane Loss Projection Methodology

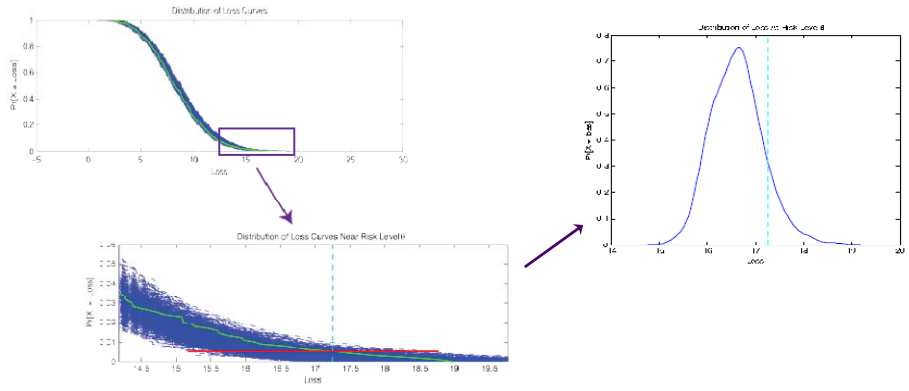
Source: **Catastrophe Risk Pricing in the Traditional Market,** Major and Kreps, Alternative Risk Strategies, 2002, p214

Your own Model Comparison



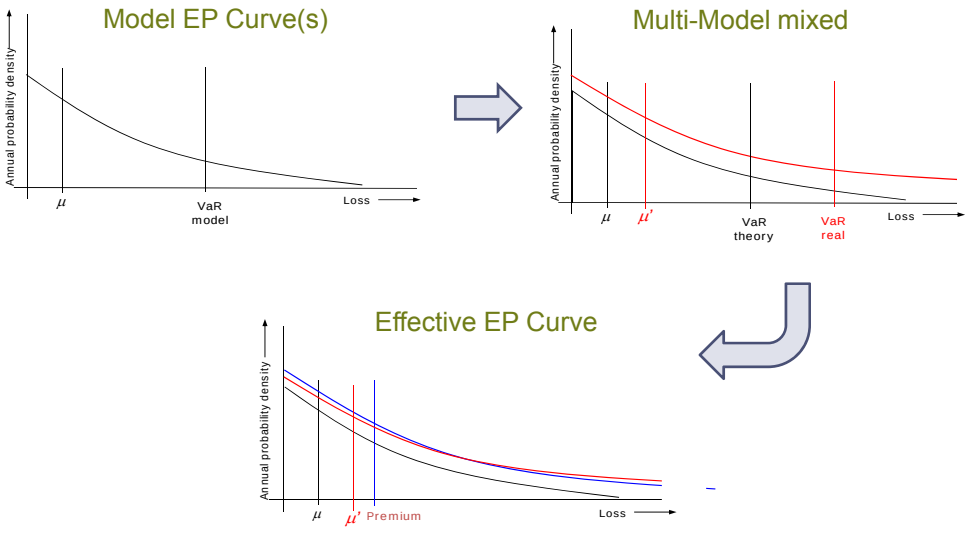
Independent Estimates

Northern California Quake



Source: Mistry and McSharry (2010), Working paper, Smith School of Enterprise and the Environment, University of Oxford [www.smithschool.ox.ac.uk/crf]

Effective EP Curves



"Solvency II is the gift of financial services to the physical sciences"

Lenny Smith, Royal Society Conference 2010, "Handling uncertainty in science"

Many-headed Monster

Hydra

- Data
- Internal Model
- Risk Appetite
- Correlations
- Capital Allocation
- Outwards Reinsurance Credit Risk

Lloyd's SII Guidance - External Models and Data

A managing agent's use of external models and data sets should be:

- appropriate to the nature and complexity of the risks incorporated in its risk strategy, business objectives and modelling methodologies;
- appropriate to the availability of internal data;
- and should be suitable for use in its internal model.

Its (Internal Model) documentation explains how it meets the requirements of the six internal model tests, namely the use test, the statistical quality standards test, the calibration standards test, the profit and loss attribution test, the validation standards test, and the documentation standards test. It must also identify whether the use of external models or data sets introduces any deficiencies into its internal model or data, and document how it has dealt with any such deficiencies.

A managing agent must recognise and document the risks arising from the use of external data sets and models. If the risks are material and quantifiable they should be taken into account in the SCR calculation. This should be accompanied by an explanation of how it has managed or mitigated those risks, and how it has reflected any material and quantifiable residual risks in its SCR calculation.

