Solvency II and Predictive Analytics in LTC and Beyond

HOW U.S. COMPANIES CAN IMPROVE ERM BY USING ADVANCED TECHNIQUES DEVELOPED FOR SOLVENCY II AND EMERGING PREDICTIVE ANALYTICS METHODS

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Framework of Our Talk

ERM

Solvency II Framework

Advanced Predictive Analytics
Using Solvency II Techniques to Develop A U.S. ERM Program
Introduction

Why the subject of LTC?
- Social issue
- Uncertainties about the extent of the future situation
- Relatively new risk
- High potential of business development for insurers

Facing this long term, evolving, and still relatively unknown risk, the ERM approach contributes to
- Manage the risks
- Determine the Solvency Capital Requirement
- Design the future products

We will be discussing Solvency II / ERM in the context of LTC, but the application can be broadly applied across other life businesses
The first contracts were issued in the mid 1980s
About 25 insurers participate in the market
Most business is heavily reinsured
Product structures include
- Stand-alone individual LTC with life-time benefits
- Group policies with fixed benefit period or lifetime options
- LTC Riders attached to other life products
- LTC embedded with health products
Second largest market in the world after the U.S.
- 5.7 million of insureds
- €660 million of which 75% is generated by traditional insurance companies
- Paid claims around €236 million per year, 24,700 claims (annuities) in service
- Technical reserves estimated about €4.6 billion
Solvency II Increases Capital Requirement by 12x

Solvency II does not provide explicit technical specification for LTC
- Stress tests not calibrated for LTC
- No correlation between longevity and disability risks
- No Entity Specific Standard Formula yet developed and implemented

This results in a much higher capital requirement
- Solvency II Capital = 12 \times \text{Solvency I Capital}

ERM process is critical to produce profitable business
### Source of Solvency Capital Requirement (SCR)

<table>
<thead>
<tr>
<th>Source</th>
<th>% of Underwriting SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>0%</td>
</tr>
<tr>
<td>Longevity</td>
<td>47%</td>
</tr>
<tr>
<td>Disability</td>
<td>45%</td>
</tr>
<tr>
<td>Expenses</td>
<td>1%</td>
</tr>
<tr>
<td>Lapses</td>
<td>7%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>
Governance and Risk Management, Pillar 2

1. Identify the Risks
2. Define the Key Risk Indicators
3. Determine the Management Actions
4. Develop an Adapted Risk Culture
5. Optimize the Risk Reduction Measures
1. Identify the Risks

**Evolution of regulation**
- Anticipate
  - Participate in the market debate
  - Market watch
  - Scenario-based valuation

**Reputation RISK**
- Prevent
  - Client communication
  - Follow-up of client complaints
  - Gradual pricing increase over years

**Basis RISK**
- Monitor
  - Organize the portfolio experience return

**Model RISK**
- Reduce
  - Documentation, Control, Audits
  - Sensitivity tests

**Outsourcing RISK**
- Limit
  - Write service agreements and guidelines
  - Control
2. Define the Key Risk Indicators

- Monitor the technical, financial and management risks
- Justify assumptions
- Alert in case of surpassing limits and correction measures
- Reporting to the “LTC Experts Committee” and “Risk Committee”
3. Determine the Management Actions

Define the premium rate increase policy

- Based on the key risk indicators
- Taking into account the insured behavior
- Using the long-term duration of the contracts
- Reintroducing benefit revaluation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>ΔSCR Underwriting</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) +3% p.a. during 10 years</td>
<td>-40%</td>
</tr>
<tr>
<td>(2) +3% p.a. during 10 years and double termination rates</td>
<td>-35%</td>
</tr>
<tr>
<td>(3) +3% p.a. during 10 years, double termination, and increase benefit level 0.5%</td>
<td>-20%</td>
</tr>
</tbody>
</table>

- Reduce the reputation risk
- Confirm the assumptions

Indexed premium
+ revaluation of
benefits in a long-term process
4. Develop an Adapted Risk Culture

Relevant and efficient communication at all levels, with illustrations

Transform the KRI in visual indicators easily understandable

Traffic light symbols to communicate the claims experience

Illustrate the risk characteristics

Breakdown of the liabilities by age of occurrence

1/3 of the incidence rate is not yet observed
4. Develop an Adapted Risk Culture

The company, the sales force and policyholder should expect annual premium increase like in health insurance or P&C.

