Advancements in Implementing Operational Risk, Stress Testing and Risk Appetite for ORSA

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The Evolution of ERM

Section 1
The Evolution of ERM

**Prediction**

- Risk Management
- ERM 1.0

**Explanation**

- ERM 2.0
- ERM 3.0

**The Dawn of Risk Management**
- Basic analysis of individual risk types
- Attempts to understand variation in key factors.

**The Era of ALM and Financial Risk**
- Development of ALM to capture balance sheet interactions.
- Acceleration of financial risk techniques.
- Results aggregated to the enterprise level.

**The Era of Reward and Governance**
- Perspective of risk related to rewards.
- ORSA
- Concept of risk appetite.
- Focus on management as well as measurement.

**The Era of Culture and Resilience**
- Embedding of risk and understanding it through culture.
- Resilience concept emerges.
- Focus on risk dynamics and interrelationships.
What business decisions do we need to take given we are exposed to risk and uncertainty?

Risk
P&L and Balance Sheet Modelling

Uncertainty
Scenarios

Business Decisions
Embedding
ORSA: Balance Sheet Risk Management

Components and Inter-relationships

- Market Value of Assets
- Own Funds
- Reserves
- Market Consistent Value of Liabilities
- Surplus Capital
- Economic Capital

Risk Appetite Process
- Operational
- Liquidity
- Counterparty
- Mortality
- Morbidity
- Behaviour, e.g. persistency
- Demographics

ALM Process
- Credit
- Volatility
- Market levels
- Interest rates
ORSA: P&L Risk Management

Understanding the drivers of P&L uncertainty

- Sales
- Distribution Costs
- Manufacturing Costs
- Expense Costs
- Operational Risk Costs
- Operating Profit Margins

**Sustainability of growth**
Quality of business
→ Multiple interrelated drivers of demand (e.g. behaviour, economics)

**Alignment of incentives b/w customer, distributor, manufacturer**
→ Persistency risk, churn

**Operational capacity, availability, utilisation, productivity**
Economic, market drivers

**Experience of demographic, market and behavioural risks**

**Earnings and margin uncertainty driven by complex interaction between above factors**

**Direct hit to the bottom line**
Need to manage these risks (e.g. fraud, mis-selling, mis-pricing)
Prediction ≠ Explanation

Need to move from pure statistical to causal risk frameworks

Which different events could cause me to lose this much?
Complex systems mean you can’t understand the whole by only studying the sum of the parts.

It is the inherent and dynamic relationships between risks, causal drivers and outcomes that is key.

Simple measures of dependency such as linear correlation are typically misleading.

Risks relating to complex adaptive systems exhibit emergent properties.
Current and Emerging Challenges

- Risk governance
- Risk processes
- Operational risk
- ORSA pillar 2
  - Strategic / holistic risk assessment
  - Operational risk
  - Risk appetite
  - Scenario / stress testing
  - Risk interdependencies
  - Risk reporting
- Operational risk systems

ERM 2.0

ERM 3.0

- Resilience
- Risk culture
- Behavioural risks
- Emerging risk
- Reverse stress testing
- Risk dynamics and inter-relationships through systems science
- Causal light models focused on explanation, not just prediction
- Risk engagement with business
- Integration of predictive analytics
Technical Developments

*What you know*

Section 2a
Companies are Complex Adaptive Systems

Risk is an undesirable outcome of a complex system

Traditional Risk Management Frameworks
Statistical models, assuming constant drivers
Registers assuming single characteristics
Scenarios “imagined”
Emerging risks by spotting events

Frameworks based on complex systems
Descriptions of risk profile taken holistically
Scenarios derived from risk profile
Models integrate all types of information
Emerging risks spotted early from system

Risk management can be hard if looked at it through the wrong lens
Data is only part of the information set

What you know: judgment

What you see: data

The System: information
Describing the System

“If the data was lost by a partner there would be contractual issues to resolve which would strain the relationship and there would be damages to claim. This could cause a loss of confidence in the partner themselves.”
Cognitive Analysis

Produce a “minimally complex” summary

Identify unfinished explanations more clearly

Find the most important elements of the “system”

Nodes which lead to multiple highly connected nodes

Ultimately connected to many nodes

Immediately connected to many nodes
What are the Risks to the Actuarial Profession?
Relative Importance of Risk Drivers
Deriving the Full Risk Profile
Forced Outage Causal Drivers

- Dominated by asset management drivers and other potent drivers
- Note multiple feedback loops: e.g. Quality of people, maintenance strategy
Technical Developments

What you see

Section 2b
Using Data to Move Beyond Point Estimates

What do key risk indicators (KRIs) tell us about the likelihood of each type of risk outcome?