Data

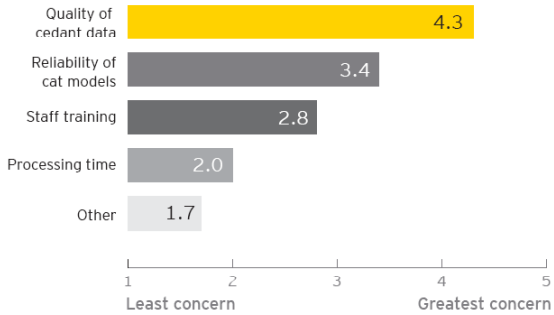
Lloyd's SII Guidance – Data Quality Standards

"A managing agent must establish a data policy, setting out its requirements on data quality and data update. This policy is subject to agreement with Lloyd's, and any major changes to it require prior approval from Lloyd's.

Accuracy, completeness and appropriateness must be demonstrated against these criteria:

- data used is free from material mistakes, errors and omissions (accuracy);
- data is to a large degree consistent in time such that the model output refers to a well-defined point in time (accuracy);
- it has at its disposal comprehensive data for all business lines under consideration and, where possible, all relevant model variables (completeness);
- no relevant data available is excluded from consideration without justification (completeness);
- the granularity of data is sufficient to allow for adequate actuarial and statistical techniques to be used (appropriateness);
- data used is relevant to its business and the portfolio of risks being analysed (appropriateness);
- data used for prediction exercises is a good guide to the future (appropriateness)."

Data Quality

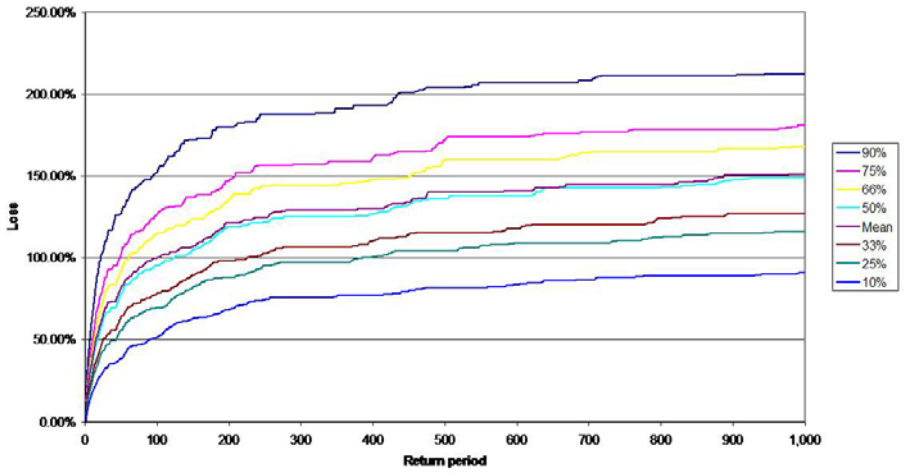


CRITERIA:

- Timely?
- Accurate?
- Complete?
- Sensitivity Tests?

Source: Ernst&Young 2008, survey with a group of leading reinsurers

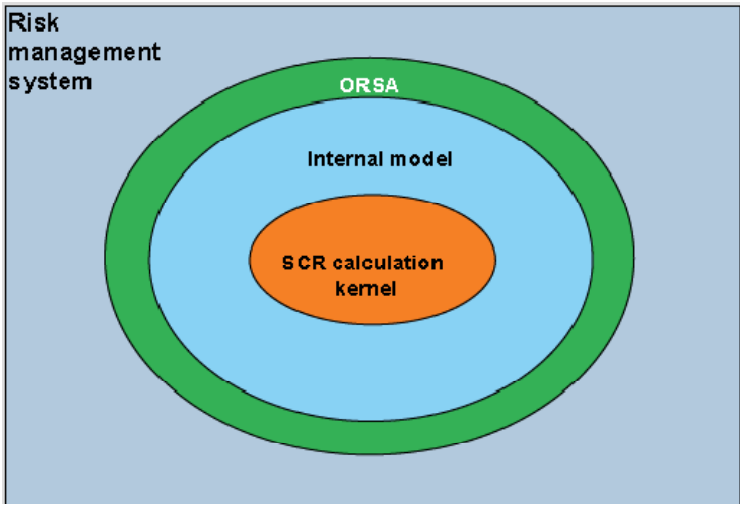
Sensitivity Tests



Source: Conor McMenamin, private communication

Internal Model

Solvency II – Internal Model



Source: Lloyd's

Internal Model

"An insurer must demonstrate that its internal model is widely used in and plays an important role in its system of governance"