In the French market, LTC is a long term policy but with non-life premium mechanisms.
5. Optimize the Risk Reduction Measures

Reinsurance

**Increase ceded shares**
- Transfer risk and reduce capital needs
- The Reinsurer brings expertise (can not be considered Best Estimate)
- Pay attention to the treaty wording

Diversification with other risks

**Package LTC and death risk**

Additional reserves ‘Equalization Reserve’

**Maintain even if not recognized by Solvency II**
- Constitutes equity
- Monitoring tool for short and mid-term evolutions and earnings
Solvency II increases Capital by $12x$

This necessitates an ERM process to ensure long-term viability of the business.

ERM, in turn, improves future product development and company embedded value.
Using New Advanced Predictive Analytics Techniques within an ERM Program
What are Predictive Analytics?

Professional Experience / Insight

Prior Information

Data

Algorithms / Modeling

Actuarial Science / Statistics

Machine Learning / Pattern Recognition

Predictions

Improved Insight

Predictions → Improved Insight → Algorithms / Modeling

Algorithms / Modeling → Actuarial Science / Statistics

Actuarial Science / Statistics → Data

Data → Prior Information

Prior Information → Professional Experience / Insight

Professional Experience / Insight → Predictions
What is Different Now?

- New Players
- Improved Algorithms and Techniques
- More Powerful Hardware
- Vastly Improved Software
- Profoundly Improved Analytics
Using Predictive Analytics in a U.S. ERM Program

Internal Risk Model

Level of Risk

Volatility of Risk, Correlation among Risks
Our Focus Today

There are many methods, techniques within Predictive Analytics toolbox

We will focus on one very powerful, flexible technique which has broad application:

State Space Modeling
State Space Modeling

State Space Modeling

- Interest Rate Risk
- Longevity

Internal Risk Model

- Level of Risk
- Volatility of Risk, Correlation among Risks
A Battle Ships Game Analogy

\[ \text{State}_t = \text{Actual Position of Ship at time } t \]

\[ \text{Observation}_t = \text{Noisy Radar Reading at time } t \]
A Bayesian Network Representation
Solving the Model

The techniques used to solve state space models are often not trivial
But, there is extensive literature to help

Our preferred method:
Full Bayesian Model, solved using Markov chain Monte Carlo techniques

Advantages:
- Provides a complete solution
- Method is adaptable across many projects

Disadvantages:
- Requires lots of computing power (and potentially time)
A Longevity Risk Analysis Example

Model:

\[ q_x = \text{mortality rates from a given table (e.g. VBT 2008)} \]
\[ q^t_x = \text{mortality rates at time } t \text{ adjusted for improvement} \]
\[ TMM_t = \text{Total Mortality Multiple at time } t \]
\[ q^t_x = TMM_t \times q_x \]

Questions:

- What are \( TMM_t \) for \( t = 0 \) to \( T \)
- What is the confidence interval round each \( TMM_t \)
- How are \( TMM_t \) expected to evolve in the future
Longevity Risk State Space Representation

- **State**: TMM$_0$, TMM$_1$, TMM$_2$
- **Observation**: Deaths & Survivals$_0$, Deaths & Survivals$_1$, Deaths & Survivals$_2$
The Full Bayesian Longevity Model

\[ TMM_t = TMM_{t-1} + \beta + \eta_t \]
\[ death(\text{insured})_t \sim \text{Bernoulli}(TMM_t \cdot q[x]_{t+1}) \]
\[ \eta_t \sim \text{Normal}(\text{mean} = 0, \text{sd} = \sigma_\eta) \]

Prior Assumptions:
\[ \beta \sim \text{Normal}(\text{mean} = \mu_\beta, \text{sd} = \sigma_\beta) \text{... trend coefficient} \]
\[ TMM_0 \sim \text{Normal}(\text{mean} = \mu_{TMM}, \text{sd} = \sigma_{TMM}) \]
\[ \sigma_\eta \sim \text{Normal}(0,.1) \& \sigma_\eta > 0 \]

* The above model is somewhat of a simplification to the one we use in practice but is useful for pedagogical purposes
Hypothetical Example

Background:
- 50,000 Insured lives, male and female, aged 40 to 60
- Followed for 10 years

True (but unknown) Mortality:
- 90% of 2008 VBT at issue (TMM_0 = 90%)
- Mortality Improvement = 1% p.a. for 4 years, 2% p.a. thereafter

Approach:
- Simulate Mortality based on true mortality
- Use State Space Model on simulated outcomes to “reverse engineer” true mortality
Assumed Mortality Assumptions
Simulated Mortality

Mortality Relative to Base Table
Portfolio Size: 50,000; Exposure 10 years

Total Mortality Multiple
- True_TMM
- Actual_To_Expected

Graph showing changes in the Total Mortality Multiple over time (t) from 0 to 9 years.
State Space Model