- “There is a 5% chance of no occurrence”
- “There is a 40% chance of impact size A”
- “There is a 25% chance of impact size B and C”
- “There is a 5% chance of impact size D”
Causal Modelling with Bayesian Inference
Prediction with Explanation

Causal modelling techniques can be used to formally demonstrate how indicators flow through to the business outcomes being studied. Framework retains the dynamic links between causes and losses so risks are viewed in context and incorrect conclusions from silo-thinking are avoided.
A Bayesian Approach

- Bayesian networks are a method which can integrate dependencies directly between trigger events, risk drivers, and consequences.
- Simultaneously assess all levels of outcomes (profit, capital).
- Can think of the prior as the “theory”, and the evidence as “observation”.
  - All scientific fields use Bayesian statistics, so why don’t we!

\[
P(A, B) = p(A/B) \cdot p(B) \\
P(B, A) = p(B/A) \cdot p(A) \\
\therefore P(A/B) = \frac{p(B/A) \cdot p(A)}{p(B)}
\]

where
- \(P(A)\) is the prior
- \(P(A/B)\) is the posterior
- \(P(B/A)/P(B)\) is the evidence
What is a Causal Model?

- A causal model is one which conditions outcomes directly upon a set of interrelated causal factors.
- Causal factors are defined directly in terms of business language.
- It captures the complex web of interrelationships and dependencies directly from the outset.
Simple BN Case Study - Flood Model

- **Outcomes:**
  - Prob(Flood)

- **Risk indicators**
  - Rain (forecast)
  - Dam levels (avg)

- **Risk mitigants**
  - Quality of flood defenses (measurable but uncertain)

Source: AgenaRisk
Risk Monitoring

- Prior water = medium
- Risk level changes as the states of causal drivers change
- Consistent states of other variables calculated using Bayesian inference
Reverse Stress Test

- Flood = 100%
- What does the system look like?
- Bayesian inference used to resolve states of related drivers
- This is how we resolve risk appetite statements into consistent risk driver limits
Technical Developments

Relationships

Section 2c
Unsupervised vs Supervised Techniques

Derivation of rules / algorithms to search data to uncover correlations and patterns

- Decision trees
- Random forests
- Neural nets
- Nearest neighbours
- Support vector machines
- Cluster modelling
- Mutual information

Human judgment required to either structure the analysis or as an information source itself

- Linear multifactor regression
- Conditional / Bayesian probability
- Non-linear copulas
- Cognitive mapping
- Bayesian networks
- Phylogenetics
- Network analysis
Data Analytics

*Data is a key strategic asset, but only part of the solution*

- **Big Data**: Supply of multiple different data sets
- **Processing**: Data preparation
- **Reporting**: Descriptive analytics
- **Analytics**: Predictive analytics

- **Structured and unstructured data**
- **Indexed, organised and optimized data**
- **Ex-post analysis**
- **Ex-ante scenarios**
- **Automatically prescribe and take action**
Information Theory Shows us the Way

- Perhaps the most critical question in risk management:
  
  “Do I have any information upon which to condition an outcome / risk driver etc. and what quality level do I place on it?”

- Information theory concepts:
  - **Entropy**: quantifies the uncertainty involved in predicting the value of a random variable
  - **Mutual information**: quantifies the amount of information in common between two random variables
    
    \[ I(x) = -\log p(x) \]

- In light of no other information, the principle of maximum entropy applies: all outcomes are equally likely
Connectivity – Capturing Non-Linearity

- Typical correlation measures cannot spot non-linear dependency
- Mutual information sharing can

Example
\[ \Theta \sim U[0, 2\pi] \]
\[ R \sim U[4, 5] \]
\[ X = R \cos \Theta \]
\[ Y = R \sin \Theta \]

Sample of 1000

Correlation = 0.0
Mutual Info = 1.0
Assessing Network Connectivity & Complexity

Non-linear measures of dependence are critical

- Complexity changes significantly over the year, with several of the key drivers changing between 2003 to 2005
Aggregate Loss – Dependency Structure

- A profoundly different way of aggregating risks

- Diversification at all parts of the loss distribution can now be explained by the states and interrelationships of business drivers

- No need for abstract correlations, copulas
Correlation from Cause

Validating Dependency Structures

- Correlations measure a degree of co-variation. You can determine this co-variation for complex phenomena by using causal models of their dynamic relationships.
- The models more naturally allow for an understanding of regime shifts in behaviours and allow you to meaningfully stress dependency parameters used in other models.
Applications
Operational Risk

Section 3a

Milliman Research Report 2013
Risk - Failure to recruit, retain and develop staff

*Cognitive Map Analysis*

- **Key concepts:**
  - *Impacts*: customer service worsens, quality of work deteriorates
  - *Drivers*: failure to provide adequate staff training, unmanageable work volume, failure to align staff with business needs
  - *Controls*: staff appraisal process, performance management process