- Article 120 – Use Test
- Article 121 – Statistical Quality Standards
- Article 122 – Calibration Standards
- Article 123 – Profit & Loss Attribution
- Article 124 – Validation Standards
- Article 125 – Documentation Standards

"Where practicable, insurers shall derive the SCR directly from the probability distribution forecast generated by the internal model, using:"

"Value-at-Risk of the basic own funds of an insurance or reinsurance undertaking subject to a confidence level of 99,5 % over a one-year period"

Lloyd's SII Guidance - Statistical Quality Standards

"A managing agent must:

- Identify all assumptions inherent to the internal model.
- Be able, at any time, to explain and justify in detail those assumptions to Lloyd's, taking account of all the following factors:
  - their significance;
  - how they limit the model, whether in terms of application or performance;
  - their implications for model risk, i.e. deviations between the model and reality;
  - possible alternative assumptions and their implications.
- Assess the materiality of assumptions chosen and possible alternatives. This requires a qualitative assessment. In line with the proportionality principle and where practicable and reasonable, an agent must conduct a quantitative assessment in addition.
- Document all internal model assumptions, their justifications and the corresponding procedure."

Tackling Model Risk – Round 2

- Model Risk
  - Fold it back into pdf

  or
  - Apply Adjustment Factors

  or
  - Add as Operational Risk

Adjustment Factors

Category	Factor
Data	Insured Values
	Interest Characteristics
	Out-of-date Schedules
	Geo-coding
Modelled Inadequacies	Base Model Risk
	BI
	Demand Surge
	Flood
	Storm Surge
	Fire Following
	Anti-selection
Non-modelled inadequacies	Tsunami
	Contingent BI
	Loss Adjustment Expenses

ADJUSTING:

- Insured Values?
- Estimated Exposures?
- Damage Factors?
- Calculated Losses?

Operational Risk

- A frequency/severity pair?

Impact / Probability Guidance

Impact - the level to which the risk would effect the ability of Conducter to deliver its strategy and objectives based on the scoring A - D	A	No material impact
	B	Material impact, no significant lasting risk to Conducter
	C	Significant risk to Conducter
	D	Potential failure of Conducter
Probability - likelihood that the risk will occur within the next 12 months based on the scoring 1 - 4 and management experience and intuition	1	< 5% likelihood
	2	5% to 20% likelihood
	3	20% to 50% likelihood
	4	>50% likelihood

	A	B	C	D
1	GREEN	GREEN	YELLOW	RED
2	GREEN	YELLOW	AMBER	RED
3	YELLOW	YELLOW	AMBER	RED
4	YELLOW	AMBER	RED	RED

- Frequency plus a severity histogram?

Annual Frequency :	0.05	**Annual Frequency Narrative :**	Lorem ipsum dolor sit amet, consectetu magna aliqua. Ut enim ad minim veniar consequat. Duis aute irure dolor in repr Excepteur sint occaecat cupidatat non p
Max Impact (£):	1,000,000	**Max Impact Narrative :**	At vero eos et accusamus et iusto odio corrupti quos dolores et quas molestias officia deserunt mollitia animi, id est lat distinctio. Nam libero tempore, cum sol placeat facere possimus, omnis volupta

	£0-1k %	£1-10k %	£10-100k %	£100-1m %	£1m-10m %	£>10m %	Total %
Distribution Loss Ranges :	0	0	0	100	0	0	100

Still has to end up as a pdf for Kernel

Risk Appetite

Realistic Disaster Scenarios?

Once in 200 years VaR?

