ECONOMIC CAPITAL MODELING

CARe Seminar

JUNE 2016

Boston

Catherine Eska – The Hanover Insurance Group
Paul Silberbush – Guy Carpenter & Co.
Ronald Wilkins - PartnerRe

Economic Capital Modeling
Safe Harbor Notice

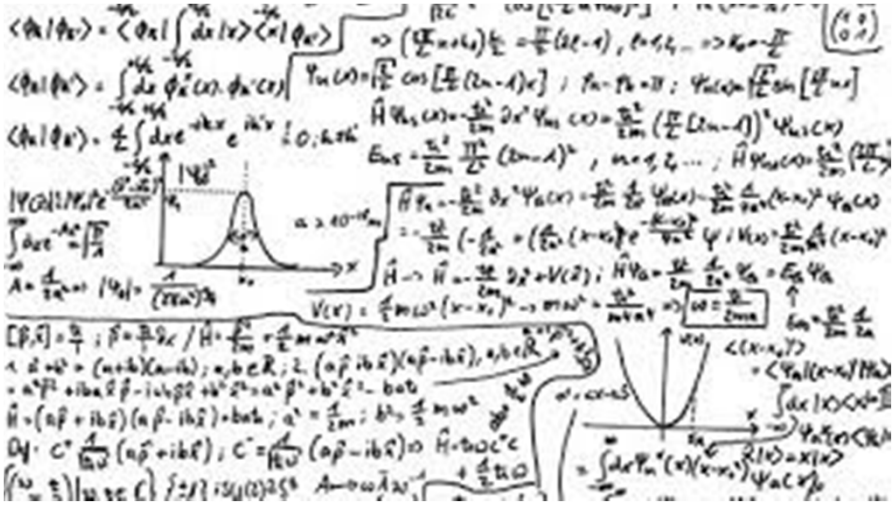
The following presentation is for general information, education and discussion purposes only, in connection with the Casualty Actuarial Society Seminar on Reinsurance. Any views or opinions expressed, whether oral or in writing are those of the speakers alone. They do not constitute legal or professional advice; and do not necessarily reflect, in whole or in part, any corporate position, opinion or view of the Casualty Actuarial Society, PartnerRe, Guy Carpenter, The Hanover Insurance Group, or their affiliates, or a corporate endorsement, position or preference with respect to any issue or area covered in the presentation.

Economic Capital Modeling
Agenda Items

- Introduction and background
  - *what is it?*
  - *what is needed?*
  - *what risks are modeled*
  - *components of an Economic Capital Model*
  - *what is the output?*
- The use of industry-wide benchmarks in selecting capital model parameters.
- How should the underwriting cycle be considered when selecting capital model parameters?
- Model Validation
- Uses of the Economic Capital Model
  - *Application to business decisions*
  - *Capital attribution*

Economic Capital Modelling

- “It’s not complicated; it’s just difficult”
  - Don Mango



or

Economic Capital Modelling
What is it?

- A major *quantitative* part of the ERM program
- A way to *measure* capital needed; for various stakeholders
  - Internal ERM (e.g. board, management)
  - Regulators (e.g. SII, ORSA)
  - Rating Agencies (AM Best, S&P)
- May be *deterministic* or *stochastic*
- May be *"home-built"* or in a *professional software package*
- More and more companies are utilizing stochastic models in professional software packages

Economic Capital Modelling (ECM)
What is needed?

- ECM is emerging as its own (actuarial) discipline
- Works best with dedicated resources
  - Depends on size, complexity of company
- Modelling team is often part of the ERM function
- Requires interaction with
  - Actuarial (Pricing and Reserving)
  - Ceded Reinsurance
  - Cat modelling
  - Finance
  - Business Unit Leaders
  - Senior Management

For model "buy-in" : more later

Economic Capital Modelling
What are the costs?