Mortality Relative to Base Table
Portfolio Size: 50,000; Exposure 10 years

Total Mortality Multiple
- True_TMM
- Actual_To_Expected
- State_Space_TMM

TMM
0.65 0.70 0.75 0.80 0.85 0.90 0.95 1.00 1.05 1.10

time (t)
0 1 2 3 4 5 6 7 8 9
State Space Model
with 10% to 90% Confidence Interval
Advantage of the State Space Approach

We now understand **how mortality has evolved** over the investigation period
- State space terminology: “smoothed” set of TMM states

We have a best estimate for **the current level of TMM** rather than an average over the investigation
- State space terminology: “filtered” TMM states

We know the **average trend** in mortality improvement, and the uncertainty/volatility of this estimate

We know what the **confidence interval** of our estimates for the current TMM
- The confidence interval shrinks with more data (deaths)

We can **project TMM going** forward with a data driven estimate for the volatility (uncertainty) associated with
- Current TMM value; Improvement Trend

We do not need to guess as to what **reasonable sensitivity test level** should be
An Interest Rate Risk Example

Motivation:
- Duration-based ALM encapsulates parallel changes in yield curve well, but not changes in shape of the yield curve
- Many arbitrage-free models do not show good historical empirical fits to the data
- Uncertainty as to how to estimate the *degree* of volatility in interest rates when setting capital levels
State Space Approach to Interest Risk

- Fit a Parametric Curve to Yield Curve at each point in time
- Adopt a dynamic approach to model
- Use a state space to represent changes in the parameters of the Nelson Siegal Curve
- Implement in ERM
- Use same model to project yield curve going forward to estimate interest rate risk exposure

Nelson-Siegel Model
The Dynamic Nelson-Siegel Model

\[ y_t(\tau) = \text{yield at time } t \text{ for duration } \tau \]

\[ y_t(\tau) = \text{level}_t + \text{slope}_t \cdot \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} \right) + \text{curvature}_t \cdot \left( \frac{1 - e^{-\lambda \tau}}{\lambda \tau} - e^{-\lambda \tau} \right) + \eta_{\text{yield,}t} \]

\[ \text{state}(t) = \begin{bmatrix} \text{level}_t \\ \text{slope}_t \\ \text{curvature}_t \end{bmatrix} \]

\[ \text{state}(t) \sim \text{normal}(\text{mean} = \mu_{\text{state}} + \rho(\text{state}(t-1) - \mu_{\text{state}}), \text{sd} = \sigma_{\text{state}}) \]

\[ \eta_{\text{yield,}t} \sim \text{normal}(\text{mean} = 0, \text{sd} = \sigma_{\text{yield,}t}) \]
Interest Risk State Space Representation

State Space Representation:

- State: Level, Slope, Curvature
- Observation: Yield Curve

1. Level, Slope, Curvature
2. Level, Slope, Curvature
3. Level, Slope, Curvature

Yield Curve

Yield Curve

Yield Curve

1, 2, 3
Historic Dynamic Fit of Model

Press Shift F5 to view dynamic fit
Yield Curve Projections
Possible Extensions to the model

Regime Switching: Include a “regime” change element to reflect the fact that current rates are at a historic low and that there is a reasonable risk that rates will revert to prior, higher levels.

Dynamic λ: Include λ in the state space. This parameter sets the point of maximum curvature of the yield curve.

Dynamic Volatility: Allow for changing volatility to represent periods of higher uncertainty.

Multi-country: Include multi-country yield curves in model so as to assess correlation of cross-border interest rate risk.

Credit Spreads: Include spreads in the model to allow for dynamic modeling of credit spread risk.
Advantages of the State Space Approach

We are able to match asset and liabilities by hedging:
- Changes to the level of interest rates
- Changes to slope of yield curve
- Changes to the curvature of yield curve

We have a distribution of possible future yield curve paths and shapes

We can simulate future changes in yield curves using a model that is consistent with historical data

We can create confidence limits on our projections and justify these limits:
- No need to guess at sensitivity scenarios

Simulation projections allow for concurrent changes in Level, Slope, Curvature
Summary

ERM requires a well-developed infrastructure and company-wide implementation

General approaches developed under Solvency II can be used in the U.S.

ERM includes both business management and technical analysis which need to be well integrated

Without standard capital margin formulae, U.S. companies need powerful and flexible predictive analytics to quantify risk and volatility

State Space Modeling is one such tool that offer greater insights into many of an insurer’s risk

- It has broad application
- Provides insight into level, volatility and direction of risks