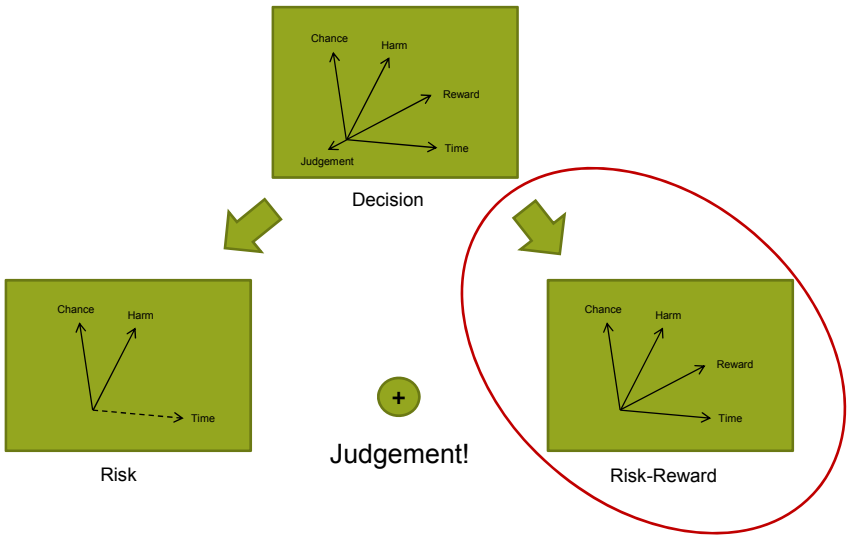
with lashings of Model Risk?

er ... what was it we were in business for?

Profitable Return on Capital

Around once every 25 years

Dimensions of Risk Decisions



The Risk-Reward View

- Solvency II Regulators assess risk at a once in 200 year risk of ruin (VaR) for 1 year's capital

whereas

- Businesses run on a shorter time horizon such as once in 25 years risk of a certain level of loss (TVaR) and longer capital period such as 5-10 years