- Dedicated staff
  - Depends on size/complexity of company
  - Minimum for even a company of modest size is 1-2 FTE
- Hardware: Technology is now so advanced and hardware costs so low that powerful desktops (e.g. 12 core machines) are common and inexpensive
- Software: License fee or more staff to build/maintain in-house
  - There are several commonly available packages
  - In-house systems beyond spreadsheets require highly skilled developers
- Consulting costs: can be expensive! Easy to use, easy to learn software will eliminate most of this.
- Total cost of ownership is usually very reasonable compared to the benefit: *modelling the company's capital at risk!*

Economic Capital Modelling
What risks are typically modelled? [For a P&C (re)insurance company]

- Should cover most quantifiable, material risks to the company
- In practice this usually means the following
  - Underwriting risk (including cat risk): Future accident year(s)
  - Reserve risk: Changes in past accident years
  - Asset (investment) risk
  - Reinsurer Default Risk
  - Operational Risk
- Reinsurance may be managed in different ways
  - Model may be net of reinsurance
  - Model may be gross of reinsurance with reinsurance overlaid
  - Model may be a combination of these
- The correlation (or dependence) structure is highly important

Components of an Economic Capital Model

Economic Capital Modelling
What data is needed?

- Quite a lot for a “robust” stochastic model!
- For UW risk (non-cat): need frequency/severity parameters for each line of business or segment in desired level of granularity
- For cat risk, need cat modelling by region, peril, LOB, segment. etc.
- For reserve risk need “reserve runoff parameters” – payout, volatility
- For asset risk need current asset holding and economic scenarios
- Reinsurer default and operational risk rarely have explicit data/parameters available and require more judgment
- Modelling of reinsurance requires all treaty details
- Data needs underscore the need for the modelling team to work with actuarial, reinsurance and finance (or asset management)

Economic Capital Modelling
What is the output?

- There is much variety possible
- The most basic output is the “capital need” usually defined as a tail point of a defined “total capital” metric
  - E.g. 1 in 200 VaR or TVaR
- Sample “Total Capital” metric (simplified)

  Underwriting Risk + Reserve Risk - Asset Risk, where
  - Underwriting Risk = Net Underwriting Loss = Loss – Premium + Expense
  - Reserve Risk = Change in Reserves
  - Asset Risk = Investment Income + Capital Gains
- Usual output is the distribution of each component and the total
  - *This reflects diversification and the correlation (dependence) structure*
  - *Shows the importance of dependence*

Economic Capital Modelling
Sample Output – "Total Risk"

	UW	Reserve	Asset	Total
95.0%	17.3	22.7	12.1	23.4
98.0%	26.9	30.2	13.9	34.4
99.0%	33.2	36.2	15.0	42.5
99.5%	39.9	41.7	15.8	50.0

No correlation between UW and Reserve Risk

	UW	Reserve	Asset	Total
95.0%	17.0	22.8	12.0	28.6
98.0%	26.6	30.5	13.9	42.7
99.0%	33.3	36.1	15.0	53.2
99.5%	39.7	41.4	15.8	63.2

With correlation between UW and Reserve Risk

Economic Capital Modelling
Sample Output

- Another key output is the distribution of year-end surplus
  - This is a left-tail distribution

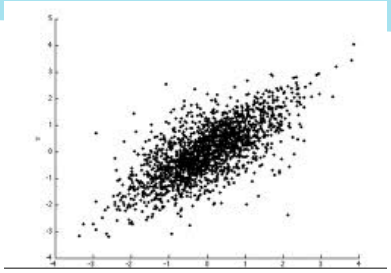
0.10%	499.7
0.50%	534.7
1.00%	550.1
2.00%	565.6
5.00%	585.5
10.00%	597.5
Mean	627.5
80.00%	647.5
90.00%	655.9
95.00%	662.5

Initial PHS = 600m

1% chance of loss of 9% of initial surplus

- Useful for setting/monitoring risk tolerance statements
- "We want a <1% chance of losing 10% of surplus"

Economic Capital Modelling
How do we model correlation (dependence)?



- Correlation between what?
  - Within risk categories (between LOBs for underwriting or reserve risk)
  - Between risk categories (between underwriting and reserve risk)
  - Between assets and liabilities (uw/reserve risk and asset risk)
- Correlations for natural perils (e.g. EQ and FF or one peril across multiple regions) is generally built into the cat models so it is reflected in the capital model
- Mathematical methods – usually for non-cat underwriting risk, reserve risk
  - Copulas
  - Factor-based (e.g. indexes also known as “common drivers”)
  - Correlation vs. Causation
- Economic scenarios – for assets and inflation
- Developing parameters requires judgment (data may be limited)
  - Industry benchmarks can assist

Economic Capital Modelling
What are economic scenarios?