- **Map properties**

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<tr>
<td>Loops?</td>
<td>✓</td>
</tr>
</tbody>
</table>
Risk - Failure to recruit, retain and develop staff

Risk Quantification using a Bayesian Network

- Aggregate Loss:
  - Mean: $X_m$
  - 99.5%: $Y_m$
- Sources of loss: Unbudgeted recruitment, training and resourcing costs
- Business inputs: Resourcing, Training and Recruitment budgets
- Sensitivity Analysis:

![Bayesian Network Diagram]
Operational Risk Capital

Unique

Common
Assessing Extreme Risk Events

Rogue Trader Scenario
Applications

*Risk Appetite*

Section 3b

*Peter Clark award for best paper in 2012 in UK Profession*
Primary Risk Appetite Challenge:
Aggregating / cascading RAS thresholds $\leftrightarrow$ risk limits

Knowing how these ...interact... ...to produce these

It is essentially a large, complex multi-objective optimisation and control challenge
Risk Appetite Components

- Planned outcome
- Tolerated outcome
- Frequency
- Preferences

Sources of uncertainty

Business drivers

Objectives

Adaptation and emergence make this “hard”
Business Objectives Linked to Risk Sources

- Risk Sources:
  - Market
  - Credit Counterparty Default
  - Liquidity
  - Underwriting
  - Operational

- Contribution of risk source to overall risk set from:
  - Capital analysis
  - Profit analysis
  - Expert judgment
Identify Sources of Uncertainty for Each Risk

- **Credit:**
  - Reinsurance counterparty
  - Distribution counterparty
  - Derivative counterparty (or classified under market)

- **Market:**
  - Equity
  - Credit spreads
  - Inflation
  - Foreign exchange
  - Interest rate
Model now links business objectives to sources of risk and indicators

- Capture multiple influences: operational risk in particular links to more than one risk characteristic
Setting Risk Appetite

- Use propagation properties of Bayesian Networks

Setting an outcome here…

…tells us what the states ought to be here
Propagating Evidence Down

- Setting desired appetite levels at the top, translates into information about underlying limits e.g. counterparty credit
Monitoring Risk Levels Against Appetite

- Use propagation properties of Bayesian Networks

...gives us an estimate of risk levels here

Entering observed values here...
Propagating Evidence Up

- Entering actual observed indicator values gives information about risk levels versus appetite
Applications

Stress Testing

Section 3c

Award for “Practical Risk Management Applications” at ERM Symposium 2013
Stress / Scenario Testing: Overload But Incomplete

These are lots of different variations we thought of for how loss type X could happen.

They are actually specific examples contributing to the aggregate loss of type X.

…but so are these that we didn’t think of!
Codifying Business Intelligence
Cognitive Mapping & Analysis

1. Detailed notes from each workshop used to translate the risk discussion into cognitive maps
   - separate cognitive maps merged together to give complete description of risk profile

2. Connectivity analysis identifies key features of risk system

3. Collapsed view provides a 'minimally complex' description of the system
   - Retains the key features necessary to understanding drivers of uncertainty
Identifying Critical Drivers

*Highly connected drivers across the various silos*

- Structure of the map broadly reflects the key areas discussed within the workshops
  - Financial, Agent Channel, Product, Customer, Reputation, External, Bank Sales Channel
- Visually represents the distinct risk profile of each sales channel

Cognitive analysis identified key interactions between the risk profiles
Qualitative Scenario Creation

Understand full narrative of causes to consequences

“The life company does not deliver effective agent training with respect to current regulation, industry best practice, and product knowledge. This leads to a gradual decline in the ability of sales agents to offer compliant advice and meet required sales standards.

Out-of-date and incomplete sales advice leads to increased incidence of product mis-selling across the business’s product offering.

A build up of customer complaints is picked up by industry press and the regulator decides to review current sales practise.”

1. Minimally complex view of the system studied to identify interesting pathways between concepts

2. Pathways used as a framework for the scenarios, with additional context included from the full cognitive map
All Shapes And Sizes

The transition from A to B will be sudden not smooth

A
B
Applications

*Interest Rate Risk*

Section 3d
Causal Factor Explanation of Corporate Bonds

Corporate Bond Total Return Decomposition by Year and 10 Year Annualised

- Real Cash Rate
- Realised Inflation
- Cash Duration RP
- Nominal Duration RP
- Credit Spreads
- Total Return

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Long Term US S&P Return Decomposition

Source: Priest et al (2007)
Eliciting the Causal System Structure to Understand Inter-relationships
Modelling Full Dynamic Risk Factor Distributions

- Condition uncertainty in key capital market variables upon risk factors/drivers (subjective & objective)
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Questions?

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