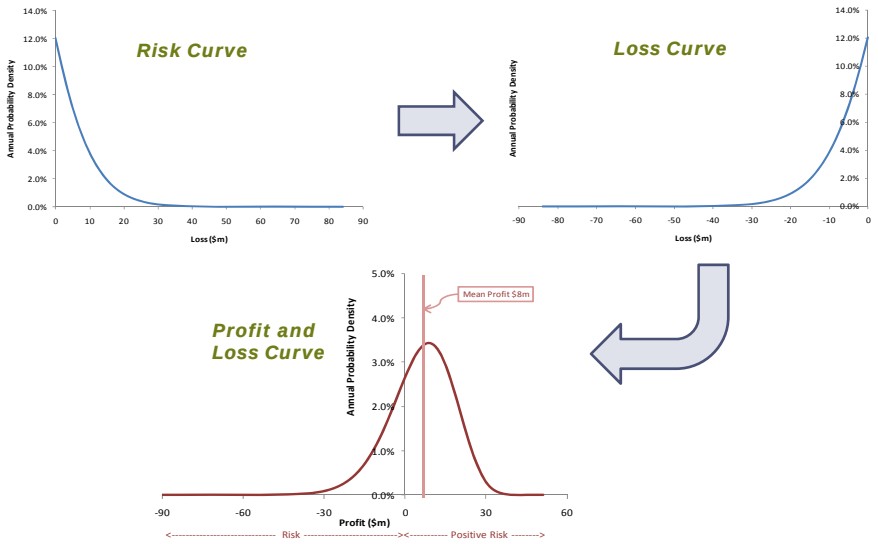
and

- Make decisions on risk appetite of profit against loss

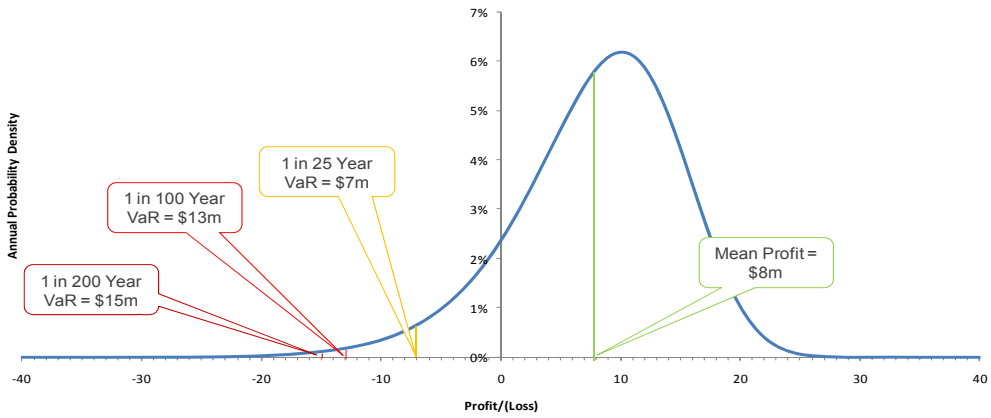
so

- Regulators and Businesses are measuring two different risks in different ways

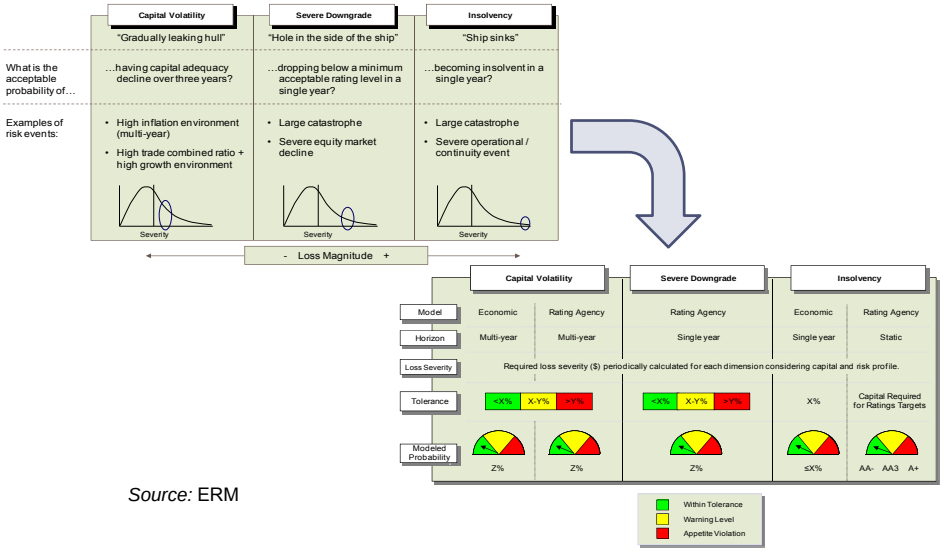
Positive Risk



Different Return Periods, Different Risk Measures



Probing the Risk Curve for Appetite



Source: ERM

Risk Appetite

- Set “loss measure” for Risk
- Reward relative to this Risk
- Portfolio Benefits
  - Diversification
  - Cash-flow
- Subject to regulatory capital constraint

Risk Appetite - Losses

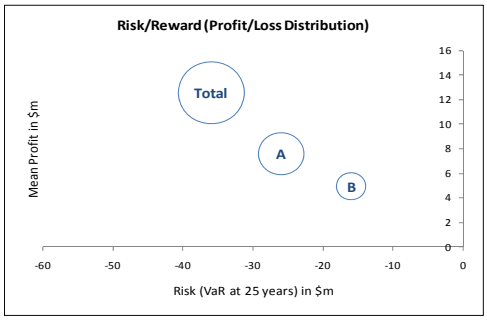
Harm/Chance: What timescale for embarrassment?

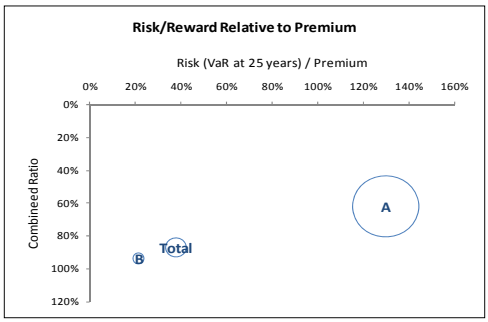
Time: How long before failure is judged?

Measure: What is being protected?

Factor	Factor	Regulator	Business
Harm/Chance	Loss Horizon	Risk of Ruin Once in 200 years	Risk of volatility embarrassment – 25 years (say)
Time	Capital Period	1 year	5 years (say)
Measure	Risk Measure	How much capital to stay within Loss Horizon? **VaR**	How much would lose on average if Loss Horizon exceeded? **TVaR**