- Think of an “event set” for asset returns and inflations
- Typically includes bond yield curves, equity returns and inflations
- Naturally correlates all variables (similar to cat models)
- Produced by several major vendors
- *A standard input to most capital modelling software packages*

'Scenario	TimeStep	USA_appreciation	USA_divYield	CorpAAA _(0.25)	CorpAAA _(1)	CorpAAA _(2)	CorpAAA _(5)	CorpAAA _(10)	CorpAAA _(15)	CorpAAA _(30)	CorpAAA _default	CorpAAA LossGivendefault	CPIUSA InflationIndex	MedicalUSA InflationIndex
[Data]														
1	0	0.0000000	0.0000000	0.0028980	0.0048520	0.0096270	0.0264800	0.0429500	0.0491100	0.0524100	0.0000000	0.0000000	0.0000000	0.0000000
1	1	0.0610000	0.0184900	0.0101800	0.0127400	0.0184200	0.0310600	0.0413800	0.0454600	0.0484900	0.0000000	0.3500000	0.0218800	0.0340500
1	2	-0.0777568	0.0185900	0.0176100	0.0202800	0.0265500	0.0415900	0.0540700	0.0579300	0.0590100	0.0000000	0.3500000	0.0334400	0.0513800
1	3	-0.0247317	0.0208800	0.0193900	0.0219900	0.0278300	0.0419000	0.0535700	0.0572000	0.0582900	0.0000000	0.3500000	0.0259500	0.0438400
1	4	0.3203395	0.0173400	0.0138600	0.0155400	0.0193700	0.0295200	0.0398200	0.0443100	0.0479800	0.0000000	0.3500000	0.0002011	0.0277200
1	5	0.0047619	0.0178700	0.0160300	0.0178700	0.0220800	0.0331100	0.0437200	0.0480100	0.0509800	0.0000000	0.3500000	-0.0142700	0.0149600
1	6	0	0	0	0	0	0	0	0	0	0	0	-0.0116100	0.0096710
1	7	0	0	0	0	0	0	0	0	0	0	0	-0.0023170	0.0275900
1	8	0	0	0	0	0	0	0	0	0	0	0	0.0217800	0.0525900
1	9	0	0	0	0	0	0	0	0	0	0	0	0.0192900	0.0339400
1	10	0	0	0	0	0	0	0	0	0	0	0	-0.0054940	-0.0191400

Equity Returns

Bond Yield Curves

Bond Defaults

Inflations

Economic Capital Modelling
Other considerations

- Single or multiyear
  - Multiyear can be extremely complicated: do you really need it?
  - Years are not independent; requires “decision rules”
  - If planning is multiyear, consider a deterministic model beyond year one
- Does it match “plan” at the mean for premiums, loss ratios, etc.?
  - Generally desirable to get “buy-in”
  - Matching both “gross” and “net” plan is not so easy
- Can the capital model be used for
  - Financial planning and not just ERM (solvency capital)
  - Time-sensitive reinsurance decisions
  - Capital allocation
  - Cat management

Economic Capital Modelling
When is it most effective?

- When there is business unit and management “buy-in”
  - Capital models should be used in planning and for business decisions
  - Business unit leaders can help validate the model
  - Management (and the board) should understand what the model does
- When there is dedicated modelling staff in the ERM department
- When actuarial, reinsurance and finance all support ERM
- When the model is not more complex than needed
- When it is seen as a benefit and not a cost
- When there is good communication between all stakeholders

Economic Capital Model
Process Overview

INPUTS

Independently Modeled Risk Towers

Underwriting Risk

Catastrophe Risk
- *RMS and AIR by LOB and peril*
- *Model blending*

Reinsurance Recovery Risk
- *Schedule F data*
- *Reinsurer treaty participations*
- *Defaults based on AM Best FSR*

Ex Cat UW Risk
- *Claims data by LOB*
  - *Attritional*
  - *Large*
- *Reinsurance treaties*
- *LOB correlation*
- *Inflation scenarios*