Risk-Reward charts





Correlations

Correlations

- Typically:
  - Correlation matrix

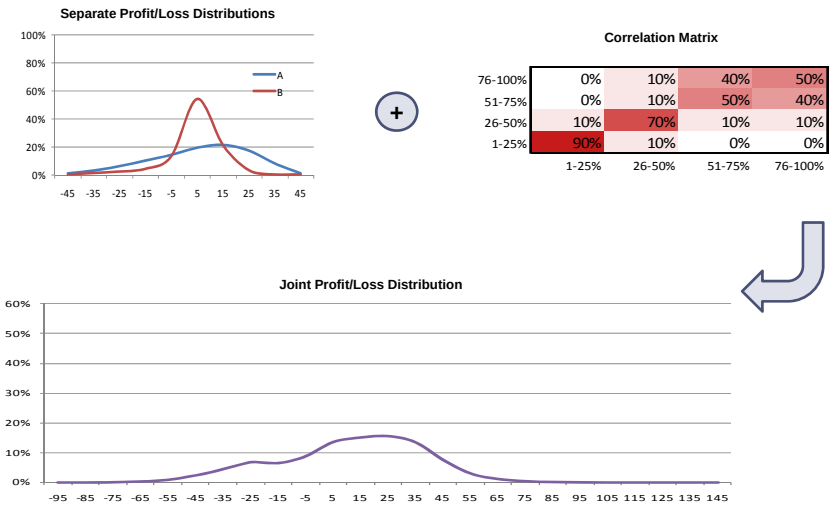
  or
  - Gaussian copula

  or
  - (for cat) common event set

	LoB 1	LoB 2	LoB 3	Risk 2
LoB 1	1			
LoB 2	0.2	1		
LoB 3	0.3	0.5	1	
Risk 2	0.1	0.1	0.1	1

- But what of long-tail fat-tail correlations?

Percentile Correlation Method



Percentile Correlation Matrices

1. Independent

R^2 = 0

	1-25%	26-50%	51-75%	76-100%
76-100%	25%	25%	25%	25%
51-75%	25%	25%	25%	25%
26-50%	25%	25%	25%	25%
1-25%	25%	25%	25%	25%

2. Full Four by Four Correlation

R^2 = 0.94

	1-25%	26-50%	51-75%	76-100%
76-100%	0%	0%	0%	100%
51-75%	0%	0%	100%	0%
26-50%	0%	100%	0%	0%
1-25%	100%	0%	0%	0%

3. Low-end Correlation

R^2 = 0.75

	1-25%	26-50%	51-75%	76-100%
76-100%	0%	10%	40%	50%
51-75%	0%	10%	50%	40%
26-50%	10%	70%	10%	10%
1-25%	90%	10%	0%	0%

4. High-end Correlation

R^2 = 0.75

	1-25%	26-50%	51-75%	76-100%
76-100%	0%	0%	10%	90%
51-75%	10%	10%	70%	10%
26-50%	40%	50%	10%	0%
1-25%	50%	40%	10%	0%

5. Fuzzy Low-end

R^2 = 0.47

	1-25%	26-50%	51-75%	76-100%
76-100%	5%	15%	30%	50%
51-75%	15%	15%	40%	30%
26-50%	40%	30%	15%	15%
1-25%	40%	40%	15%	5%

6. Fuzzy High-end

R^2 = 0.47

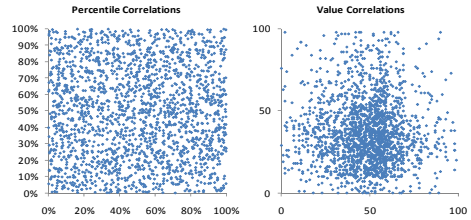
	1-25%	26-50%	51-75%	76-100%
76-100%	5%	15%	40%	40%
51-75%	15%	15%	30%	40%
26-50%	30%	40%	15%	15%
1-25%	50%	30%	15%	5%

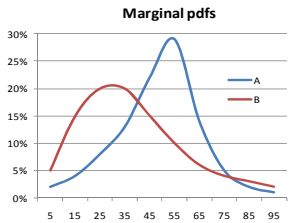
Independent

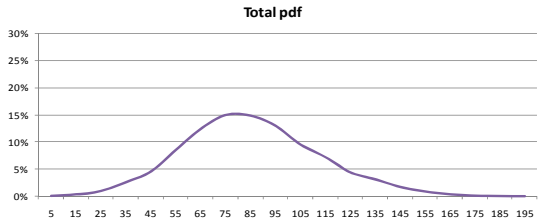
Correlation Matrix **1. Independent**

	Mean	SD	Var 25	VaR 200
A	48.2	17.2	76.0	94.0
B	37.7	21.1	80.0	97.0
Total	85.9	27.0	134.0	160.0
Diversification Benefit:		11.3	22.0	31.0

R^2	
Sample	**Values**
0.00	0.00





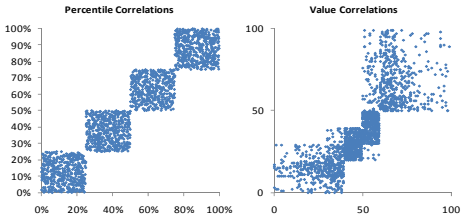


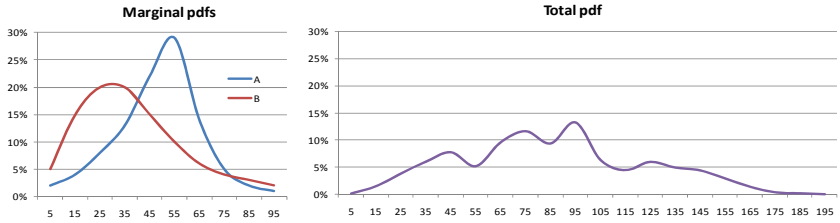
Correlated

Correlation Matrix **2. Full Four by Four Correlation**

	Mean	SD	Var 25	VaR 200
A	48.3	16.9	75.0	95.0
B	37.8	20.8	79.0	96.0
Total	86.1	35.9	149.0	174.0
Diversification Benefit:		1.9	5.0	17.0

R^2	
Sample	**Values**
0.94	0.80



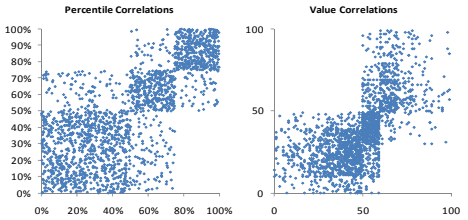


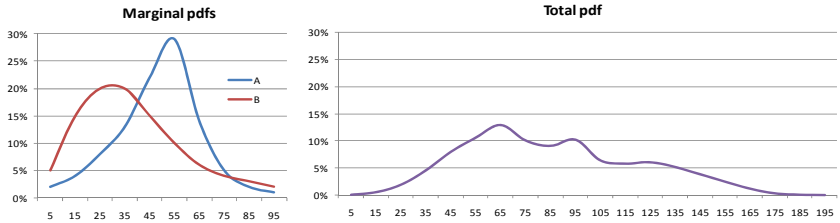
High-end

Correlation Matrix **3. High-end Correlation**

	Mean	SD	Var 25	VaR 200
A	48.1	17.4	76.0	96.0
B	37.7	21.0	80.0	97.0
Total	85.8	34.8	149.0	173.0
Diversification Benefit:		3.6	7.0	20.0