Reserve Risk
- *Development scenarios by line of business*
- *LOB correlation*
- *Inflation scenarios*

Investment Risk
- *ESG files*
- *Year end bond holdings*

Operational Risk
- *Not yet quantified*

OUTPUTS

Tower Results Combined

Pre-tax profit/loss results from Risk Towers combined via correlation matrix

Capital Indications

Aggregate Risk Tower results used to measure overall capital adequacy at target

Link to risk preferences to establish a required amount of capital to run the business

RORAC

Risk measures by LOB used to allocate indicated capital based upon target return

Parameterizing Economic Capital Model
Use of Industry Benchmarks

- Correlation: benchmarks appear to be more readily available within a particular risk category rather than between risk categories
- Coefficient of Variation (CV)
  - Ratio of standard deviation to mean
  - Popular measure of variability
- Early years (new to EC Model) highly dependent
  - Align with companies of comparable size
  - Challenges
    - Inclusive of catastrophes
    - Specialty lines may not be representative of internal appetite
- Later years use as reasonability test
  - More heavily rely upon internal claim statistics
  - Still used for emerging businesses
  - Balance qualitative and quantitative analysis

Parameterizing Economic Capital Model
Use of Industry Benchmarks

- Helpful as a cross-check even for segments in which your company has a long and credible history.
- Should be based on a long and credible data series, ideally after scrubbing to reduce the impact of data anomalies.
- Potential Challenges:
  - If benchmarks were derived from data that included all perils, they would not be applicable to the non-cat pillar of the ECM.
  - When working on the ECM of a reinsurance company:
    - How applicable are the product line definitions used in annual statement data?
    - How should parameters vary by layer?

Parameterizing Economic Capital Model
Industry Benchmark Data: Correlation in the Ultimate Loss Ratio

Line of Business	CAL	CMP	GLC	GLO	HO	MPLC	MPLO	PPA	PLC	PLO	WC	Auto-Correlation
CAL	100%											87%
CMP	76%	100%										73%
GLC	54%	56%	100%									82%
GLO	78%	78%	89%	100%								86%
HO	16%	58%	14%	17%	100%							21%
MPLC	74%	83%	76%	94%	21%	100%						90%
MPLO	66%	75%	67%	84%	20%	92%	100%					72%
PPA	42%	2%	15%	10%	15%	-8%	-16%	100%				86%
PLC	54%	55%	59%	71%	24%	61%	44%	30%	100%			26%
PLO	60%	69%	88%	86%	21%	87%	78%	6%	50%	100%		70%
WC	61%	15%	58%	52%	-8%	28%	24%	71%	38%	34%	100%	86%
All Lines	**80%**	**74%**	**74%**	**82%**	**49%**	**70%**	**62%**	**50%**	**64%**	**69%**	**67%**	**69%**

- This table shows the correlation between the actual ultimate loss ratio by line of business.
- It can be used by management to determine the inherent correlation of the actual ultimate loss ratios between different lines of business.

Source: Guy Carpenter Insurance Risk Benchmark Research October 2015

Parameterizing Economic Capital Model
Blending Qualitative and Quantitative

- Risk Driver Framework - Correlation
  - Identify sources of risk and risk drivers within each
    - Economic; Social; Legal; Political; Technological; Environmental; Operations; Other
    - Short-term inflation; Compensation Culture; War; IT Infrastructure; Global Warming; Claims Practices; Emerging Risks
  - Weight importance of each risk driver
  - Assign sensitivity of each line to each risk driver
  - Calculate score for each pair of lines
  - Rank risk drivers to gain qualitative perspective on strength of correlation
- Leverage quantitative analysis to inform selection on relative size of correlation

Parameterizing Economic Capital Model
Considering the UW Cycle and Market Conditions

- Industry Risk-Based Capital (RBC) takes the perspective of modeling an unknown insurer facing an unknown upcoming accident year, for a particular line of insurance.
- When parameterizing an internal capital model, much more information is known:
  - The ECM focuses on a specific insurer facing a specific year and line.
  - You know a great deal about your company's exposures in each line and these may differ from the industry average.
  - You have an approximate estimate of where the upcoming year will be situated within the underwriting cycle.
- When using industry benchmarks, be aware of what adjustments (if any) were made to remove the underwriting cycle.