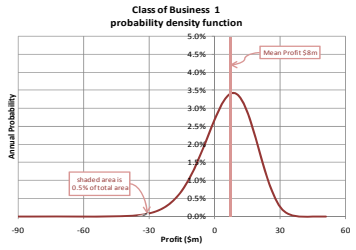
R^2	
Sample	**Values**
0.75	0.64

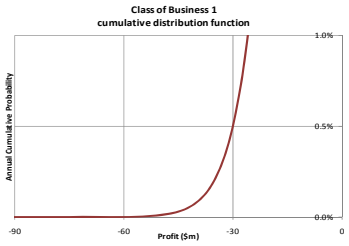


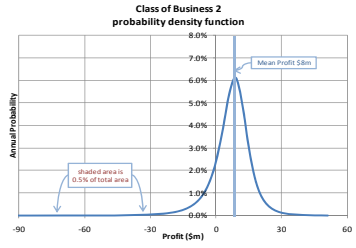


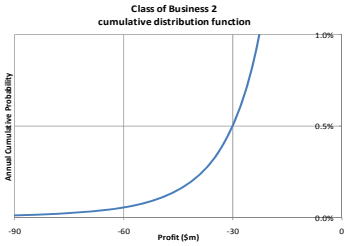
Capital Allocation

Classes of Business with same 99.5% capital requirement and mean profit

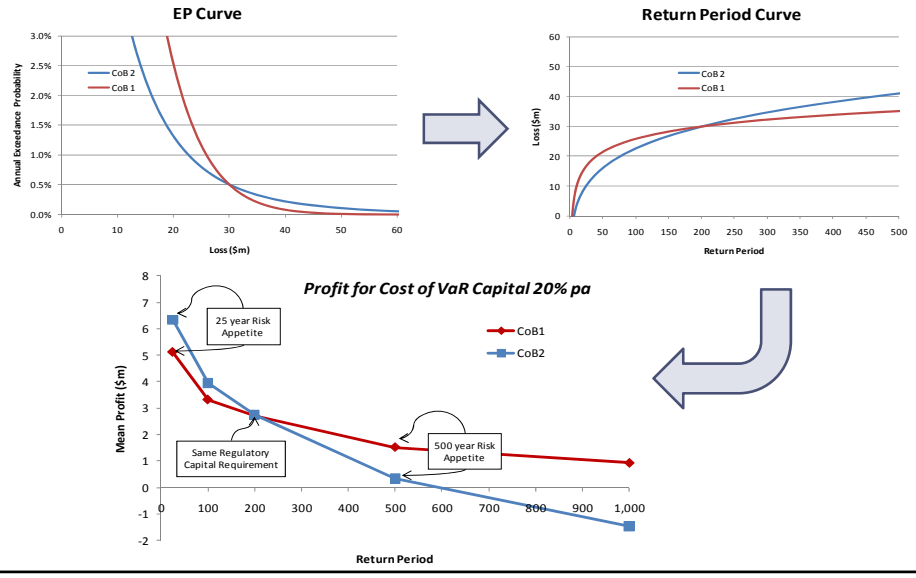




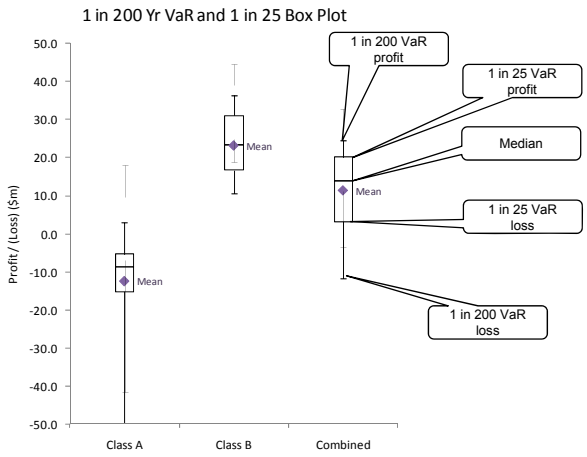




When is a Loss a Profit?



Representing Return Variability



RI Credit Risk

RI Credit Risk

The usual

- Credit Ratings
- Diversification with multiple reinsurers
- Correlations between reinsurers

and

- **Market Risk Correlations to Catastrophe!**

Where Solvency II Meets Business

Regulators are obsessed with the downside for extremities about which we know **little**

whereas

Business is about making profit at levels of exposure and over timescales about which we know **quite a lot**

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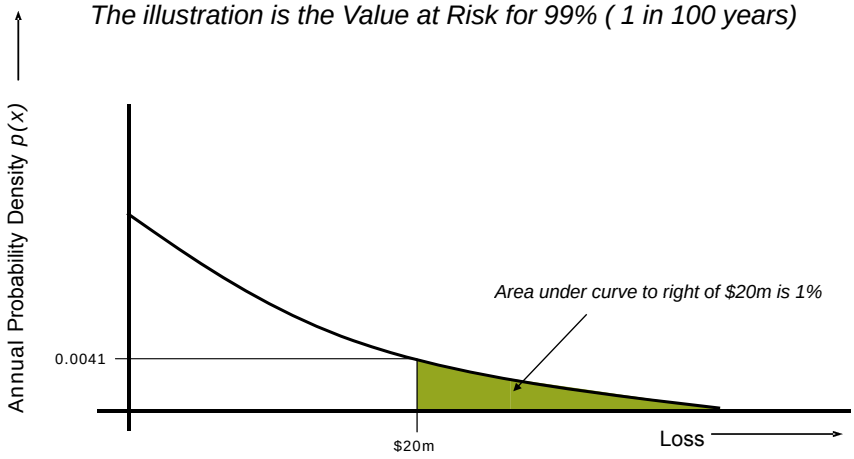
Loss Probability Curve and VaR

The illustration is the Value at Risk for 99% (1 in 100 years)



EP Curve and TVaR

ES = renormalised TVaR $ES(\alpha) = \frac{1}{1-\alpha}\int_{VaR(\alpha)}^{\infty} xp(x)dx$

TVaR = average excess of VaR for percentile α*:* $TVaR(\alpha) = \int_{VaR(\alpha)}^{\infty} xp(x)dx$

The EP curve is: $EP(y) = \int_{y}^{\infty} p(x)dx = 1 - \int_{0}^{y} p(x)dx$

Hence: $\boxed{TVaR(\alpha) = VaR(\alpha)*(1-\alpha) + \int_{VaR(\alpha)}^{\infty} EP(x)dx}$

Up to VaR point: $VaR(\alpha)*(1-\alpha)$

Area under curve: $\int_{VaR(\alpha)}^{\infty} EP(x)dx$