Parameterizing Economic Capital Model
Considering the UW Cycle and Market Conditions

- The UW cycle is implicit in the loss ratio forecast used to establish mean losses for each line.
- Should correlation change?
  - Are results by line more likely to move together?
- Should coefficient of variation change?
- Should you add pricing risk to the model?
  - Model focuses on losses: perhaps add volatility around rates premium
- For the reserve pillar – should the model assume that the current booked reserves are the mean of the distribution?
  - The ECM team should interact with the appointed actuary

Model Validation

- The model requires validation of individual parameters to ensure they are reasonable
- Validation should include some if not all of the following:
  - Back-testing
  - Sensitivity testing
  - Scenario testing (Stress testing)
  - Reverse stress testing
- A validation framework would classify all model parameters along two scales
  - Materiality
  - Reliance on Expert Judgement
  - Test the most material parameters that have a high degree of expert judgement
- Validation should cover internal model assumptions as well as external models

Model Validation – Sensitivity Testing Example

- Sensitivity testing is key to measuring the materiality of parameters and is particularly important for parameters that require a high degree of expert judgement
- One such area is the correlation parameters
  - Between the risk towers (underwriting excl. catastrophes, catastrophes, reserving, reinsurance recoverables, investments)
  - Between Lines of Business within a risk tower

Sensitivity Testing

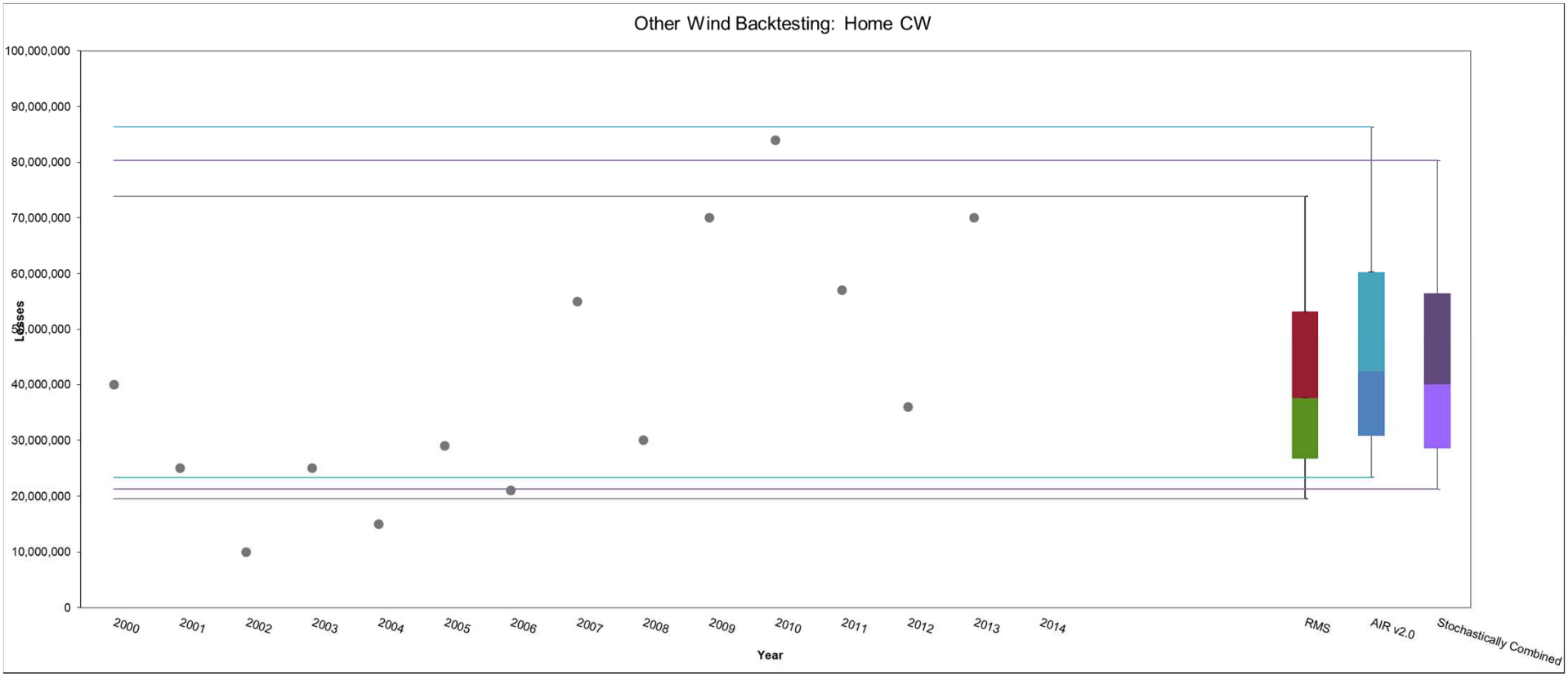
Test #	Test Category	Base (1)	Change	Base 1:250	Stressed 1:250	Impact $	Impact %	Result (2)	Comment
1	Line of Business Correlation	Base	Reserve Correlation at 10/25/50	-1,000 m	-950 m	50 m	-5.0%	pass	A large decrease in correlation among lines for reserve risk has less than a 10% impact on the 1:250
2	Risk Tower Correlation	Base	Low 10% Risk Tower Correlation	-1,000 m	-1,250 m	-250 m	25.0%	fail	Material assumption requiring high degree of expert judgement. 10% is an unreasonably low degree of correlation among several risk tower pairs, underwriting and reserving for example.
3	Risk Tower Correlation	Base	Medium 25% Risk Tower Correlation	-1,000 m	-980 m	20 m	-2.0%	pass	Material assumption requiring high degree of expert judgement. Selected correlation produces a slightly lower result than a uniform 25% correlation.
4	Risk Tower Correlation	Base	High 50% Risk Tower Correlation	-1,000 m	-1,200 m	-200 m	20.0%	fail	Material assumption requiring high degree of expert judgement. 50% is an unreasonably high degree of correlation among several risk tower pairs, underwriting and investment for example.

NOTES:

(1) **Base** The 1:250 VaR using 2015 Plan Net Loss Ratio; 25/50/75 Reserve Risk Correlation and **Selected** Risk Tower Correlation.

(2) **Test Criteria** An impact of less than or equal to 10% is an automatic pass. All test failures are reviewed with the EC Model Working Group

Model Validation – External Catastrophe Models
Example of Back-testing Severe Convective Storm Models



- Box-Whisker plots represent model loss distribution for in-force exposures
- Whiskers at 10% and 90% percentile, 20% probability of outlier
- Historical losses (trended to in-force exposure date and adjusted for geographic mix change) are displayed as dots.
- Over 15 years there are three outliers so test passes
- Test should be performed by state if data allows

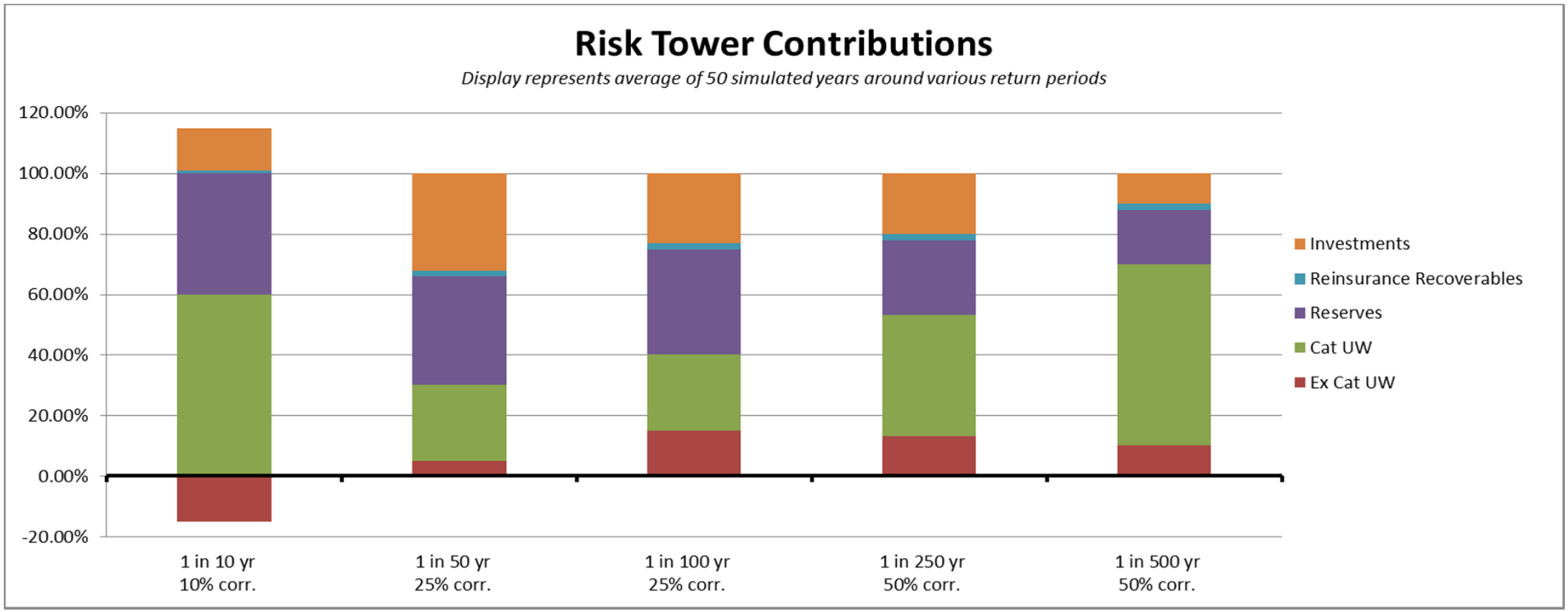
Uses of Economic Capital Models
Applying Model Results to Business Decisions

- Understanding Tail Risk
  - Risk Drivers
  - Risk Monitoring
  - Required Capital
- Capital Attribution - RORAC
  - Profit provisions – Complement of the target combined ratio (TCR)
  - Based on an Internal Rate of Return (IRR) model – TCR required to achieve target return on risk adjusted capital given cash flows over life of a policy
  - Risk Based Performance Measurement
- Portfolio Optimization, Acquisitions
- Planning – study the capital needs of segments based on the plan
- Reinsurance - efficiently spend budget to achieve desired results

Capital Attribution
Risk measurement approaches

	Benefits	Shortcomings
Regulatory – S&P CAR	• Defacto regulator • International • Widely understood (published factors) and used • Actions in all lines must be responsive to this measure	• Allocation of company wide capital to business units is based on broad assumptions • Less explicit recognition of company volatility
Volatility - Standard Deviation	• Helps assign capital in line with goal of earnings stability by requiring more capital for high volatility lines	• Volatility does not capture the shape of the loss curve, the potential for large yet rare events
Tail - Window VaR	• Helps recognize and assign capital towards the potential risk associated with tail • Relative tail risk for each line independently • Volume matters to size of tail risk	• Selecting different threshold changes the results • Very sensitive to parameter uncertainty at low probabilities
Marginal - CoXTVaR	• Helps recognize and account for the impact of diversification • Contribution of each line to extreme tail • Distance of tail from the mean to emphasize skewness of distribution over volume	• Selecting different threshold changes the results • Very sensitive to parameter uncertainty (Catastrophe in particular) at low probabilities

Marginal Contribution by Risk Tower Example



- Illustrates the marginal contribution of each risk tower to the company result at various return periods
- Note how source of risk changes as one moves further into the tail of the distribution

Conclusion

- Economic capital modeling provides many benefits:
  - Improved understanding of the company's business
  - Meaningful and useful capital attribution
  - Improved strategic decision making
- Perspective: Insurers, Reinsurers, and Brokers
  - Broad model structure likely to be similar (UW risk, reserve risk, asset risk, etc.)
  - The greatest difference tends to be in the data available to parameterize reserve risk and non-cat UW risk (and hence in the models used for those pillars).
  - Brokers
    - offer capital modeling software.
    - compile useful modeling benchmarks.
    - provide insights into insurer and reinsurer capital models.
- We welcome your questions